PROCEEDINGS

WESTERN SECTION AMERICAN SOCIETY OF ANIMAL SCIENCE

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JUNE 21-23, 2006

2006 WSASAS
Organizing Committee
Utah State University

Dr. Kenneth C. Olson, Chair
Dr. Dale R. ZoBell

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Western Section
American Society of Animal Science
Committee Assignments 2005-2006
*** Denotes Committee Chair**

Executive
1. J. Thompson, President (07, Oregon State Univ.)*
2. T. Ross, President-Elect (08, New Mexico State Univ
3. E. E. Grings, Past- President (06, USDA-ARS, Miles City)
4. K. C. Olson, Secretary-Treasurer (09, Utah State Univ.)
5. D. Hallford, ASAS Board Director (07, New Mexico State Univ.)
6. B. L. Christensen, Industry Director (06, Virtus Nutrition)
7. J. B. Glaze A& C Chair (06 Univ. Idaho)

Awards
1. T. Ross (06, New Mexico State Univ.)*
2. T. DelCurto (06, Oregon State Univ.)
3. M. K. Peterson (06, New Mexico State Univ.)
4. T. W. Geary (07, USDA-ARS Miles City)
5. B. Hess (07, University of Wyoming)
6. J. Bowman (07, Montana State University)

Symposium
1. T. Engle (06, Colorado State University)*
2. M. Wise (06, New Mexico State University)
3. M. MacNeil (06, USDA-ARS, Miles City)
4. C. Mueller (07, Oregon State University)
5. G. Moss (07, University of Wyoming)
6. G. Duff (07, University of Arizona)

Advising and Coordinating
1. J. B. Glaze (07, Univ. Idaho)*
2. J. M. Rumph (06, Montana State Univ.)
3. S. J. Filley (06, Oregon State Univ.)
4. J. B. Lamb (07, BYU-Idaho)
5. J. Sprinkle (07, Univ. Arizona)
6. S. I. Paisley (07, Univ. Wyoming)
7. L. B. Bruce (07, Univ. Nevada)
8. S. Daugherty (07, Cal Poly)
9. J. Busboom (07, Washington Sate University)
10. D. Garrick (07, Colorado State Univ.)
11. C. A. Loest (08, New Mexico State Univ.)
12. D. Drake (08, Univ. California, Davis)
13. R. Wiedmeier (08, Utah State University)
14. T. Bodine (08, Western Feed Supplements)
15. J. Stellflug (08, USDA-ARS)

Paper Competition
1. R. M. Enns (06, Colorado State Univ.) *
2. D. H. Crews (06, Ag Canada, Lethbridge)
3. P. A. Ludden (06, Univ. Wyoming)
4. D. W. Bohnert (07, Oregon State Univ.)
5. T. Bodine (07, Western Feed Supplements. Washington)
6. S. Sota-Navarro (08, New Mexico State University)
7. J. Rumph (08, Montana State University)
8. A. Ahmadzadeh (08, University Idaho)

Academic Quadrathalon
1. N.A. Irlbeck (Colorado State Univ.)*
2. J.B. Lamb (BYU – Idaho)
3. W. E. Plummer (Cal Poly State Univ.)
4. C. W. Hunt (Univ. Idaho)
5. L. M. Surber (Montana Sate University)
6. P.D. French (Oregon State University)
7. S. Soto-Navarro (New Mexico State University)
8. S. Wickler (Cal Poly, Pomona)
9. R. D. Wiedmeier (Utah State Univ.)
10. D. C. Rule (Univ. Wyoming)

Extension
1. D. Zobell (06, Utah Sate Univ.)*
2. R. Zinn (06, Univ. California, Davis)
3. M. Encinias (07, New Mexico State Univ.)
4. R. Hathaway (07, Oregon State Univ.)
5. S. Paisley (08, University of Wyoming)
6. J. Ahola (08, Univ. Idaho)
7. J. Paterson (08 Montana State University)

Necrology
1. J. C. Whittier, (06, Colorado State Univ.)

Nominating
1. E. E. Grings, Past- President (06, USDA-ARS, Miles City)
2. B. L. Christensen (06, Virtus Nutrition)
3. J. C. Whittier, (06, Colorado State Univ.)

Minutes of the Western Section of the American Society of Animal Science Business Meeting

June 24, 2005
New Mexico State University
Las Cruces, NM

President Elaine Grings called the meeting to order at 8:00 am.

Acceptance of the minutes of the 2005 business meeting.
The minutes of the 2005 business meeting were approved as printed in the Proceedings of the Western Section of the American Society of Animal Science.

Advisory and Coordinating Committee Report
Ken Olson, Chair

Issues Addressed**:** Only one issue was presented to the A&C Committee for consideration this year.

WSASAS Beef Symposium Policy

The committee was asked to draft a policy statement to be incorporated into the WSASAS Handbook for conduct of the annual Beef Symposium. Particular concerns to be addressed were to develop a consistent standard for reimbursement of speaker travel costs and to separate the budget for the Beef Symposium from the general WSASAS budget to allow tracking of the financial status of the symposium.

Action:
The A&C committee is working with a draft policy statement and intends to finalize it at their meeting during the WSASAS meeting in Las Cruces. This policy statement recommendation will be presented to the Executive Committee during their meeting on Friday, June 24.

Extension Committee Report

Extension Committee:
1. H. H. Patterson (05, South Dakota State Univ.)*
2. J. A. Scanga (05, Colorado State Univ.)
3. W. F. Gipp (05, Montana State Univ.)
4. D. Zobell (06, Utah Sate Univ.)
5. R. Zinn (06, Univ. California, Davis)
6. M. Encinias (07, New Mexico State Univ.)
7. R. Hathaway (07, Oregon State Univ.)

The Extension Committee met via telephone and email correspondence in February to plan the 2005 Extension Symposium. The committee decided to focus on a theme of "Livestock Identification, Traceability, and Meat Safety/Quality." We designed a symposium to address 1) effects of disease and border issues on meat markets; 2) a description of the various livestock identification programs/pilot studies taking place in the western United States, 3) Extension programs that enhance quality and safety of meat products.

We invited speakers from industry and academia from throughout the western United States to present on these topics. A list of Extension Symposium presentations follows:

1. Effects of BSE and border/trade issues on cattle and meat markets. J. G. Robb*, Livestock Marketing Information Center, Lakewood, CO.

2. Estimates of the effectiveness of current beef cattle tracking systems. K. Ringwall*, Dickinson Research Extension Center, Dickinson, ND.

3. Tracking cattle from the ranch to the packer: The Montana Beef Network and National ID Pilot Project. J. Paterson*[1], L. Duffey[1], J. Peterson[1], S. Pilcher[2], and M. Bridges[3], [1]Montana State University, Bozeman, [2]Montana Stockgrowers Association, Helena, [3]Montana Department of Livestock, Helena.

4. Tri-National National Animal Identification System (NAIS) Project Synopsis. J. C. Whittier*[1], J. Scanga[1], W. Umberger[1], W. Cunningham[2], C. Heckendorf[2], and J. Heller[3], [1]Colorado State University, Ft. Collins, [2] Colorado Department of Agriculture, Lakewood, CO, [3] Research Management Systems Inc., Ft. Collins, CO.

5. The Northwest Pilot Project: Finding real world solutions to animal identification. J. A. Morrison[1], R. R. Stott[2], J. B. Glaze Jr.*[3], and J. K. Ahola[4], [1] Idaho Cattle Association, Boise, ID, [2] Agri Beef Company, Boise, ID, [3] University of Idaho, Twin Falls, [4] University of Idaho, Caldwell.

6. Colorado Sheep ID Project: Using RFID for tracking sheep. J. Parsons*[1,2], C. Kimberling[2], G. Parsons[2], and S. LeValley[2], [1]Optimal Ag Consulting Inc., Ft. Collins, CO, [2]Colorado State University, Fort Collins.

7. Extension programs monitoring market animal quality. W. F. Gipp*, Montana State University, Bozeman.

8. Developing beef quality assurance materials for youth. L. Holmgren*, D. R. ZoBell, and C. Kim Chapman, Utah State University.

Academic Quadrathlon Report

The 2005 Regional Academic Quadrathlon contest was graciously hosted by Utah State University on March 18 and 19, 2005. Eight teams participated in this year's contest, and they were as follows: 1) Brigham Young University—Idaho advised by Dr. Kerry Powell; 2) Colorado State University advised by Dr. Nancy Irlbeck and Mr. Eddie Behrends; 3) Montana State University advised by Dr. Lisa Suber; 4) New Mexico State University advised by Dr. Rachel Endicott; 5) Oregon State University advised by Dr. Patrick French; 6) University of Idaho advised by Ms. Tiffany Skow; 7) Utah State University advised by Dr. Randy Wiedmeier and Ms. Tami Spackman; and 8) University of Wyoming advised by Dr. Dan Rule. Dr. Carl Hunt (University of Idaho) was responsible for the written examination. Dr. Randy Weidmeier and Dr. Nancy Irlbeck created the oral presentation topic, and Dr. Rachel Endicott was responsible for the quiz bowl portion of the contest—and has taken on the task of rebuilding the database of quiz bowl questions for 2006. Dr. Patrick French secured over $2,500 in book awards. Dr. Jim Lamb was in charge of awards, and unfortunately, the $5,000 scholarship donation from Monsanto Company was not renewed this year. Dr. Dan Rule did find funding for Montana Silver Belt Buckles for the Overall Winning Team. All winning teams were awarded a plaque engraved with their names, advisor, and university. Securing another source of scholarship dollars is the primary focus of the committee in the coming year. Dr. Lisa Suber served as proxy advisor to all advisors as past chairman. Mr. Brett Bowman from the Utah State University played a major role in development of the Lab Practicum, and Ms. Tami Spackman was essential to the organization of the meeting. Thanks to all for the time and effort required to make this contest a success and serve as a valuable education tool for our students.

The contest results were as follows:

Quiz Bowl

1st Place	New Mexico State University
2nd Place	Oregon State University
3rd Place	BYU-Idaho University

Written Examination

1st Place	New Mexico State University
2nd Place	University of Idaho
3rd Place	Oregon State University

Oral Presentation

1st Place	Oregon State University
2nd Place	University of Wyoming
3rd Place	Colorado State University

Lab Practicum

1st Place	Utah State University
2nd Place	Oregon State University
3rd Place	Montana State University

Overall Placing

1st Place	Oregon State University
2nd Place	New Mexico State University
3rd Place	Utah State University

The AQ Advisor Recognition Award was given to Dr. Lisa Suber of Montana State for her support and commitment to the AQ program and for always having an answer for the rest of us advisors when we needed it. Dr. Suber has been an invaluable resource for the Western Section Academic Quadrathlon, providing the "institutional memory" needed to provide a successful and consistent contest. She has served as advisor for the Montana State University quadrathlon teams for many years.

Last year's first place quadrathlon team was from Utah State University, and they represented the Western Section in the National Collegiate Quiz Bowl during the National Cattlemen's Beef Association convention in San Antonio, TX. The 2005 overall winners from Oregon State University will represent the Western Section at next years NCBA meeting, which will be held in February 1-4, 2006 in Denver, CO.

The 2006 Regional Academic Quadrathlon contest will be hosted by the University of Wyoming and will be held on April 7-8, 2006.

WSASAS Awards Committee Report

Committee Members:
Dr. Raymond Ansotegui, Montana State University
Dr. Dean Hawkins, New Mexico State University
Dr. Mark Petersen, New Mexico State University
Dr. Tim DelCurto, Oregon State University
Dr. James M. Thompson, Oregon State University

Distinguished Service Award (1 nomination):
Recipient: Dr. Mark Petersen

New Mexico State University
Las Cruces, New Mexico

Sponsor: DSM Nutritional Products
c/o Dr. Scot Williams
45 Waterview Boulevard
Parsippany, NJ 07054-1298
Scot-N.Williams@DSM.com

Co-Nominators: Dr. Dean Hawkins
Dr. Mark Wise

Distinguished Teacher Award (1 nomination):

Recipient: Dr. C. Christopher Calvert
Univ. of California – Davis
Davis, CA

Sponsor: Elanco Animal Health
c/o Dr. Scott Laudert
209 S. Boundary
Woodland Park, CO 80863
sbl@lilly.com

Nominator: Dr. Gary Anderson

Extension Award (2 nominations):

Recipient: Dr. Clay Mathis
New Mexico State University
Las Cruces, New Mexico

Sponsor: Fort Dodge Animal Health
c/o Dr. Frank Prouty
9401 Indian Creek Parkway
Overland Park, KS 66225-5945
P.O. Box 25945
FPROUTY@fdah.com

Co-Nominators: Dr. Dean Hawkins
Dr. Mark Wise

Young Scientist Award (3 nominations):

Recipient: Dr. David Bohnert
Oregon State University
Eastern Oregon Ag Research Ctr.
Burns, OR

Sponsor: Ridley Block Operations
c/o Dr. Dan Dhuyvetter
424 N. Riverfront Drive
P.O. Box 8500
Mankato, MN 56002
ddhuyvetter@ridleyinc.com

Co-Nominators: Dr. Tim DelCurto
Dr. James Males

2005 Western Section ASAS Graduate Student Competition Committee Report

Submitted by D. H. "Denny" Crews Jr. (Chair)

The 2005 Western Section ASAS Graduate Student Competition was held on Thursday, June 23, as part of the annual meetings in Las Cruces, NM on the campus of New Mexico State University. Out of 14 abstracts originally submitted, 13 accompanying manuscripts were received and distributed to the committee for evaluation. Abstract number 97 (Cheatham et al., University of Arizona, Tucson) was withdrawn from the competition, and complete scores were tabulated for the remaining 12 competitors.

Committee members who provided both written and oral scores for the 12 competition papers were: Dr. Denny Crews (AAFC – Lethbridge, Chair), Dr. Jim Berardinelli (Montana State University), Dr. Paul Ludden (University of Wyoming), Dr. Clint Loest (New Mexico State University), Dr. Dave Bohnert (Oregon State University), Dr. Tim Bodine (Western Feed), and Dr. Mark Enns (Colorado State University). The oral presentation session was moderated by Dr. Milton Thomas, New Mexico State University, and the Committee extends thanks to Dr. Thomas for his efforts.

Following the oral session, the committee convened to compute scores and final rankings and conduct the annual meeting. The final individual ranks were as follows:

Rank	Abstract	Competitor	Institution
1	98	T. M. Thelen	New Mexico State University
2	94	C. M. Murrieta	University of Wyoming
3	92	R. L. Atkinson	University of Wyoming

The institution with the highest average score among those with at least 2 competitors was the University of Wyoming. Acceptance of the individual and institutional final results was properly moved, seconded, and passed by unanimous vote of the Committee. Individual and institutional awards were presented at the Western Section ASAS awards program on the evening of Thursday, June 23. At the request of the Committee, special thanks are extended to Dr. Elaine Grings, Paula Schultz, and Marilyn Hallford for their work in distributing electronic copies of competition manuscripts to the Committee and for preparation of the award certificates.

Dr. Clint Loest informed the Committee that his term expires in 2005, and the recommendation was made that a replacement from New Mexico State University be appointed to serve on the Committee. Dr. Mark Enns from Colorado State University was unanimously voted to be chair of the committee for 2005-06.

The committee also discussed changes to the manuscript formatting requirements. Although Journal Of Animal Science Style and Form guidelines indicate that the Implications section for full manuscripts should be considered optional where appropriate, the committee voted to retain the requirement for this section in Western Section Graduate Competition manuscripts. The committee noted the need for graduate students to understand and appreciate the implications of their work and that this section of the manuscript was important to graduate student training. The committee recommends that Western Section guidelines for submission of manuscripts to the Graduate Competition emphasize that Implications be included as a separate section. The 4 page total manuscript length limit was adopted for the competition in 2005 in accordance with the standards for all Western Section manuscripts, and this criterion was included in the score sheet that was made available to all competitors.

The Committee meeting was adjourned at 1:30 PM on Thursday, June 23.

Nominating Committee Report

President	James Thompson
President-elect	Tim Ross
Secretary/Treasurer	Ken Olson

Western Section Symposium Report

- WSASAS Svrnposium Committee Members:
  - P. D. Bums (05)
  - T. E. Engle (06)
  - T. W. Geary (05)
  - M. D. MacNeil (06)
  - J. E. Sawyer (05)
  - M. A. Wise (06)

- 2005 WSASAS Symposium Agenda:

Your Beef Cattle Industry in 2025

7:00-8:00	Registration
8:00-8:15	Introductions & Welcome Elaine Grings - WSASAS president Tom Geary - Symposium Chair Mark Wise, New Mexico State University - Animal & Range Sci. Dept. Chair
8:15-9:00	Implementation of Best Management Practices: Feedlot to Retail Product Wayne Smith, Manager Hergert Cattle Feeding, CAB Feeder of the Year 2003
9:00 - 9:45	Implementation of Best Management Practices: Cow/Calf Producer R. W. (Butch) Whitman, Nutrition Tech Services
9:45-10:15	BREAK
10:15-11:00	Implementation of Best Management Practices: Purebred Producer Mark Cowan, General Manager Camp Cooley Ranch, BIF 2004 Seedstock Operation of the Year
11:00-11:45	What have we learned from efforts to develop coordinated supply chains? Ronnie Green, USDA-ARS National Program Leader, Food Animal Production
11:45-12:00	Introduction of Sponsors
12:00-1:30	LUNCH
1:30-2:15	What challenges does the Beef Industry need to overcome? Barry Dunn, TAMU Kingsville, King Ranch School of Ranch Management
2:15-2:45	BREAK
2:45-3:30	Bovine Genome: What tools will really be provided to the Beef Industry? Eduardo Casas, USDA-ARS, Clay Center
3:30-4:00	Panel of Speakers - Questions

2005 WSASAS Symposium Challenges:
Current rules/exceptions for payment of travel of invited speakers are vague and need to be established. Amount of money available for expenses was unclear.
Rules for soliciting sponsors and which sponsors are to be excluded would be beneficial.

- Budget:

	Anticipated Income
ASAS Donation	$1,500
Registration Income	$4,500
Total Income	**$6,000**

	Anticipated Expenses
Room & Break Refreshments	$ 685
Travel Allowances (6 x $700)	$4,200
Total Expenses	**$4,885**

- Suggestions:

Establish rules for travel expenses.
Consider hosted dinner for invited speakers the evening before the symposium.
Choose 3 new members (2 of which are from the 2006 & 2007 WSASAS host universities if possible)

2005 WSASAS NECROLOGY REPORT
Patrick G. Hatfield
Montana State University
Ross Christian, University of Idaho
Joe Urich, USDA-ARS, Miles City, MT
Joe V. Whiteman, Oklahoma State University and New Mexico Extension Service
James L. Van Horn, Montana State University
Glen Lofgren, New Mexico State University and University of California

Chris Dinkel, South Dakota State University

Financial Report
Tim Ross
American Society of Animal Science
Western Section
Financial Report as of December 31, 2004

Balance as of December 31, 2003		**46,405.13**
Revenue and Support		
Donations - General	1,000.00	
Donations - Awards	3,000.00	
Meeting Registrations	24,670.00	
Ticketed Events	5,780.50	
Proceedings	9,765.00	
ASAS - Symposium Support	1,500.00	
ASAS - Dues	1,132.50	
Interest Income	2,278.94	
Miscellaneous Income		
Total Revenue and Support		49,126.94
Expense		
Program	342.03	
Call for Papers/Abstracts	428.14	
Awards/Plaques	6,209.12	
Quadrathalon	5,126.60	
Convention Fees	27,346.07	
Proceedings	4,702.84	
Postage/Supplies	78.74	
Travel-Speaker	690.68	
Travel	1,525.04	
Telephone	15.07	
Miscellaneous	220.00	
Staff Support	4,155.37	
Total Expenses		50,839.70
Net Revenue over Expense		(1,712.76)
Balance as of December 31, 2004		**44,692.37**

New Business
Dr. Jim Males, President ASAS, and Dr. Jerry Baker, Executive Director ASAS, reported on the state of ASAS and FASS.

Old Business

Constitutional Amendment

The amendment was **approved.**

Other Business

Tim Ross reported that the meetings were well attended with 215 registered participants. He thanked the local organizing committee (Dennis Hallford, Milton Thomas, Clint Loest, Sergio Soto, and Marilyn Hallford) for their time and effort. He also extended special thanks to Marilyn Hallford and Gail Silver for their hard work in making the meetings run smoothly. Finally, he thanked the many graduate and undergraduate students from NMSU for their assistance during the meetings.

Elaine Grings passed the gavel to Jim Thompson, and Jim thanked Elaine for serving as president and presented her with the past president's plaque.

Meeting was adjourned at 8:55 am.

Proceedings, Western Section, American Society of Animal Science

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STRATEGIC LOW COST SUPPLEMENTATION

M.K. Petersen[1]

Dept. of Animal and Range Sciences, New Mexico State University, Las Cruces, NM

ABSTRACT: A number of forces influence nutritional management decisions of western rangeland ranchers. These forces include resource condition, cowherd condition, production goals achievement, labor cost, when to supplement, what to supplement, how much to supplement and the marginal returns to supplemental feed investment. Our range nutrition program has a research goal to develop a nutritional management program that includes desirable flexibility, biological results, financial benefits, and practical implementation considerations. We have progressed in achieving this goal by a series of collaborative research and extension efforts. We have tried to incorporate the results of the last forty-five years of range nutrition research at New Mexico State University into a well thought-out strategy. The foundation of this plan first focuses on range management and the continued improvement of range health while providing cows with all they can eat every day. Next, we ask ourselves if the color of the vegetation is green or brown. If it is brown, then we know that a protein supplement will most likely improve digestibility and intake. Third, the expected nutrient intake is compared with predicted cow nutrient requirements. If nutrient intake is unacceptable and productivity will be negatively, influenced then supplementation options are explored. Minerals and vitamins should be continually available to diminish the potential of productivity impacts due to deficiencies. The mineral and vitamin program should be implemented yearlong. If protein supplementation is needed, then one of five supplements can be fed based on a number of criteria. The five supplements are fed at different rates; minute (58 g per day-self fed), minimum (250 g per day - self fed or 1.5 kg 1 day per week), moderate (454 g per day - fed 2 to 3 times per week), maximum (908 g per day - fed 2 to 3 times per week) and supermax (908 g per day-fed 2 to 3 times per week). Minimum number of days protein supplement is fed is 80 days per year. The number of days can change depending upon forage, climatic, and animal conditions. This program will allow for a 90% plus fall pregnancy rate within a 60 day or less breeding season with total feed cost of less than $30 per cow per year. The purpose of this program is to provide strategic supplementation guidelines that will enhance cow nutrient status. This is accomplished cow needs in a timely manner. Overall, the program is designed to be efficient, satisfy cow nutrient needs and achieve production goals while minimizing purchased feed costs.

Key Words: range beef cows, supplementation, management

Introduction

One of the obstacles facing range cow/calf producers striving for profitable low cost production is developing nutritional management flexibility. A management scheme that is dynamic - that can change as years - change has the potential to reduce spending when appropriate and strategically enhance nutritional intervention when needed. Low cost producers are aware of the ease at which over, under, or incorrect feeding can occur. In any of these cases, the provision of supplemental nutrients may not provide any positive production response. Guidelines for nutritional managers to aid in supplemental feeding decisions oriented towards low cost production have been elusive. Included in such a guide should be the digestive or metabolic goal for each particular supplement. The supplements available to low cost producers require a minimum level of palatability, while providing biologically potent formulations that target those discrete nutrients that limit cow productivity. Lastly, supplements require low labor and ease of delivery while being easy to handle, transport, and store.

Dr. Joe Wallace provided the foundation for our strategic nutritional management plan. In 1993 in a paper entitled “What we have learned”, Dr. Wallace summarized the major findings of his research career at New Mexico State University. An important assumption of his research program was to insure that management of the range always allowed for adequate forage daily for every cow in the herd. He showed that high protein supplements (CP > 30%) would improve intake, digestibility and reduce weight loss equal to a larger amount of supplement fed providing an equal amount of total protein but at lower percentage (CP $\leq$ 20%). The provision of grain (low protein, CP < 15%) as a supplement will substitute for grazed forage with little if any improvement in animal production. Most likely 2.3 kg or more of a high grain-low protein supplement needs to be fed per day if a manager is attempting to improve body condition above what the native vegetation can provide. Another important finding was that supplementation 2 times (or once) per week was as effective as daily (while supplying the same quantity of protein) This work illustrated the importance of providing limiting nutrients in

[1]**Acknowledgments;** The author wishes to thank the Western Section American Society of Animal Science for the Distinguished Service Award and DSM Nutritional Products Inc. for sponsoring the award. I would also like to thank my many colleagues and graduate students for their collaboration in the work cited in this paper. Thanks

a concentrated form and the benefits of reducing the inputs required to deliver supplements.

Supplementation used effectively can be profit generating. Supplements can enhance health, alter milk production, improve reproduction, and maintain body condition. However, supplementation is also a cost. The cost is not only composed of the feed itself but also the associated costs of delivery to the pasture, storage, transport from a production site, and other logistic processes. Every year is different so that calls for a different supplementation regime when supplied strategically. The long-term objectives have been to develop a practical, low cost, effective, simple strategy for supplementing the cowherd at the Corona Range and Livestock Research Center with the potential of application to other ranches in the West.

Discussion

Approach. The overall program goal has been to develop a nutritional management plan that provides for at least a 90% pregnancy rate, with 80% of the cows calving in the first 30 days of the breeding season while spending no more than $30 per cow per year in 3 out of 5 years. In New Mexico, cows graze dormant brown-colored vegetation for 9 months of each year. The lack of green color is indicative that diet consumed is of low nutritional quality. Dormant native vegetation contains a high concentration of slowly digestible fiber; low concentrations of highly digestible cell solubles and contains less than 7% CP (probably 5% CP or less). This class of forage is usually less than 50% digestible.

When cattle consume a low protein diet as described above, digestibility, intake and productivity are negatively impacted. Usually this negative effect occurs when forage crude protein content is less than 7%. Protein supplements that supply approximately 0.3 lb of ruminally degradable crude protein per day (0.45 kg of a 40% CP supplement) will usually improve digestibility and intake. Intake may improve from 5% up to 40% (on rare occasions) and digestibility will increase 2 to 5 percentage units. If a cow is consuming 9.1 kg of forage per day (50% digestible or 50% TDN) and she consumes 0.45 kg of a 40% crude protein supplement (70% TDN), we might expect a 5% (0.45 kg) increase in grazed forage intake. Both protein nutrition and energy nutrition are improved when protein supplements are fed to cattle grazing dormant range forage. There are many sources of protein available; these include non-protein nitrogen (NPN) such as urea, and natural protein sources such as oil seed meals (soybean, cottonseed, sunflower meals) and byproduct feeds (brewers dried grains, distillers dried grains, corn gluten meal, blood meal, feather meal, fish meal, etc.). Singular or combination additions of these sources in protein supplements have been shown to improve forage intake in many situations when forage protein was low

Strategic low cost supplementation. For strategic supplementation to be successful cows must first use available forage energy and mobilized body fat depots to supply metabolizable energy needs. Supplements are used only to complement metabolizable energy. Secondly, mineral intake limiting animal performance is balanced with a yearlong self-fed loose salt and mineral mix available at all times. Mineral intake is continually monitored and it is assumed that after implementation no mineral deficiencies exist. The third component of the management plan is the implementation of protein supplementation. We have developed "Five Strategies" that make up protein management depending upon magnitude of nutritional stress, physiological state and production goals. By using combinations of protein sources described previously, five defined high protein supplements (36% crude protein and greater) have been put into practice. They are:

Minute – 58 g supplement (80% CP) mixed with mineral (self-fed)

Mini – 250 g supplement (36% CP) per day (fed 1 day per week)

Moderate – 450 g supplement (36% CP) per day (fed daily to 2 times per week)

Max – 908 g supplement (36% CP) per day (fed 2 times per week)

Super Max – 908 g supplement (36% CP) per day (fed 2 times per week)

Minute is a self fed supplement in the form of a meal that is composed of 50% mineral mix and 50% protein sources which contain approximately 70% ruminally undegradable protein. The complete supplement is consumed at a rate of at least 120 g per day. Self-feeders are refilled once each week. It is effective when cows need a small amount of supplement to optimize the environment in the rumen. This supplement has been shown to be effective after weaning in the fall when nutritional stress is mild and body condition is moderate. The protein is used very efficiently. In a 3-year field trial this minute supplement was equivalent (in the reduction of body weight loss) to 450 g per day of a cottonseed/wheat middlings supplement (36% CP) fed 3 times per week (Table 1, Sawyer et a.,. 2005, Sawyer et al., 2000, Sawyer et al., 1998 and Stalker et al., 2002). The daily cow cost of this supplement may range from 25 to 50% of the Moderate supplement.

Mini provides twice the CP that Minute supplement provides; however, this supplement contains only 35 to 40% ruminally undegradable protein. This supplement is preferably fed as cubes (or block) hand fed to range cattle. Since the daily feeding rate is low at 250 g per day, this does not provide enough supplement to be fed to a group of cows at one time. Cibils (personnel communication, 2006) has measured cube consumption rates in two and 3 year old cows and found that it varies by a magnitude of 10 - fold. To minimize over and under consumption by individual cows the recommendation is to feed this supplement one time per week at a rate of 1,600 g per cow to provide enough supplement to create opportunities for all cows to consume supplement. This strategy is best employed for cows or heifers when nutritional stress is low, as found in the fall after weaning and before consistent winter, weather sets in. In the fall of 2004 and 2005, replacement heifers (7 to 10 month old) developed at the Corona Range and Livestock Research Center were fed Mini supplement from November until February and gained from 45 to 270 g per day. The daily

cow cost of this supplement will be 50% of the Moderate supplement.

Moderate is a traditional formulation using oil seed meals and contains less than 40% ruminally undegradable protein. This supplement is most appropriate when cows are experiencing increased nutritional stress from either of two sources: pregnancy or winter stress. This supplement can be fed 2 times per week or more frequently, either as cubes or blocks. Prior to calving this supplement will reduce weight loss by 50% compared to non supplemented cows (Miner et al., 1990) and can add one-quarter to half of a body condition score when non-supplemented cows maintain body condition during the winter. (Figure 1). We consider this supplement our standard or traditional formulation that we compare to all other supplements. The daily cost of this supplement will range from $0.10 to $0.15 per cow per day.

Max is formulated to reduce body condition losses associated with serious nutritional stress. (Miner et al., 1990, Huntington and Richards, 2005). The Max supplement is most effective during severe winter weather events during pregnancy and after parturition when intake is inadequate and body weight loss is rapid. This supplement is programmed to be fed at a rate of 450 to 910 g per day and can be fed as infrequently as two times per week as either cubes or blocks. The protein in this supplement is composed of 50% ruminally undegradable protein (RUP). It is suggested that the increased fraction of RUP compared to the moderate reduces protein tissue catabolism as the supplementary RUP is utilized most likely for gluconeogenesis (Reynolds 2005). We can generalize that supplements with this type of formulation may decrease body protein tissue catabolism and supply limiting glucose precursors in the form of glucogenic amino acids for the pre-partum range cow (Van Saun et.al., 1993, Miner et al., 1990). Fed to the post-partum range cow this supplement has been shown to decrease milk fat, decrease days to first estrus after parturition and increase pregnancy rate depending on basal diet quality. (Hunter et al., 1989, Wiley et. al., 1990, Triplett et al., 1993, Appeddu et al., 1996 and 1997, Knox et al., 1998, Waterman et al., 2006). This supplement has also been effectively fed to developing replacement heifers in a four-year field study. It was shown to improve pregnancy rate 14% (66 versus 80%, $P<0.05$) over heifers fed the moderate supplement and reduced pregnant heifer development costs ($124.67) compared to feedlot ($163.25) raised heifers (Hawkins et al., 2005).

Super Max formulation contains the same ingredients as the Max supplement with the addition of 80 g per day propionate salt. Our research has shown that this supplement will improve insulin sensitivity, decrease milk yield and fat while decreasing days to first estrus (Waterman et al., 2006 and Endecott et al., 2005). Even though the propionate salt adds considerable cost per ton of feed it can decrease the number of days a cow requires to get pregnant. This improvement in days to first estrus has been calculated to pay for the additional cost of the propionate salt and improve total return per cow (Endecott et al., 2005; Table 2.

Implementation at Corona Range and Livestock Research Center. The strategic supplementation concept is currently implemented with the Corona Range and Livestock Research Center cowherd. As a part of the supplementation strategy all cows have;

- Loose salt and mineral available year long targeted at 58 g consumption per cow per day (Cost $0.022 per day or $8.03 per year)
- Super Max supplement fed for a minimum of 60 days postpartum fed at a rate of 908 g per cow per day (Cost $0.35 per day or $21.00 per year)
- Minute supplement fed for 30 days prior to parturition (Cost $0.057 per day or $1.73 per year)
- Minimum total purchased feed cost per cow per year $30.75 ($8.03 + $21.00 + 1.73)

Due to changes in rainfall and vegetation production, purchased feed costs vary from year to year (ranging from less than $30 to nearly $50 per cow per year). According to our IRM-SPA analysis (26 May 2005) we achieved a 91% weaning percentage of cows exposed to bulls with 86% of our calves born in 42 days. In comparison to our contemporary ranches in the IRM-SPA analysis, we are in the top quartile for net return per cow.

There are two important underpinnings to an effective strategic supplementation program. The first is that a cow must have the ability to consume all of the forage required every day and secondly there needs to be continual assessment of forage and cow conditions to implement the most effective and lowest cost nutritional intervention to achieve production goals.

Implications

We have attempted to organize various supplement designs into a single nutritional management plan creating flexibility, a measure of control over costs, and impact. Supplying range cows with biologically potent, discrete supplements provided in a manner to reduce delivery and other associated expenses has implications towards reducing variable costs of running a cowherd while achieving production goals.

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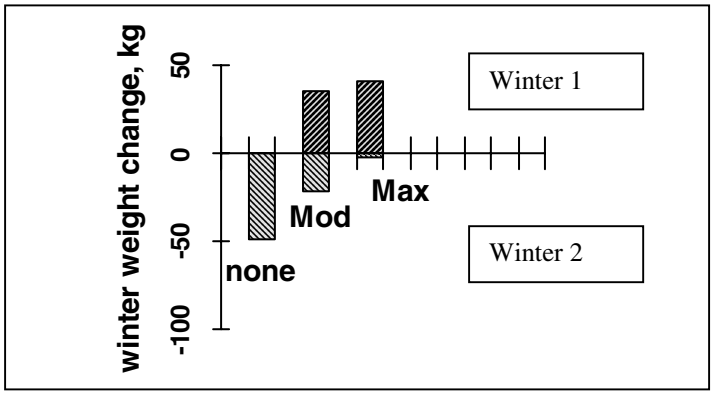

Figure 1. When pregnant range cows cattle lost weight in winter 2 the Max supplementreduced (P<0.05) weight loss. (Miner et al. 1990) Mod=moderate and Max=Maximum

Table 1. Feeding rate, duration of the supplementation period, and total amount ofsupplement fed to cows receiving different supplemental feeds during three years.

Item	Moderate	Minute	Control
Year 1			
Late, g/d	953	281	454
Duration, d	27	27	9.5
Total fed, kg	25.7	7.6	4.3
Year 2			
Rate, g/d	757	172	454
Duration, d	62	62	8
Total fed, kg	46.9	10.7	3.6
Year 3			
Rate, g/d	454	249	0
Duration, d	93	93	0
Total fed, kg	42.2	23.1	0
Average			
Rate, g/d	721	200	454
Duration, d	60	60	8
Total fed, kg	38.2	13.8	2.6
Body wt change	-0.2	1.8	-12.6
BCS change	-0.1	-0.1	-0.4
Cost, $	10.08	5.30	0.68

Table 2. Economic comparison of 3 different postpartum supplements fed to young cows at Corona Range and Livestock Research Center 1995 to 2004.

Item	Moderate	Max	SuperMax
Supplement $/ton	230	245	345
Feed cost/cow	16.10	17.15	24.15
Calf age weaning	205	215	214
Calf weaning wt	451	473	471
Lb calf weaned/cow exposed	388	412	424
Calf $ at weaning	388	412	424
Income diff. $	--	24	36
Feed cost diff $	--	1.05	8.05
Net income diff $	--	22.95	27.95

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EFFECTS OF SUPPLEMENTAL RDP VERSUS INCREASING SUPPLEMENTAL RUP ON VISCERAL N FLUX IN LAMBS FED A LOW-QUALITY FORAGE

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ABSTRACT: Sixteen multi-catheterized wether lambs (BW = 32 ± 5 kg) were used in a completely randomized designed experiment to measure net flux of N metabolites across the portal-drained viscera (PDV) and liver in response to supplementation with ruminally degradable protein (RDP) or increasing amounts of ruminally undegradable protein (RUP). Lambs were fed a basal diet of crested wheatgrass hay (4.9%CP) for ad libitum consumption, plus one of four protein supplements: isolated soy protein, a source of RDP, fed to meet estimated RDP requirements (**CON**), or corn gluten meal (RUP) fed at 50, 100, or 150% of the supplemental N provided by CON (**C50**, **C100**, and **C150**, respectively). Although forage N intake was not affected ($P \geq 0.29$) by treatment, total N intake increased ($P = 0.003$) with increasing RUP, and was similar ($P = 1.00$) between CON and C100. Net release of ammonia N from the PDV was greater ($P = 0.02$) for CON than C100 and increased linearly ($P = 0.002$) as level of RUP increased. Consequently, net uptake of ammonia N by the liver was not affected ($P = 0.23$) by protein degradability, but increased linearly ($P = 0.04$) as level of RUP increased. However, net urea N release from the liver was not affected ($P \geq 0.58$) by treatment. Net uptake of urea N by the PDV was greater ($P = 0.02$) for C100 than CON, and increased linearly ($P = 0.04$) with increasing RUP. Neither net release from the PDV nor hepatic uptake of α-amino N were affected ($P \geq 0.12$) by treatment. Hepatic ammonia N uptake accounted for 82, 38, 98, and 79% of net urea N release from the liver for the CON, C50, C100, and C150 treatments, respectively. However, hepatic α-amino N uptake for all treatments greatly exceeded that required for the remaining urea N release by the liver, suggesting that α-amino N may serve as a temporary means of storing excess N by the liver between supplementation events. However, the pattern of net release or uptake of N metabolites between supplementation events remains to be investigated.

Key Words: Ruminally Undegradable Protein, N Recycling, Ureagenesis

Introduction

Because low quality forages are often limiting in the supply of protein, a positive relationship exists between ruminally degradable protein (**RDP**) supplementation and forage utilization. When dietary RDP is inadequate, the animal can sustain an adequate ruminal N supply through recycling of blood urea N. However, the NRC (1985) suggests that if recycled N makes up a large proportion of the total supply of RDP, the long-term protein needs of the animal may be underestimated, resulting in decreased production. To counterbalance this effect, our hypothesis is that providing the animal with additional ruminally undegradable protein (**RUP**) will not only provide additional metabolizable protein for tissue deposition, but a portion of that RUP will serve as a source of N for endogenous recycling. In addition to moderating ruminal ammonia levels immediately following supplementation, the prolonged deamination of amino acids contained in supplemental RUP may support a more stable ruminal environment by providing the animal with a more sustained source of recyclable N. Consequently, forage intake and utilization by the animal may be maintained concomitant with a potential reduction in the need for supplemental protein. Alternatively, greater reliance upon the N recycling process in this manner could decrease the overall efficiency of protein utilization, resulting in an additional demand for supplemental protein. Therefore, our objective was to examine the effects of supplemental RDP verses increasing amounts of RUP on the net flux of N metabolites across visceral tissues in growing lambs fed low quality forage.

Materials and Methods

Animals and diets:

Sixteen multi-catheterized wether lambs (BW = 32 ± 5 kg) were used in a completely randomized designed experiment to examine nutrient flux across visceral tissues. Lambs were surgically fitted with chronic indwelling catheters in a hepatic vein, the hepatic portal vein, a mesenteric vein, and a mesenteric artery as described by McLeod et al. (1997). Catheters were prepared and maintained as described by Huntington et al. (1989). All surgical and animal care protocols were approved by the University of Wyoming Animal Care and Use Committee.

Wethers were maintained in individual metabolism crates (1.4 × 0.6 m) at a constant room temperature (20°C) under continuous lighting. Wethers had ad libitum access to fresh water and a trace-mineralized salt block (Iofix T-M, Morton Salt; Chicago, IL). Wethers were fed a basal diet of mature crested wheatgrass hay (4.2% CP, 59% NDF, 42% ADF, 62% RDP) for ad libitum consumption in two equal portions at 0630 and 1600 daily. Lambs were supplemented at 0600 daily with one of four supplemental protein treatments (Table 1): isolated soy protein (RDP

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source) fed to meet estimated RDP requirements assuming a microbial efficiency of 11% of TDN (**CON**), or corn gluten meal (RUP source) fed at 50, 100, or 150% of the supplemental N provided by CON (**C50**, **C100**, and **C150**, respectively). The forage RDP value was determined by protein fractionation as described by Sniffen et al. (1996).

Table 1. Composition of supplements

	RDP[a]	RUP
Ingredient, % of DM		
Isolated soy-protein[b]	73.1	
Corn gluten meal[c]		75.8
Calcium carbonate	11.7	11.1
Vitamin premix[d]	10.2	8.1
Dried molasses	5.0	5.0
Chemical		
DM, %	95.8	93.9
OM, % of DM	87.9	90.1
CP, % of DM	73.9	54.3
NDF, % of DM	8.0	15.9
ADF, % of DM	6.9	11.3

[a]RDP = ruminally degradable protein, RUP = ruminally undegradable protein.
[b]ARDEX® AF, Archer Daniels Midland Company, Decatur, IN. Assumed to be 100% RDP (% of CP).
[c]RUP source. Assumed to be 60% RUP (% of CP).
[d]Contained 3,628,739 vitamin A 3,628,739 vitamin D3 and 18,144 vitamin E IU/kg.

Sample collection and analysis:

Lambs were adapted to their respective diets prior to surgery and given a one week recovery period from surgeries before blood sampling. On the day of sampling, a 15-mL priming dose of 1.5% (wt/vol) *p*-amino hippurate (PAH, pH = 7.4) was administered through a 0.45-μM filter (Whatman, Sanford, ME) into the mesenteric vein catheter followed by continuous infusion of 1.5% PAH (0.8 mL/min; model 22 syringe pump, Harvard Apparatus, Holliston, MA). After allowing 60 min for equilibration of blood PAH concentrations (Huntington et al., 1989), simultaneous arterial, portal, and hepatic blood samples (5 mL) were collected at 0-h (prior to supplementation) and hourly until 6-h post-supplementation. This protocol was repeated one week later from 12- to 18-h after supplementation. Blood was collected into heparinized syringes, transferred to EDTA blood collection tubes (Kendall Monoject, Mansfield, MA), centrifuged (2500 × g, 10 min), and the resulting plasma was placed on ice and transported to the laboratory. Plasma samples were analyzed for ammonia N by the L-glutamate dehydrogenase enzyme assay (Da Fonseca-Wollheim, 1973) and urea N by diacetylmonoxime method (Marsh et al., 1965). Plasma (500 μL) was deproteinized with an equal volume of 0.6 *N* $HClO_4$ and centrifuged (13,000 × g, 15 min), and the supernatant was analyzed for α-amino N (AAN) (Palmer and Peters, 1969) and PAH concentrations (Harvey and Brothers, 1962).

For three days prior to and the day of each sampling feed and orts were sampled and analyzed for DM and ash (AOAC, 1990), N (Model FP-528 Nitrogen determinator, LECO Corp., St. Joseph, MI), and NDF and ADF content (ANKOM 200 fiber analyzer, ANKOM Technology, Fairport, NY).

Computations & Statistical Analysis

Plasma flows through the PDV and liver were calculated using the Fick principle (Katz and Bergman, 1969): $PF = IR_{PAH}/(Cv_{PAH} - Ca_{PAH})$, where PF represents plasma flow (L/h), IR_{PAH} is PAH infusion rate (mg/h), and Cv_{PAH} and Ca_{PAH} are PAH concentrations (mg/L) in venous and arterial plasma, respectively. Hepatic arterial plasma flow (APF) was calculated by difference between portal and hepatic venous flows. Net fluxes of nutrients across the PDV, hepatic, and total splanchnic (TS) vascular beds were computed using the following equations: PDV flux = PPF × (Cp-Ca), TS flux = HPF × (Ch-Ca), and hepatic flux = TS flux – PDV flux, where PPF and HPF are portal and hepatic venous plasma flow (L/h), and Ca, Cp, and Ch are nutrient concentrations in arterial, portal, and hepatic plasma, respectively. A positive net flux denotes absorption or release of a nutrient and a negative net flux denotes uptake or utilization of that nutrient. Hepatic extraction ratios (HR) were calculated using the equation: HR = [HPF × Ch / ((PPF × Cp) + (APF × Ca))] – 1. A positive ratio indicates production, and a negative ratio indicates extraction or uptake by the liver.

Means were computed, within lamb, for arterial, portal, and hepatic concentrations of ammonia N, urea N, AAN, and PAH. Individual blood flows deviating more than 2 SD from the mean were removed, and the mean was recalculated. All data were analyzed using the MIXED procedures of SAS (SAS inst. Inc, Cary, NC) for a completely randomized design. The model included the effect of treatment, time, and interaction. Because no treatment × time interactions were detected, only treatment means are reported. When *F*-tests were significant, single degree of freedom contrasts (Steele and Torrie, 1980) were used to determine linear and quadratic effects within RUP supplementation treatments and to compare CON and C100 (RDP vs RUP on isonitrogenous basis). Effects were considered significant at $P \leq 0.10$.

Results and Discussion

Forage DM intake was not affected ($P \geq 0.52$) by protein degradability or increasing levels of RUP ($P \geq 0.65$; Table 2). Moreover, total DMI was not affected ($P \geq 0.43$) by protein degradability or level of RUP. Because forage intake was unaffected by treatment, forage N intake did not differ ($P = 0.29$). However, total N intake increased ($P \leq 0.01$) with increasing RUP due to the increase ($P = 0.001$) in N provided by the supplement, but was unaffected ($P = 1.00$) by protein degradability. Similarly, Swanson et al. (2000) and Salisbury et al. (2004) did not observe differences in forage intake in mature ewes or in wethers fed supplemental RUP. These authors suggested that RDP from forage might have been adequate for maintaining ruminal fermentation. However, the forage fed in the current experiment was of low digestibility and of limited quantity (4.2% CP) which necessitated supplementation with RDP to meet requirements. Because lambs fed C100

were fed approximately 38% less RDP, but were still able to maintain forage intake and digestion in spite of this apparent RDP deficiency. This lack of response in forage intake would suggest that lambs supplemented with RUP were recycling sufficient N to compensate for the RDP deficiency, potentially utilizing the increased supply of amino acids reaching the small intestine as a source of recyclable N.

Neither protein degradability (P = 0.93) nor level of RUP ($P \geq 0.19$) were a significant source of variation in portal venous plasma flow. However, hepatic arterial (P =0.09) and hepatic venous (P = 0.07) plasma flows increased with increasing RUP. Because feeding low-quality forage at ad libitum intake should minimize differences in blood flow with time after feeding (Goetsch et al., 1994), this increase in plasma flow must be attributed to the increased level of supplemental RUP.

Release of ammonia N by the PDV was greater (P = 0.02) for CON versus C100 lambs. However, within the RUP treatments PDV release of ammonia N increased (P = 0.002) with increasing level of RUP. Similarly, Ferrell et al. (1999) observed an increase in PDV release of ammonia N in sheep supplemented with soybean meal versus sheep supplemented with RUP while consuming a low quality forage. Hepatic uptake of ammonia N mirrored PDV release, increasing (P = 0.04) with increased level of RUP, but, was not affected (P = 0.23) by protein degradability. Net splanchnic uptake of ammonia N was not affected (P = 0.39) by protein degradability or by level of RUP (P = 0.49), suggesting that the liver had sufficient capacity to detoxify the ammonia N at the levels presented.

Neither protein degradability (P = 0.41) nor level of RUP (P = 0.17) affected PDV release of AAN. Hepatic uptake of AAN tended (P = 0.12) to be greater for CON lambs compared to C100 lambs but was not influenced (P = 0.71) by level of RUP. Similarly, Ferrell et al. (1999) did not observe a difference in PDV release of AAN or in hepatic uptake of AAN in sheep supplemented with either soybean meal or RUP while consuming low-quality forage. In the current study, the hepatic ratio of AAN tended (P = 0.16) to be less negative for C100 lambs compared to CON lambs, indicating a greater proportion of AAN was removed by the liver of C100 supplemented lambs. This observation of AAN removed by the liver is similar to that observed by Bohnert et al. (1999) in lambs supplemented with various RUP sources compared to lambs supplemented with soybean meal.

In spite of the difference in hepatic uptake of ammonia N, hepatic release of urea N was not affected ($P \geq 0.49$) by treatment. Nonetheless, uptake of urea N by the PDV was greater (P = 0.02) for C100 compared to CON and increased linearly (P = 0.04) as level of RUP increased. The increased removal of urea N by the PDV with the inclusion of RUP would suggest enhancement of N recycling to the gastrointestinal tract. Kennedy and Milligan (1980) suggested that transfer of blood urea into the rumen is affected by ruminal ammonia concentration and amount of OM fermented in the rumen. In lambs fed similar diets, in a companion study (Atkinson et al., 2006) ruminal ammonia concentrations were decreased with the inclusion of RUP, but OM fermentation was not affected. This suggests that the increased removal of urea N by the PDV with the inclusion of RUP is influenced by ruminal ammonia concentrations. In contrast, Bohnert et al. (1999) and Ferrell et al. (1999) observed that protein degradability (SBM vs. RUP) did not influence PDV uptake of urea N.

Total N uptake (NH_3N + AAN) by the liver, accounted for 99.5% of urea N synthesis in the C50 lambs, but accounted for only 51.2%, 68.1%, and 64.0% in CON, C100, and C150 lambs, respectively. Consequently, 32 to 49% of the N removed by the liver cannot be accounted for by hepatic ureagenesis. Similarly, Bohnert et al. (1999) could not account for 34 to 43% of the N removed by the liver via hepatic ureagenesis, suggesting that the liver must have converted AAN to some form other than urea. We further believe that the inclusion of RUP results in a slower rate of ureagenesis from AAN, and that synthesis of labile proteins from AAN in the liver may serve as a temporary means of storing excess N between supplementation events.

Implications

Decreasing the ruminal degradability of supplemental protein fed to ruminants consuming low-quality forages has the potential to enhance nitrogen recycling to the portal-drained viscera. This greater reliance upon amino acid versus ammonia nitrogen for ureagenesis may permit the short-term storage of excess N by the liver between supplementation events, thereby enhancing the potential for recycling at times removed from supplementation. Consequently, forage intake and digestion can be maintained in spite of an apparent deficiency in the dietary supply of ruminally degradable protein.

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Table 2. Effects of protein supplementation on intake, blood flow, and net flux of N metabolites in wethers consuming low-quality crested wheatgrass hay ad libitum.

	Treatment[a]					Contrasts, $P <$[b]		
Item	CON	C50	C100	C150	SEM	L	Q	1
DMI, g/d								
Forage	629	640	683	625	56.0	0.85	0.86	0.52
Supplement	55	41	68	94	0.00	0.001	0.001	0.001
Total	684	681	751	719	56.0	0.65	0.69	0.43
N intake, g/d								
Forage	4.79	4.12	5.19	4.33	0.48	0.76	0.29	0.57
Supplement	5.78	2.88	5.38	8.44	0.00	0.001	0.001	0.001
Total	10.57	7.00	10.57	12.77	0.48	0.003	0.01	1.00
Blood flow, L/h								
Portal vein	124	115	126	143	14.3	0.19	0.57	0.93
Hepatic artery	81	24	53	90	25.0	0.09	0.20	0.42
Hepatic vein	201	125	191	239	40.2	0.07	0.19	0.86
Ammonia N net release, mmol/h								
Portal	35.82[c]	20.70[d]	23.38[d]	39.44[c]	3.30	0.002	0.05	0.02
Hepatic	-32.67	-19.14	-22.63	-38.30	5.82	0.04	0.27	0.23
Splanchnic	-0.30	-0.66	-0.94	4.72	5.00	0.47	0.99	0.92
Hepatic ratio	-0.86	-0.90	-0.78	-0.76	0.07	0.19	0.41	0.40
Alpha-amino N net release, mmol/h								
Portal	8.95	0.81	17.15	0.96	6.79	0.99	0.17	0.41
Hepatic	-45.01	-31.62	-11.25	-38.94	14.6	0.71	0.85	0.12
Splanchnic	-35.63[d]	-27.52[cd]	12.02[c]	-37.55[d]	14.5	0.61	0.40	0.04
Hepatic ratio	-0.08	-0.09	-0.02	-0.06	0.03	0.36	0.21	0.16
Urea N net release, mmol/h								
Portal	-0.41[c]	-17.89[d]	-22.77[de]	-36.46[e]	5.81	0.04	0.39	0.02
Hepatic	39.75	50.53	23.08	49.49	22.0	0.97	0.49	0.58
Splanchnic	32.32	25.64	3.49	2.42	24.1	0.48	0.80	0.39
Hepatic ratio	0.04	0.03	0.02	0.03	0.02	0.82	0.76	0.42

[a]Treatments: CON= isolated soy protein (RDP); C100 = corn gluten meal (RUP) fed on an isonitrogenous basis to CON; C50 = corn gluten meal fed at 50% less than C100; C150 = corn gluten meal fed at 50% more than C100.

[b]L = linear contrast for RUP treatments; Q = quadratic contrast for RUP treatments; Contrast 1: CON vs C100.

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BODY CONDITION SCORE AT PARTURITION AND DAY OF LACTATION AFFECT LIPOGENIC ENZYME MESSENGER RNA ABUNDANCE IN MILK SOMATIC CELLS IN LACTATING BEEF COWS FED SUPPLEMENTAL FAT

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ABSTRACT: Our objective was to determine mammary RNA transcript abundance by measuring messenger RNA in milk somatic cells of three-year-old Angus × Gelbvieh beef cows nutritionally managed to achieve a BCS of 4 ± 0.07 (BW = 479 ± 36 kg; n = 18) or 6 ± 0.07 (BW = 579 ± 53 kg; n = 18) at parturition. Beginning 3 d postpartum, cows within each BCS were assigned equally and randomly to a hay diet plus low-fat control supplement or supplements with either cracked high-linoleate safflower seeds or cracked high-oleate safflower seeds until d 60 of lactation. Diets were formulated to be isonitrogenous and isocaloric, and diets with safflower seeds had 5% of DMI as fat. At d 30 and 60 of lactation, somatic cells from 500 mL of milk were collected for RNA extraction, and ribonuclease protection assay was used to measure transcript abundance for lipoprotein lipase (**LPL**), acetyl-CoA carboxylase (**ACC**), stearoyl-CoA desaturase (**SCD**), and fatty acid synthase (**FAS**). Cow BCS tended to affect transcript abundance for LPL (P = 0.13) and ACC (P = 0.16). Transcript abundance was greater for FAS (P = 0.02) and SCD (P = 0.04) in cows of BCS 4 than 6, suggesting that mammary tissue of cows in BCS 4 had less adipose tissue to draw upon for milk fat synthesis. Dietary treatment had no effect (P = 0.27 to 0.43) on transcript abundance. Greater (P = 0.002) LPL transcript abundance from d 30 to 60 likely reflected increased demand for uptake of fatty acids from circulating triacylglycerols by the mammary gland. Decreased (P = 0.004) transcript abundance for FAS from d 30 to 60 of lactation indicated that peak lactation could have passed when the 60-d sample was obtained. In conclusion, cow BCS, as well as day of lactation had the greatest impact on messenger RNA abundance for lipogenic enzymes in the lactating mammary gland of the beef cows. Moreover, transcription of lipogenic enzyme RNA might be up-regulated in mammary glands of cows in BCS of 4 to counter the lower supply of fatty acids from body fat reserves.

Key words: Milk, Messenger RNA, Lipogenesis

Introduction

Because reproductive success is affected by nutritional status (Hess et al., 2005), our laboratory has focused on the use of dietary lipid supplements as a strategy to minimize loss of BCS in beef cows during early lactation (Bottger et al., 2002; Lake et al., 2005). Bottger et al. (2002) demonstrated that feeding a high-linoleate supplement helped lactating beef cows maintain BCS, whereas feeding beef cows a high-oleate supplement increased milk fat percentage. We postulated that the apparent repartitioning effects were associated with changing supply of biohydrogenation intermediates because Scholljegerdes et al. (2004) demonstrated that supplemental safflower seeds increased duodenal flow of *trans*-vaccenic acid and other biohydrogenation intermediates. In a follow up study, Lake et al. (2004) reported greater (P < 0.001) concentrations of CLA as well as 18:1*trans*-10 and 18:1*trans-11* in milk fat of cows fed either supplemental high-linoleate or high-oleate safflower seeds. These biohydrogenation intermediates have been implicated in reducing mRNA for acetyl-coA carboxylase (**ACC**) and inducing milk fat depression (Griinari et al., 1998; Piperova et al., 2000). Mammary lipogenic enzymes lipoprotein lipase (**LPL**), ACC, stearoyl-coA desaturase (**SCD**), and fatty acid synthase (**FAS**) are regulated, in part, through mRNA transcription (Munday, 2002; Stoeckman and Towle, 2002); thus, quantifying the respective mRNA should provide insight into the potential mechanism of dietary lipid supplements as possible regulators of mammary lipogenesis. Our laboratory has also substantiated milk somatic cells as a reliable source of mRNA to study transcription of mammary lipogenic enzymes (Murrieta et al., 2005). For the current study, our hypothesis was that fatty acids made available from feeding dietary safflower seed supplements to provide 5% of DMI as fat would alter mRNA abundance of several lipogenic enzymes in the mammary gland of lactating beef cows. Our objective was to evaluate the effects of BCS at parturition and cracked high-linoleic or cracked high-oleic acid safflower seed supplements on mRNA abundance of LPL, ACC, SCD, and FAS from milk somatic cells at 30 and 60 d of lactation in beef cows.

Materials and Methods

General. The University of Wyoming Institutional Animal Care and Use Committee approved all procedures for the following study. Thirty-six, 3-yr-old Angus × Gelbvieh beef cows were nutritionally managed to achieve either a BCS of 4 (479 ± 36 kg of BW) or 6 (579 ± 53 kg of BW) at parturition (Lake et al., 2005). Cow BCS was determined 3 d postpartum and again on d 30 and 60 of lactation by three independent evaluators and validated using ultrasound measurements. Cows were assigned randomly within BCS group to postpartum dietary treatments consisting of either

a low-fat control or a high-linoleate or high-oleate safflower seed supplement (Table 1). Previous research at the University of Wyoming indicated that cows of similar genetics produced 9 kg of milk during peak lactation (Bottger et al., 2002). Therefore, diets were formulated to meet nutrient requirements of a 544-kg beef cow producing 9 kg of milk at peak lactation (NRC, 2001). Equal quantities of N and TDN were provided among diets, and lipid-supplemented diets contained 5% of DMI as fat.

Sampling and Laboratory Analyses. Cows were milked using a mechanical milking device as described by Lake et al. (2005). Sterile conditions were used to ensure integrity of milk somatic cell RNA. Approximately 500 mL of milk was collected into sterile 50-mL centrifuge tubes. Following centrifugation and milk fat removal, the cellular pellets from each tube were washed in PBS (pH 7.4, 4°C) to remove remaining infranatant. The total somatic cell pellet was resuspended in 0.75 mL of Tri Reagent LS (Molecular Research, Inc., Cincinnati, OH) for total RNA extraction, and then suspended in 50 μL of sterile water containing 0.1% diethyl pyrocarbonate and stored at -80°C. Total RNA integrity was verified by using a denaturing 6% acrylamide gel. Ten micrograms of total RNA was used for ribonuclease protection assay to quantify mRNA transcript abundance for LPL, ACC, SCD, and FAS, with 28s RNA used as reference transcript. Probes were generated from bovine mammary RNA as described by Lee et al. (2002) and Murrieta et al. (2005), and ribonuclease protection assay was conducted as described by Murrieta et al. (2005).
Statistical analyses. Data were analyzed as a split-plot within a completely randomized design using the MIXED procedure of SAS (vs. 9.1, SAS Institute, Cary, NC). The main plot was arranged as a 2 × 3 factorial arrangement of treatments with day of lactation as the subplot. The main plot error term was the random effect of animal within BCS × dietary treatment. There were no interactions between BCS, dietary treatment, or day of lactation for LPL, ACC, SCD, or FAS (P = 0.40 to 0.67); therefore, only main effects were reported.

Results and Discussion

Effects of BCS, dietary treatment, and day of lactation on milk somatic cell mRNA abundance are shown in Table 2. Cows with a BCS of 4 tended to have greater mRNA transcript abundance for LPL (P = 0.13) and ACC (P = 0.16) compared with BCS 6 cows. Abundance of SCD (P = 0.04) and FAS (P = 0.02) mRNA were greater for BCS 4 cows compared with BCS 6 cows. Lake et al. (2006) reported lower plasma NEFA concentrations in BCS 4 cows compared with BCS 6 cows used in the current study. Greater plasma NEFA concentrations generally reflect greater fatty acid mobilization from adipose tissue to support milk fat production during lactation (McNamara et al., 1995). Results of the current study suggest mammary lipogenic enzyme transcription increased in the BCS 4 compared with the BCS 6 cows in response to less mobilization of fatty acids from adipose tissue so that the BCS 4 cows could maintain milk fat production. Total milk fat yield was similar between BCS 4 and BCS 6 cows (Lake et al., 2005).

Dietary lipid supplements did not affect LPL (P = 0.34), ACC (P = 0.28), SCD (P = 0.27), or FAS (P = 0.43) mRNA transcript abundance. Thus, our results were not consistent with our hypothesis that dietary lipid supplements, fed at 5% of DMI, will differentially influence expression of genes involved with lipogenesis in the mammary gland of beef cows during early lactation. Our results were in partial agreement with Bernard et al. (2005) who reported an increase in LPL mRNA abundance and a decrease in SCD mRNA abundance, whereas ACC and FAS mRNA abundance remained unchanged in the mammary gland of lactating goats as a result of feeding rumen-protected vegetable lipids. Our results were more consistent with Murrieta et al. (2005), wherein feeding high-linoleate supplements to lactating beef cows tended to increase LPL mRNA, but ACC, SCD, and FAS were not affected by provision of supplemental safflower seeds.

Abundance of LPL mRNA increased (P = 0.002) from d 30 to 60 of lactation. Plasma NEFA concentrations decreased for these cows from d 30 to 60 of lactation (Lake et al., 2006) indicating less fatty acids were mobilized from adipose tissue to support milk fat production. The abundance of LPL transcripts was positively related to LPL activity in bovine muscle and adipose tissues (Hocquette et al., 1998). Thus, increased LPL mRNA abundance at d 60 of lactation could reflect a mammary response to garner fatty acids from circulating lipoproteins. This suggestion would support the lack of differences in milk fat production observed between d 30 and d 60 of lactation for these cows (Lake et al., 2005).

It was not clear why mRNA for FAS decreased and those of ACC (P = 0.92) and SCD (P = 0.64) did not change from d 30 to 60 of lactation; however, peak lactation could have passed before d 60 and FAS transcript abundance had begun to decline. The opposite differences in mRNA abundance observed for LPL and FAS, as well as lack of differences observed for mRNA abundance for ACC (P = 0.92) and SCD (P = 0.64), could be related to diverse transcriptional regulation associated with different signaling pathways (Schroeder et al., 2001).

Implications

The biohydrogenation intermediates supplied to the beef cow mammary gland as a result of dietary lipid supplements was inadequate to affect mRNA abundance of mammary lipogenic enzymes. An alternate strategy to provide these intermediates to the mammary gland is needed to overcome the inherent metabolic requirements to support milk fat production especially for cows in less than optimal body condition.

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Table 1. Ingredient and chemical composition of diets consumed by lactating beef cows[1]

	CON	LIN	OLE
--------Ingredients----(% of DM)----------			
Bromegrass hay	87.2	89.7	89.6
High-linoleate safflower seed	-	8.1	
High-oleate safflower seed	-	-	7.6
Soybean meal	0.7	-	0.6
Molasses	0.6	0.6	0.6
Beet pulp	10.0	-	-
Minerals	1.6	1.6	1.6
---------Chemical composition----------			
CP	11.2	11.4	11.4
TDN[2]	69.7	70.1	70.1
Crude fat	2.2	5.0	5.0
Fatty acid profile of diet (g/100 g total fatty acids)			
16:0	19.8	10.0	8.0
18:0	2.7	3.2	0.2
18:1*cis-9*	10.4	10.3	71.3
18:2*cis-9,12*	22.4	68.1	10.9
18:3*cis-9, 12, 15*	1.7	0.4	0.6

[1]Diets were formulated to be isocaloric and isonitrogenous and to meet the nutrient requirements of a 544 kg beef cow producing 9 kg of milk during peak lactation; low fat control (**CON)**; high-linoleate (**LIN)**; high-oleate (**OLE)**.
[2]TDN for hay samples was estimated from ADF values (Linn and Martin, 1989), whereas tabular values (NRC, 2001) were used to calculate TDN of supplemental ingredients.

Table 2. Abundance of lipogenic enzyme transcripts of milk somatic cells from lactating beef cows

	BCS[1]		Diet			Day			*P*- value		
Transcript[2]	4	6	C	L	O	30	60	SEM[3]	BCS	Diet	Day
LPL	0.12	0.09	0.08	0.10	0.12	0.08	0.13	0.02	0.13	0.34	0.002
ACC	0.23	0.18	0.16	0.22	0.23	0.20	0.21	0.03	0.16	0.28	0.92
SCD	0.23	0.15	0.15	0.20	0.22	0.18	0.20	0.03	0.04	0.27	0.64
FAS	0.28	0.16	0.20	0.26	0.20	0.25	0.18	0.04	0.02	0.43	0.004

[1]Data expressed as optical density units of each transcript normalized for optical density of 28s RNA; BCS presented as 4 or 6; low fat control diet (**C**); high-linoleate (**L**); high-oleate (**O**); day of lactation 30 or 60 d postpartum.
[2]LPL = lipoprotein lipase; ACC = acetyl coA carboxylase; SCD = stearoyl coA desaturase; FAS = fatty acid synthase.
[3]n = 18 for BCS, 12 for Diet, 36 for Day; Greatest SEM values were presented.

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BODY CONDITION AND SOMATOTROPIN INFLUENCE ENDOCRINE AND FOLLICULAR DYNAMICS OF POSTPARTUM BRAHMAN-INFLUENCED COWS[1]

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ABSTRACT: Influence of body condition (BC) and bovine somatotropin (bST) on number of follicles, diameter of largest follicle, and concentrations of GH, IGF-I, triiodothyronine (T_3), thyroxine (T_4), and prolactin were examined in postpartum Brahman-influenced beef cows. Cows (n = 99) were managed to achieve low (BCS = 4.3 ± 0.1) or moderate (BCS = 6.1 ± 0.1) BC at parturition and treated with bST every 2 wk for 6 wk beginning at 35 d prior to breeding (d 0) or no bST (control). Blood was collected on d -35, -28, -21, -7, and 0 to quantify concentrations of GH, IGF-I, T_3, T_4, and prolactin. All cows received a controlled internal drug releasing (CIDR) device 7 d prior to breeding. On d 0, CIDR were removed, and cows received prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$). Ultrasound was performed on d 1 after CIDR-$PGF_{2\alpha}$ to determine number of small (2 to 9 mm) and large (≥ 10mm) follicles, and diameter of largest follicle. Cows treated with bST had increased ($P < 0.05$) GH on d -28, -21, -7, and 0. Cows treated with bST in low BC had increased ($P < 0.05$) IGF-I vs. control-low BC cows on d -28, -21, -7, and 0. Number of small and large follicles were not influenced by BC and (or) bST. Triiodothyronine was greater ($P < 0.05$) in moderate BC vs. low BC cows on all sample dates. Thyroxine was greater ($P < 0.05$) in moderate BC cows on d -28, -21, -7, and 0 vs. low BC cows. On d -28 and 0, bST-treated cows had greater ($P < 0.05$) T_4 vs. control cows. Prolactin was greater ($P < 0.05$) in moderate BC vs. low BC cows on all sample dates. Diameter of largest follicle was correlated with IGF-I ($r \geq 0.18$; $P \leq 0.08$), T_3 ($r \geq 0.17$, $P \leq 0.10$), and prolactin ($r \geq 0.20$, $P \leq 0.05$). Treatment with bST increased IGF-I in low BC cows, and IGF-I was correlated with diameter of the largest follicle 1 d after CIDR-$PGF_{2\alpha}$. Endocrine influences on follicular dynamics can be mediated by BC, GH and (or) IGF-I.

Key Words: Beef cows, Body condition, Follicles, Insulin-like growth factor-I, Somatotropin

INTRODUCTION

Energy intake regulates ovarian function in beef cattle (Wettemann et al., 2003), and greater BCS at calving improves reproductive performance of beef cows (Lake et al., 2005). Growth hormone may serve as an endocrine mediator of nutritional status on reproduction (Hess et al., 2005), and treatment with bovine somatotropin (**bST**) increases IGF-I in beef cattle (Andrade et al., 1996; Bilby et al., 1999). Nutritionally induced changes in GH and IGF-I may partially explain the infertility and anestrus in undernourished cattle (Chase et al., 1998). Nutrient restriction uncouples the positive relationship of the GH-IGF-I axis with increased concentrations of GH and reduced IGF-I (Butler et al., 2003). Consequently, one of the endocrine signals most likely to inform the reproductive axis of the nutritional status in cattle is IGF-I (Meikle et al., 2004). Britt (1992) estimated 60 to 80 d for a bovine follicle to grow from the early pre-antral stage to the mature stage ready for ovulation. Thus, alterations of endocrine function affecting follicular development in thin cows would begin several weeks prior to ovulation. Effects of bST on reproductive performance of dairy cattle have been reported (Santos et al., 2004); however, less is known of the effects of BCS and bST on ovarian and endocrine function in beef cattle, especially Brahman-influenced cows. The objectives were to evaluate the effects of body condition (**BC**) and bST on the number of small and large follicles, diameter of the largest follicle, and concentrations of GH, IGF-I, triiodothyronine (**T_3**), thyroxine (**T_4**), and prolactin in postpartum Brahman-influenced beef cows.

MATERIALS AND METHODS

Spring-calving crossbred (1/4 to 3/8) multiparous Brahman-influenced cows were managed to achieve low or moderate BC at parturition. Cows grazed stockpiled and spring-growth, endophyte-infected tall fescue (*Festuca arundinacea* Schreb.) pastures to obtain desired BC at a stocking rate of either 1 cow/0.3 ha (low BC) or 1 cow/0.8 ha (moderate BC) for approximately 162 d prior to initiation of treatment. Mean BCS of low (n = 50; mean BW = 423 ± 15.8 kg) and moderate (n = 49; mean BW = 530.1 ± 16.0 kg) BC cows was 4.3 ± 0.1 and 6.1 ± 0.1 (1 = emaciated to 9 = obese), respectively.

Beginning 32 ± 2 d postpartum, cows within each BC were randomly assigned to treatment with or without bST in a 2 x 2 factorial arrangement. Control cows received no treatment, and treated cows were administered bST (500 mg, s.c.; Posilac, St. Louis, MO) on d -35, -21, and -7. On d -7, all cows received a controlled internal drug-releasing (**CIDR**, 1.38 g of progesterone [**P_4**]; Pharmacia & Upjohn Co., Kalamazoo, MI) device. On d 0

[1]Names are necessary to report factually on available data; however, the USDA does not guarantee or warrant the standard of the product, and the use of the name by the USDA implies no approval of the product to the exclusion of others that also may be suitable.

(start of 70-d breeding season), CIDR were removed, and all cows received prostaglandin $F_{2\alpha}$ (**$PGF_{2\alpha}$**, 25 mg, i.m.; Lutalyse, Pharmacia & Upjohn Co., Kalamazoo, MI). Calves were maintained with cows at all times.

Ultrasonography (Aloka SSD 500 V ultrasound scanner equipped with a 7.5 MHz linear array transrectal transducer; Aloka Co. Ltd., Wallingford, CT) was performed on d 1 after CIDR removal and $PGF_{2\alpha}$ to determine number of small (2 to 9 mm) and large (≥ 10mm) follicles and diameter of the largest follicle. Blood samples were obtained from cows at bST treatment (d -35, -21, and -7) and d -28 and 0. Blood samples were collected by venipuncture of the tail, allowed to clot for 24 h at 4°C, and centrifuged (1,500 x *g* for 25 min). Serum samples were stored at -20°C until analyses.

Concentrations of hormones were determined in duplicate aliquots using RIA procedures. Serum concentrations of GH were determined as described by Hoefler and Hallford (1987) with an intra-assay CV of 8%. Serum concentrations of IGF-I were determined as described by Berrie et al. (1995) with intra- and inter-assay CV of 12 and 16%, respectively. Serum concentrations of T_3 were determined using Coat-A-Count Kits (Diagnostic Products Corp., Los Angeles, CA; Wells et al., 2003); intra- and inter-assay CV were 4 and 9%, respectively. Serum concentrations of T_4 were determined using Coat-A-Count Kits (Richards et al., 1999) with intra- and inter-assay CV of 3 and 5%, respectively. The procedures of Spoon and Hallford (1989) were used to determine serum concentrations of prolactin with an intra-assay CV of 7%.

Serum samples collected on d -35, -28, and -21, were analyzed for concentrations of P_4; Coat-A-Count Kits; (Schneider and Hallford, 1996) to determine the percentage of anestrous cows at the initiation of treatment. Intra- and inter-assay CV were 5 and 1%, respectively. Cows were classified as either cyclic (concentrations of $P_4 \geq 1$ ng/mL in 2 consecutive weekly blood samples) or anestrus (concentrations of $P_4 < 1$ ng/mL in 2 consecutive weekly blood samples).

Data were analyzed by ANOVA as a 2 x 2 factorial arrangement of treatments (low or moderate BC and bST or no bST treatment) within a completely randomized design with cow as the experimental unit. Number of small and large follicles, and diameter of the largest follicle were analyzed by ANOVA utilizing the GLM procedure of SAS (SAS Inst., Inc., Cary, NC). The model included treatment, BC, and the interaction. Comparisons of concentrations of GH, IGF-I, T_3, T_4, and prolactin on d -35, -28, -21, -7, and 0 were analyzed using the MIXED procedure of SAS for repeated measures. The model included treatment, BC, day and all interactions. The most appropriate covariance structure for each analysis was chosen from unstructured, compound symmetric, spatial power, and ante-dependence structures utilizing Akaike's Information Criterion and Schwarz' Bayesian Criterion. Kenward-Rogers's approximation was used for calculation of the df of the pooled error term. The random effect of cow within each level of BC and treatment (specified in the RANDOM statement) accounted for the correlations among repeated observations on the same cow. If the interaction of treatment x day, BC x day, or treatment x BC x day interaction was significant ($P < 0.05$), then means separations were evaluated on each day using the PDIFF function of SAS. Pearson correlations were generated with the CORR procedure of SAS to evaluate relationships between concentrations of hormones and diameter of the largest follicle 1 d following CIDR removal and $PGF_{2\alpha}$.

RESULTS AND DISCUSSION

Eighty-eight percent (87/99) of cows were anestrous at the initiation of bST treatment. Number of small and large follicles 1 d following CIDR removal and $PGF_{2\alpha}$ was not influenced ($P > 0.10$) by treatment and (or) BC. Diameter of the largest follicle 1 d following CIDR-$PGF_{2\alpha}$ was influenced ($P = 0.06$) by a treatment x BC interaction. Diameter of the largest follicle was greater for control-moderate BC (17.5 ± 1.0 mm), bST-moderate BC (17.0 ± 1.0 mm), and bST-low BC (16.2 ± 1.0 mm) cows vs. control-low BC (13.0 ± 1.0 mm) cows. Our observations agree with Lucy (2000) that treatment with GH influences ovarian follicular development.

Serum concentrations of GH were influenced ($P = 0.01$) by a treatment x BC x day interaction (Figure 1A). Following bST treatment, low and moderate BC cows had increased concentrations of GH with bST-low BC cows having greater concentrations of GH than bST-moderate BC cows. Administration of bST increases concentrations of GH in beef cattle (Andrade et al., 1996; Bilby et al., 1999).

Serum concentrations of IGF-I were influenced ($P = 0.001$) by a treatment x BC x day interaction (Figure 1B). On d -28, -21, -7, and 0, bST-moderate BC cows had greater concentrations of IGF-I compared with bST-low BC, control-moderate BC, and control-low BC cows. However, bST-low BC cows had greater concentrations of IGF-I than control-low BC cows on d -28, -21, -7, and 0, indicating the GH:IGF axis may have been re-coupled in low BC cows treated with bST. Recently, Lake et al. (2006) reported that beef cows with a BCS of 4 at parturition had increased GH and decreased IGF-I during early lactation compared with cows with a BCS of 6, suggesting that regulation of IGF by GH may have been uncoupled in thin cows. In the present study, treatment of low BC cows with bST prior to initiation of the breeding season increased concentrations of IGF-I, suggesting that regulation of IGF-I synthesis by GH may be influenced by bST administration in thin beef cows.

Serum concentrations of IGF-I at d -28 ($r = 0.18$; $P = 0.08$), -7 ($r = 0.22$; $P = 0.03$), and 0 ($r = 0.19$; $P = 0.07$) were positively correlated with the diameter of the largest follicle 1 d following CIDR-$PGF_{2\alpha}$. This may further explain why the diameter of the largest follicle of bST-low BC cows was similar to the diameter of the largest follicle of control-moderate BC and bST-moderate BC cows.

Serum concentrations of T_3 were influenced by a BC x day interaction ($P = 0.001$; Figure 1C). On all sample dates, moderate BC cows had greater concentrations of T_3 compared with low BC cows. Serum concentrations of T_4 were influenced by a treatment x day ($P = 0.001$; Figure

1D) and BC x day ($P = 0.001$; Figure 1E) interaction. On d -28 and 0, bST-treated cows had increased concentrations of T_4 vs. control cows. Concentrations of T_4 were greater in moderate BC cows on d -28, -21, -7, and 0 vs. low BC cows. Direct effects of thyroid hormones on ovarian function are unclear. Spicer et al. (2001) reported direct stimulatory effects of T_3 and T_4 on thecal cell steroidogenesis which may result in increased estrogen production by the follicle. In the present study, concentrations of T_3 on d -35 (r = 0.24; $P = 0.02$), -28 (r = 0.18; $P = 0.09$), -21 (r = 0.25; $P = 0.01$), -7 (r = 0.17; $P = 0.10$), and 0 (r = 0.23; $P = 0.03$) were positively correlated with diameter of the largest follicle 1 d following CIDR-$PGF_{2\alpha}$. Further research is warranted to determine the relationship of thyroid hormones and ovarian function in cattle.

Serum concentrations of prolactin were influenced by a BC x day interaction ($P = 0.001$; Figure 1F). On all sample dates, moderate BC cows had greater concentrations of prolactin compared with low BC cows. Similar to concentrations of T_3, concentrations of prolactin on d -35 (r = 0.28; $P = 0.01$), d -28 (r = 0.25; $P = 0.02$), -21 (r = 0.29; $P = 0.01$), -7 (r = 0.28; $P = 0.01$), and 0 (r = 0.20; $P = 0.06$) were positively correlated with the diameter of the largest follicle 1 d following CIDR-$PGF_{2\alpha}$. Prolactin is important for the maintenance and secretory activity of the corpus luteum in rodents (Freeman et al., 2000); less is known of prolactin effects on follicular dynamics in beef cattle. To our knowledge, this is the first report describing relationships among concentrations of prolactin prior to breeding and diameter of the largest follicle following CIDR-$PGF_{2\alpha}$ in beef cattle.

IMPLICATIONS

Treatment with bST prior to breeding increased concentrations of GH and IGF-I of low and moderate BC Brahman-influenced beef cows. Increased concentrations of GH and IGF-I of thin cows suggests the nutritional and endocrine status prior to breeding may be influenced by treatment with bST. The positive relationships among IGF-I, T_3, and prolactin, and diameter of the largest follicle may be components of the complex hormonal milieu mediating nutritional effects on ovarian function in cattle.

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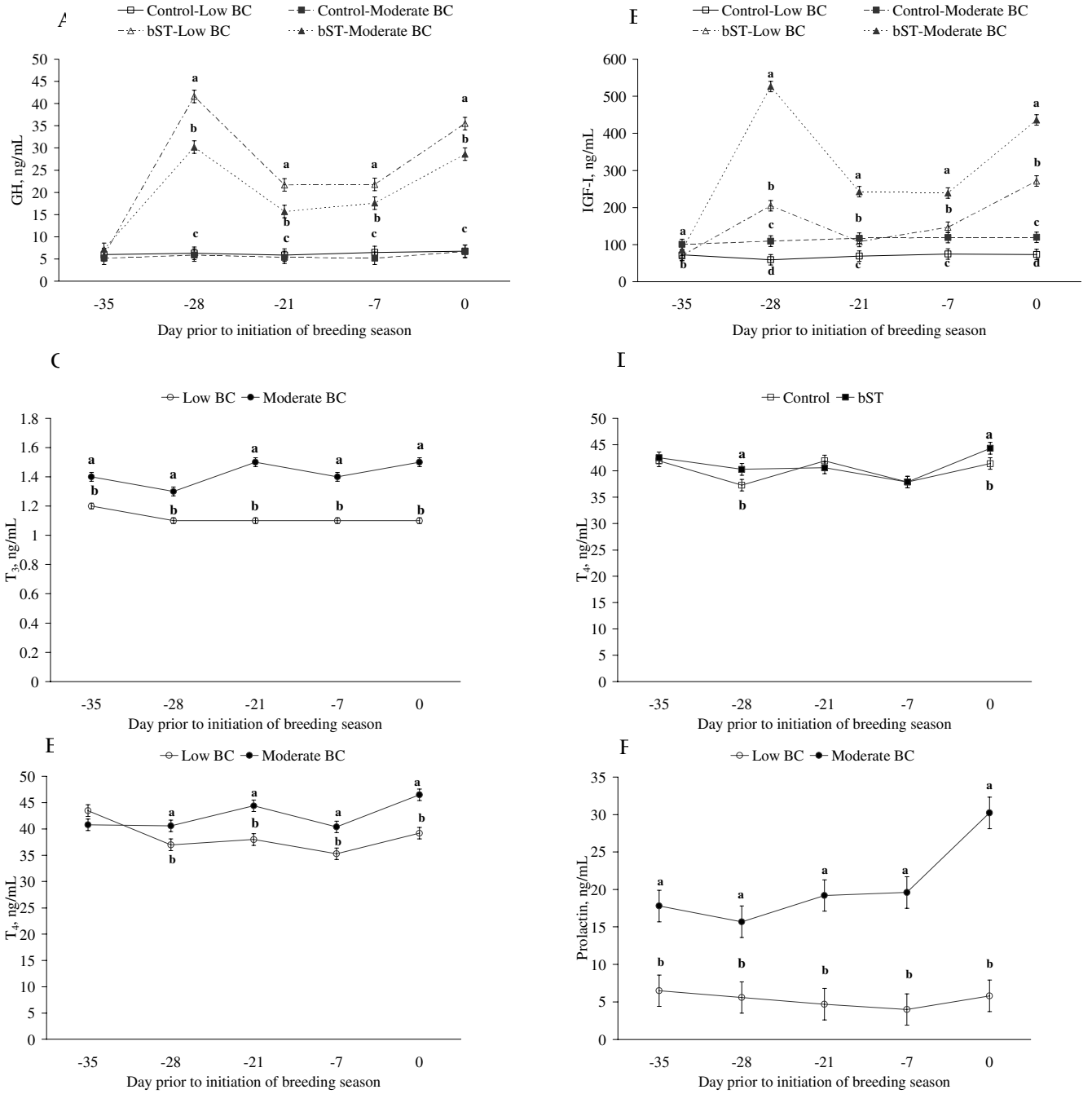

Figure 1. Serum concentrations of GH, IGF-I, triiodothyronine (T_3), thyroxine (T_4), and prolactin of low (BCS = 4.2 ± 0.1) and moderate (BCS = 6.1 ± 0.1) body condition (BC) Brahman-influenced cows treated with or without bovine somatotropin (bST). Cows were control (no bST) or treated with bST every 2 wk for 6 wk prior to the initiation of the breeding season (d 0). Serum was collected at bST treatment (d -35, -21, and -7) and on d -28 and 0. [a,b,c,d]Means without common superscripts differ ($P < 0.05$).

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AP-2γ IS NECESSARY FOR NORMAL EMBRYONIC EPITHELIAL DEVELOPMENT

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ABSTRACT: Skin is needed for an animal to survive. Therefore, any errors in skin formation can have detrimental effects on an animal's ability to grow and produce an agricultural product. The embryonic formation of epithelium depends on the correct expression of genes needed to drive proper skin differentiation, growth and development. AP-2γ is one such gene needed for proper skin development. AP-2γ is a transcription factor that binds to a specific DNA consensus sequence in other genes and stimulates their expression. During embryonic skin development AP-2γ is expressed in the basal layer of epithelium, a layer known to contain proliferating keratinocytes. When traditional knock out methods were used to disrupt AP-2γ, embryos died around 7.5 dpc; therefore to study the skin the Cre/lox P system was used to bypass this early lethality. AP-2γ mutant mice do not develop a proper epithelial layer and die shortly before or at birth. Skin histology revealed that mutant skin had abnormal stratification showing a lack of differentiation. Protein expression in embryonic stages 10.5, 12.5, 14.5 and 16.5dpc skin showed that mice mutant for AP-2γ had delayed expression of the skin proteins K1, K14, and p63. To investigate gene expression further, mRNA expression was analyzed using Microarrays. These arrays were performed on 16.5dpc mutant embryos and control littermate skin samples and detected differential expression in an important late embryonic skin differentiation gene filaggrin. Quantitative real-time PCR verified that AP-2γ mutants have lower expression of filaggrin. It appears as though AP-2γ plays an important role in driving differentiation in the development of the skin. Proper regulation of epithelium is critical to the function of many tissues in the animal including mammary glands. Understanding the role of AP-2γ in mammary epithelium could impact the study of breast cancer and dairy science.
Keywords: AP-2γ, Epithelium, Mouse Development

Introduction

Skin provides a necessary line of defense against external environmental factors. It acts as a barrier to protect against dehydration, injury and infection. To properly fulfill its role as an impermeable barrier and major protector, epithelia undergo a renewable and elaborate process of differentiation. Mammalian epidermis consists of both dermal and epidermal components: this paper will primarily focus on epidermal components and more specifically the keratinocytes. The epidermal layer is a stratified tissue, which is anchored to a basement membrane, the cells directly contacting this membrane (the basal layer) are proliferating keratinocytes (Alonso and Fuchs, 2003). Keratinocytes undergo a highly regulated terminal differentiation program, which is driven by the expression of unique keratin differentiation genes (Koster and Roop, 2004).

One possible gene needed for proper keratinocyte differentiation is AP-2γ. AP-2γ is a transcription factor that regulates the expression of genes by binding G-C rich consensus sequences on targeted DNA (McPherson and Weigel, 1999; Shen et al., 1997). It has previously been shown that AP-2γ is expressed in the nuclei of basal, spinous and granular cell layers of the epithelium (Takahashi et al, 2000). Also, AP-2γ has been shown to have binding affinity with the keratinocyte differentiation factors K1 and K14 (Oyama et al., 2002). When traditional gene knock out methods were used to remove AP-2γ, null embryos died around E7.5. This early embryonic lethality was due to malformed extraembryonic tissues (Auman et al., 2002). Therefore, Sox2Cre mice were used to induce the AP-2γ mutation only in the embryo proper allowing the null animals to survive. Therefore, the objective for our study was to characterize the phenotype of developing epithelium in AP-2γ null mice. This research will prove that AP-2γ plays an integral role in driving the proper gene expression for epithelial differentiation.

Materials and Methods

Animals. Sox2Cre mice were purchased from Jackson Labs (Bar Harbor, Maine). Mice containing AP-2γ null and floxed allele were provided by Trevor Williams (University of Colorado Health Sciences Center). The generation and characterization of mice harboring the conditional AP-2γ allele, AP-2γ floxed, in which loxP sites flank exon 6, will be described elsewhere (J.H. and T.W., Manuscript in preparation). To produce AP-2γ knock out embryos, male mice were generated that contained the Sox2Cre transgene along with an AP-2γ null allele, which were then bred to females homozygous for the AP-2γ floxed allele. This produced embryos which contained both an AP-2γ null allele as well as an AP-2γ flox-deleted, making the embryos AP-2γ null. For timed pregnancies, specific matings were set up in the afternoon, and the mice were checked for vaginal plugs the following mornings. Noon of the day of the vaginal plug was considered 0.5 (E0.5) days of gestation.

Mouse Genotyping. Mouse tail and yolk sac genomic DNA were extracted using lysis buffer and proteinase K and genotyped using PCR. PCR reactions for AP-2γ knock out, Sox2Cre were carried out for 35 cycles (94°C, 40 sec; 67°C, 40 sec; 72°C, 40 sec) in a buffer containing 25mM $MgCl_2$. Primer sequences are available upon request.

Histology. Embryos or tissues were washed in PBS then fixed in either Bouin's Solution or Formalin overnight at 4°C. Samples were then dehydrated, embedded and sectioned at 4 µm and mounted. For routine histological analysis slides were stained with hematoxylin and eosin using standard procedures. Immunofluorescent staining was performed by Maranke Koster at Baylor College of Medicine. Protein was detected using antibodies for the skin differentiation factors p63, K1 and K14.

Reverse Transcription PCR. Total RNA was collected from mouse tissues and extracted using Qiagen's RNeasy kit (Qiagen, Santa Clarita, Ca) according to manufacturer's specifications. cDNA was then prepared by annealing random primers (3µg) to 1µg of total RNA at 65°C for 5 minutes. Samples were then incubated at room temperature for 5 minutes. A buffer containing 5X RT buffer, 100mM DTT, and 10mM dNTPs was added and incubated at 42°C for 2 minutes. Superscript II reverse transcriptase (Invitrogen) was added and reactions were incubated at 42°C for 1 hour and then 94°C for 3 minutes. The resulting cDNA was then analyzed by PCR for the following genes: *AP-2γ, AP-2γ floxed, AP-2γ floxed-deleted.*

Microarrays. Three biological replicates each of AP-2γ mutant and wild type epithelial RNA were submitted to the Center for Integrated Biosystems at Utah State University (Logan, UT) for preparation of cRNA and hybridization to mouse 430_2 Affymetrix gene array chips. RNA was extracted as described above. Gene expression differences between mutant and wild type skin were determined using the ArrayAssist (Strategene) software program by applying Plier analysis followed by t-test statistical analysis ($p<0.05$ shows significant gene expression difference).

Quantitative Reverse Transcription PCR. Skin samples were taken from E16.5 mice. RNA was extracted as described above. Real time reactions were prepared to test Filaggrin expression using Applied Biosystems Taqman Demand Assay Mix according to manufacturer's specifications (#mm01716522_m1).

Results and Discussion

In order to produce full AP-2γ mutant animals, male AP-2γ knock out heterozygotes with the Sox2Cre gene were crossed to AP-2γ flox allele homozygous females. We expected the birth of live mutants which we could use to study the mutant skin phenotype. It was believed that AP-2γ was only necessary for the proper formation of extraembryonic tissue during embryonic development (Auman et al., 2002). This mating was expected to yield AP-2γ mutants in a one in four pups ratio. However, genotyping of 150 pups born from this mating produced no AP-2γ null pups, indicating that homozygous deletion of AP-2γ was embryonic lethal. Genotypes of neonates and embryos were then investigated to determine the stage of AP-2γ null embryo death. Since the Sox2Cre gene does not begin to express until E6.5 we began looking for AP-2γ null mice at E10.5. PCR analysis of embryos from E10.5-18.5 showed that AP-2γ null embryos could be found at every stage tested. Upon further investigation it was found that AP-2γ null pups were either dying before birth or delivered unviable. AP-2γ null embryos often had a very noticeable phenotype. They showed obvious skeletal and size abnormalities indicating that AP-2γ plays a role in the formation of tissues other than skin during development (Fig. 1).

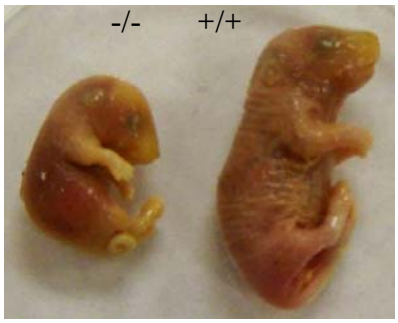

Figure 1. AP-2γ mutant embryos show anatomical deformities. AP-2γ null (-/-), AP-2γ WT (+/+)

Epidermal histology of the AP-2γ null embryos showed severe malformations. At E10.5 AP-2γ skin showed lack of stratification and differentiation when compared to wild-type littermates (Fig. 2, A and B). This lack of proper skin differentiation continued in later stages. By E16.5 epithelium should be showing near complete stratification in the skin, appearing as three distinct layers, the basal, spinous and granular. However, skin histology from E16.5 showed that mutant epidermis had not yet stratified into layers and was in fact missing completely from parts of the face, limbs and on the ventral side (Fig. 2, C and D). Also the epidermis that was present on the other areas of the null embryos was very thin.

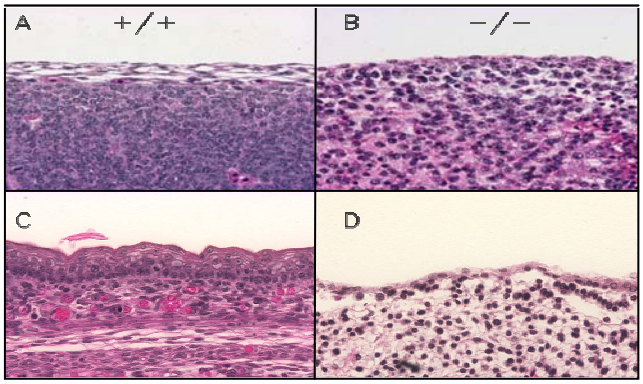

Figure 2. H&E staining of embryonic epithelium. E10.5 (A and B) and E16.5 (C and D), null epithelium at both stages show a lack of differentiation and stratification.

It was also observed that these embryos did not have normal hair follicle formation when compared to littermate controls (data not shown). The histology showed that removal of AP-2γ altered skin development. The epithelial stratification layers were not formed in mutant samples.

To help elucidate the cause of the abnormal stratification seen in mutant skin, expression patterns of epithelial differentiation gene markers were studied. K14 and p63 turn on at E8.5 and mark early stratification in keratinocytes of the epithelial basal layer (Koster and Roop,

2004). The expression of these genes begins the commitment of keratinocytes to stratification. Epithelial samples from AP-2γ null embryos and wild-type littermates were stained using immunofluorescent antibodies for these genes to determine if there was a difference in expression pattern of epithelial differentiation genes. At E10.5 AP-2γ null embryos showed no K14 or p63 staining[3]. This explained the lack of stratification seen in the histology, since K14 and p63 were not expressed in mutant skin the keratinocytes had not begun to stratify. The gene K1 begins expression at E10.5 and leads to the formation of the spinous layer in developing skin (Koster and Roop, 2004). By E16.5 mutant skin showed normal K14 and p63 expression indicating that mutant skin had indeed entered commitment to stratification. However, the null skin lacked normal expression of the mid-keratinocyte differentiation factor K1[3]. Again this explained the lack of stratification and layers seen in the histology. While littermate control embryos had developed spinous layers and begun granular layer development, AP-2γ null mice had only progressed into early epithelial development. It has previously been shown that AP-2γ has binding affinity to K1 and K14, so the altered protein expression seen in mutant skin was not surprising (Oyama et al., 2002). However, the lack of K14 and p63 expression at E10.5 and normal appearance by E16.5 suggested that AP-2γ may be causing a delay in keratinocyte differentiation. It is possible that another transcription factor from the AP-2 family is acting in a redundant role with AP-2γ, turning on at a later stage and inducing K14 and p63 expression.

To further investigate embryonic skin gene expression we dissected skin from three mutant and three wild type 16.5dpc embryos and analyzed gene expression using the Affymetrix Mouse 430_2 arrays. Gene expression differences between mutant and wild type skin were determined using the ArrayAssist (Strategene) software program by applying Plier analysis followed by t-test statistical analysis. The array data identified several epidermal gene factors with gene expression levels that were significantly altered in the mutant mice. Three early keratinocyte differentiation genes, K8, K12 and K18, were found to have higher expression in AP-2γ null samples than controls. The increased presence of early differentiation genes until E16.5 in mutants further supported the theory that the mutation of AP-2γ is causing a delay in epithelial development since we expected the genes to have declined by this stage. Five other genes were identified from our microarray data that are involved in skin differentiation and are down regulated in the mutant; sprr2d, corneodesmosin, slurp1, repetin and filaggrin. Sprr2 is a structural protein and corneodesmosin is an extracellular component of the cornified cell envelope, both are expressed late in differentiation (Song et al., 1999; Yang et al., 2004). Slurp1 is localized to skin keratinocytes below the stratified outer layer and is necessary to maintain the structural integrity of skin (Mastrangeli et al., 2003). Betacellulin is a member of the epidermal growth factor (EGF) family and is likely to elicit diverse physiological functions. Filaggrin and repetin are markers of late epidermal differentiation and act as keratin filament associated proteins (McKinley-Grant et al., 1989; List et al., 2003; Krieg et al., 1997; Koch et al., 2000). Each of these genes is a potential candidate for AP-2γ regulation and for having a role in our mutant phenotype. Interestingly, most of these genes mark late epidermal differentiation suggesting AP-2γ plays a role at all stages of epithelial development including the formation of the granular layer (Wang et al., 2006, Takahasi et al., 2000). The decreased expression of the genes suggested that AP-2γ null skin was not entering the last stages of skin development.

The last stage of epidermal differentiation is the formation of the granular layer and the cornified envelope. The formation of these two structures completes the skin's ability to act as a functional barrier. Beginning at E16.5 filaggrin expression marks the cells undergoing this final transformation (Koster and Roop, 2004). To determine if AP-2γ mutant skin ever reached terminal differentiation, quantitative real-time PCR was performed to measure filaggrin expression. Mutants showed a 20 fold decrease in filaggrin expression at E16.5 and E18.5. The lack of filaggrin expression in AP-2γ null embryos indicates that the epithelial layer does not fully develop a granular layer or a functional barrier prior to birth. The lack of proper skin development at such a late stage would lead to failure of the skin to function. The failure of the skin to properly develop would leave the null embryos extremely fragile, and susceptible to infection and dehydration. It is likely the mutant neonates die either during birth or directly afterwards due to dehydration.

Implications

Animal agriculture is dependant upon the maintenance of healthy animals with the ability to successfully reproduce. Mice containing an AP-2γ mutation cannot produce a functional skin layer resulting in the death of mutant embryos. This research supports the necessity of AP-2γ during epithelial differentiation and suggests that correct gene expression patterns, controlled by AP-2γ, must be maintained to support skin differentiation. Differentiation of mammalian epithelium is important for proper function of several other tissues including the mammary gland and gut epithelium. Improving our understanding of how AP-2γ regulates gene expression in epithelium will one day lead to advances in dairy and nutrition sciences producing improvements in animal agriculture production.

[3] Immunofluorescent color pictures are available upon request from qwinger@cc.usu.edu

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GROWING BEEF STEERS DO NOT REQUIRE SUPPLEMENTAL DIETARY METHIONINE DURING AN ENDOTOXIN CHALLENGE

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ABSTRACT: Acute phase response protein synthesis by the immune system during gram(-) bacterial infection increases metabolic amino acid demand in non-ruminants and limits efficiency of N utilization for growth in newly received feedlot calves. Therefore, we hypothesized that steers would have increased requirements for amino acids, such as Met, during an endotoxin challenge. This study evaluated the effects of supplemental dietary Met on N balance and blood metabolites in Angus-cross steers (n = 20; BW = 262 ± 6.3 kg) exposed to an endotoxin (**LPS**; gram(-) bacterial lipopolysaccharide, Sigma). Treatments (2 × 2 factorial) were LPS infusion and dietary Met addition (0 vs. 14 g/d rumen-protected; Smartamine M, Adisseo). Steers were adapted to a corn-based diet (DM intake = 1.4% of BW) and supplemental Met for 14 d, and were then infused (1 mL/min via i.v. catheter) with LPS on d 1 (**LPS1**; 2 ug/kg BW) and 3 (**LPS2**; 1 ug/kg BW) of a 5-d N balance collection period. Blood was collected prior to LPS infusions and every 2 h thereafter for 12 h. Serum cortisol peaked 4 h following LPS1, and remained elevated ($P < 0.01$) for 12 h. Cortisol peaked 2 h after LPS2 and remained elevated ($P < 0.01$) for 6 h (LPS × hour interaction, $P < 0.01$). Plasma Met was greater ($P < 0.01$) for Met-supplemented steers prior to LPS administration, but declined ($P < 0.01$) for steers infused with LPS such that plasma Met concentrations at 4 to 10 h post-LPS were not different ($P > 0.09$) from both non-stressed and LPS-challenged steers that received no supplemental Met (LPS × Met × hour interaction, $P < 0.01$). Infusion of LPS increased ($P < 0.05$) urinary N excretion and decreased ($P < 0.01$) N retention resulting in a negative N balance for LPS-challenged steers. Supplementation of Met did not affect ($P = 0.49$) N retention, and the absence of an LPS × Met interaction ($P = 0.25$) for N retention indicates that supplemental dietary Met does not improve the efficiency of N utilization for growing beef steers during an endotoxin challenge.

Key Words: Methionine, Endotoxin challenge, Steers.

Introduction

Morbidity and disease in feedlot cattle negatively impact performance and profitability (Waggoner et al., 2006). Gram(-) bacterial infection has been implicated in the pathology of many diseases, including shipping fever and pneumonia (Cullor, 1992). The inflammatory response to infection occurs due to recognition of lipopolysaccharide (**LPS**) within the bacterial cell wall. Administration of purified LPS stimulates the immune system and mimics symptoms of bacterial infection (Steiger et al., 1999).

During immunological stress, AA are directed away from tissue deposition to support the immune response. This occurs due to increased demands for AA to synthesize acute phase response proteins and glucogenic precursors (Le Floc'h et al., 2003). Grimble and Grimble (1998) suggested that insufficient supplies of sulfur AA (Met and Cys) limit acute phase response protein synthesis and contribute to increased N excretion during sepsis in humans. Furthermore, Met is a limiting AA in growing cattle (Greenwood and Titgemeyer, 2000). Therefore, it was hypothesized that Met requirements would increase for endotoxin-challenged steers.

The objective of this study was to evaluate effects of supplemental dietary Met on N balance and blood metabolites of growing steers during an endotoxin challenge.

Materials and Methods

Animals, Facilities, and Diet. Procedures were approved by the New Mexico State University Institutional Animal Care and Use Committee. Twenty Angus crossbred steers (262 ± 6.3 kg initial BW) were individually housed in tie stalls of a metabolism building with evaporative cooling and continuous lighting. Steers had free access to fresh water and were limit-fed a corn-based diet (Table 1) at 1.4% of BW (DM basis). The diet was divided into two equal portions and fed twice daily at 0700 and 1900.

Design and Treatments. The experiment was a randomized block design and lasted 20 d, which allowed 14 d for adaptation to diets and dietary treatments, and 5 d for collections. On d 14, indwelling jugular catheters (J-457A; Jorgensen Laboratories, Loveland, CO) were inserted. Treatments, in a 2 × 2 factorial arrangement, were two levels of LPS infusion and two levels of dietary Met supplementation. Dietary Met levels included 0 (**-MET**) vs. 14 g/d (**+MET**) rumen-protected Met (Smartamine M, Adisseo, Alpharetta, GA). Rumen-protected Met was divided into two portions and mixed with each portion of the daily diet before feeding. Levels of LPS included no LPS (**-LPS**) vs. a prolonged low dose of LPS (**+LPS**; Steiger et al., 1999). At 3 h after feeding on d 1 of the collection period, LPS (*E. coli* O55:B55; Sigma Chem. Co., St. Louis, MO) dissolved in 100 mL of sterile saline was infused (1 mL/min via i.v. catheter) at 2 μg LPS/kg BW. A second dose of LPS was administered at the same time on d 3 of the collection period. However, the dose was reduced to 1 μg LPS/kg BW (dissolved in 50 mL of saline) due to the death of a steer on d 1. An equal volume of sterile saline was administered at a similar rate to -LPS steers.

Table 1. Diet composition

Item	% of DM
Ingredient	
Cracked corn	35.0
Alfalfa hay	25.0
Corn silage	20.0
Sorghum, sudan hay	12.4
Molasses	4.0
Supplement[a]	3.6
Nutrient	
CP	12.8
Ca	0.70
P	0.29

[a] Composition (% of supplement DM): Soybean meal (33), Sodium caseinate (28), Urea (17), Salt (8), Limestone (8), Dicalcium P (3), Vitamin E (0.56), Rumensin (0.53), Sodium selenite (0.42), Zinc sulfate (0.25), Vitamin A (0.24), Copper sulfate (0.10).

Collections. Dietary samples, total feed refusals (if any), and fecal and urinary excreta from each steer were collected daily during the 5-d collection period. Urine was collected via vacuum pouches into vessels containing 600 mL of 3 *N* HCl (to prevent NH_3 loss). Total fecal and urinary output was weighed, and representative samples of feces (10%) and urine (1%) were frozen for later analysis. Steers were fed Cr-EDTA containing (400 g) and Yb-labeled (120 g) diet on d 1 of the collection period. Fecal grab samples were obtained every 24 h for 5 d. Rectal temperatures were measured (Cooper TM99A digital thermometer, Cooper Atkins Corp., Middlefield, CT), and blood samples were collected via catheters prior to LPS infusion and every 2 h for 12 h post-LPS infusion on d 1 and 3 of the collection period. Blood samples were collected into vacuum tubes (Corvac serum separator and Monoject 15% EDTA, Kendall, Ontario, CA). Blood samples for serum were allowed to coagulate at room temperature for 30 min, whereas samples for plasma were immediately placed on ice. All samples were centrifuged at 1,500 × *g* for 20 min at 10°C and then frozen.

Sample Analysis. Diet, feed refusals, and fecal samples were dried at 55ºC in a forced air oven, and ground to pass a 2-mm screen. Samples were analyzed for DM (105ºC for 24 h) and N by total combustion (Leco FP-528, Leco Corp., St. Joseph, MI). Urine samples were also analyzed for N. Fecal grab samples were analyzed for Cr and Yb via inductively coupled plasma (Optima 4300; Perkin Elmer, Wellesley, MA). Liquid (Cr) and solid (Yb) passage rates (%/h) were determined from the slope of the natural log of Cr (24 to 96 h) and Yb (48 to 120 h) concentrations regressed against hour.

Serum samples were analyzed for cortisol by RIA using components of commercially available kit validated for cattle (Kiyma et al., 2004). Tumor necrosis factor alpha (**TNFα**) concentrations were determined via double antibody RIA in serum samples obtained prior to LPS infusion and at 2, 4, and 6 h post-LPS on d 1 and 3 of the collection period. Antisera to bovine TNFα was obtained from Serotec Inc. (Raleigh, NC). Recombinant bovine TNFα (R & D Systems, Minneapolis, MN) was used as the standard and to prepare ^{125}I-bTNFα (chloramine T method). Assay sensitivity (90% displacement) was 0.4 ng/tube and addition of increasing amounts of bovine serum resulted in TNFα values that paralleled the standard curve. Within and between assay CV were less than 15% for cortisol and TNFα . Plasma AA concentrations were determined via gas chromatography (Varian CP-3800, Varian, Walnut Creek, CA) using a commercially available kit (EZ:FAAST; Phenomenex, Torrance, CA).

Statistics. All data were analyzed using the Mixed procedure of SAS (SAS Inst. Inc., Cary, NC). The model included effects of Met, LPS, and Met × LPS for all dietary measures. Rectal temperature, serum cortisol and TNFα, and plasma AA were analyzed as repeated measures (covariance structure = autoregressive order one). The model included all possible combinations of Met, LPS, hour, and day. Effects of day were evaluated for serum cortisol and TNFα only, to characterize LPS dose effects between d 1 and 3. Data are presented as least squares means with differences considered significant at $P < 0.05$.

Results

An LPS × hour × day interaction ($P < 0.05$) was observed for serum concentrations of cortisol (Figure 1) and TNFα (Figure 2). Serum cortisol peaked 4 h following LPS infusion on d 1, and remained elevated ($P < 0.01$) for 12 h; cortisol peaked 2 h after LPS infusion on d 2 and remained elevated ($P < 0.01$) for 6 h. Serum TNFα peaked 2 h following LPS infusion, but peak concentrations were greater ($P < 0.01$) on d 1 (57.2 ng/mL) than d 3 (6.5 ng/mL). Supplemental Met reduced serum cortisol in +LPS steers, but not –LPS steers (LPS × Met interaction, $P < 0.05$). Rectal temperature (Table 2) was elevated ($P < 0.05$) in response to LPS, but not affected by Met addition.

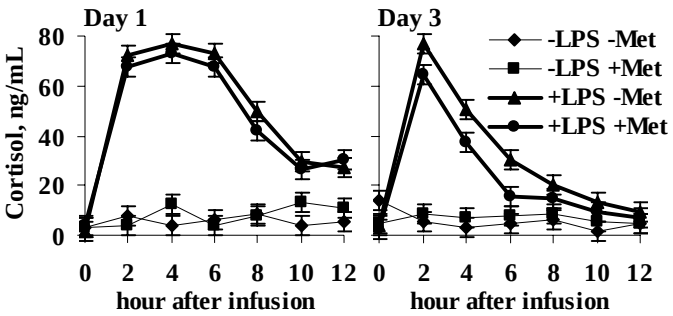

Figure 1. Serum cortisol concentrations in response to Met supplementation and endotoxin challenge in steers. Effects of LPS × hour × day ($P < 0.01$), and LPS × hour ($P < 0.01$).

No LPS × Met interactions ($P = 0.25$ to 0.99) were observed for dietary DM and N intake, feces, and urine, or passage rates. Also, DM intake and fecal DM were not affected ($P = 0.08$ to 0.95) by LPS and Met (Table 2). However, DM digested decreased ($P < 0.05$) in response to LPS, likely due to a tendency ($P = 0.13$) for lower DM intake in +LPS steers. Infusion of LPS did not affect ($P = 0.23$ to 0.82) N intake, fecal N excretion, and N digested. However, LPS increased ($P < 0.05$) urinary N excretion and decreased ($P < 0.01$) N retention resulting in a negative N balance for +LPS steers. Supplementation of Met increased

($P < 0.05$) fecal N excretion of steers, but did not affect ($P = 0.42$ to 0.99) N intake and urinary N excretion. Supplemental Met did not alter ($P = 0.42$) N digested and N retained regardless of increased fecal N excretion. Liquid (Cr) and solid (Yb) passage were decreased ($P < 0.01$) by LPS, but increased ($P < 0.05$) in response to Met supplementation.

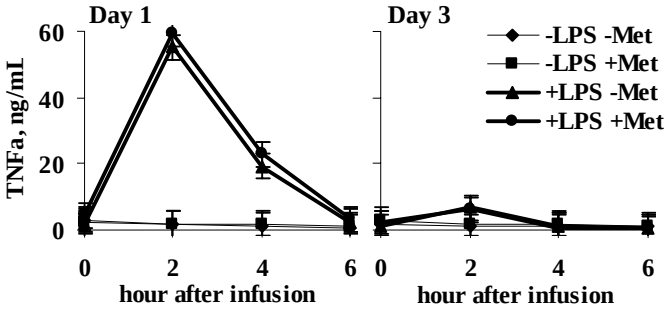

Figure 2. Serum tumor necrosis factor alpha (TNFα) concentrations in response to Met supplementation and endotoxin challenge in steers. Effects of LPS × hour × day ($P < 0.01$), and LPS × hour ($P < 0.01$).

Plasma Met (Figure 3) was greater ($P < 0.01$) for +Met steers prior to LPS infusion, but declined ($P < 0.01$) for +LPS steers such that their plasma Met at 4 to 10 h post-LPS were not different ($P > 0.09$) from non-supplemented steers (LPS × Met × hour interaction, $P < 0.01$). An LPS × hour interaction ($P < 0.01$) occurred for plasma concentrations of Lys, Leu, Ile, Phe, Trp, and total nonessential AA (**NEAA**). Plasma concentrations of Lys decreased ($P < 0.05$) at h 4, 8, and 12 after LPS. Plasma concentrations decreased from 4 to 8 h for Leu ($P < 0.05$), from 2 to 12 h for Ile ($P < 0.05$), from 4 to 10 h for Phe ($P < 0.05$), and from 2 to 12 h for Trp ($P < 0.01$). Total NEAA decreased ($P < 0.01$) from 4 to 12 h post-LPS. The pattern of decline for total NEAA is due to LPS × hour interactions ($P < 0.01$) for plasma concentrations of Gly, Ser, Pro, and Asn (data not shown). Infusion of LPS decreased ($P < 0.01$) plasma concentrations of Val (154.4 vs. 137.2 μ*M*) and Thr (59.0 vs. 40.8 μ*M*). Plasma His concentrations were not affected by LPS and Met.

Discussion

Observed increases in serum cortisol, and TNFα are indicative of the level of immunostimulation invoked by infusion of LPS. Cortisol increased as a result of stimulation of the hypothalamic-pituitary-adrenal axis. The rise in TNFα, a cytokine, is attributed to local stimulation of activated immune cells. Cytokines stimulate hepatic synthesis of acute phase response proteins, which increases metabolic AA demand (Le Floc' h et al., 2004).

The increase in N excretion following LPS likely arises due to mobilization of tissue protein to meet the AA demands of the activated immune system. During immunological stress, AA are partitioned away from tissue accretion to support the immune response. Reeds and Jahoor (2001) speculated that increased N excretion in humans during sepsis occurred due to imbalances between the supply of AA from mobilized tissue protein and the AA composition of acute phase response proteins. These imbalances result in mobilization of excess tissue protein which is catabolized and excreted as N. The absence of an interaction between LPS and rumen protected Met for N retention indicates that LPS-challenged steers did not exhibit increased requirements for Met and that Met was likely not limiting for steers exposed to LPS. The decline in plasma Met of Met-supplemented steers following LPS, and lack of a similar decline in non-supplemented steers suggests, that the Met provided was either utilized by the immune system or catabolized by the liver.

Acute phase response proteins are primarily composed of Phe, Trp, Lys, Cys, and Ser in humans (Reeds and Jahoor, 2001). Therefore the observed decline in plasma concentrations of Phe, Trp, Lys, Leu, Ile, and NEAA may partially be due to increased acute phase response protein synthesis. However the decline in plasma concentrations may also be indicative of increased demand for glucogenic precursors.

Implications

These findings imply that supplemental dietary methionine does not alleviate the negative effects of bacterial lipopolysaccharide on nitrogen utilization, and that metabolic demands for other amino acids may increase following exposure to bacterial lipopolysaccharide.

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Table 2. Effects of Met supplementation and endotoxin challenge on rectal temperature and dietary intakes, feces, urinary N, and passage rates of growing beef steers

	Treatments[a]							
	-LPS		+LPS			*P* value		
Item	-MET	+MET	-MET	+MET	SEM[b]	LPS	Met	LPS × Met
n	5	5	5	4				
Rectal Temp, ºC	38.7	38.7	39.0	38.9	0.10	0.03	0.90	0.77
DM, g/d								
Intake	3755	3755	3474	3494	160	0.13	0.95	0.95
Fecal	993	1141	971	1087	68.2	0.60	0.08	0.82
Digested	2762	2614	2503	2408	102	0.04	0.27	0.81
N, g/d								
Intake	78.2	78.2	73.2	73.3	4.98	0.36	0.99	0.99
Fecal	26.1	30.9	27.8	30.0	1.36	0.82	0.03	0.38
Digested	52.0	47.2	45.5	43.3	4.00	0.23	0.42	0.75
Urinary	30.8	32.3	50.4	47.2	5.81	0.01	0.88	0.70
Retained	21.2	14.9	-5.0	-3.9	2.96	< 0.01	0.42	0.25
Passage, %/h								
Cr	4.81	5.29	2.88	3.85	0.30	< 0.01	0.03	0.44
Yb	2.49	2.88	1.38	2.08	0.21	< 0.01	0.02	0.47

[a] Infusion (i.v.) of sterile saline (-LPS) vs. lipopolysaccharide (+LPS), and supplementation of 0 g/d (-MET) vs. 14 g/d (+MET) of rumen protected Met.
[b] Standard error of the mean for 5 steers per treatment.

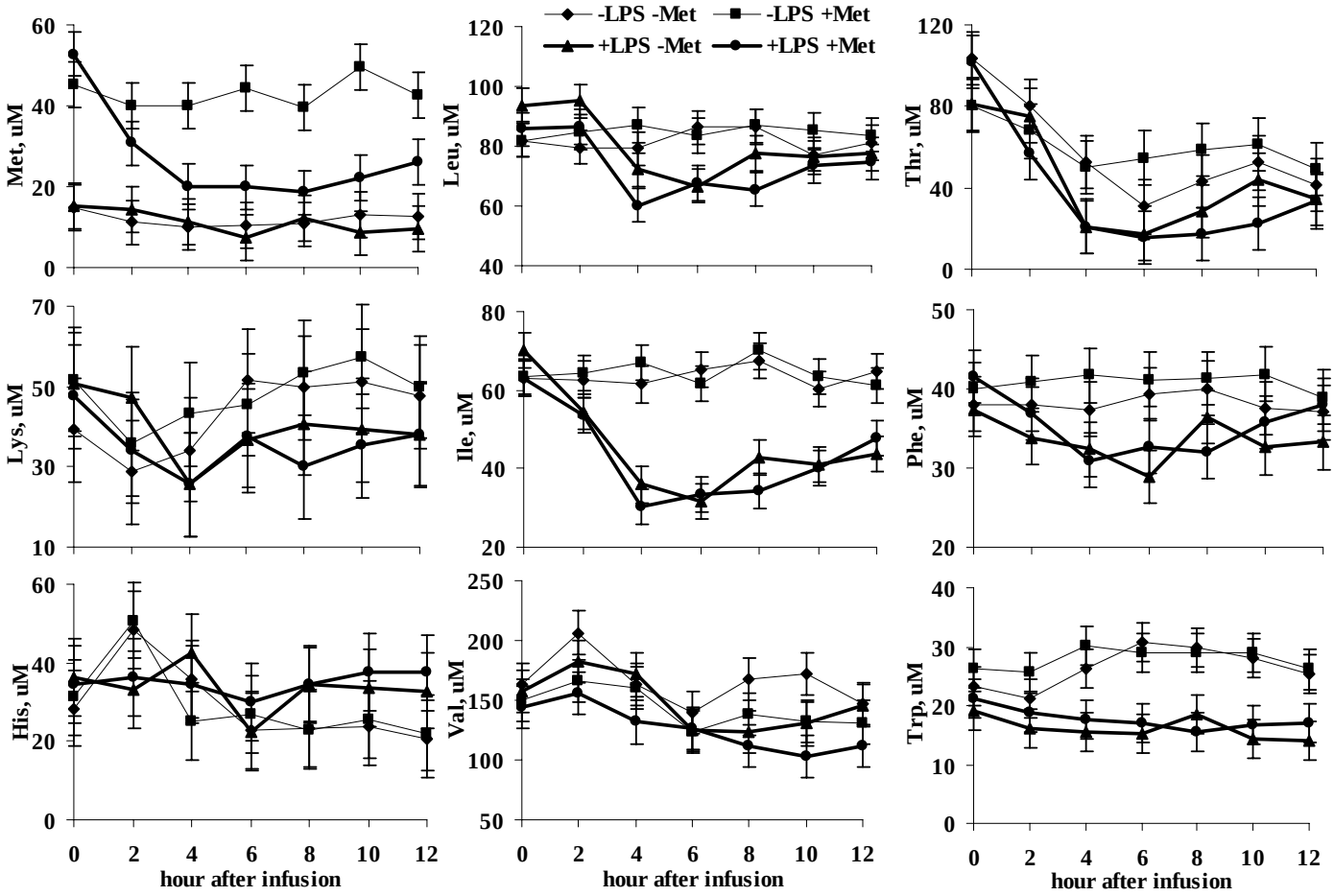

Figure 3. Plasma amino acid concentrations in response to Met supplementation and endotoxin challenge in steers. Effects of LPS × Met × hour ($P < 0.01$) for plasma Met, LPS × hour ($P < 0.01$) for plasma Lys, Leu, Ile, Phe, and Trp, and LPS ($P < 0.01$) for Val and Thr.

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INHERITANCE OF HAIR SLICKNESS SCORE AND ITS CORRELATION WITH GROWTH

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ABSTRACT: Cattle hair length and time of shedding are variable and in combination with temperature can affect performance. In a highly humid, subtropical region such as Brazil, where temperatures often reach 43°C during the summer, cattle that shed hair early and maintain a short hair coat tend to be more productive. The objective of this research was to determine heritability of hair slickness score and its correlation with growth. Hair scores were collected on Limousin cattle (n = 1807) in the United States and (n = 428) in Brazil in the summer of 2004. Records represented 347 sires and included 1775 females and 32 males in the United States. Brazilian records represented 84 sires and included 369 females and 59 males. Hair slickness scores were based on coat length and extent of shedding, and ranged from 1 (short, early shedding) to 5 (long, late-shedding). Hair slickness score, weaning weight, and post weaning gain were analyzed using a multivariate model in ASREML. This model was fit using the fixed effects age of dam, sex, and relevant contemporary group effects. Animal was included as a random effect. Day of age at the time of scoring, weaning age, and yearling age were fit as covariates in the model. Heritability estimated in the United States for hair slickness score was 0.33 ± 0.07. Estimated genetic correlations between hair slickness score and growth traits from US data were 0.04 ± 0.31 for weaning weight direct and 0.14 ± 0.32 for post weaning gain. Brazilian data was inadequate for reliable estimation of genetic parameters, but raw phenotypic correlations were negative, being –0.17 for weaning weight direct and –0.30 for post weaning gain. Sires whose progeny were slick haired had higher weaning weights and post weaning gains than progeny of non-slick sires. The ability of an animal to shed hair could be evaluated and the resultant EPDs may aid cattle producers selecting bulls from the United States to improve offspring growth in Brazil.

KEY WORDS: Cattle, hair score, growth, adaptation

Introduction

Heat tolerant cattle outperform temperate cattle in subtropical regions (Colditz and Kellaway, 1972; Olson et al., 1991; Hammond and Olson, 1994). This may be due to anatomical, coat type, or physiological differences. Temperate cattle typically have wooly coats that are darker in color while heat tolerant cattle have a lighter-colored hair coat that is sleek and shiny (Hansen, 1990). Slick coats are associated with high growth rates (Schleger and Turner, 1960; Peters et al., 1982; Prayaga, 2003) and low body temperatures (Peters et al., 1982). Deep body temperatures have been indirectly associated with heat tolerance and hair length (Olson et al., 2003; Prayaga, 2003), thus hair length is an important aspect of heat tolerance and may be genetically determined. The objective of this research was to determine heritability of hair slickness score and its correlation with growth in Limousin cattle.

Materials and Methods

Hair scores provided by the North American Limousin Foundation (**NALF**) were collected on Limousin cattle in the United States (**US**; n = 1807) and Brazil (**BR**; n = 428) in the summer of 2004. Hair slickness scores were based on coat length and extent of shedding: short, straight, slick hair, sheds early (1), shorter, slicker and straighter than average (2), average hair and shedding (3), longer, curlier and slower to shed than average (4), or long, curly and late shedding hair (5). Individuals scored in the US were progeny of 347 sires and included 1775 females and 32 males. Individuals scored in BR were progeny of 84 sires and included 369 females and 59 males.

Genetic correlations and heritabilities for hair slickness score were estimated using ASREML (Version 1.10, VSN International, Ltd., Hampstead, England). Multivariate models for the US and BR data separately or jointly used hair score, adjusted weaning weight, and post weaning gain as response variables. Adjusted 205-day weaning weight and adjusted 365-day yearling weight were calculated according to BIF Guidelines (BIF, 2002). Post weaning gain (**PWG**) was calculated by subtracting adjusted yearling weight from adjusted weaning weight.

Sex, hair score (**HS**) contemporary group, and age of dam were fit as fixed effects and animal as a random effect for HS. Contemporary group for HS consisted of herd and score date with linear covariates of age in days at the time of scoring and age in days squared. Age of dam and weaning contemporary group were fit as fixed effects and animal was a random effect for weaning weight direct (**WWD**). An additional random effect for weaning weight was a maternal genetic effect. Weaning contemporary group consisted of weaning work group, breeder weaning management code, NALF weaning contemporary group, sex, percent Limousin, creep/foster code, and recipient cow breed if an embryo transfer. Weaning age in days was fit as a linear covariate for weaning weight. Fixed effects for PWG included age of dam and yearling contemporary group while animal was a random effect. Yearling contemporary group consisted of weaning contemporary group, yearling work group, yearling management code, NALF yearling contemporary group, sex, and percent

Limousin. A linear covariate of yearling age in days was fit for PWG.

A similar multivariate model was used for the BR cattle. However, weaning contemporary group consisted of herd prefix, weaning date, sex, and recipient cow breed if an embryo transfer. Yearling contemporary group consisted of herd prefix, weaning contemporary group, yearling date, and sex. Age in days at the time of scoring was the only linear covariate fit for HS.

Parameters for PWG and weaning weight including covariances were assumed from literature values. Assumed heritabilities of PWG, WWD, and weaning weight maternal (**WWM)** were 0.22, 0.27, and 0.15, respectively. The genetic correlation between PWG and WWD was assumed at 0.55 while the residual correlation was assumed at 0.16. Only variances and covariances with HS were treated as unknown and estimated from the data. All correlations involving WWM, with the exception of HS, were assumed to be zero.

Results and Discussion

Hair slickness score was moderately heritable in the US (h^2 = 0.33 ± 0.07) in agreement with the 0.38 estimate of Jenkinson et al. (1975). There was essentially no genetic or phenotypic association (Tables 1 and 2) between HS and genetic or phenotypic PWG and weaning weight. This lack of association may be unique to the mild climate typical of the areas of the US where these records originated.

Bivariate analysis between US adults and yearlings generated a genetic correlation estimate of 0.74 indicating adult and yearling HS were much the same trait. However, inadequate yearling data prevented estimating the genetic correlation between adults and yearlings in Brazil. Heritability for hair slickness score in BR adult cattle was 0.17 ± 0.12, however, the high standard error indicates this estimate is not very reliable (Samuels and Witmer, 2003) perhaps simply reflecting the small data set. Genetic correlations between adult hair scores measured in BR and the US could not be calculated because the pooled data sets provided practically no information for this parameter as reflected by a ridge in the likelihood surface. Positive, negative, and zero genetic correlations were equally supported.

Phenotypic analysis of BR hair score, weaning weight, and post weaning gain indicated hair score was negatively correlated with weaning weight (r_p = -0.17) and post weaning gain (r_p = -0.30) in that country. Schleger and Turner (1960) determined the phenotypic correlation between gain and hair length to be -0.47 and Prayaga (2003) determined the same correlation to be -0.35, in agreement with the values calculated in the current study. These results differ from the US and may reflect the harsher climate of Brazil where summer temperatures can reach as high as 43°C.

The US data contained a larger number of related individuals and a more even proportion of individuals in each HS category compared to the BR data. In addition, hair slickness score was more heritable with a lower standard error indicating the US data provided a more reliable estimate.

Hair slickness score is moderately heritable and is negatively associated with weaning weight and post weaning gain in Brazil but not in the US. This indicates the possibility of selecting bulls in the US based on hair score to improve offspring growth in a subtropical climate. Caution should be used when implementing these findings because these associations were estimated using a small data set, which included unrelated animals and no indication to the number of observers collecting the scores. A larger data set with more related animals and hair scores collected by a single observer would provide more reliable estimates for heritability of hair slickness score and its associations with weaning weight and post weaning gain.

Implications

Hair score appears to be genetically controlled and correlated with growth in Brazil. Thus, hair score may be used to indirectly select for increased growth performance in subtropical climates. The results suggest EPDs for hair score measured in the US may aid cattle producers selecting bulls from this country to improve offspring growth in Brazil.

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Effects of hCG and Progesterone Administered to Ewes Post Breeding on Serum Concentrations of Progesterone and Estradiol[1]

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ABSTRACT: The objective of the experiment was to increase serum concentrations of progesterone (P_4) and estradiol (E_2) in the ewe during the period of maternal recognition of pregnancy. Thirty multiparous ewes were randomly assigned a treatment of control, hCG, and hCG + progesterone. Vasectomized rams were used to determine onset of estrus (d 0) in all ewes and fertile rams were hand mated to each ewe at onset of estrus and 12 h post onset. Control ewes were given 0.1 ml of saline and 0.1 ml (100 IU) hCG was administered to both hCG and hCG + progesterone treated ewes on d 11.5. Progesterone (0.3 mg) was administered via CIDR to hCG + progesterone treated ewes on d 4 and removed on d 18 post breeding. Blood samples were collected on d 11, 12, 13, and 18 from each ewe. Serum E_2 and P_4 concentrations were analyzed using RIA. No difference in P_4 concentrations were observed among treatments on d 11 ($P > 0.1$) or d 18 ($P > 0.5$). Day 12 serum P_4 concentrations were greater ($P = 0.01$) for hCG + progesterone ewes than hCG and control ewes, however, d 13 P_4 concentrations were greater ($P < 0.05$) for hCG and hCG + progesterone treated ewes than for control ewes. No difference in E_2 concentrations were observed among treatments for d 11 ($P > 0.1$) and d 18 ($P > 0.5$). Estradiol concentrations for hCG and hCG + progesterone treated ewes were greater than controls for both d 12 ($P < 0.05$) and d 13 ($P < 0.01$). In conclusion P_4 containing CIDRs had no effect on serum P_4 concentrations on d 11 (before hCG injections) or d 18 (after hCG effects diminished) and only increased d 12 and 13 serum P_4 concentrations after hCG injections. Also, hCG increased E_2 concentrations on d 12 and 13, while increasing P_4 on d 13.

Keywords: sheep, progesterone, human chorionic gonadotropins, CIDR

Introduction

Reproductive inefficiency is a significant economic loss to the sheep rancher. When evaluating lamb loss in range ewes, Redden et al. (2006) found that 31% potential lambs were absent at weaning and 76% of the lamb loss occurred before birth. Diskin and Sreenan (1980) indicated that early bovine embryonic death accounts for about 75 to 80 percent of all embryonic and fetal losses. For an embryo to survive through the first estrous cycle, progesterone (P_4) must go through three important phases (Wilmut et al., 1985). Progesterone needs to be in low concentrations in the plasma from ovulation to d 3 post mating, rise continually through d 7 post mating, and remain elevated until the placental mass can produce sufficient P_4 to sustain the pregnancy. Progesterone has been proven to play a significant role in synchrony of the ovine uterus and embryo when supplemented with exogenous P_4 before luteal P_4 production begins (Lawson and Cahill, 1983). Inhibiting synthesis of P_4 with epostane on d 11 and 12 post mating depressed embryonic survival, while epostane treatments on d 9 and 10, d 10 and 11, and d 12 and 13 were not different from controls (as reviewed by Parr et al., 1992). Kleeman et al. (1991) increased embryonic survival in highly ovulating ewes with exogenous P_4 supplementation from d 4 through d 14 post mating. Increases in growth of the embryo can also be attributed to supplementing exogenous progesterone (Kleemann et al., 1994; Nephew et al., 1994), granted it can be advantageous and/or detrimental to the livelihood of the conceptus depending on the degree and timing of growth. Faris et al. (2004) administered P_4 containing CIDR (controlled internal drug release) devices post mating, which raised serum P_4 concentrations in the ewe, but no difference was detected in embryonic survivability. Nephew et al. (1994) gave injections of hCG (100 IU; human chorionic gonadotropins) on d 11.5 which increased endogenous production of P_4 and estradiol (E_2), increased interferon tau (maternal recognition of pregnancy protein) concentrations, increased embryonic growth, and tended to increase embryonic survival. Cam and Kuran (2004) gave hCG injections (150 IU) which increased d 45 fetal weights , increased birth weights, and improved embryonic survival. Therefore, this study was conducted to measure the effects of P_4 containing CIDRs and hCG

[1]The authors' wish to thanks Dr. Dennis Hallford for conducting the hormone assays.

injections on serum concentrations of P_4 and E_2 at the time of maternal recognition in the ewe.

Material and Methods

Multiparous Suffolk ewes (n=30) were randomly assigned to treatments of control, hCG, or hCG + CIDR and treatments were equally divided into four pens. Ewes were fed chopped alfalfa (2.3 kg/ewe) and ground corn (0.45 kg/ewe) two weeks prior to the trial and throughout the breeding season. Vasectomized rams equipped with crayon marking harnesses detected estrus and ewes were checked daily for marks at 0600 and 1800 for 20 days. Ewes marked (d 0) were hand mated to a fertile ram at onset of estrus and 12 h post onset. Four days after breeding hCG + CIDR treated ewes received a CIDR (0.3 g; Pharmacia & Upjohn, Rydalmere, AU) and all CIDRs were removed on d 18. On d 11.5, control ewes were injected (i.m.) with 0.1 mL of saline, while hCG and hCG + CIDR received an i.m. injection of 0.1 mL of hCG (100 IU; Intervet Inc., Millsboro, DE). Blood samples were collected (jugular venipuncture) using 10 mL vacuum serum separator tubes from all ewes on d 11, 12, 13, and 18. Blood was centrifuged (1500 X g) for 15 min and serum was harvested and stored frozen (-20ºC). All procedures were approved by the NMSU, Institutional Animal Care and Use Committtee (2005-019).

Serum P_4 concentrations were determined via RIA using components of a commercial kit (Diagnostics Products Corp., Los Angeles, CA) and validated for use in ruminants as described by Schneider and Hallford (1996). Serum Estradiol 17β RIA utilized components of a diagnostic system kit (Webster, TX) with prior extraction using ethyl acetate:hexanes (2:1, volume:volume). Coefficient of variations for both assays was less than 10%.

Serum hormone concentrations were analyzed as a split-plot design (PROC GLM of SAS; SAS Inst., Inc. Cary, NC). When a treatment by day interaction ($P < 0.05$) occurred, data were analyzed within day.

Results and Discussion

Serum P_4 concentrations were greater ($P < 0.05$) at d 12 (12 h after hCG injections) for the hCG + CIDR treated ewes than for hCG and control ewes (Table 1). On d 13, both hCG and hCG + CIDR treatments had greater ($P < 0.05$) serum P_4 concentrations than controls (Table 1). No difference ($P > 0.5$) in P_4 concentrations were found among treatments on d 11 and 18, which reveals that the P_4 CIDR devices were not affecting serum P_4 concentrations, contrary to Faris et al. (2004). Faris et al. (2004) demonstrated an average increase of 2 ng/mL of serum P_4 concentrations when CIDRs were administered on d 4 and removed on d 20. Similarly, Duffey et al. (2003) showed that CIDRs will elevate serum P_4 in ovariectomized ewes by at least 2 ng/mL for 8 days, however intact ewes given CIDRs on d 0 will have lower serum P_4 concentrations after d 8 than control intact ewes.

Serum E_2 concentrations were not different ($P > 0.1$) among treatments on d 11 (before hCG injections), while serum E_2 concentrations on d 12 and d 13 (12 and 36 h after injections, respectively) for hCG and hCG + CIDR treatments were greater ($P < 0.05$) than the controls. Day 18 serum E_2 concentrations were not different ($P > 0.5$) among treatments. Consistent with our study, Nephew et al. (1994) injected ewes with hCG and increase serum P_4 and E_2 concentrations for 36 h post injections.

Exogenous progesterone (CIDR) supplementation had no effect on serum E_2 concentrations, and had little effect on serum P_4 concentrations. A potential explanation for our inability to detect a serum P_4 response to exogenous P_4 supplementation is that the P_4 CIDRs down regulated the endogenous production of P_4 or up regulated the metabolism/deposition of P_4 in tissues. However, injecting hCG increases the ewes' endogenous production of P_4 and E_2 for at least 36 hours post injections.

Implications

We successfully measured elevated serum P_4 and E_2 concentrations during the time of maternal recognition in the ewe with hCG injections and progesterone CIDRs. Since increases in embryonic survival of reproductively inefficient ewes have been seen with supplementation of P_4 (Diskin and Niswender, 1989; Kleemann et al., 1991) and E_2 (Nephew et al., 1994), this protocol may be implemented as a one time easily administered method to improve reproductive efficiency. However, subsequent research is needed to prove that this protocol or a modified version of the protocol will consistently improve embryonic survival.

Additionally, the mechanism that did not allow serum P_4 concentrations to be elevated by exogenous P_4 supplementation warrants further research.

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Table 1: Serum concentrations of estradiol and progesterone in plasma of ewes after administrations of saline (control), human chorionic gonadotropins (hCG), or hCG plus a controlled intravaginal releasing device (CIDR).[1,2]

	Progesterone, ng/mL				Estradiol, pg/mL			
	Control	hCG	hCG+CIDR	SE	Control	hCG	hCG+CIDR	SE
Day 11	4.5	3.8	4.6	0.38	3.8	3.4	3.2	0.36
Day 12	4.7[a]	5.2[a]	6.6[b]	0.45	3.6[a]	4.9[b]	4.8[b]	0.37
Day 13	4.8[a]	5.8[b]	6.1[b]	0.35	3.4[a]	6.4[b]	6.6[b]	0.50
Day 18	5.0	4.6	5.1	0.49	3.3	3.4	3.4	0.34
n[3]	10	10	9		10	10	9	

[1] Thirty multiparous ewes were randomly assigned to treatments. Treatments were equally divided among four pens. Ewe represents the experimental unit. Treatment x day interactions for both hormones occurred ($P < 0.05$), so means were analyzed within day.

[2] Saline and hCG injections were given on d 11.5 and CIDRs were inserted on d 4 and removed on d 18 post onset of estrus. Vasectomized rams determined onset of estrus.

[3] One ewe lost the CIDR on d 14 and was removed from the experiment.

[ab] Row means with serum hormone concentrations (Progesterone and Estradiol) with different superscripts differ ($P < 0.05$).

Table 1. Heritability (diagonal) and genetic correlations (above diagonal) for hair slickness score (Score) (parameter ± SE), post weaning gain (PWG), weaning weight direct (WWD), and weaning weight maternal (WWM) for the United States Limousin cattle (n = 1807).

	Score	PWG	WWD	WWM
Score	0.33 ± 0.07	0.05 ± 0.25	0.07 ± 0.24	-0.11 ± 0.06
PWG		0.22[a]	0.55	0
WWD			0.27[a]	0
WWM				0.15[a]

[a] Parameters without standard errors were assumed from literature values.

Table 2. Phenotypic standard deviations (diagonal) and phenotypic correlations (below diagonal) for hair slickness score (Score) (parameter ± SE), post weaning gain (PWG), and weaning weight (WWT) for the United States Limousin cattle (n = 1807).

	Score	PWG	WWT
Score	1.05[a]		
PWG	-0.05 ± 0.04	41.44[a]	
WWT	-0.03 ± 0.05	0.55[a]	46.26[a]

[a] Parameters without standard errors were assumed from literature values.

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EFFECTS OF LEAFY SPURGE (*EUPHORBIA ESULA*) ON RUMINANT GAS PRODUCTION AND IN VITRO DIGESTION

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ABSTRACT: Leafy spurge (**LS**; *Euphorbia esula*) is indigenous to Eurasia and is rapidly changing the landscape in the northern Great Plains and Intermountain West. Sheep consume LS at a higher rate than cattle. Our objectives were to investigate LS in vitro digestibility and gas production by bovine vs ovine inoculum with or without LS in the diet. Two phases were used with two ruminally cannulated cows and ewes as rumen liquor donors. Each phase allowed for 7 d adaptation to diets. Phase 1 consisted of animals fed a diet of (DM basis) 15% LS (21.9% CP, 48% NDF, DM basis) and 85% barley hay (**BH**; 12% CP, 56% NDF, DM basis) based on previous day intake. Phase 2 animals were fed 100% BH. Substrates for in vitro digestion and gas production consisted of alfalfa or LS : BH ratio in 10% increasing increments for a total of 12 treatments. Gas production extent (mL) and rate (mL/h) were calculated after 96 h of incubation. There was a LS exposure × treatment interaction (P<0.01) observed for extent of gas production. Extent of gas production with increasing LS was reduced by 9% when animals were exposed to LS and by 11% with no LS exposure. A species × LS exposure interaction for rate of gas production (P=0.02) was observed. Exposure to LS decreased rate of gas production by 5% for bovine compared to ovine. However, no exposure to LS caused the opposite effect with a 5% increase in bovine rate of gas production. In vitro digestion was evaluated after 48 h incubation. Model main effects of treatment and species were significant for IVDMD (P<0.01 and P=0.06, respectively). Increasing LS:BH ratio in the substrate resulted in an 18% increase in IVDMD and bovine IVDMD was higher than ovine (72.1 vs 71.3 $\pm$ 0.31%). Alfalfa, BH, and LS IVDMD was 63, 65, and 81 $\pm$ 0.7%, respectively. These data indicate LS is highly digestible and prior exposure to LS may change rumen microbial ecology and ultimately influence utilization of LS in vivo.

Key words: Leafy Spurge, rumen microbiology, IVDMD

Introduction

Leafy spurge (**LS**; *Euphorbia esula* L.) infestation of rangelands in the Northern Great Plains is responsible for $130 million in losses to agricultural producers each year (Leistritz et al., 1995). Areas of rangeland infested with LS are responsive to control strategies involving herbicides and intensive grazing however, complete eradication of LS may be economically infeasible. Livestock grazing strategies for controlling LS are attractive to producers because of the ease of implementation.

Grazing ruminants exhibit a species difference in regards to LS consumption (Kronberg and Walker, 1999). Sheep tend to graze LS readily while cattle tend to avoid LS infested areas. Chemical composition of secondary plant metabolites in LS is one factor thought responsible for cattle avoidance. Various secondary metabolites have been isolated from LS plant tissue (Hirota et al., 1980; Kronberg et al., 1995) including compounds of diterpenoid ingenol ester origin, other diterpenes, and glucoronic acids (Wagner et al., 1970). These compounds have been correlated to digestive upset and LS intake aversion in cattle (Hein and Miller, 1992). Unfortunately, cattle avoidance of LS cannot be directly linked to a single plant metabolite making it difficult to pinpoint the metabolite responsible.

Ruminants possess a complex microbial population within their rumen that aids in feedstuff digestion and detoxification of plant compounds. Differences in composition and/or response of the microbial population to secondary plant metabolites could account for differences in LS consumption between cattle and sheep. The objective of this study was to determine the effect of LS on in vitro digestibility and in vitro gas production using substrate with increasing amounts of LS inoculated with rumen liquor supplied from cattle or sheep that either had been exposed or were naïve to LS.

Materials and Methods

Leafy spurge collection and preparation

Leafy spurge was collected three times in varying growth stages during the summer of 2005. The first collection was used for laboratory analysis and substrate for in vitro digestibility and gas production experiments. Second and third collections were used to feed donor animals supplying the rumen liquor portion of the inoculum for the in vitro digestibility and gas production experiments.

Initial collection took place on June 24, 2005. Leafy spurge was hand clipped at the soil surface in the early shoot, pre-bloom stage (approximately 8 cm in height) on Bureau of Land Management property near Terry, MT (46° 47’ 35” latitude and 105° 18’ 40” longitude) at an average elevation of 687 m and annual precipitation of 293 mm with the majority of precipitation occurring from early spring to late summer (WRCC, 2006). Hand clippings were placed in paper bags, sealed,

and stored in a cooler (32°C) to protect the integrity of the LS prior to transport to Fort Keogh Livestock and Range Research Laboratory (**LARRL**) in Miles City, MT. In the laboratory, leaves were manually stripped from harvested LS and stored in plastic bags at 20°C. The resulting leaves were freeze dried and analyzed by a commercial laboratory for DM, CP, NDF, and TDN. The subsequent LS collections were on July 8 & 13, 2005 respectively, near Terry, MT on Bureau of Land Management property running parallel to the Yellowstone River. A hand held, gas, sickle mower was used to harvest LS. All stages of growth were mowed and collected. Harvested LS was placed on plastic sheets in the bed of a pickup truck and immediately transported to LARRL. Upon arrival at LARRL, LS was separated from other plant species collected during harvest. The resulting LS was placed in paper bags, weighed, and stored at -20°C for future incorporation into experimental diets. A grab sample from each LS collection was sent to a commercial laboratory for analysis of DM, CP, NDF, and TDN.

Animals and management

Two ruminally cannulated mature cows weighing approximately 770 kg and two ruminally cannulated sheep weighing approximately 90 kg were used as rumen liquor donors. The Institutional Animal Care and Use Committee at LARRL approved animal care and management practices. Animals were monitored daily for any discomfort or adverse effects resulting from the consumption of LS throughout the experiment. Animals were housed individually in large holding pens at LARRL and were provided ad libitum access to water. Animals were adapted to the research pens and fed a diet consisting of 100% barley hay (**BH**) for 14 d. Animals were fed once per day at 0800. Feed refusals from the previous day were collected, weighed and recorded prior to feeding each morning.

To determine the effect of prior exposure to LS on in vitro digestibility and gas production, donor animals were fed and ruminal liquor was collected in two phases consisting of 14 d each. Upon completion of the adaptation period animals switched experimental diets. In Phase 1 diets contained 85% BH (12.0% CP, 33.7% NDF, and 64.1% TDN on a DM basis) and 15% LS (21.9% CP, 48% NDF, and 86.1% TDN on a DM basis). Animals were fed at 2.0% of body weight (DM basis) and LS was adjusted so that it was 15% of previous day total intake (BH + LS). Leafy spurge was hand cut to a length of < 8.0 cm. Each animal was fed the LS portion of the diet via the rumen cannula. During phase 2 animals were fed 100% BH at 2.0% of body weight (DM basis).

Digesta collection and preparation of fermentation samples

The substrate for in vitro digestibility and gas production was alfalfa (control) and LS replacing BH in 10% increments, for twelve treatments. Samples of LS, alfalfa, and BH were individually packaged in zip-lock bags, frozen at 4°C, and lyophilized. Lyophilized samples of LS, alfalfa, and BH were ground to pass a 2 mm screen. Roller bottles were used to ensure complete mixing of LS:BH combinations. Exactly 0.5 g of each treatment was weighed out and placed in 30 mL in vitro digestion tubes and 100 mL gas production syringes.

In vitro digestion (Tilley and Terry, 1963) was conducted in two phases. Rumen liquor was collected at 0600 on d 7 of each experimental phase. Rumen extrusa boluses were collected at the mat layer interface and strained through four layers of cheesecloth into collection thermoses that had been heated to 37°C for 24 h. A 350 mL sample of rumen liquor was collected from each animal of each species. The samples were transported to LARRL. Upon arrival at LARRL, the initial pH was taken from each rumen liquor sample. Additional 20-mL aliquots were collected for initial VFA concentrations. The remaining rumen liquor from each animal (250 mL) was combined to make a 500 mL sample for each species. The 500 mL of rumen liquor was then combined with 500 mL of pre-made phosphate buffer (70.8% Na_2HPO_4 and 29.2% KH_2PO_4; Menke et al., 1979) and 1000 mL of McDougal's buffer (Tilley and Terry, 1963). In vitro tubes with substrate were filled with 15 mL of inoculum, flushed with CO_2, and sealed with a plastic screw on tube cap. Tubes were randomly placed in 1 of 4 racks and manually agitated 10 times and inserted into the incubator (37°C) and were agitated every two hours for twelve hours and then every four hours until 48h. Tubes incubated for 0, 2, 6, 12, 24, and 48 h. Upon removal from the incubator, a 10 mL sample was removed for VFA analysis (fixed with 2 mL of 6N HCl) and stored at -20°C. Concentrations of VFA were measured using gas chromatography (Hewlett-Packard 5890 series II gas chromatograph, 2 m × 2 mm column, Supelco 10% SP-1200/1% H_3PO_4 on 80/100 Chromosorb WAW, N_2 carrier at 20 mL/min, flame ionization detector at 195°C).

Gas production (Blümmel and Ørskov, 1993) was also conducted in two phases with rumen liquor collected on d 14 of each phase. Gas production syringes (100 mL) were filled with 20 mL of inoculum and 0.5 g substrate, excess air was released, plungers inserted, and then placed into the 120-slot water bath (37°C). Gas measurements were recorded 0, 2, 4, 6, 8, 10, 12, 14, 16, 24, 30 36, 48, 54, 60, 72 and 96 h. Gas syringes were reset when gas produced exceeded 80 mL.

In vitro dry matter digestibility (**IVDMD**) was calculated from the amount of substrate remaining after digestion with rumen liquor inoculum at 24 and 48 h (DM basis). Rate and extent of gas production were calculated using GraphPad Prism (GraphPad, 2003). The exponential model $y = B * (1\text{-}exp^{-c*(t\text{-}lag)})$ assumed one pool of gas production (B) with a constant fractional rate of gas production (c) with a lag phase (lag) in the onset of gas production.

Statistical analysis

Data were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). The model included

treatment, species, phase, and appropriate interactions. When significant ($P < 0.05$) treatment means were separated using LS means and pdiff.

Results and Discussion

Treatment and exposure to LS had a significant effect on 48 h IVDMD ($P < 0.01$ and $P < 0.01$, respectively). As LS level increased, IVDMD increased with 100% LS more digestible than alfalfa and BH (80.7, 63.8 and 65.8, $\pm$ 0.7%, respectively; Table 1). Exposure of the donor animal to LS decreased IVDMD (64.3 vs 73.3 + 1.1%). Species of the donor animal had tendency to effect IVDMD ($P = 0.06$) with bovine inoculum having a greater IVDMD than ovine (72.1 vs 71.3 $\pm$ 0.3%). The LS used as substrate to evaluate IVDMD was in the early shoot, pre-bloom stage and the BH was a lower quality more mature forage. The nutrient content of LS was comparable to immature alfalfa or cool season grasses (NRC, 2001). In vitro digestibility values obtained in this experiment indicate that LS is a highly digestible feed.

The *in vitro* gas production is a predictive tool by which the kinetics of rumen fermentation can be assessed. Relationships have been observed between a feed's gas production profile and *in vivo* parameters, such as digestibility and feed intake (Russell and Strobel, 1988). Since the gas production technique simulates fermentation in the rumen, it could conceivably be used to predict the pattern of rumen fermentation of LS. Gas production extent (mL) and rate (mL/h) were calculated after 96 h of incubation. There was a LS exposure × treatment interaction ($P < 0.01$) observed for extent of gas production. Extent of gas production with increasing LS was reduced by 9% when animals were exposed to LS and by 11% with no LS exposure. A species × LS exposure interaction for rate of gas production ($P = 0.02$) was observed. Exposure to LS decreased rate of gas production by 5% for bovine compared to ovine. However, no exposure to LS caused the opposite effect with a 5% increase in bovine rate of gas production.

Fermentation of the carbohydrate portions of the diet results in the formation of short chain fatty acids which in turn are the main source of energy for maintenance and production in the ruminant. Production of VFAs are also an indicator of fermentation activity of the rumen microbial population (Dehority, 1997). It has been speculated that the differences in foraging behavior between cattle and sheep in regards to LS consumption may be due to differences in metabolism of the secondary metabolites by ruminal microbes present in different species (Kronberg et al., 2006). Our data indicate that acetate, propionate, and total VFA production is influenced by the concentration of LS within the in vitro digestion substrate and if donor animals had been exposed to LS. Acetate, propionate, and total VFA production was influenced by treatment and LS exposure (treatment × LS exposure; $P < 0.01$). When donors animals were not exposed to LS there was an increase in acetate, propionate, and total VFA production when 10 or 20% LS was added compared to all other treatments ($P < 0.01$). When greater than 30% LS was added to in vitro incubation VFA levels were similar to alfalfa and BH ($P > 0.10$; data not presented).

These data indicate that secondary plant metabolites present in LS may not be directly detrimental to key ruminal microbes responsible for VFA production. Additionally, gradually introducing animals to LS may increase the rate of LS consumption by allowing the rumen microbial population to adapt to the metabolites present in LS. Adaptation of ruminal microbes to secondary metabolites has been demonstrated with plants that accumulate oxalates and animals naïve to mimosine (Allison and Cook, 1981; Allison et al., 1990)

Acetate and total VFA displayed a species × LS exposure interaction ($P < 0.01$; Figure 1). Incubations using inoculum from ovine that had been exposed to LS produced more total VFA and acetate than bovine ($P < 0.05$). Greater production of VFA may be one method coping with secondary plant metabolites present in LS by sheep and goats and indicate a difference in microbial population present in sheep vs. cattle. Small ruminants are more resistant to aversion of LS after consumption (Kronberg et al., 2006).

Implications

These data indicate that leafy spurge is a high quality forage and ruminal fermentation is not compromised by including leafy spurge in ruminant diets. Consumption of leafy spurge by ruminants will help to alleviate this invasive weed from rangeland in the Northern Great Plains while yielding a high quality protein product in early spring to mid summer for the consumer. Additional studies to examine the biotransformation of the chemical components of leafy spurge by rumen microbial population of the bovine and ovine need to be conducted. These additional studies will aid in determining what is causing the foraging behavior differences between sheep and cattle.

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Table 1. Fermentation responses to barley hay and leafy spurge on in vitro dry matter digestibility and rate of gas production.

	Treatment (barley hay:leafy spurge)												
Item	100:0	90:10	80:20	70:30	60:40	50:50	40:60	30:70	20:80	10:90	0:100	Alfalfa	SEM
IVDMD[a]	60.9^{x}	61.2^{x}	64.7^{x}	64.5^{x}	66.3^{x}	67.6^{x}	69.1^{y}	71.2^{yz}	82.4	77.5^{z}	79.1	61.6^{x}	2.73
GP[b]													
Rate[c]	0.055^{t}	0.051$^{tu}_{x}$	0.048$^{u}_{v}$	0.050$^{tu}_{vw}$	0.051$^{tu}_{vx}$	0.052$^{tu}_{vy}$	0.055$^{tu}_{xy}$	0.057^{ty}	0.051$^{tu}_{wxy}$	0.057^{ty}	0.057^{ty}	0.072^{z}	0.002

[a]IVDMD = in vitro dry matter digestibility.
[b]Gas Production.
[c]mL/h.
[t,u,v,w,x,y,z]Means within a row lacking a common superscript letter differ (P <0.05).

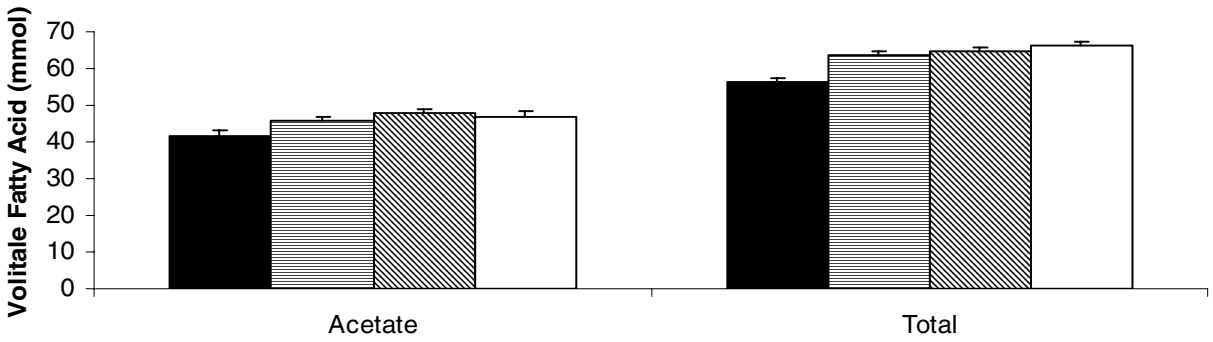

Figure 1. Mean concentration (mmol) of acetate and total VFA for species × leafy spurge exposure interaction (P > 0.01) where species consumed LS prior to sampling (■ bovine ▨ Ovine) and no prior exposure to LS (▭ bovine □ Ovine).

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EFFECTS OF RACTOPAMINE IN COMBINATION WITH VARIOUS HORMONE IMPLANT REGIMENS ON GROWTH AND CARCASS ATTRIBUTES IN CALF-FED HOLSTEIN STEERS.

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ABSTRACT: Anabolic steroid hormone implants have been used commercially in feedlot cattle for several decades. Recently, the β-adrenergic agonist, ractopamine (**RAC**), has been approved for use as a feed supplement in beef cattle to increase lean muscle deposition, ADG, and improve feed efficiency. The effects of several anabolic steroid implants were examined with or without RAC to determine feedlot and carcass performance of calf-fed Holstein steers. In a completely randomized design, 800 cattle were evaluated; cattle were divided into eight treatments (**Table; contains treatment abbreviations**). Terminal implants were administered 104d prior to harvest, and RAC was fed (200mg/hd*d) continuously during the 36d immediately preceding harvest. Cattle administered RAC had improved HCW and LM area (**LMA**) of 5.7 kg and 1.94 cm^2 (P<0.05) respectively over cattle not fed RAC. All RAC plus implant treatments had greater final weights, HCW, and LMA than C (P<0.05). In addition, treatments MTR and EP resulted in mean HCW greater than R (P<0.05); treatments MT and MTR resulted in greater REA than R (P<0.05); treatments MT+R, MT, HT+R, HT, and EP+R resulted in larger LMA than R (P<0.05). Treatment MT+R had the largest mean LMA overall (P<0.05). Overall, the addition of RAC to feedlot diets increased ADG, HCW, and LMA in a manner that is additive to implant effects.

	Ractopamine Treatment	
Implant Treatment	**(-) RAC**	**(+) RAC**
Control	C	R
20 mg EB[a] 200 mg P_4[b]	EP	EP+R
24 mg E_2[c] 120 mg TBA[d]	HT	HT+R
16 mg E_2 80 mg TBA	MT	MT+R

[a] Estradiol Benzoate
[b] Progesterone
[c] Estradiol
[d] Trenbolone Acetate

Key words: ractopamine, Holstein steer, β-agonist

Introduction

Improving the efficiency of animal production and increasing meat yields are goals of feedlot managers. Traditionally, feedlots fed cattle of conventional beef breeds such as Hereford, Angus, and crossbreds. In the last few decades, feedlots have increased their numbers of Holstein steers, a byproduct of the dairy industry. Holstein carcasses yield smaller LM areas (**LMA**), and similar marbling scores without excessive backfat, when compared to typical beef breeds (Perry et al., 1991). As a means of improving size of LMA and lean deposition in the body anabolic hormonal implant steroids are routinely used. In addition, other means of improving lean deposition have been evaluated. 1991). Ractopamine is a β-agonist that stimulates β-adrenoceptors on muscle cells which in turn activates a series of responses resulting in phosphorylation of enzymes and regulatory factors important in metabolic regulation. These metabolic initiations increase protein synthesis, in addition to catabolism of lipids which are used for other metabolic processes (Moody et al., 2000). Studies involving swine have reported that the nutrient repartitioning agent, ractopamine, improves lean deposition as well as feed efficiency (Moloney et al.,

Numerous studies have demonstrated the benefits of ractopamine on growth and red meat yield (Moloney et al., 1990), yet few have examined the effects of ractopamine used in combination with anabolic hormone implants. There is also little information on the combined effect on Holstein cattle in a feedlot. Therefore, the objective of this study was to feed ractopamine hydrochloride (**RAC**) with three different anabolic hormone treatments to Holstein steers, and determine the effect on carcass quality, yield, and tenderness.

Materials and Methods

Management. Eight hundred Holstein steers averaging 442kg and 12-14 months of age were weighed and allotted (one hundred animals per treatment) to one of eight treatments: 1) non-implanted non-ractopamine fed control (**C**); 2) implanted with 20mg estradiol (E_2) plus 200mg progesterone (**EP**); 3) implanted with 24mg E_2 plus 120mg trenbolone acetate (**TBA**) (**HT**); 4) implanted with 16mg E_2 plus 80mg TBA (**MT**); 5) non-implanted and administered 200mg/hd*d ractopamine-HCl (**R**) in the feed; 6) implanted with EP and and administered 200mg/hd*d ractopamine-HCl (**EP+R**) in the feed; 7) implanted with HT and administered 200mg/hd*d ractopamine-HCl (**HT+R**) in the feed; 8) implanted with MT and administered 200mg/hd*d ractopamine-HCl (**MT+R**) in the feed. Steers were implanted and weighed 104d prior to harvest, and administered RAC 36d prior to harvest. Steers were fed a corn-alfalfa based ration typical of diets fed in Southwestern US feedyards.

Carcass Data Collection. Steers were transported to a commercial harvest facility by truck where they were kept separate according to treatment. Individual animal identity was maintained throughout the harvest process. Following a 48 h chill, carcasses were evaluated for: percent KPH, marbling score on a scale of 400 to 900 (400 to 499 = slight, 500 to 599 = small, 600 to 699 = modest,

700 to 799 = moderate, 800 to 899 = slightly abundant, 900 to 999 = moderately abundant), adjusted fat thickness (**FT**) was measured, and LMA was assessed using a digital imaging camera[1].

Results

All results are expressed as mean comparisons. No difference (P>0.05) was identified between live finish weights of cattle treated with RAC and without. Treatments EP and HT+R had heavier finish weights than C and R (P<0.05). All individual treatments, however, resulted in significantly greater finish weights than that of C (P<0.05) (Table 1). No difference was found between RAC and non-RAC treatments in steer ADG. The EP, MT, HT, MT+R, and HT+R had greater ADG than that of control cattle (*P*<0.05) (Table 1). There were no significant relative weight gain per head difference between RAC and non-RAC treatment means observed. Treatment means of EP, MT, HT, MT+R, and HT+R showed greater relative weight gain (P<0.05) than C (Table 1).

Cattle on RAC treatment had heavier HCW than cattle without (P<0.05). Treatments EP, MT+R, and HT+R had significantly greater HCW (P<0.05) than C and R. All treatments resulted in HCW greater than that of controls (P<0.05). Treatments EP+R and MT+R had greater HCW (*P*<0.05) than treatments HT, HT+R, R, and C. Treatment MT had greater HCW (*P*<0.05) than HT, R, and controls (Table 1).

No difference (P>0.05) was reported for KPH percentage between cattle treated with RAC and non-RAC. Treatment HT had significantly higher KPH percentages (P<0.05) than that of MT+R and HT+R. Groups EP, HT, and EP+R resulted in higher KPH percentages (P<0.05) than MT+R (Table 2). No differences in marbling scores were identified between RAC and non-RAC treatments. Cattle that were not implanted yielded significantly higher marbling scores (P<0.05) than those with implants. Carcasses from the R treatment group had significantly higher mean marbling scores (P<0.05) than all other treatments. Treatment groups HT and C resulted in mean marbling scores higher than that of EP, MT, EP+R, MT+R, HT+R (P<0.05). Groups EP and EP+R had greater marbling scores (P<0.05) than that of MT and MT+R (Table 2). Adjusted fat thickness resulted in no significant difference between RAC and non-RAC treated cattle. Cattle treated with MT resulted in the lowest adjusted fat thickness scores (P<0.05). Carcasses from cattle in the control treatment group had adjusted fat thickness scores greater than MT, HT, EP+R, MT+R, HT+R (P<0.05). Likewise, group R had adjusted fat thickness scores greater than MT and MT+R (P<0.05) (Table 2).

Carcasses from cattle administered RAC had a greater mean LMA (P<0.05). Carcasses from cattle treated with MT+R yielded larger average LMA (P<0.05) than all other treatments. Treatment groups MT, HT, ES+O, and HT+R resulted in greater REA (P<0.05) than the EP, C, and R treatments. Treatment EP and R had higher LMA (P<0.05) than control (Table 2).

[1] RMS Research, Fort Collins, CO, USA

Discussion

The finish weights as well as individual relative weight gain per head of implanted cattle versus non-implanted cattle of the recent study are concomitant to those of previous studies (Mader et al., 1994). The higher finish weights associated with the EP and HT+R treatments, relative to cattle with C and R treatments, was expected. Estradiol-containing implants have been shown to perform better than non-implanted cattle, or cattle given β-agonists alone, with respect to finish weights (Dawson et al., 1991). Interestingly, β-agonists have shown in previous studies to result in similar final live weights when compared to negative control animals (Moloney et al., 1990). In the current trial, however, all of the groups administered β-agonists resulted in heavier live weights than control. This effect may be due to the differences between RAC and other previously used commercial β-agonists.

It has been shown in previous studies that cattle fed β-agonists in the form of clenbuterol resulted in higher ADG than those not fed the supplement (Ricks et al., 1984). This study suggests no difference between the RAC and non-RAC treatments in respect to ADG, possibly due to the lower doses of RAC administered as compared to previous trials. The potential for higher rates of ADG with increased RAC dosages remains to be examined. One must also take into account that the previous trial involved native cattle as opposed to Holstein steers used in the current study. The Holstein breed, which tends to grow in a dissimilar pattern compared to native cattle (Wegner et al., 2000), could help elucidate why the β-agonist, RAC, did not perform the same as the earlier study.

All implanted groups resulted in higher ADG when compared to the non-implanted treatments, consistent with the improved gains found in previous work (Apple et al., 1991) using these anabolic steroids. Higher ADG was produced by the EP, MT, HT, MT+R and HT+R over control cattle. These results were expected and can be explained once again by the improvement of gain associated with all of these products. Interestingly, unlike the final live weight results, the EP+R group did not have significantly higher ADG over C in the first study; the reasons for this are undetermined.

Improved weight gain from cattle receiving implants was observed as expected. Similar results were observed with individual treatments involving implants and RAC when compared to the control cattle. These results are most likely outcomes due to anabolic effects on muscle tissue in addition to improved gain commonly associated with hormone implants or ractopamine (Ricks et al., 1984).

Carcasses from cattle administered RAC resulted in heavier mean HCW over non-RAC treated cattle. This was observed in a previous study conducted with β-agonist (clenbuterol)-treated angus steers (Schiavetta et al., 1990). However, unlike the previous study, this project found no effect of β-agonists regarding live weight. The improved HCW of implanted cattle were expected by the documented muscle deposition effects of anabolic steroids (Herschler et al., 1995). The findings related to combination implant/RAC treatments resulting in greater HCW than that

of C and R alone indicate potential growth benefits to combining the two growth enhancement treatments. These two growth interventions elicit their effects through completely different mechanisms causing two separate anabolic actions occurring upon a muscle cell. This dual action may potentially increase the gain even further than that of a steroid or β-agonist alone.

Carcass KPH data were similar to previous research using β-agonists, in that no differences were reported (Schiavetta et al., 1990). It has been suggested that β-agonists have a tendency to decrease internal fat depositions in steers (Moloney et al., 1990). The same has been observed for anabolic steroid hormone implants with respect to decreasing internal fat depositions (Herschler et al., 1995). This was not the case however in the recent study that demonstrated both aggressive hormone implants treatments rendering higher KPH percentages than the moderately aggressive implant. In pursuing the KPH deposition further we find that many of the RAC plus implant treatments reveal similar results to that of the C treatment cattle. These results may be explained by uncontrolled environmental affects, and further investigation should be conducted.

Marbling score results of the current study are similar to previous work in that carcasses from non-implanted cattle have higher marbling scores than those from implanted cattle. An interesting and unexpected finding was the R treatment had the greatest marbling scores compared to all other treatments, including the control treatment group. This differs with previously published data which showed either no significant difference between marbling score of control animals and those administered a β-agonist, or significantly greater scores with control animals over those administered a β-agonist (Ricks et al., 1984; Schiavetta et al., 1990). However, as predicted, cattle in the C group rendered carcasses with greater mean marbling scores than almost all other treatments utilizing implant only, or implant plus RAC. This may be a result of the diversion of nutrients to lean rather than fat deposition by β-agonists (Moody et al., 2000) in addition to the dilution factor of the intramuscular fat as a result of the increased LMA (Duckett et al., 1999).

Carcass LMA was seen to improve with the use of RAC treatment as would be expected due to improved muscle deposition from the β-agonist which has been seen in previous trials (Schiavetta et al., 1990). Likewise, all implanted cattle resulted in mean LMA greater than the non-implanted cattle which has been seen in previous studies (Scheffler et al., 2003), however these results have not been found as prevalent with β-agonists in regards to LMA. Cattle treated with MT+R showed greater LMA for both studies suggesting this to be the optimum treatment out of the eight treatments for improved LMA. This is commonly a concern with the Holstein breed as they tend to produce smaller LMA than those found in typical beef breeds (Perry et al., 1991). It is interesting however that the more moderate implant treatment resulted in a larger LMA than the more aggressive implant using TBA and E_2. This occurrence may imply that the interaction between TBA plus E_2 type implants and RAC works well. However, this may also imply that too much TBA plus E_2 interacting with RAC may have little, or negative, effects in response to LMA. Further investigations are needed to determine the interaction between RAC and TBA plus E_2.

No differences of mean FT were found between RAC and non-RAC treatments. This is possibly due to the Holstein breed tending to deposit little in the way of 12th rib backfat (Perry et al., 1991). However, non-implanted cattle yielded FT means greater than those who received implants. This can be explained by the lessening effect on fat deposition generally seen in relation to hormone implants in beef cattle (Herschler et al., 1995). Interestingly, MT+R was found to have some of the smallest FT scores which correspond well with the low marbling scores and increased LMA than several other treatments. These results suggest the potential of the MT+R cattle was not yet fully achieved. In addition, they may have still been in a transitional phase from muscle to fat deposition as would be suggested by the priority of tissue deposition stated by previous research (Bauman et al., 1982).

Implications

The study has shown the potential for Holstein steers to perform well with a ractopamine treatment in combination with certain anabolic steroid implants. Further research is needed to find optimal timing programs for the individual implant/ractopamine treatments. The findings of the combination implant/ractopamine treatments resulting in improved carcass weights and larger *longissimus* muscle areas than ractopamine or control alone indicate great potential in combining the growth enhancement treatments. The use of these implant/β-agonist regimens shows potential in providing the beef industry with a more efficient, and cost beneficial Holstein steer.

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Table 1. Effects of ractopamine, implant, and combined ractopamine-implants on live animal characteristics of Holstein steers.

	Live Finish Wt. (kg)	Gain per hd (kg)	ADG (kg)	HCW (kg)
Ractopamine	587.8[a]	136.6[a]	1.32[a]	359.2[a]
Non-Ractopamine	583.4[a]	132.3[a]	1.27[a]	356.1[b]
EP	590.5[c]	139.4[c]	1.34[d]	360.4[c]
MT	588.6[cd]	137.4[c]	1.32[d]	359.3[cd]
HT	584.8[cd]	133.7[c]	1.28[d]	357.3[cd]
C	569.8[e]	118.8[d]	1.14[d]	347.6[e]
EP+R	583.3[cd]	132.2[cd]	1.27[cd]	56.0[cd]
MT+R	594.0[cd]	142.8[c]	1.36[c]	364.6[c]
HT+R	592.1[c]	141.0[c]	1.36[c]	361.2[c]
R	582.0[d]	130.9[cd]	1.26[cd]	355.1[d]

[a-b] Differences between superscripts within columns denote significant differences (P<0.05)
[c-e] Differences between superscripts within columns denote significant differences (P<0.05)

Table 2. Effects of ractopamine, implant, and combined ractopamine-implants on carcass characteristics of Holstein steers.

	% KPH	Marbling Score	Adj. FT (cm)	REA (cm^2)
Ractopamine	2.61[a]	554.1[a]	0.68[a]	74.8[a]
Non-ractopamine	2.66[a]	551.8[a]	0.69[a]	72.9[b]
EP	2.66[cd]	542.1[e]	0.69[cde]	72.3[e]
MT	2.62[cde]	520.9[f]	0.63[f]	75.5[f]
HT	2.71[c]	564.6[d]	0.68[def]	74.8[d]
C	2.63[cde]	579.8[d]	0.76[c]	69.0[f]
EP+R	2.69[cd]	542.5[e]	0.67[def]	74.8[d]
MT+R	2.53[e]	518.8[f]	0.65[ef]	78.1[c]
HT+R	2.61[de]	535.2[ef]	0.68[def]	74.8[d]
R	2.62[cde]	619.2[c]	0.72[cd]	71.6[e]

Carcass traits analyzed: %KPH, skeletal maturity on a scale of 1 to 100, lean maturity on a scale of 1 to 100, marbling score on a scale of 400 to 900 (400 to 499 = slight, 500 to 599 = small, 600 to 699 = modest, 700 to 799 = moderate, 800 to 899 = slightly abundant, 900 to 999 = moderately abundant), adjusted fat thickness (FT) was measured (cm), and REA (cm^2).
[a-b] Differences between superscripts within columns denote significant differences (P<0.05)
[c-f] Differences between superscripts within columns denote significant differences (P<0.05)

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GENETIC PARAMETERS FOR MATURE WEIGHT AND LIFETIME LITTER WEIGHT WEANED IN RAMBOUILLET AND TARGHEE EWES

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ABSTRACT: Records of ewe weights and lifetime production measured as lifetime litter weaning weight were analyzed to determine the genetic parameters associated with mature weight **(EMW)** and lifetime litter weight weaned **(LWW)**. Data consisted of 24,438 ewe weights measured a maximum of three times per year, and 2,930 records of lifetime weaning weight produced in four lines of Rambouillet and one line of Targhee ewes managed together at the Red Bluff Research Ranch near Norris, Montana. Based on the likelihood ratio test, the model that best fit the EMW data included only the random effects of direct genetic, maternal genetic, and the direct-maternal genetic correlation. Although direct permanent environment was not a significant source of variation, it was also included to account for repeatability due to repeated records across years and seasons. Fixed effects included in the model for EMW were year measured, season, and body condition score as well as a linear and quadratic covariate for date weighed. Random effects included in the model for LWW included direct genetic, maternal genetic, and direct-maternal genetic correlation. Fixed effects included were year of ewe birth and line. Estimates of direct heritability were 0.59 and 0.30 for EMW and LWW, respectively. The estimate of direct genetic correlation of EMW with LWW was 0.25. Estimates of maternal heritability were 0.18 and 0.15 with a maternal genetic correlation of 0.93. Mature weight is a highly heritable trait that can be used to make selection decisions. Furthermore, EMW is highly correlated with LWW, indicating that larger ewes will be more productive as measured in lifetime kg of lambs weaned.

Key Words: Lifetime Production, Litter Weight Weaned, Mature Weight

Introduction

In order for livestock producers to be successful it is critical for them to be able to evaluate the productive efficiency of their flocks. For more than 10 years, beef cattle producers have had the availability of genetic parameters to evaluate the production potential of their cattle via mature weight and height (Arango et al., 2002), although it has been limited and largely breed dependent. Additionally, in beef cattle, the relationship is known between these mature female traits and other production traits, such as weaning (Bullock et al., 1993) and yearling weight (Northcutt and Wilson, 1993). However, there has been limited research conducted to determine the genetic components of ewe weight and the relationship between ewe weight and other production traits is limited. By knowing these parameters, it could be possible to include ewe weight in selection decisions to increase ewe performance by increasing lamb output production, which is considered one of the two most economically important traits for sheep producers, the other being wool (Ercanbrack and Knight, 1998).

Increasing the output efficiency of lamb production will benefit producers by increasing the receipts from the sale of lambs (Gaskins et al., 2005). A useful measure of overall range lamb production is total litter weight weaned (Bromley et al., 2001) and this could have an important economic impact to sheep producers, leading to an increase in revenue (Ercanbrack and Knight, 1998). Understanding the relationship between litter weights and other production traits will allow for more efficient selection to occur.

The objectives of this study were to estimate the genetic parameters for mature weight and lifetime weaning weight in sheep as well as their correlation in order to determine if these traits could be used together to make selection decisions.

Materials and Methods

Records were available on ewes from four lines of Rambouillet (1,562) and one line of Targhee (1,368) ewes managed together at the Red Bluff Research Ranch near Norris, Montana. Records included in this analysis were measured from 1987 to 2005. Ewe weight records consisted of 24,438 ewe weights, measured a maximum of three times per year on 3,290 ewes. Weights were taken prelambing (3,990 records, March 1-8), at spring turnout (10,288 records, May 25-June 2), and at weaning (10,160 records, August 16-26).

The model used for mature ewe weight (**EMW**) was determined based on preliminary unpublished analyses using the likelihood ratio test. The likelihood ratio test statistic was used in pairwise comparisons between models and assumed to be distributed as χ^2 with the difference in the number of parameters between models being the degrees of freedom. Statistical significance for models was set at $P < 0.01$. The most appropriate model included only the random effects of direct genetic, maternal genetic, and residual. However due to the fact that individual ewes had repeated measures, an additional random effect of direct permanent environment was included to account for this. Therefore, the model equation for mature weight that was used in the bivariate analysis with litter weight weaned was:

$$\mathbf{y} = \mathbf{X\beta} + \mathbf{Z_a a} + \mathbf{Z_m m} + \mathbf{Z_c c} + \mathbf{e}$$

where:

- **y** is a vector of observed measures;
- **β** is a vector of fixed effects including year measured, season, and body condition score;
- **a** is a vector of direct genetic effects;
- **m** is a vector of maternal genetic effects;
- **c** is a vector of direct permanent environmental effects;
- **e** is a vector of random error effects;
- **X** is a known incidence matrix associating fixed effects with records in **y**; and
- $\mathbf{Z_a}$, $\mathbf{Z_m}$, and $\mathbf{Z_c}$ are known incidence matrices associating random effects with records in **y** with zero columns associated with animals in the pedigree that do not have records

Lifetime weaning weight was defined as the summation of the weights of all lambs alive at weaning that were produced by a ewe throughout her lifetime and consisted of 2,930 records.

For lifetime litter weight weaned **(LWW)**, the model that best fit the data included the random effects of direct genetic, maternal genetic, and residual. This model was used by Rumph et al. (2004) when analyzing litter weight weaned in this population of animals. The model equation, therefore, was similar to that for mature weight, with the omission of $\mathbf{Z_c c}$ because there were no repeated records and the fixed effects in the **β** vector were only ewe year of birth and line. This corresponds to an overall bivariate model equation as shown in Figure 1 with E[**y**] = **Xβ** and the variance structure shown in Figure 2.

Genetic parameters were estimated using the multiple-trait derivative-free REML program (MTDFREML) of Boldman et al. (1995) modified by Dodenhoff et al. (1998) for calculation of standard error estimates of genetic paramenters for certain models using the Kachman adjustment (Steve Kachman, personal communication).

Results and Discussion

The estimates of the genetic parameters are shown in Table 1. For EMW, the estimate of direct heritability was high, with an estimate of 0.59 (0.05). This is in agreement with previously reported estimates in both sheep (Nasholm and Danell, 1996) and beef cattle (Arango et al., 2002; Rumph et al., 2002; and Nephawe et al., 2004).

Maternal genetic effects are not often included in analyses of mature weight, but in this analysis it was found to be significant with an estimated maternal heritability of 0.18 (0.03) and is similar to the estimate found in Hereford cattle by Rumph et al. (2002) and to that found in Swedish finewool sheep by Nasholm and Danell (1996). The estimate of direct-maternal correlation was 0.10 (0.08) which is positive and lower in magnitude than the negative estimate obtained by Rumph et al. (2002) for mature weight in Hereford cattle.

As expected from results of preliminary analyses, the proportion of variance that can be attributed to permanent environmental effects was non-significant with an estimate of 0.00 (0.02).

The estimate of direct heritability for LWW was 0.30 (0.05). This is higher than the estimate found in cattle by Martinez et al. (2004) for cumulative weaning weight of calves which ranged in heritability from 0.06 to 0.16. The estimate from the current study is also higher than the estimate of heritability for litter weight weaned in sheep (Bromley et al., 2001; Hanford et al., 2005) and pigs (Ehlers et al., 2005). The increase in heritability when considering lifetime weaning weight vs. annual weaning weight is similar to the increase in heritability estimated by Gregory et al. (1997) when comparing ovulation measured once vs. ovulation rate measured over multiple months in cattle.

The maternal heritability for LWW was estimated to be 0.15 (0.06) which is similar to the estimate found for litter weight (Hanford et al., 2005). The correlation between direct and genetic effects for LWW for this study was estimated to be -0.60 (0.13), which is typical of the direct-maternal correlation found when analyzing many weight traits.

The direct genetic correlation between EMW and LWW was estimated at 0.25 (0.05) with a maternal genetic correlation of 0.93 (0.05). Estimates of the genetic correlation between mature ewe weight and various lamb weights have ranged from 0.36 to 0.85 (Nasholm and Danell, 1996) in other studies. Bullock et al. (1993) found the genetic correlation between mature cow weight and weaning weight to be 0.80 and the phenotypic correlation to be 0.43. These results are higher than that found by Brinks et al. (1962), where a genetic correlation between mature weight and weaning weight was reported as 0.40. Mature weight had genetic correlations of 0.62 and 0.45 with 205-d weight and 365-d weight, respectively (Northcutt and Wilson, 1993).

Fertility rates have been shown to be positively influenced by weight at breeding and total weight gain from weaning to breeding (Gaskins et al., 2005). This, combined with the results from this study, show that selection for ewes with larger mature weights will result in more kg of lambs produced in a lifetime. Few studies have focused on the possibility of a correlation between mature weight and weaning weight, especially in sheep. The high level of correlation that has been found in this study suggests that selecting for mature weight will lead to improved weaning weights.

Implications

The mature weight of ewes is a key component of many aspects of production. It will affect not only individual ewe weight, but also the performance of their offspring as shown in this study. The correlation of these two traits provides more information that can be used in genetic evaluations to more accurately evaluate ewe performance and will consequently help producers be more efficient in their selection decisions.

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$$\begin{bmatrix}\mathbf{y}_{EMW}\\ \mathbf{y}_{LWW}\end{bmatrix}=\begin{bmatrix}\mathbf{X}_{EMW} & 0\\ 0 & \mathbf{X}_{LWW}\end{bmatrix}\begin{bmatrix}\beta_{EMW}\\ \beta_{LWW}\end{bmatrix}+\begin{bmatrix}\mathbf{Z}_{aEMW} & \mathbf{Z}_{mEMW} & \mathbf{Z}_{cEMW} & 0 & 0\\ 0 & 0 & 0 & \mathbf{Z}_{aLWW} & \mathbf{Z}_{mLWW}\end{bmatrix}\begin{bmatrix}\mathbf{a}_{EMW}\\ \mathbf{m}_{EMW}\\ \mathbf{c}_{EMW}\\ \mathbf{a}_{LWW}\\ \mathbf{m}_{LWW}\end{bmatrix}+\begin{bmatrix}\mathbf{e}_{EMW}\\ \mathbf{e}_{LWW}\end{bmatrix}$$

Figure 1. Bivariate model equation

$$V\begin{bmatrix}\mathbf{a}_{\mathbf{EMW}}\\ \mathbf{m}_{\mathbf{EMW}}\\ \mathbf{c}_{\mathbf{EMW}}\\ \mathbf{e}_{\mathbf{EMW}}\\ \mathbf{a}_{\mathbf{LWW}}\\ \mathbf{m}_{\mathbf{LWW}}\\ \mathbf{e}_{\mathbf{LWW}}\end{bmatrix}=\begin{bmatrix}\mathbf{A}\sigma^2_{aEMW} & \mathbf{A}\sigma^2_{aEMWmEMW} & 0 & 0 & \mathbf{A}\sigma^2_{aEMWaLWW} & \mathbf{A}\sigma^2_{aEMWmLWW} & 0\\ \mathbf{A}\sigma^2_{aEMWmEMW} & \mathbf{A}\sigma^2_{mEMW} & 0 & 0 & \mathbf{A}\sigma^2_{aEMWmLWW} & \mathbf{A}\sigma^2_{mEMWmLWW} & 0\\ 0 & 0 & \mathbf{I}\sigma^2_{cEMW} & 0 & 0 & 0 & 0\\ 0 & 0 & 0 & \mathbf{I}\sigma^2_{eEMW} & 0 & 0 & \mathbf{I}\sigma^2_{eEMWeLWW}\\ \mathbf{A}\sigma^2_{aEMWaLWW} & \mathbf{A}\sigma^2_{aEMWmLWW} & 0 & 0 & \mathbf{A}\sigma^2_{aLWW} & \mathbf{A}\sigma^2_{aLWWmLWW} & 0\\ \mathbf{A}\sigma^2_{mEMWmLWW} & \mathbf{A}\sigma^2_{mEMWmLWW} & 0 & 0 & \mathbf{A}\sigma^2_{aLWWmLWW} & \mathbf{A}\sigma^2_{mLWW} & 0\\ 0 & 0 & 0 & \mathbf{I}\sigma^2_{eEMWeLWW} & 0 & 0 & \mathbf{I}\sigma^2_{eLWW}\end{bmatrix}$$

Figure 2. Variance structure of the bivariate model

Table 1. Genetic parameter estimates (and associated s.e.) obtained from analysis of ewe mature weight (EMW) with lifetime weight weaned (LWW)

Genetic Parameters[i]	EMW	LWW
$\mathbf{h^2}$	0.59 (0.05)	0.30 (0.05)
$\mathbf{r_a}$	0.25 (0.05)	
$\mathbf{h_m^2}$	0.18 (0.03)	0.15 (0.06)
$\mathbf{r_m}$	0.93 (0.05)	
$\mathbf{r_{am}}$	0.10 (0.08)	-0.60 (0.13)
$\mathbf{c^2}$	0.00 (0.02)	
$\mathbf{e_t^2}$	0.19 (0.01)	0.68 (0.03)
$\mathbf{r_e}$	0.13 (0.01)	
$\boldsymbol{\sigma_p^2}$	90.03 kg^2	4113.92 kg^2

[i] h^2=direct heritability estimates, r_a=direct genetic correlation, h_m^2=maternal heritability estimates, r_m=maternal genetic correlation, r_{am} =direct maternal genetic correlation, c^2=proportion of variance due to permanent environmental effects, e_t^2=proportion of variance due to temporary environmental effects, r_e =residual correlation; σ_p^2=phenotypic variance

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ESTIMATION OF DIGESTA KINETICS OF FORAGE KOCHIA AND TALL WHEATGRASS USING YB AND DY WHEN FED ALONE OR MIXED TOGETHER [1]

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ABSTRACT: Little is known about the nutritional value of forage kochia (*Kochia prostrata*) for grazing beef cattle when mixed in low-quality forage diets. Our objectives were to evaluate digesta kinetics using different ratios of forage kochia and tall wheatgrass (*Agropyron elongatum*) and to examine the use of two rare earth markers to simultaneously measure the kinetics of each feedstuff. Five ruminally fistulated beef steers (mean BW = 504 kg) were allocated to 6 treatments in a 5 by 6 incomplete Latin square design. Treatments were arranged in a 3 by 2 factorial arrangement of diets (0:100, 50:50, and 100:0 of forage kochia and tall wheatgrass) and markers (Yb or Dy attached to kochia or wheatgrass). Steers were fed twice daily at 110% of mean intake over the previous 5 d. Steers were allowed a 12 d adaptation period. Feed intake and fecal output were measured during the following 7 d. After this, digesta kinetics were determined using pulse doses of Yb- or Dy-labeled forages. Rectal fecal grab samples were collected at 0 (before marker dose), 4, 8, 12, 16, 20, 24, 28, 32, 36, 42, 48, 54, 60, 72, 84, 96, 108, and 120 h post dosing. Data were analyzed in a Latin square-design in the MIXED procedure of SAS. Diet, marker, and forage did not interact ($P > 0.30$) for passage rate or retention time. As the amount of kochia increased in the diets, passage rate increased linearly ($P = 0.0005$) and mean retention time decreased quadratically ($P = 0.0034$). Passage rate estimates tended ($P = 0.12$) to be higher using Dy than Yb, but retention time estimates did not differ ($P = 0.78$) between markers. Kochia tended to pass more quickly ($P = 0.11$) and have a shorter retention time ($P = 0.06$) than wheatgrass, regardless of the diet they were in. Kochia affects digestive tract kinetics in a low quality diet by increasing the rate of passage and decreasing retention time as the level of kochia increases in the diet. Two rare-earth markers can be used to simultaneously measure kinetics of two forages that are mixed in the diet.

Key words: Beef cattle, forage kochia, rare earth markers

Introduction

Forage kochia has been shown to be good forage for livestock, especially during the fall and winter grazing seasons because it is high in CP when other forages are dormant (Stonecipher et al., 2005; Otsyina et al. 1984; Stevens et al., 1985). However, there is little quantitative information available about the digestive kinetics of forage kochia. Dysprosium and ytterbium are rare earth metals commonly used to measure digesta kinetics, but are seldom used to simultaneously measure kinetics of two feedstuffs in a diet. It would be useful to measure two feedstuffs in a diet because we could determine digesta kinetics of each and how they interact in the animal's digestive tract.

The objectives of this study were to evaluate digesta kinetics in diets of beef cattle using different dietary ratios of forage kochia and tall wheatgrass (*Agropyron elongatum*) straw, and to examine the use of two rare earth markers to simultaneously measure the kinetics of each feedstuff.

Materials and Methods

Five ruminally fistulated beef steers (mean BW = 504 kg) were allocated to 6 treatments in a 5 × 6 incomplete Latin square design. Treatments were arranged in a 3 × 2 factorial arrangement of diets (0:100, 50:50, and 100:0 of forage kochia and tall wheatgrass on an as-fed basis) and markers (Yb or Dy attached to forage kochia or tall wheatgrass). Which forage the marker was attached to was nested within marker.

Steers were housed in individual metabolism crates (2.4 by 1.1 m) at the Utah Sate University North Logan farm. Crates were located in a shed with one open wall facing south. Each steer had ad libitum access to water and a trace mineralized salt block (Table 1). They were let out for exercise every other day except during the 7 d of total fecal collections. The experimental protocol was approved by the Utah State University Institutional Animal Care and Use Committee.

Forage kochia was harvested from a pure stand as hay with the seed heads attached. Tall wheatgrass straw was harvested after seed had been combine-harvested. Tall wheatgrass and forage kochia were chopped to 4 to 6 cm.

Each experimental period consisted of 12 to 13 d of adaptation, 7 d of total fecal and urine collection, and 6 d of fecal marker sampling and *in situ* bag insertion. Data reported herein are derived from the 6 d period of fecal marker sampling. Steers were fed twice daily at 0700 and 1900 at 10% more than the average intake for the previous 5 d. The mixed diet (50:50) was mixed in a portable cement mixer. Feed offered and refused was weighed and sampled daily.

Ytterbium and Dy for pulse dosing were attached to tall wheatgrass and forage kochia by soaking in $YbCl_3$ or $DyCl_3$ and rinsing according to the procedures described by Teeter et. al (1984). Forage was then dried for 48 h at 60ºC. Steers on 100:0 received 200 g of marked forage kochia,

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steers on 50:50 received 200 g of marked forage kochia and 200 g of marked tall wheatgrass, and steers on 0:100 received 200 g of marked tall wheatgrass. Yb and Dy-marked forage was divided into 50 g portions and placed in tissue paper bags made from craft tissue paper (Luginbuhl, et. al, 1994). Bags were placed directly into the rumen in four different locations immediately before the morning meal on d 19. Fecal samples were collected from the rectum at 0 (immediately before dosing markers), 4, 8, 12, 16, 20, 24, 28, 32, 36, 42, 48, 54, 60, 72, 84, 96, 108, 120 h after Yb and Dy dosing. Fecal samples were frozen for later analysis. In period 5 two markers were accidentally switched so that the steer that should have received tall wheatgrass marked with Yb received tall wheatgrass (0:100) marked with Dy and the steer that should have received forage kochia (100:0) marked with Dy received forage kochia marked with Yb.

Laboratory Analysis. Daily feed samples were dried at 60ºC and kept separate in paper bags until ground in a Wiley mill to pass through a 1-mm screen. Equal amounts of daily samples from days 10 to 17 of each period were composited. Duplicate feed samples were dried overnight at 105ºC to determine DM, ashed to determine OM (AOAC, 1996), analyzed for ADF and NDF in an Ankom 200 Fiber Analyzer (Ankom Technology, Fairport, NY) and N content by the combustion method (AOAC, 1996) using a Leco N analyzer (Leco, St. Joseph, MI, Table 2).

Labeled fecal samples were dried at 60ºC and ground to pass a 1-mm screen in a Wiley mill. Samples of Yb- and Dy-marked forage were ground and used to calculate amount dosed. Fecal and marked forage samples were digested (Ellis et. al, 1982) and Yb and Dy concentration were read by inductively coupled plasma emission spectroscopy (ICP, Thermo Jarrell-Ash, Iris Advantage, Madison, WI).

Statistical analysis. Fecal concentrations of Yb and Dy were fit to a single-compartment model using the SAS nonlinear regression procedure (PROC NLIN, SAS Institute, Cary, NC) as explained by Pond et al. (1987). Estimates for k_o, L_1 and tau were used to calculate passage rate and retention time for each diet, marker, and marked forage combination. Passage rate and retention time responses were then analyzed in a Latin square-repeated measures design using the MIXED procedure of SAS (PROC MIXED, SAS Institute, Cary, NC). The treatment structure was a 3 diet × 2 marker factorial with the marked forage (forage kochia or tall wheatgrass) nested within marker. Steer was considered a random effect and period was considered a repeated measure. Denominator degrees of freedom were calculated using the Kenward-Roger option. The compound symmetry variance-covariance matrix was used for both response variables based on the best goodness-of-fit using the Schwartz-Bayesian criterion. Least squares means were calculated and linear and quadratic contrast statements were used to determine the influence of the increasing percentage of dietary forage kochia.

Results and Discussion

Dry matter, organic matter, ADF and NDF percentages were higher for tall wheatgrass than forage kochia (Table 2). Crude protein was higher for forage kochia than for tall wheatgrass. Thus, the tall wheatgrass straw was a low-quality forage because the CP level was lower than the 7 % required by rumen microorganisms to meet their growth requirements (Van Soest, 1994). Also, the percentage of NDF and ADF indicated that the amount of cell wall was higher in diets containing more tall wheatgrass. Forage kochia CP was higher than 7 % and thus may cause a positive associative effect when mixed with the tall wheatgrass (Olson, 2005).

The main effects of diet, marker, and forage did not interact ($P > 0.30$) for passage rate or retention time. This means that each variable acted independently of the others; thus the marker measurement did not depend on the feedstuff the marker was attached to or the diet it was mixed in.

As the amount of forage kochia increased in the diets, passage rate increased linearly ($P = 0.0005$) and mean retention time decreased quadratically ($P = 0.0034$, Table 3). This was probably because the 100:0 diet had CP levels above the microbial requirement of 7 %, while 0:100 and 50:50 did not (Table 2). We had expected the 50:50 mixture to have the highest passage rate and lowest retention time because of protein and energy interactions, but it did not meet rumen microorganism CP requirements of 7 %. However, the 50:50 diet did have higher CP levels than the 0:100 diet, indicating that it did improve diet quality some. Increased protein levels apparently stimulated microbial growth, allowing them to ferment the feedstuffs more rapidly, which causes more rapid particle size reduction and increased passage rate (Hess et al., 1994). Higher passage rates in diets with more forage kochia was consistent with data from Stonecipher et al. (2005), who also reported that passage rate increased linearly with increasing levels of forage kochia in the diet.

Passage rate estimates tended ($P = 0.13$) to be higher using Dy than Yb (2.49 and 2.21 % hr^{-1}, respectively, SE = 0.171), but retention time estimates did not differ ($P = 0.78$) between markers (81.79±3.21 and 82.73±3.22 h, for Dy and Yb, respectively). Differences between markers for kinetic responses were not expected. The fact that there was only a tendency for difference in passage rate estimates suggests that the two markers behaved similarly.

Forage kochia tended to pass more quickly than tall wheatgrass ($P = 0.11$, 2.50 and 2.16 % hr^{-1}, for forage kochia and tall wheatgrass, respectively, SE = 0.166) and had a shorter retention time ($P = 0.06$, 78.5 and 86.3 h for forage kochia and tall wheatgrass, respectively, SE = 3.43), regardless of the diet they were in or the marker that was attached to them.

Lamb et al. (2002) reported lower digestibility and slower passage rates for mature than immature forages because of structural changes that make plants more resistant to microbial breakdown. This was the case for tall wheatgrass. The tall wheatgrass straw was very mature and therefore contained large amounts of stem material with highly developed cell walls. This reduced the content of cell solubles. Digesting fiber from the cell wall is a slower process than digesting cell solubles. As a result, release of nutrients by fermentation would be reduced, thus reducing microbial growth, further exacerbating the slow rate of

particle size reduction associated with mature forages. Shrubs, like forage kochia, have thinner cell walls with more cell solubles than grasses, like tall wheatgrass (Van Soest, 1994). Thinner cell walls are reduced to small particles more rapidly, allowing particles to pass more quickly from the rumen. Thus, shrubs like forage kochia have more rapid passage rates. Forage kochia also contained leaves and seeds along with stems, which were high in cell solubles. These components would ferment rapidly, leading to rapid particle size reduction and passage.

Implications

Forage kochia affected digestive tract kinetics when mixed with a low quality forage by increasing the rate of passage and decreasing retention time as the level of forage kochia increased. This means that beef cows wintering on low quality forages like tall wheatgrass may increase their passage rate by increasing forage kochia consumption. Forage kochia can also improve cattle nutritional status by providing more protein in protein-deficient diets that are more typical in winter months. This can cause increased energy utilization due to positive associative effects of increased fiber digestion provided in the tall wheatgrass. In turn, this may reduce winter feed costs for producers because they can reduce or eliminate protein supplementation.

Two rare-earth markers can be used to simultaneously measure kinetics of two forages. This allowed the conclusion that the forage kochia passed more rapidly than the tall wheatgrass. Simultaneous use of multiple markers will be useful in future research to measure passage rate and retention time of more than one forage that an animal is consuming. This will allow better evaluation of interactions between forages in the animals' digestive tracts.

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Table 1. Composition of trace-mineralized salt block [a]

Item	Concentration
Salt (NaCl) minimum	95.5 %
Salt (NaCl) maximum	98.5 %
Zinc (Zn) minimum	3,500 ppm
Iron (Fe) minimum	2,000 ppm
Manganese (Mn) minimum	1,800 ppm
Copper (Cu) minimum	280 ppm
Copper (Cu) maximum	420 ppm
Iodine (I) minimum	100 ppm
Cobalt (Co) minimum	60 ppm

[a] Ingredients: salt, zinc oxide, ferrous carbonate, manganous oxide, magnesium oxide, copper oxide, calcium iodate, cobalt carbonate, red iron oxide for color.

Table 2. Chemical composition of diets containing the following ratios of forage kochia and tall wheatgrass

	Diet Treatment		
Item	0:100	50:50	100:0
DM, %	95.77	95.21	95.03
OM, %	92.52	92.47	90.86
	------ % of DM ------		
CP	3.45	5.78	8.85
NDF	79.68	71.31	59.91
ADF	54.55	51.08	43.86

Table 3. Influence of forage kochia on digesta kinetics for cattle consuming different levels of forage kochia and tall wheatgrass straw. All results reported on a DM basis

	Treatment				Contrast	
Item	0:100	50:50	100:0	*P*[a]	L[b]	Q[c]
Particulate passage rate, % h^{-1}	1.67±0.0209	2.44±0.0148	2.88±0.0209	0.0014	0.0005	0.2972
Mean particulate retention time, h	102.36±4.19	76.24±3.13	68.60±4.20	<0.0001	<0.0001	0.0034

[a]Probability of a greater F.
[b]L = Linear effect.
[c]Q = Quadratic effect

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EFFECTS OF OVARIECTOMIZATION AND SYNOVEX-PLUS IMPLANTS ON THE SOMATOTROPIC AXIS IN FEEDLOT HEIFERS

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ABSTRACT: A 2 x 2 factorial design was used to evaluate the effects of ovariectomization (**OVX**) and implantantation (200 mg of trenbolone acetate and 28 mg of estradiol benzoate; Synovex-Plus) on performance, serum urea nitrogen (**SUN**), serum IGF-1 (**SIGF**), and mRNA expression of hepatic IGF-1 (**HIGF**), total growth hormone receptor (**HGHR**) and estrogen receptor-α (**HERA**) as well as pituitary growth hormone (**GH**), estrogen receptor-α (**PERA**) and growth hormone releasing factor receptor (**GRFR**). Thirty-two British x Continental heifers were randomly assigned to one of two gender groups (**OVX or INTACT**) and then either a non-implanted control (**CON**) or to receive a Synovex-Plus implant (**IMP**) and fed a 90% concentrate steam-flaked corn based diet for 42 d. Liver biopsies were taken prior to OVX for baseline expression of HIGF, HGHR and HERA, which did not differ ($P > 0.45$). Blood and BW were taken on d 0, 28 and 42 and one heifer/pen was slaughtered on d 42 for liver and pituitary samples. Initial and final BW did not differ ($P > 0.19$) due to OVX or IMP. No gender x treatment interaction ($P > 0.24$) was observed for ADG or end BW. Neither OVX nor IMP affected ADG for the final 14 d of the feeding period ($P > 0.48$), but 28 ($P = 0.03$) and 42 d ADG ($P = 0.02$) are greater in IMP than CON. No two or three way interactions with day were observed for SUN ($P > 0.26$). SUN was greater in CON heifers than in IMP heifers ($P < 0.01$), but gender had no effect ($P = 0.31$). Both IMP and OVX increased SIGF ($P < 0.01$) and a gender x treatment interaction ($P < 0.01$) was observed. Neither gender nor treatment affected HERA, HIGF, HGHR, GRFR, GH, or PERA ($P > 0.06$). Data indicate that reductions in performance of OVX heifers can be eliminated through the use of implant programs. This is likely due to the implant related increase of SIGF, but the reason for this increase cannot be explained by mRNA expression of key somatotropic genes in the present study.

Key Words: Beef Heifers, Gender, Implant, mRNA, Somatotropic Axis

Introduction

According to federal law, feeder heifers entering the United States from Mexico must be ovariectomized upon entry. This is of particular importance in the southwest as many of the crossbred heifers on feed are cattle of Mexican origin. Early research showed that ovariectomization (**OVX**) decreased rate and efficiency of growth (Dinusson et al., 1950; Ray et al., 1969), but more recent research has indicated that OVX did not reduce ADG (Hamernik et al., 1985; Klindt and Crouse, 1990). However, research on the effects of anabolic implants in OVX heifers is limited. Garber et al. (1990) indicated that OVX heifers exhibited a four-fold greater response to implantation than intact heifers and Adams et al. (1990) reported that implanting OVX heifers with Synovex-H resulted in weight gains similar to those in intact heifers implanted with Synovex-H. The combination of these studies indicates that the effects of endogenous estrogen can be replaced through implantation. However, the physiological explanation for this has not been evaluated. Vestergaard et. al. (1995) found that OVX did not affect circulating IGF-1 in unimplanted Holstein heifers, and Mader and Kreikemeier (2006) found IGF-1 concentrations to be higher in E+TBA implanted heifers compared with unimplanted heifers. Additionally, Johnson et al. (1998) found that implanting lambs with E+TBA increased hepatic mRNA expression of IGF-1 and implanting steers with E+TBA increased expression of IGF-1 in the muscle. However, those authors did not report on IGF-1 gene expression in the liver.

Therefore, the purpose of this study was to utilize real-time polymerase chain reaction (**RT-PCR**) technology to ascertain the physiological mechanisms by which anabolic implants improve performance of intact and OVX heifers in the feedlot.

Materials and Methods

All procedures were approved by the University of Arizona Institutional Animal Care and Use Committee.

A 2 x 2 factorial design was used to evaluate the effects of OVX and implantantation with Synovex-Plus (200 mg of trenbolone acetate and 28 mg of estradiol benzoate; Fort Dodge Animal Health) on ADG, serum urea nitrogen (**SUN**), serum IGF-1 (**SIGF**), and mRNA expression of hepatic IGF-1 (**HIGF**), total growth hormone receptor (**HGHR**) and estrogen receptor α (**HERA**) as well as growth hormone (**GH**), estrogen receptor α (**PERA**) and growth hormone releasing factor receptor (**GRFR**) in the pituitary.

Cattle Management: Thirty-two British x Continental heifers with an initial BW of 374 ± 3.8 kg (mean ± SEM) were randomly assigned and blocked to one of two gender groups (OVX or **INTACT**) and 1 of 2 treatments [implanted (**IMP**) or non-implanted (**CON**)] and then to 1 of 16, partially shaded, soil surfaced pens (6.1 x 21.3m; two heifers/pen), with concrete feed bunks and a shared water source, for a 42 d feeding period. On d 0, cattle assigned to

the IMP group were implanted with Synovex-Plus and subsequently fed a 90% concentrate diet consisting of alfalfa hay, 10%; steam flaked corn, 78.25%; urea, 1.25%; tallow, 3%; cane molasses, 5%; and a mineral supplement, 2.5% (limestone, 47.059%; dicalcium phosphate, 1.036%; potassium chloride, 8.000%; magnesium oxide, 3.448%; ammonium sulfate, 6.667%; salt, 12.000%; cobalt carbonate, 0.002%; copper sulfate, 0.157%; iron sulfate, 0.133%; calcium iodate, 0.003%; manganese sulfate, 0.500%; selenium premix (0.16%), 0.125%; zinc sulfate, 0.845%; vitamin A (30,000 IU/g), 0.264%; vitamin E (500 IU/g) 0.540%; Rumensin-80, 0.675%; Tylan 40, 0.450%.; ground corn, 18.096%). Dietary DM (87%) was determined via drying at 55˚C for 48 h or until no further weight loss was observed and the nutrient composition (DM basis; Dairy One, Forage Testing Laboratory, Dairy One, Inc., Ithaca, NY 14850) was: CP, 13.0%; ADF, 6.7%; Ash, 4.7%; Soluble CP (% of CP), 45.7%; NEm 2.1 Mcal/kg and NEg 1.4(Mcal/kg).

Surgical Procedures and Sample Collection: All surgical procedures were performed by, or under the direct supervision of, a licensed veterinarian. Liver biopsies were taken on d −14 between the 11th and 12th ribs on the perceptual line from the tuber coxae to the point of the scapula and snap frozen in liquid N until transportation to the University of Arizona Ruminant Nutrition Laboratory for storage (−80˚C) until later mRNA expression analysis. Bi-lateral ovariectomies were performed, via entrance through the left para lumbar fossa, on animals assigned to the OVX group on d −7 and −5. Body weight was recorded and blood was taken, via jugular puncture, on d 0, 28 and 42 and allowed to clot at room temperature before serum was harvested and stored (−20º C) for later analysis of SUN and SIGF.

On d 42, following a 12 h fast, one heifer/pen was slaughtered, via captive bolt and exsanguination, beginning at 0′700 at the University of Arizona Meats Laboratory, to obtain liver and pituitary samples. All samples were snap frozen in liquid N until they were transported to the University of Arizona Ruminant Nutrition Laboratory and stored (−80˚C) for later mRNA expression analysis.

Serum Analysis: Serum urea N was determined using a direct colorimetric determination method (TECO Diagnostics, Anaheim, CA 92807) and is expressed in mg/dL. Serum IGF-1 was determined as described by (Berrie et al., 1995) and reported in ng/mL

Gene Expression analysis: Forward (***For***) and reverse (***Rev***) primer sequences are as follows (5′ − 3′): **GH receptor**: (*For:* GGT ATG GAT CTC TGG CAG CTG; *Rev:* CTC TGA CAA GGA AAG CTG GTG TG; Radcliff et al., 2003); **IGF-1**: (*For:* TTG GTG GAT GCT CTC CAG TTC; *Rev:* GCA CTC ATC CAC GAT TCC TGT; Radcliff et al., 2003); **HPRT**: (*For:* GAG AGT CCG AGT TGA GTT TGG AA; *Rev:* GGC TCG TAG TGC AAA TGA AGA GT; M.L. Rhoads Personal Communications); **GH**: (*For:* CCG GAG GGA CAG AGA TAC TC; R*ev:* GAG TGG CAC CTT CCA GGG TC; Chen et al., 1997); **ER-α**: (*For:* AGG GAA GCT CCT ATT TGC TCC; *Rev:* CGG TGG ATG TGG TCC TTC TCT; Lamote et al., 2006); and **GRFR**: (*For:* CGG TGG ATG TGG TCC TTC TCT; *Rev:* TCG GCA GCT TGT AGA CAT GCT; GenBank Accession # AF1848960).

Pituitary (0.2 to 0.3 g; as-is basis), liver biopsy (0.1 g; as-is basis) and post-mortem liver (0.1 g as-is basis) samples were homogenized (Polytron, Brinkmann Instruments, Inc., Westbury NY) and total RNA was extracted with TRIzol (Invitrogen; Carlsbad, CA) according to manufacturers guidelines. A chloroform extraction was then performed followed by an isopropanol precipitation and a double ethanol (70%) wash. Pelleted RNA was then re-suspended in molecular biology grade H_2O (150 µL) and stored (−80˚C). Total RNA was cleaned up using the RNeasy Kit (Qiagen; Valencia, CA) with DNase-treatement (DNase I – Amplification grade, Invitrogen) and final sample concentration and quality was determined through nano-drop analysis using undiluted total RNA. Aliquots were then taken from pituitary and liver DNase treated RNA and normalized to a concentration of 1 µg/µL or 0.4 µg/µL, respectively and cDNA was created using Super Script III (Super Script III First-Strand Synthesis System for RT-PCR; Invitrogen) according to product guidelines.

Real Time PCR was performed at the University of Arizona Genomic Analysis and Technology Core facilities on an ABI PRISM 7300 Sequence Detection System (Applied Biosystems; Foster City, CA) and ABI PRISM 7300 Sequence Detection System Software (Applied Biosystems) was used to visualize and interpret data. Real Time PCR conditions for all genes of interest were 1 cycle at 50˚C (2 min) for hot start, 1 cycle at 95˚C (3min) for denaturation, followed by 40 cycles of 95˚C (15 s) and 66˚C (60s) for annealing and 1 cycle at 95˚C (15 s) and 60˚C (30 s) for dissociation. Disassociation curves were ran on every plate to ensure single product amplification per primer set. A sample volume of 25 µL was identical for each sample well on every plate and all samples were ran with iTaq SYBR Green Supermix with ROX (Bio-Rad Laboratories, Hercules, CA), in triplicate, alongside triplicate standard curves, in 96 well optical reaction plates with an optical reaction cover (Applied Biosystems).

Following each run, primer efficiencies were calculated using the equation: Efficiency = $1 - 10^{(-1/\text{slope of the standard curve})}$. Average of all triplicates across all genes resulted in efficiencies of 98, 94 and 97% for liver biopsy, post-mortem liver, and pituitary plates, respectively. Standard deviation and CV values were calculated for cycle threshold values and all values had a CV of lower than 1.0 %. Cycle threshold values for HPRT were statistically analyzed to ensure no treatment or gender differences existed, thereby quantifying the proper choice for an endogenous reference gene. The mathematical model used to quantify the relative expression of each target gene is described by Pffafl (2001).

Statistical Analysis: Statistical analysis was performed using the PROC MIXED procedures of SAS (SAS Inst. Inc., Cary, NC, USA). The model for all data included gender (INTACT vs. OVX), treatment (IMP vs. CON) and the gender x treatment interaction as fixed effects and the random effect was pen (experimental unit). The model for SUN and SIGF also included day as a repeated measure and tested all two and three way interactions with day and the gender x treatment x day interaction was considered the residual. Additionally, d 0 SUN was analyzed a covariant within sampling date due to initial differences observed

between gender groups. Significance was considered $P < 0.05$ and LS means along with the most conservative estimate for SEM were reported for each variable.

Results and Discussion

Performance: For the sake of brevity, discussion concerning BW, ADG, SUN and SIGF (Table 1) is omitted. No differences in d 0 BW ($P > 0.19$) were detected. No gender x treatment interaction was observed for any performance parameters ($P > 0.24$) and d 42 BW was not changed as a result of gender or treatment ($P > 0.19$). Likewise, ADG for the final 14 d of the feeding period was not affected ($P = 0.94$) by gender or treatment. However, ADG for the initial 28 d ($P = 0.03$) and for the overall feeding period was greater in IMP than CON heifers but not affected by gender ($P > 0.07$). No two or three way interactions with day were observed for SUN ($P > 0.26$); therefore, with the exception of d 0, only main effect means were reported, which indicated SUN was greater in CON heifers than in IMP heifers ($P < 0.01$) and gender had no effect ($P = 0.31$). Statistical analysis of baseline SIGF showed no differences in gender or treatment and no gender x treatment interaction ($P > 0.44$) on d 0. Both IMP and OVX increased SIGF ($P < 0.01$) and the gender x treatment interaction was also observed ($P < 0.01$) with LS means of 267.4 (INTACT/IMP), 170.9 (INTACT/CON), 434.3 (OVX/IMP) and 167.0 (OVX/CON).

Relative mRNA expression (Table 2): An initial liver biopsy was taken on d −14 to quantify the expression of HIGF, HERA, and HGHR. Relative gene expression analysis revealed no pre-treatment differences ($P > 0.45$; data not reported) for any of the genes examined.

Surprisingly, given the strong response of SIGF to OVX and IMP, no differences were detected in post mortem HIGF expression as a result of OVX ($P = 0.31$) or IMP ($P = 0.69$). However, we did see a trend ($P = 0.11$) for a gender x treatment interaction with LS means of 0.70 (INTACT/IMP), 1.18 (INTACT/CON), 1.80 (OVX/IMP) and 0.89 (OVX/CON). This trend is exciting in that it is similar to the response we observed for SIGF, specifically the difference in the relative HIGF expression between INTACT/IMP and OVX/IMP heifers ($P = 0.07$), which could explain the reason for an increased response of OVX heifers to anabolic implants.

On the surface, HERA is not affected by treatment ($P = 0.72$) and there is no gender x treatment interaction ($P = 0.38$), but there is a strong trend toward INTACT heifers having a greater HERA expression than OVX heifers ($P = 0.06$). A more in depth analysis reveals that this trend may be influenced by the near significant reduction in the relative expression of HERA in OVX/IMP heifers (LS mean = 0.43) compared to INTACT/IMP heifers (LS mean = 0.76; SEM = 0.16; $P = 0.06$). This could suggest that E supplied by the implant acts anabolically through the IGF-1 receptor as was demonstrated in the mouse (Klotz et al., 2002). However further research should be conducted analyzing IGF-1 receptor expression to potentially validate this hypothesis.

Pituitary ERA expression results are different, in that treatment ($P = 0.07$) and not gender ($P = 0.28$), causes suppression of PERA. However, although the overall gender x treatment interaction ($P = 0.31$) is not statistically significant, there are points of interest. Notably, OVX/IMP heifers (LS mean = 0.39) exhibit lower ($P \leq 0.05$) PERA expression than INTACT/CON (LS mean = 0.82) and OVX/CON (LS mean = 0.81) heifers and they also tend to express lower ($P = 0.13$) PERA than INTACT/IMP heifers (LS mean = 0.69). These effects suggest that implantation with E+TBA implants may also suppress PERA more in OVX heifers than in INTACT heifers which could also suggest an increase in binding to the IGF-1 receptor. However, further analysis must be done to quantify this hypothesis.

Gender not only did not affect GRFR ($P = 0.70$), GH ($P = 0.97$) or HGHR ($P = 0.66$), but treatment also had no effect on GRFR ($P = 0.70$), GH ($P = 0.97$) or HGHR ($P = 0.66$), and there were no gender x treatment interactions observed for GRFR ($P = 0.74$), GH ($P = 0.70$) or HGHR ($P = 0.56$). Lack of differences in the relative expression of mRNA from these genes strengthens the hypothesis that E+TBA implants are acting outside the somatotropic axis to increase IGF-1.

Conclusion:

Data indicate that reductions in performance of OVX heifers can undoubtedly be eliminated through the use of an E+TBA implant which is likely due to an increase in SIGF. However, the reason for the increase in SIGF is still unclear, although trends in gene expression analysis suggest the possibility that the increase in SIGF is mechanistically controlled outside of the somatotropic axis. Consequently, further research is warranted for an in depth explanation of the effects of OVX and IMP on the somatotropic axis.

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Table 1: Effects of OVX and Synovex-Plus implants on performance and serum metabolites in feedlot heifers

	Gender		Contrasts		Implant		Contrasts	
Item	INTACT	OVX	SEM[a]	*P*-value	+	–	SEM[a]	*P*-value
No. of pens	8	8	–	–	8	8	–	–
BW, kg								
Day 0	378	371	5.5	0.49	374	375	5.5	0.86
Day 42	436	423	6.8	0.19	433	426	6.8	0.45
ADG, kg								
Day 0 – 28	1.3	1.2	0.1	0.29	1.4	1.1	0.1	0.03
Day 28 – 42	1.6	1.4	0.2	0.49	1.5	1.5	0.2	0.94
Overall	1.4	1.2	0.1	0.07	1.4	1.2	0.1	0.02
SUN mg/dL								
Day 0	11.0	14.3	0.6	< 0.01	12.3	13.1	0.6	0.40
Main effect	11.5	10.6	0.6	0.31	9.3	12.9	0.5	< 0.01
SIGF ng/mL								
Day 0	186.0	190.9	22.9	0.88	186.1	190.8	24.0	0.88
Main effect[c]	219.2	300.7	17.7	< 0.01	350.9	169.0	17.7	< 0.01

[a] Standard error of the mean (Most conservative estimate reported).
[b] Main effect means include d 28 and d 42, but not d 0.
[c] Gender x treatment interaction ($P < 0.01$; LS means listed in text)

Table 2: Effects of OVX and Synovex-Plus implants on relative somatotropic mRNA expression in feedlot heifers

	Gender		Contrasts		Implant		Contrasts	
Item	Intact	OVX	SEM[a]	*P*-value	+	–	SEM[a]	*P*-value
Liver post-mortem								
HIGF	0.94	1.34	0.30	0.33	1.24	1.03	0.28	0.60
HGHR	0.92	0.83	0.14	0.63	0.78	0.98	0.13	0.29
HERA	0.73	0.50	0.08	0.06	0.60	0.64	0.08	0.72
Pituitary								
GH	2.06	2.04	0.38	0.97	2.33	1.77	0.38	0.31
GRFR	0.78	0.73	0.10	0.70	0.85	0.66	0.10	0.21
PERA	0.75	0.60	0.10	0.28	0.54	0.82	0.10	0.07

[a] Standard error of the mean (Most conservative estimate reported)

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EFFECTS OF SUPPLEMENTAL SAFFLOWER AND VITAMIN E DURING LATE GESTATION ON LAMB GROWTH, SERUM METABOLITES AND THERMOGENESIS

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ABSTRACT: Fifty-one twin bearing Targhee ewes (Trial 1) and 620 white face range ewes (Trial 2) were used in a 2 x 2 factorial arrangement of treatments to determine the effect of supplemental energy source **(S)** and level of vitamin E **(V)** on lamb serum metabolites and thermogenesis (Trial 1), and lamb growth (Trial 2). During the last 30 d of gestation, ewes were individually (Trial 1) or group (Trial 2) fed a daily supplement. Treatment supplements were: 226 g safflower seeds **(SS)** and either 350 **(VE)** or 0 **(VC)** IU vitamin E or 340 g of a grain-based supplement **(SC)** and either VE or VC. At 1 h postpartum in Trial 1, twin born lambs were placed in a 0°C dry cold chamber for 30 min. Lamb rectal temperature was recorded every 60 s and blood samples were taken via jugular puncture immediately before and after cold exposure. Samples were analyzed for percent change in blood urea nitrogen **(BUN)**, triiodothyronine **(T_3)**, and thyroxine **(T_4)**, cortisol, and NEFA. In Trial 2 lambs were weighed at birth, spring turnout and weaning. Ewe was the experimental unit. Lamb weights were summed within ewe to calculate kilograms of live lamb/ewe. Percent changes in serum BUN, T_3, T_4, and cortisol did not differ ($P > 0.16$) between VE and VC lambs. Percent change in serum levels of T_3, T_4 and cortisol did not differ ($P > 0.22$) between SS and SC lambs. However, serum BUN increased in SS lambs and decreased in SC lambs ($P = 0.01$). The SSVC lambs had lower ($P < 0.01$) body temperature than lambs in other treatment groups. Kilograms of lamb/ewe at birth, turnout, and weaning did not differ ($P > 0.14$) among treatments. Based on lower body temperature in SSVC lambs at birth, and a greater change in BUN during the cold exposure for SS than SC lambs, it appears that SSVC supplemented ewes gave birth to lambs with an apparent decrease in basal metabolic rate. This may compromise the newborn lamb's ability to adapt to extreme environmental conditions.

Keywords: Safflower, Sheep, Vitamin E

Introduction

Hypothermia, starvation, scours, and pneumonia are the major causes of neonatal lamb mortality with 50% of lamb losses occurring within 24 hours of birth (Rowland et al., 1992). Alexander (1961) estimated that 50% of the heat generated by ruminant neonates comes from non-shivering thermogenesis which is fueled by brown adipose tissue (BAT). Linoleic and linolenic acid supplements such as safflower seeds increased the thermogenic capacity of BAT by 75% and doubled the content of uncoupling protein-1 in rats (Nedergaard et al., 1983). Encinias et al. (2004) reported that lambs born to ewes fed a late gestation diet including 4.6% safflower seeds had increased survivability and lowered pneumonia rates than lambs born to ewes fed a 1.9% fat, isocaloric prepartum diet. Lammoglia et al. (1999) found similar results in calves that were born to cows fed a high fat diet (5.1%) when compared to calves born to cows fed a low fat (2.2%) control diet. Increased heat production from BAT increases oxidation of BAT resulting in the formation of free radicals. Free radicals cause damage to cellular membranes; therefore more antioxidants may be needed to maintain cell integrity.

Vitamin E, a potent antioxidant, protects cellular membranes by sequestering free radicals and spares cell membranes from oxidative degradation (Horton et al., 1996). Ewes lambing early in the season and fed harvested forages may have low plasma vitamin E concentrations because dry, stored feeds have lower vitamin E content than fresh, spring forage (Hatfield et al., 1999).

It is unknown if feeding supplemental safflower seeds to increase the thermogenic capacity of BAT will increase anti-oxidant requirements in sheep. Therefore, the objective of this study was to determine the effects of safflower seed and vitamin E, supplemented to late gestating ewes, on lamb growth, serum metabolites, and thermogenesis in lambs born to spring-lambing ewes.

Materials and Methods

Trial 1: Fifty-one twin bearing Targhee ewes were assigned randomly to treatments in a 2 x 2 factorial arrangement. Isocaloric and isonitrogenous treatments were: 226 $g \cdot ewe^{-1} \cdot d^{-1}$ safflower seeds (SS) and either 350 (VE) or 0 (VC) $IU \cdot ewe^{-1} \cdot d^{-1}$ vitamin E or 340 $g \cdot ewe^{-1} \cdot d^{-1}$ of a grain-based supplement (SC) and either VE or VC(Table 1). An additional 115 g of SC was required to provide an equal amount of energy as the SS supplement. Real-time ultrasound was used to identify ewes pregnant with twins conceived early in the breeding season from the Targhee flock managed at Montana State University's Red Bluff Research Ranch near Norris, Montana. Ewes were assigned to treatment in such a way that the average age of each treatment group was 4.4 to 4.5 yr. Experimental ewes were moved from the range flock to the Fort Ellis Sheep Facilities near Bozeman, Montana where they were housed in a large pen with ad libitum access to alfalfa hay (Table 1) and water. Ewes were placed in individual pens once daily to receive supplemental treatments. Treatments were administered March 7, 2005 to April 10, 2005. Immediately before lambing, ewes were returned to the range flock at Red Bluff. All animal procedures were approved by the Montana State University Institutional Animal Care and Use Committee (protocol #AA-030).

Table 1. Analysis (DM basis) of feed fed to ewes the last 30 d gestation

		Energy Supplement[2]		Vitamin Supplement[3]	
	Alfalfa[1]	SS	SC	VE	VC
CP (%)	15.2	19.6	16.2	24.2	24.2
TDN (%)	58.6	107.4	71.4	78.3	78.4
Ether Extract (%)	1.3	49.3	2.8	3.9	3.70
Vitamin E (IU/kg)	15	53	24	355	35

[1] Ad libitum access, same alfalfa used in Trial 1 and Trial 2
[2] SS = 226 g·ewe^{-1}·d^{-1} safflower seeds; SC = 340 g·ewe^{-1}·d^{-1} isocaloric and isonitrogenous grain based control
[3] VE = 350 IU·ewe^{-1}·d^{-1} supplemental vitamin E; VC = 0 IU·ewe^{-1}·d^{-1} supplemental Vitamin E (VC)

Ewes were observed 24 h/d during lambing. Forty-two of the 51 ewes were identified at parturition and lambs born to these ewes were used to evaluate treatment effects on lamb body temperature and blood metabolites. When ewes were observed to be in labor they were monitored constantly until parturition. Immediately after birth, lambs were prevented from suckling. Vigorous lambs were muzzled if required. The ewe and her lambs were placed in a pen (1.5 m^2) for 30 min to 1 h to allow maternal bonding. At 1 h postpartum, lamb sex and birth weight were recorded and the umbilical cord was clipped and dipped in iodine. Lambs were then bled via jugular puncture using non-hepranized vacutainers. Lambs were fitted with a rectal temperature sensor connected to a mini-logger 2000 (Mini Mitter Company, Inc, Surviver, OR). After an initial temperature reading, both twin lambs were placed in a crate (183 cm^2) and put in a 0^{o}C dry cold environmental chamber for 30 min and lamb rectal temperature was recorded automatically every 60 s. After cold exposure, lambs were removed from the cold chamber, bled via jugular puncture, warmed artificially and returned to their dam.

Blood samples were centrifuged for 20 min at 1000 x *g*. Serum was then decanted into plastic tubes and stored at -20^0 C until assayed for blood urea nitrogen (BUN), NEFA, cortisol, triiodothyronine (T_3), and thyroxine (T_4). Non-etherified fatty acids were assayed using a NEFA-C kit (Wako Chemicals USA, Inc., Richmond, VA) as described in Hamadeh et al. (2000). Blood urea nitrogen was assayed using specific Flex reagent cartridges (Catalog No. DF21, DF39A, DF27, DF73), on a Dimension clinical system (DADE Behring, Inc., Newark, DE). Concentrations of BUN were determined using a bichromatic (340 and 383 nm) rate technique. Cortisol, T_3, and T_4 concentrations were assayed by a solid-phase RIA kits (Coat-A-Count; Diagnostic Products Corporation. Los Angeles, CA).

Trial 2: White-faced ewes (n = 620) were randomly assigned to the same treatments described in Trial 1. Pregnant ewes were managed at Montana State University's Red Bluff Research Ranch near Norris, Montana. Ewes were randomly assigned within breed (Columbia, Rambouillet, and Targhee) and age (2 to 7 years old) so that each treatment group had a similar average age and number of each breed. Ewes were mass fed within treatment groups their assigned supplements the last 30 days of gestation. Ewes had ad libitum access to alfalfa hay (Table 1) and water. Treatments were administered March 10, 2005 to April 10, 2005. All animal procedures were approved by the Montana State University Institutional Animal Care and Use Committee (Protocol #AA-030).

Lambs were processed according to MSU protocol at birth with sex, birth type, birth weight, birthday, and breed information recorded. Lamb body weights were recorded again at turnout and weaning with kilograms of lamb/ewe calculated. Lambs that died were included in the analysis as 0 kg body weight.

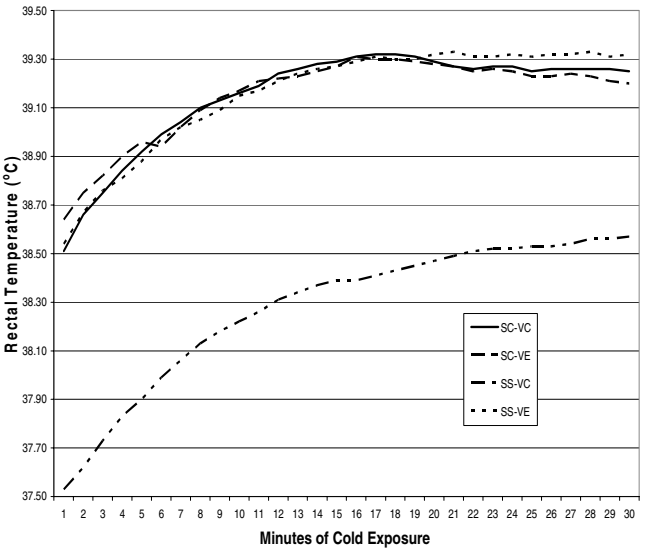

Figure 1. Least squares means of rectal temperature for twin lambs exposed to 0^{o}C for 30 min 1 h after parturition. Treatments were: SSVE = 226 g·ewe^{-1}·d^{-1} safflower seeds (SS) and 350 IU·ewe^{-1}·d^{-1} supplemental vitamin E (VE); SSVC = SS and 0 IU·ewe^{-1}·d^{-1} supplemental vitamin E (VC); SCVE= 340 g·ewe^{-1}·d^{-1} isocaloric and isonitrogenous grain based control (SC) and VE; SCVC = SC and VC. The SEM ranged from 0.189 at 30 min to 0.333 at 1 min. Repeated measures evaluations of the effects of time, and energy source vs. level of vitamin E interaction were detected ($P < 0.02$).

Statistical Analysis: Temperature data were analyzed using the repeated measures procedure of SAS (SAS Inst., Inc., Cary, NC). Production and blood metabolite data were analyzed using the GLM procedure of SAS. The model included the effects of ewe age, lambing date, energy source, level of vitamin E, and the interaction between energy source and vitamin E. Significance level was set at alpha 0.10. Ewe was the experimental unit so lamb weights were summed to calculate kilograms of lamb born, turned out, and weaned per ewe.

Table 2. Percent change[1] in serum metabolites during a 30 m 0°C dry cold exposure for newborn lambs born to ewes fed different energy sources and levels of vitamin E supplement for the last 30 d gestation

	Treatment[2]					S x V[3]	SS vs. SC	VE vs. VC
% Change	SSVE	SSVC	SCVE	SCVC	SEM	*P*-value	*P*-value	*P*-value
BUN	2.2	3.9	-4.2	-1.9	2.08	0.87	0.01	0.30
T_3	10.6	15.2	-14.7	11.9	14.24	0.35	0.23	0.19
T_4	-1.41	8.48	0.91	-2.75	6.236	0.25	0.45	0.60
T_3:T_4	16.1[a]	9.1[ab]	-13.7[b]	16.3[a]	12.96	0.08		
Cortisol	-33.5	17.7	-30.3	-11.4	11.37	0.90	0.70	0.17
NEFA	16.13[a]	-7.08[b]	8.63[ab]	15.86[a]	8.322	0.06		

[a,b] Within row, means without a common superscript letter differ, $P < 0.10$.
[1] Percent change calculated [(after cold exposure – before cold exposure)/before cold exposure] *100.
[2] SSVE = 226 g·ewe^{-1}·d^{-1} safflower seeds (SS) and 350 IU·ewe^{-1}·d^{-1} supplemental vitamin E (VE); SSVC = SS and 0 IU·ewe^{-1}·d^{-1} supplemental Vitamin E (VC); SCVE= 340 g·ewe^{-1}·d^{-1} isocaloric and isonitrogenous grain based control (SC) and VE; SCVC = SC and VC.
[3] S x V = Interaction between differing energy sources (S) and levels of vitamin E (V).

Results and Discussion

Trial 1: Percent changes in serum BUN, T_3, T_4, or cortisol did not differ ($P > 0.18$) between VE and VC lambs (Table 2). Parturition may have induced high levels of stress in both ewes and lambs overwhelming any treatment effect on cortisol. No difference was detected ($P = 0.30$) in percent change in BUN concentration, which indicated that vitamin E treatments did not affect the lamb's ability to mobilize body reserves of protein.

Percent change in T_3, T_4 and cortisol did not differ ($P > 0.22$) between SS and SC lambs (Table 2). Lammoglia et al. (1999) reported no difference in cortisol concentration between calves born to cows fed low fat prepartum diet and calves born to cows fed high fat prepartum diet. Again this might have been expected due to parturition stress. Percent changes in levels of BUN increased ($P = 0.01$) in SS lambs and decreased in SC lambs. This indicated that SS lambs might have mobilized higher levels of body protein, possibly to fuel thermogenesis.

There was an S by V interaction for the percent change in NEFA concentration and T_3:T_4 ratio ($P < 0.08$; Table 2). Percent change of NEFA decreased in SSVC lambs and increased in lambs from the other treatments, indicating that SSVC lambs were not mobilizing body reserves of fat during cold exposure as efficiently as lambs from other treatment groups. Lambs born to SCVE ewes experienced a decrease in T_3 concentration and static T_4 concentration, which caused a decrease in the T_3:T_4 ratio. The T_3:T_4 ratio increased ($P < 0.10$) in lambs of all other treatments. This indicated a metabolic shift in utilization of thyroid hormones that may be related to oxidation of BAT.

All lambs had a higher ($P < 0.02$) rectal temperature after 30 min of cold exposure relative to 0 min (Figure 1). An S by V interaction was detected ($P < 0.01$) due to SSVC lambs consistently having lower body temperature throughout the cold exposure ($P < 0.03$) than lambs in other treatments. Conflicting results have been reported for the effect of safflower seed supplementation on body temperature. Lammoglia et al. (1999) reported that calves born to cows receiving a high fat diet prepartum had a higher initial rectal temperature and maintained that temperature longer than calves born to cows receiving a low fat diet prepartum. Similarly, Encinias et al. (2004) reported that lambs born to ewes receiving 2.8% fat diet prepartum had a higher rectal temperature than lambs born to ewes receiving 5.7% fat diet prepartum. However, Dietz et al. (2003) reported no difference in response to cold stress between calves born to heifers receiving 1.5% fat control diet, 4.0% fat safflower diet, and 5.0% fat cottonseed diet. As stated previously, supplemental safflower seed increased thermogenic capacity in BAT. Increased thermogenesis causes more free radicals to be formed, which have the possibility of challenging the lamb at the cellular level. The combination of low utilization of

Table 3. Summed Body weight[1] of lambs born to ewes fed different energy sources and levels of vitamin E supplement for the last 30 d gestation

	Treatments[2]					S x V[3]	SS vs. SC	VE vs. VC
Item (kg)	SSVE	SSVC	SCVE	SCVC	SE	*P*-value	*P*-value	*P*-value
Birth Wt	19.9	19.7	19.5	20.0	0.52	0.12	0.88	0.43
Spring Wt[4]	37.6	37.9	37.4	38.4	1.89	0.62	0.85	0.38
Fall Wt[5]	98.1	99.0	99.4	100.5	4.36	0.97	0.47	0.60

[1] Body weights summed to determine kilograms of live lamb/ewe
[2] SSVE = 226 g·ewe^{-1}·d^{-1} safflower seeds (SS) and 350 IU·ewe^{-1}·d^{-1} supplemental vitamin E (VE); SSVC = SS and 0 IU·ewe^{-1}·d^{-1} supplemental Vitamin E (VC); SCVE= 340 g·ewe^{-1}·d^{-1} isocaloric and isonitrogenous grain based control (SC) and VE; SCVC = SC and VC.
[3] S x V = Interaction between differing energy sources and levels of vitamin E.
[4] May 24, 2005, kg/ewe including death loses
[5] Aug. 24, 2005, kg/ewe including death loses

fat reserves as indicated by low NEFA concentration in addition to possible high concentration of free radical formation may indicate the SSVC lambs are not able to cope with cold stress as efficiently as their counterparts in other treatments.

Trial 2: Birth weight and kilograms of live lamb per ewe at turnout and weaning did not differ ($P > 0.42$) between lambs born to VE and VC ewes (Table 3). The results agree with those of Williamson et al. (1995) who reported no difference in weaning weights of lambs born to ewes receiving two injections of vitamin E 14 d before lambing and lambs born to ewes that did not receive a vitamin E injection. Our results contradict those reported by Thomas et al. (1995) who reported that ewes fed 350 $IU \cdot d^{-1}$ vitamin E 3 wk prepartum and lambing early in the spring had lambs with greater survival rates therefore they weaned more kilograms of lamb per ewe than control ewes. Thomas et al. (1995) suggested that lambs born early in the lambing season were subject to greater levels of environmental stress than late born lambs. Both the study by Thomas et al. (1995) and our study were conducted at the Red Bluff Research Ranch. Possibly the difference in the results of these studies is a function of environmental stress. In our study, lambing conditions were very mild and our results are over the entire lambing period whereas those of Thomas et al (1995) are from the early lambing period only.

Birth weight and kilograms of lamb/ewe at turnout and weaning did not differ ($P > 0.46$) between lambs born to SS and SC ewes. In studies comparing high and low fat diets using safflower seed supplementation there were no differences in birth weights of calves and lambs (Deitz et al., 2003; Encinias et al., 2004). Bottger et al. (2002) also reported no difference in calf weaning weights when comparing safflower seed diets to isocaloric control diets.

Implications

Based on lower body temperature in SSVC lambs at birth, and a greater change in BUN during the cold exposure for SS than SC lambs, it appears that SSVC supplemented ewes gave birth to lambs with an apparent decrease in basal metabolic rate. This may compromise the newborn lamb's ability to adapt to extreme environmental conditions. However, these impacts on blood metabolites and thermogenesis did not translate to lower lamb production in ewes supplemented with SSVC during late gestation under the conditions of our study.

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INHERITANCE OF FACIAL HAIR WHORL ATTRIBUTES IN HOLSTEIN CATTLE

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ABSTRACT: Facial hair whorls are present on the forehead of most cattle but height of the whorl center (**HT**), location in relation to the midline (asymmetry, **AS**), and rotation (anti-clockwise or clockwise, **ROT**) vary considerably. Hair whorl attributes have been implicated as determinants of individual reproductive performance in bulls, left- and right-handedness in humans, and homosexual tendencies in men. These associations may result from genetic and (or) developmental associations with whorl attributes. The objective of this study was to estimate genetic parameters for facial hair whorl in Holstein cattle (n = 945). Whorl attributes were collected by a single observer for 470 related bulls and 14 half-sib sire families where measures on dam and offspring were included. The pedigree included 112 sires and 617 dams and genetic parameters were analyzed in ASREML with sex as the sole fixed effect. Heritabilities for HT, AS and ROT were 0.54 ± 0.08, 0.11 ± 0.06, and 0.14 ± 0.07, respectively. There was no evidence these traits were under simple genetic control as all mating combinations generated all offspring phenotypes, although in slightly different proportions. Pairwise bivariate analyses generated estimates of phenotypic and genetic correlations between HT and AS of 0.04 ± 0.03 and -0.08 ± 0.24, between HT and ROT of -0.04 ± 0.03 and -0.03 ± 0.22, and between AS and ROT of 0.06 ± 0.03 and -0.07 ± 0.38. Results indicated genetic control of HT, AS and ROT was independent. Bivariate analyses that examined anti- and clockwise rotations as different traits produced genetic correlations of 0.68 ± 0.24 for HT and 0.40 ± 0.58 for AS. Results suggest hair whorl height, asymmetry and rotation are moderately to highly heritable polygenic traits, whorl height and asymmetry are the same traits regardless of whorl direction, and different genes are involved in determination of each of these three attributes.

KEY WORDS: Hair whorl, Heritability, Cattle

Introduction

Hair whorls are spiral patterns of hair growth located on the crown of the head in humans or the forehead of most cattle (Hoath, 1990; Grandin et al., 1995). Formation of hair whorls occurs 10 to 18 wk post-fertilization and coincides with brain and skull development (Samlaska et al., 1989; Hoath, 1990). In humans, hair whorls were associated with abnormal brain development and developmental disorders (Smith and Gong, 1974; Nowacyk and Sutcliffe, 1999; Scott et al., 2005), and temperament, behavior, and reproductive performance in cattle (Grandin et al., 1995; Meola et al., 2004; Evans et al., 2005). Hair whorl attributes, height of the whorl center (**HT**), location in relation to the midline (asymmetry, **AS**), and rotation (anti-clockwise or clockwise, **ROT**) vary considerably among and within breeds of cattle (Grandin et al., 1995; Lanier et al., 2001). Association of these attributes with observed phenotypes in humans and cattle may result from genetic and (or) developmental associations with whorl attributes. The objective of this study was to estimate genetic parameters for facial hair whorls in Holstein cattle.

Material and Methods

Phenotypic hair whorl records were collected for Holstein bulls (n = 470) from Select Sires, Inc., (Plain City, OH; Evans et al., 2005) and 14 half-sib sire families where measures on dam and offspring were included (n = 475). Bulls were of mixed ages and born between July 1988 and March 2002. Half-sib calves were born in 2005 and sires and dams were of mixed ages.

A single observer collected hair whorl attributes on each bull at the AI collection station and on cow-calf pairs within a few weeks of birth. Whorl height (**HT**) was scored in relation to the eyes: above the top of the eyes (1), level with the top of the eyes (2), centered between the top and bottom of the eyes (3), level with the bottom of the eyes (4), or below the bottom of the eyes (5). Whorl asymmetry (**AS**) was scored in relation to facial midline: far left (1), left of center (2), center (3), right of center (4), and far right (5). Whorl rotation (**ROT**) described the type of rotation observed: anti-clockwise (A = 1), tendency for left rotation (L = 2), no rotation (N = 3), tendency for right rotation (R = 4), and clockwise rotation (C = 5). Complete description of hair whorl scoring can be found in Grandin et al. (1995) and Evans et al. (2005).

Animals with double whorls or no whorls were removed from the data set and contingency tables for HT, AS, and ROT were analyzed using Chi Square analysis and PROC FREQ of SAS (Version 9.1, SAS Inst. Inc., Cary, NC). Pairwise analyses of whorl attributes were performed using Chi Square and PROC FREQ and counts of each paired category were used to construct contour plots. Sire x dam mating combinations A x A, A x C, C x A, and C x C, were analyzed using familial data and PROC FREQ of SAS .

Heritabilities and genetic correlations for whorl attributes were estimated using ASREML (Version 1.10, VSN International, Ltd., Hempstead, England) with sex as the sole fixed effect. The pedigree included 112 sires and 617 dams.

Results and Discussion

Greater proportions ($P < 0.01$; Table 1) of hair whorls were located from the eyes to the mouth (HT3 to 5) and left of center (AS2). A majority ($P < 0.01$; Table 1) of hair whorls rotated in a clockwise (5 = C) direction. Height and AS results were similar to Evans et al. (2005) in which a majority of hair whorls were located in the middle (HT3) and low on the head (HT4 and 5), and either centered (AS3) or left of center (AS2) in Holstein bulls. This was expected as datasets overlapped between Evans et al. (2005) and the current study.

Pairwise analysis of HT and AS indicated greater (Figure 1; $P < 0.01$) percentages of hair whorls located left of the midline (AS2) and centered between the top and bottom of the eyes (HT3). These results conflicted with Lanier et al. (2001) who observed hair whorls centered between the eyes (HT3, AS3). No difference in pairwise association of HT and AS for N and R rotation directions were detected, and analysis of HT x AS for L whorl rotation was not performed because of insufficient data. A greater proportion of A (n = 344, $\chi^2 = 41.3$, $P < 0.01$) and C whorl rotations (n = 447, $\chi^2 = 32.1$, $P = 0.01$) were located left of the midline (AS2) and centered between the top and bottom of the eyes (HT3). These results were similar to those observed for HT x AS (Figure 1). In humans, C hair whorls are commonly observed in both right-handed and non-right-handed individuals, and A whorls were prevalent in non-right-handed individuals only (Klar, 2003). Thus, association of both C and A rotations with the left side of the animal's face was not expected.

Heritabilities for HT, AS and ROT were 0.54 ± 0.08, 0.11 ± 0.06, and 0.14 ± 0.07, respectively. VanCise et al. (2005) determined HT and AS were highly heritable in Holstein cattle, however, these estimates were calculated for the same dataset used by Evans et al. (2005) and did not include the familial data used in the current study. Mating combinations A x C, C x A and C x C produced all hair whorl types expect for L rotation ($P \leq 0.03$; Table 2). Percentages of A and C whorl rotations were equal for all mating combinations except for the A x A mating where a greater proportion of A hair whorls were observed ($P = 0.02$; Table 3). In humans, comparison of handedness in children from right-handed and (or) non-right-handed parents indicated percentages of non-right-handed individuals were less than right-handed individuals for all mating combinations (Ashton, 1982; Risch and Pringle, 1985). These studies estimated 20 to 29% of the variation for handedness was genetic and suggested either a single locus or polygenic model of inheritance. Similar to the human studies, whorl attributes do not appear to be under simple genetic control as all mating combinations generated all offspring phenotypes, although in different proportions.

Pairwise bivariate analyses generated estimates of phenotypic and genetic correlations between HT and AS of 0.04 ± 0.03 and -0.08 ± 0.24, between HT and ROT of -0.04 ± 0.03 and -0.03 ± 0.22, and between AS and ROT of 0.06 ± 0.03 and -0.07 ± 0.38. VanCise et al. (2005) estimated a genetic correlation of 0.10 between HT and AS, however, results from the current study indicated HT, AS and ROT were independent. The current study confirm Bishop (2001) and James and Orlebeke (2002) which suggested handedness may not be affected solely by genetics, but influenced by cultural or environmental factors. Bivariate analyses that examined A and C rotations as different traits produced genetic correlations of 0.68 ± 0.24 for HT and 0.40 ± 0.58 for AS providing no evidence HT or AS are different traits for A or C rotations.

Hair whorl formation has been attributed to molecular mechanisms, genetics, and mechanical tension (Samlaska et al., 1989). Cellular and molecular pathways of follicular morphogenesis and hair shaft eruption have been described using molecular studies (Millar, 2002; Alonso and Rosenfield, 2003); however, these studies have not been able to fully explain hair whorl patterning.

Genetics or inheritance is a favored explanation for hair whorl formation; but, Mendelian inheritance for handedness using hair whorls as a phenotypic marker has not been consistently proven in twin (Ashton, 1982; Risch and Pringle, 1985) or non-twin studies (Bishop, 2001; James and Orlebeke, 2002). In addition, research has failed to identify candidate genes or QTL using siblings in nuclear or extended families (Francks et al., 2002; Van Agtmael et al., 2002). Collectively, these studies suggest a simple genetic explanation for hair whorl formation may not be plausible. However, Guo et al. (2004) investigated *in vivo* effects of Frizzled6, a gene proposed to affect hair patterning in mice. Mice homozygous for mutated Frizzled6 had whorls on the dorsal surface of the head, C whorl rotations on the right hind feet and A whorls on the left hind feet, and C whorls on the left side and A whorls on the right side of the chest. Perhaps this particular gene and its gene family may be likely candidates for genes affecting hair whorl patterning.

Mechanical tension due to scalp stretching appears to be a likely explanation for hair whorl formation. Embryonic epithelium and underlying mesenchymal tissue create the hair follicle and as the hair shaft emerges from the scalp, it continues to grow in an oblique direction (Millar, 2002; Alonso and Rosenfield, 2003). Concomitant brain development (Dobbing and Sands, 1973; Samuelsen et al., 2003) stretches the scalp thus producing the hair whorl pattern (Smith and Gong; 1974; Hoath, 1990). Signaling molecules that regulate hair follicle development also affect brain development (Helms et al., 2005; Tannahill et al., 2005); therefore, association of parietal hair whorl formation and brain development appears to be the most likely explanation in humans. In cattle, hair whorls are commonly located on the forehead (Grandin et al., 1995) and perhaps these whorls form similarly to parietal whorls because fetal forebrain and craniofacial development occur during the same period (Diewert, 1985; Soana, 1996; Donkelaar, 2000).

Hair whorl height, asymmetry and rotation are moderately to highly heritable polygenic traits. Whorl height and asymmetry appear to be the same trait regardless of whorl direction, and different genes seem to

be involved in determination of each of these three attributes.

Implications

In related Holstein cattle, hair whorl attributes appear to be genetically controlled, albeit by different genes. Further research is required to determine if cattle temperament, behavior, or reproductive performance is due to genetic and (or) developmental association of these traits with the whorl attributes.

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Table 1. Percentage of Holstein cattle (n = 945) expressing levels of the whorl attributes height (1 = level with the top of the eyes), asymmetry (1 = far left) and rotation (1 = anti-clockwise). Chi-square results test equal proportions of attribute levels.

	Percentage						
Whorl attribute	1	2	3	4	5	χ^2	*P*-value
Height	5.8	9.2	34.7	18.0	32.3	325.4	< 0.01
Asymmetry	6.5	45.2	19.1	22.9	6.3	478.6	< 0.01
Rotation	36.4	1.4	8.7	6.2	47.3	793.2	< 0.01

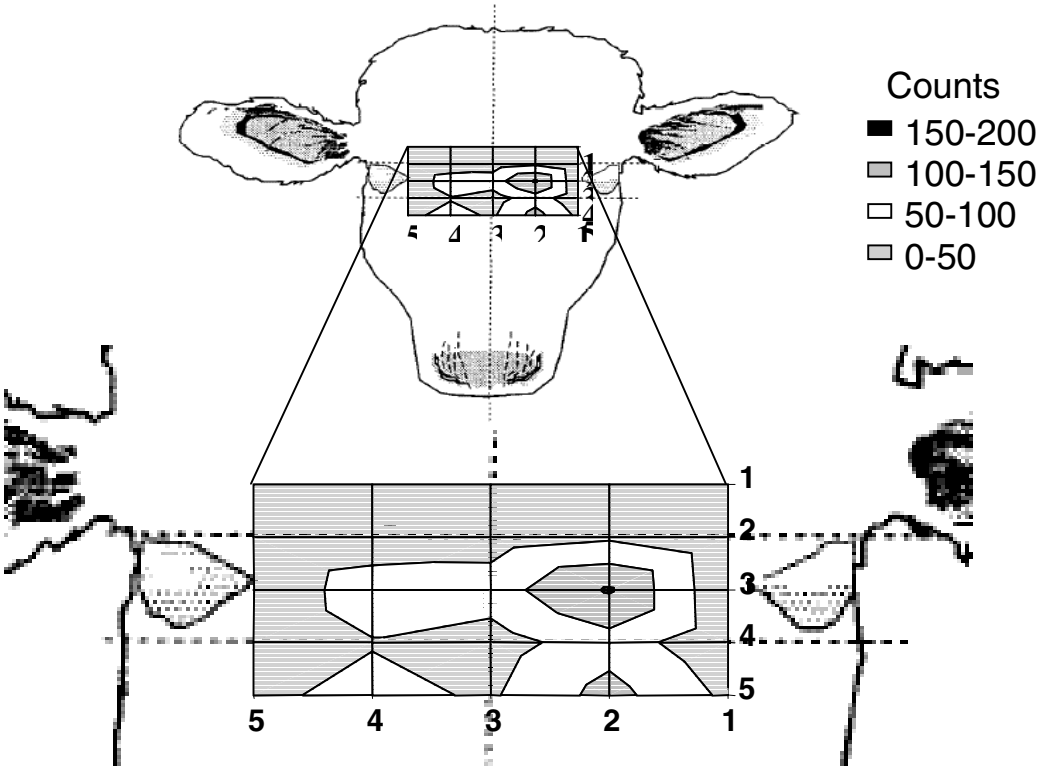
Table 2. Percentages of Holstein progeny (n = 143) expressing hair whorl rotation types observed from anti-clockwise (A) and clockwise (C) mating combinations. Chi-square result tests equal proportion of rotation levels.

		Rotation						
Sire x Dam mating	n	A	L	N	R	C	χ^2	*P*-value
A x A	32	62.5	0	3.1	9.4	25.0	27.2	< 0.01
A x C	18	38.9	5.6	11.1	5.6	38.9	10.9	0.03
C x A	63	52.4	0	3.2	4.8	39.7	46.6	< 0.01
C x C	30	53.3	0	6.7	6.7	33.3	18.5	< 0.01

Table 3. Percentages of Holstein progeny (n = 126) expressing anti-clockwise (A) or clockwise (C) hair whorl rotation types observed from A and C mating combinations. Chi-square result tests equal proportion of rotation levels.

		Rotation			
Sire x Dam mating	n	A	C	χ^2	*P*-value
A x A	28	71.4	28.6	5.1	0.02
A x C	14	50.0	50.0	0	-
C x A	58	56.9	43.1	1.1	0.09
C x C	26	61.5	38.5	1.4	0.24

Figure 1. Contour plot of hair whorl height (vertical axis) and asymmetry (horizontal axis) for the Holstein population (n = 945). Chi-square results tests equal proportions of paired HT and AS levels (χ^2 = 83.7, *P* < 0.01).



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GENETIC PARAMETERS OF FIRST LACTATION CURVE TRAITS FOR HOLSTEIN-FRIESIAN COWS IN TUNISIA

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ABSTRACT: Genetic parameters of lactation curve traits were estimated for Holstein-Friesian cows in Tunisia. A total of 17,232 first lactation records collected from 1990 to 2002 in 137 herds were used in the analysis. Records were of daughters of 246 AI bulls with at least 50 progeny each. The Incomplete Gamma function was fit to test-day yields to determine curve traits: Factors a, b, and c representing the beginning of lactation, the increasing phase before peak yield, and the decreasing phase after peak yield, respectively ; peak yield ; and persistency. Heritability estimates were determined by ML and REML applied to a sire model that included herd, calving year, and calving month as fixed effects, and by Dam on daughter regression. Phenotypic correlations were estimated using residuals from the analysis of variance of the same model without the sire effect. Heritability estimates were 0.19, 0.26, 0.24, 0.26, 0.59, and 0.25 for a, b, c, total and peak yields, and persistency, respectively. Phenotypic correlations ranged from –0.78 (a with b) to 0.76 (total with peak yields). It should be possible to change the shape of lactation curve through selection to improve yield production.

Key words: Dairy cows, lactation curves, genetic parameters

Introduction

Culling and breeding decisions are often based on the standard 305 days production (305-d). A one test day yield is rarely used to eliminate cows for many reasons; in particular, low yield in a given test-day date might be a result of stress or accidents. Records in progress could however be used to determine the shape of lactation curves and predict 305-d productions. Several works dealt with modeling full lactations and extending partial records (Shanks et al., 1981; Grossman et al., 1986; Vargas et al., 2000). Genetic aspects of the lactation curves were also studied (Shanks et al., 1981; Jarmozik and Schaeffer, 1997; Rekaya et al., 2000, Jakobson et al., 2002) for possible use of curve characteristics as selection traits. In Tunisia, phenotypic studies on the lactation curves of the Holstein-Friesian cows showed a great variability between and within production sectors (Rekik et al., 2003; Rekik et al., 2004). The objective of this study was to determine the genetic parameters of first lactation curve traits for Holstein-Friesian cows in Tunisia.

Materiel and methods

Data : Two data sets were made available by the National Center for Genetic Improvement at Sidi Thabet, Tunis. The first one had pedigree information and included the cow, the sire, the dam, and the cow's breed, herd, and birth-date. The second one included 153,885 production records of which 17,232 were first lactation records collected from 1990 to 2002 in 137 herds. The latter records were of daughters of 246 AI bulls with at least 50 progeny each. Production data included the cow's identification number, the date of freshening, the lactation number, the test-day date, and the test-day milk yield. Mean yields by test-day dates are given in table 1.

Fitting lactation curves: The Incomplete Gamma function :$Y_t = a\, t^b\, e^{-ct}$ was fit to test-day yields of each cow to determine curve traits: Factors a, b, and c representing the beginning of lactation, the increasing phase before peak yield, and the decreasing phase after peak yield, respectively. Yt is yield at time t. Peak yield and persistency were approximated by -(b+1)Ln (c) and $a(b/c)^b e^{-b}$, respectively (Tekerli et al., 2000). Fitting was carried out by the NLIN procedure in SAS (1989).

Variation of the shape of lactation curves **:** The variation of the shapes of fitted curves was studied by :

$$Y_{ijkl} = \mu + Hi + CYj + CMk + e_{ijkl} \quad (1),$$

Where: Y_{ijklmn} = a lactation curve trait (a, b, c, persistency, or peak) based on observation l in herd i (i=1 to 137) for calving year j (j=1990, ...2002), and calving month k (k=1 to 12); μ= overall mean; H= effect of herd; CY= effect of calving year; CM= effect of calving month and e= independent and identically distributed random residuals with expected value 0 and a variance of σ^2_e . Residuals from fitting the model above (1) were used to calculate Pearson phenotypic correlations among the lactation curve traits and between curve traits and 305-d yield.

Estimation of genetic parameters **:** Genetic parameters of curve traits were estimated by two methods. i) by dam on daughter regression and ii) by estimating variance components using a sire model (model 2).

Table 1. Mean yield by calving to test-day date interval.

Calving to test-day date interval (in days)		Milk yield (Kg)	
n	Mean (SD)	N	Mean (SD)
17232	24.4 (17)	17232	21.2 (7)
17232	56.0(17)	17232	22.4 (7)
17232	87.6(18)	17225	21.4 (7)
17232	119.3 (19)	17223	20.4 (7)
17232	151.1 (20)	17220	19.4 (7)
17232	183.0 (22)	17226	18.5 (7)
17226	215. 0 (24)	17222	17.8 (6)
17232	247.1 (26)	17228	16.9 (6)
17232	279.3 (29)	17230	16.1 (6)
17232	311.9 (31)	17224	14.9 (6)
17232	349.3 (36)	13231	14.1 (6)

Then, ML and REML were applied to the sire model that included the same fixed effects herd, calving year, and calving month as mode (l) , in addition to the random effects of the Sire and the error term eijklm following:

$$Y_{ijklm} = \mu + Hi + CYj + CMk + Sirel + e_{ijklm} \quad (2),$$

Where Y_{ijklmn} , μ, H, CY, and CM are as in model (1). Heritability is then $h^2 = 4\times\sigma_s^2/\sigma_y^2$ where σ_s^2= is the sire variance, σ_y^2= total variance, and σ_e^2= the variance of the error term. Variance components were obtained for differents numbers of daughters per sire : 50, 100, 150, or 200. The standard error of h^2 estimates were approximated by: $SE(h^2) = [(32*h^2)/N)]^{½}$ where N is the number of daughters per sire.

Results and discussion

Lactation curves **:** The average coefficient of determination from the individual coefficients was 0.88 and the mean absolute error was 1.45. The value of the coefficient of determination was lower than those (92 to 95%) reported by Rekik et al. (2003) for a mean first lactation curve for different production sectors on an a fewer data. The shape of lactation curves varied ($p<0.01$) with all the explanatory factors in model (1). Mean squares of variables from the analysis of variance of first lactation curve traits are given in table 2.Mean values of 16.6 (SD=8.6), 0.15 (SD=0.2), 0.003 (SD=0.002) and 6.69 (SD=0.88) were obtained for a, b, c, peak , and persistency, respectively. Examples of curves for the fall and spring seasons are given in figure 1. Milk production at the beginning of lactation « a » for example varied from 15.8 to 20.9 with the calving year. Phenotypic correlations among curve shape traits and between curve traits with 305-d yield ranged from –0.78 (a with b) to 0.76 (total with peak yields)**.** Cows that started producing milk at high levels had high peaks but low persistency; and peak yield had a higher correlation coefficient (0.76) than that of persistency with 305-d yield (0.12).

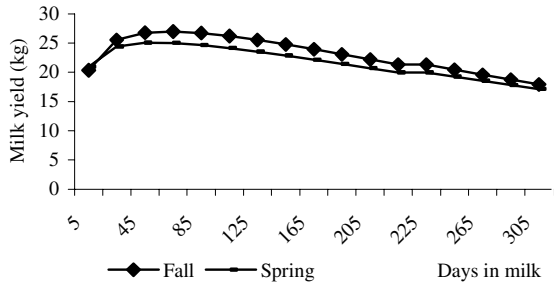

Figure 1. Curve shapes of first lactation for Holstein-Friesian cows for the fall and spring seasons.

Table 2. Mean squares of variables from the analysis of variance (model 1) of first lactation curve traits for Holstein- Friesian cows in Tunisia.

		Lactation curve traits					
Variable	df	a	b	c ($x10^{-3}$)	Peak	Persistency	$Yield_{305\text{-}d}$
Herd	122	6949.5**	1.10**	0.92**	13213.4**	33.2**	174181961.9**
Calving month	11	8773.5**	5.20**	1.41**	860.3**	97.3**	157046776.5**
Calving year	12	4102.2**	0.98**	5.75**	2194.3**	31.4**	7878060.2**
Residual	17086	65.2	0.03	0.03	17.9	0.69	1741691.3
R^2		0.15	0.06	0.07	0.6	0.08	0.62

** P<0.01.

Heritability estimates **:** Estimates of heritability by both dam on daughter regression and variance component analysis are given in table 3. Most of estimates were medium values except for that of the

peak, which was high. Unexpectedly, estimates from dam on daughter regression were lower than those obtained by half-sib analysis. This might be explained by the lack of pedigree information on dams of cows. Only 1,833 dams of cows were known. Estimates obtained by REML were consistently lower than those obtained by ML and estimates by both methods tended to decrease with the increase of number of daughters per sire. Heritability estimates were in the range of those found in the literature (Rekaya et al., 2000; Jakobsen et al., 2002; Ben Gara et al., 2006) for the main curve traits and for total yield.

Table 3. Heritability estimates of first lactation curve traits for Holstein-Friesian cows in Tunisia.

		Estimation method				
Curve trait	Number of daughters per sire	ML	REML	Dam on daughter regression		
		h^2	h^2	n	β	h^2
a	50	0.41 (0.10)	0.42 (0.10)	1833	0.11 (0.02)	0.22
	100	0.28 (0.12)	0.29 (0.12)			
	150	0.21 (0.13)	0.22 (0.13)			
	200	0.18 (0.12)	0.19 (0.12)			
b	50	0.51 (0.11)	0.48 (0.11)	1833	0.02 (0.02)	0.04
	100	0.31 (0.12)	0.32 (0.12)			
	150	0.25 (0.14)	0.26 (0.14)			
	200	0.25 (0.14)	0.26 (0.14)			
c	50	0.56 (0.12)	0.56 (0.12)	1833	0.05 (0.02)	0.10
	100	0.32 (0.12)	0.33 (0.02)			
	150	0.23 (0.13)	0.24 (0.13)			
	200	0.23 (0.13)	0.24 (0.13)			
Peak	50	0.83 (0.15)	0.86 (0.15)	803	0.49 (0.02)	0.98
	100	0.69 (0.18)	0.75 (0.18)			
	150	0.62 (0.20)	0.63 (0.20)			
	200	0.58 (0.20)	0.59 (0.20)			
Persistency	50	0.43 (0.10)	0.44 (0.10)	1524	0.10 (0.02)	0.20
	100	0.31 (0.12)	0.32 (0.12)			
	150	0.24 (0.14)	0.25 (0.14)			
	200	0.17 (0.11)	0.18 (0.11)			

(.) : Standard error.

Implications

The main traits of the first lactation curve are heritable. Heritability estimates were comparable and even higher than that of total yield (305-d yield). Moreover, peak yield and persistency were correlated with total yield. It should be therefore possible to change the shape of lactation curve through selection to improve yield production.

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BREED OF THE DAM EFFECTS ON CARCASS TRAITS AND SHEAR FORCE OF BEEF CATTLE

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ABSTRACT: Breed of dam effects on carcass traits and shear force of progeny were evaluated over four years on 534 steers and heifers. Dam breed combinations were formed by mating Hereford(H), Tarentaise(T), Angus(A), Piedmontese(P), Salers(S), and Charolais(C) bulls to Hereford, Tarentaise, and Tarentaise-Hereford cross cows. Female calves produced from these matings were bred to Simmental, Gelbvieh, Angus, Red Angus, or Hereford sires producing steers and heifers evaluated for carcass traits and tenderness. Average calf age at harvest was 428 days. Data were analyzed with GLM procedures of SAS and the model included effects of year, age of dam, sex of calf, sire within year, treatment within year, and sex by treatment within year interaction. Covariates were age at harvest, percent individual heterosis, percent maternal heterosis, and dam breed percentages. Breed of dam effects were expressed as deviations from Piedmontese. Traits analyzed were hot carcass weight (HCW), *longissimus* area (RIB), 12th rib fat (FAT), calculated yield grade (CYG), marbling score (MARB), and shear force to evaluate tenderness (SHEAR). Year was significant (P<0.01) for all traits but age of dam had no effect on the traits analyzed. Steers were different from heifers (P<0.01) with heavier HCW, greater CYG value, less MARB and greater tenderness (lower SHEAR values). Dam breed effects on hot carcass weight were lightest for P, H, and T with A, S, and C heaviest; on RIB, P were greater (P<0.01) than H, T, A, S, and C; on SHEAR, P had the lowest value with T the greatest (P<0.01); on FAT, P was less (P<0.01) than H, T ,A, S, and C. Deviations from P on SHEAR for H, T, A, S, and C were (0.47, P=0.20), (1.05, P<0.01), (0.38, P=0.23), (0.58, P=0.06) and (0.59, P=0.08) kg, respectively. Piedmontese breed combinations had largest RIB, least FAT, and smallest SHEAR. Dam breed had significant effects on carcass traits.

Keywords: Beef cattle, Dam breed, Carcass traits, Tenderness

Introduction

Breed differences in production traits are important genetic resources for improving beef production including feedlot performance, carcass yield, and carcass composition. The effect of breeds and breed crosses on carcass traits have been well documented with the emphasis on sire breeds and what they may contribute to the beef industry. Many crossbreeding programs incorporate a crossbred female and the sire breed of the dam can influence the level of production (Gregory et. al., 1987; Casas and Cundiff, 2006). Wheeler et al. (1977) reported significant sire breed differences in carcass yield traits to allow for selection and crossing among breeds to optimize the selected traits. Research on breeds that express muscle hypertrophy such as Piedmontese and breeds that express greater potential for backfat and marbling have been reported by Tatum et al. (1990) and Grings et al. (2001). The objective of this study was to evaluate breed of dam effects on carcass traits and shear force.

Materials and Methods

Steers and heifers (n=534) evaluated in this study were produced from females with differing percentage of Hereford, Tarentaise, Angus, Piedmontese, Salers, and Charolais breeding. Breed of dam combinations were formed by mating Hereford, Tarentaise, and Hereford-Tarentaise cross females to Hereford, Tarentaise, Angus, Piedmontese, Salers, and Charolais sires during a 45-d AI breeding season (Davis et al., 2001). The effect of Hereford, Tarentaise, Angus, Piedmontese, Salers, and Charolais sires on feedlot and carcass traits of steer progeny produced from these matings were reported by Anderson et al. (2001). Female progeny from these matings were bred to Simmental, Gelbvieh, Angus, Red Angus or Hereford sires producing steers or heifers for evaluating carcass traits and shear force. Calves were weaned October 1 at approximately 180 d of age and placed on hay fields to graze for 45 d prior to placement in the feedlot on November 15. Calves were finished on a high concentrate (barley) ration plus corn silage and protein supplement until harvest. Diets were balanced to meet or exceed NRC requirements and to allow 1.5 $kg \cdot d^{-1}$ gain. Approximate days on feed were 220 d.

Data collected included hot carcass weight (**HCW**), *longissimus* area (**RIB**), 12th rib fat (**FAT**), calculated yield grade (**CYG**), marbling score (**MARB**), and shear force to evaluate tenderness (**SHEAR**). Cattle were harvested after being transported 15 h with a 5-7 h stand prior to harvest. Carcass data were taken and strip loins from each carcass were collected 24-48 h after harvest, placed in vacuum-sealed bag, aged 14-d, and frozen prior to evaluation. Shear force was evaluated

utilizing standard procedures described by Choat et al. (2003) for the Warner Bratzler test.

Traits were analyzed using the general linear models procedure of SAS. Fixed effects included year of record, age of dam, sex of calf (SEX), treatment nested within year (TRT), calf sire nested within year, and the sex by treatment interaction (SEX*TRT). Age at harvest, percent individual heterosis, percent maternal heterosis,, and percent of breed types of the dam were fit as covariates (Robison et al., 1981). Dams aged 5 yrs and older were classed as 5-yr-olds. Treatments that included various nutritional and management protocols were nested within year to account for differing protocols for the four years reported, and sires were nested within year to minimize variation due to no common sires across years. Dam breed effects were expressed as deviations from Piedmontese.

Results and Discussion

Differences between steers and heifers were significant for all traits except FAT and RIB (Table 1). Values for SHEAR were greater for heifers (P<0.01) than steers in agreement with Choat et al. (2003). Heifers also had lighter carcasses, less KPH, lower CYG and greater marbling. Year effects were important (P<0.01) for all traits except KPH (Table 2). Age of dam only influenced CYG (P<0.05). Most traits studied were affected by TRT, sire, and SEX*TRT (Table 2). Age at harvest influenced RIB, CYG, and MARB (P<0.01, Table 3). Individual and maternal heterosis did not affect carcass traits in the study. This is in agreement with Gregory et al. (1987) who found that heterosis effects tended to be positive but not significant on either an age-constant or weight-constant basis harvest endpoint.

Table 1. Least squares means and standard errors of carcass traits for steers and heifers

Trait	Heifers	Steers
Shear force, kg	5.24 ± 0.09[a]	4.37 ± 0.09[b]
Carcass wt., kg	295 ± 2.30 [a]	327 ± 1.83 [b]
12th Rib fat, cm	0.98 ± 0.03	0.99 ± 0.02
Rib-eye area, cm^2	77.4 ± 0.75	77.8 ± 0.60
KPH fat, %	1.93 ± 0.02[c]	1.97 ± 0.02[d]
Yield grade	2.48 ± 0.05 [a]	2.72 ± 0.04 [b]
Marbling[e]	471 ± 9.4[c]	447 ± 7.8[d]

[ab] Rows without common superscript differ Pr<0.01
[cd] Rows without common superscript differ Pr<0.05
[e] Marbling 400 = small[00]

Breed of dam effects for Piedmontese were frequently different from other breeds (Table 4). Piedmontese was set to 0 in the analysis as it is a breed known to have distinct carcass characteristics due to a higher frequency of double muscling within the breed when compared to the other breeds evaluated in this study (Grings et al., 2001). Steaks from progeny of Tarentaise dams had the highest and significantly higher SHEAR (indicating less tender) than progeny of Piedmontese dams with the difference between the two being 1.05 kg. Steaks from the progeny of Salers (P=0.06) and Charolais (P=0.08) dams required slightly greater SHEAR than Piedmontese. There was no significant difference among Hereford, Angus and Piedmontese dams for SHEAR, in agreement with Tatum et al. (1990) and Wheeler et al. (2001). Angus and Herford were similar in SHEAR requiring less force than Salers, Charolais and Tarentaise. Breed of dam effects tended to cause larger SHEAR values from Continental breeds when compared to English breeds except for the double muscling effect from Piedmontese.

Breed of the dam affected HCW with Piedmontese, Hereford and Tarentaise lighter than Angus, Salers and Charolais. Because all steers and heifers were harvested as a group each year, the HCW difference would reflect a difference in growth of the different breed of dam groups and the smaller framed cattle would not have the growth potential of the larger framed cattle in this study. The exception to this study is the Angus cattle which exhibited similar HCW as Salers and Charolais (Table 4). There was a significant (P<0.01) effect of the Piedmontese breed of dam on FAT, RIB, and CYG with calves from Piedmontese breed of dam having less fat, greater RIB and smaller CYG which means higher cutability thus producing more retail product than the other breed of dam groups. The Angus, Hereford, and Saler breed of dam groups had more (P<0.01) FAT than the other breed of dam groups. Piedmontese had the largest RIB, Charolais and Salers were intermediate with Hereford, Angus and Tarentaise having the smallest RIB. Using HCW, FAT, RIB, and KPH to develop CYG, the highest cutability Piedmontese were followed by Charolais and Tarentaise with Hereford, Angus, and Salers being the lowest. This is similar to data reported by Anderson et al. (2001) in evaluating F1 steers sired by Angus, Charolais, Piedmontese, Salers, and Hereford-Tarentaise.

All cattle within year and sex class were harvested at the same date and when a high percentage were determined to have a MARB score of 400. Piedmontese had the smallest MARB with Angus the highest value (Table 4). Hereford, Charolais, and Salers were intermediate for MARB but greater than Tarentaise.

Implications

Piedmontese dams had a significant impact on the carcass and tenderness traits of their crossbred calves. Piedmontese dam effects produced steer and heifer carcasses that were more tender with less SHEAR, larger RIB, less FAT, lower CYG when compared to Hereford, Tarentaise, Angus, Salers, or Charolais. These data indicate carcass and tenderness traits can be influenced by the selection of breed of dam. Piedmontese have been recommended for use as terminal sires but many of the carcass benefits can be exploited if used as 50% of the dam breed in a crossbreeding program as evaluated in this study. The calves would only have 25% Piedmontese genes in the harvested animal.

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Table 2. P values (Pr<F) for main effects on carcass traits in evaluating breed of dam effects

Source	Shear force	Carcass wt.	12th rib fat	Rib-eye area	KPH	Yield grade	Marbling
Year	.0001	.0013	.0002	.0001	.4407	.0001	.0001
Age of dam	.2383	.1325	.0938	.3853	.6655	.0438	.8893
Sex	.0001	.0001	.7763	.1400	.0270	.0001	.0189
Treatment(yr)	.0001	.0001	.4417	.0001	.0009	.4056	.1931
Sire(yr)	.0048	.0001	.0001	.0001	.0001	.0001	.0001
Sex*Treat(yr)	.0001	.0010	.0278	.0001	.0247	.0024	.9303
R^2	.71	.65	.50	.53	.26	.54	.37

Table 3. P values (Pr<F) for covariates for age at harvest, heterosis and breed of dam effects with Piedmontese set to 0

Source	Shear force	Carcass wt.	12th rib fat	Rib-eye area	KPH	Yield grade	Marbling
Harvest Age	.5667	.1251	.2255	.0001	.9477	.0007	.0002
Heterosis-I[a]	.9825	.7265	.3504	.2900	.6616	.3080	.7138
Heterosis-M[b]	.3361	.6546	.2690	.5256	.2216	.6632	.6128
%Hereford[c]	.1982	.6231	.0001	.0001	.0337	.0001	.1036
%Tarentaise	.0050	.5711	.0009	.0004	.8343	.0056	.3625
%Angus	.2320	.0087	.0001	.0001	.0018	.0001	.0006
%Salers	.0583	.0053	.0001	.0011	.0271	.0001	.1126
%Charolais	.0777	.0924	.0002	.0056	.1443	.0005	.0100

[a] Individual heterosis. Values correspond to 100% individual heterosis.
[b] Maternal heterosis. Values correspond to 100% maternal heterosis.
[c] Value for breeds of dam correspond to 100% for each breed.

Table 4. Breed of dam effects as deviations from Piedmontese[a]

	Trait						
Breed of dam	Shear force, kg	Carcass wt., kg	12th rib fat, cm	Rib-eye area, cm^2	KPH %	Yield grade	Marbling score[b]
Hereford	0.47 ± 0.81	3.62 ± 7.36	0.67 ± 0.10	-12.04 ± 2.42	0.14 ± 0.07	1.03 ± 0.15	49.6 ± 30.46
Tarentaise	1.05 ± 0.37	-4.23 ± 7.46	0.32 ± 0.10	-8.77 ± 2.46	0.01 ± 0.07	0.44 ± 0.16	27.8 ± 30.51
Angus	0.38 ± 0.31	16.59 ± 6.30	0.76 ± 0.08	-8.57 ± 2.07	0.08 ± 0.06	1.00 ± 0.13	89.4 ± 25.84
Salers	0.58 ± 0.31	17.37 ± 6.20	0.54 ± 0.08	-6.69 ± 2.04	0.13 ± 0.06	0.77 ± 0.13	40.6 ± 25.58
Charolais	0.59 ± 0.34	11.33 ± 6.72	0.32 ± 0.09	-6.16 ± 2.21	0.09 ± 0.06	0.49 ± 0.14	70.9 ± 27.43

[a] Values correspond to 100% for each breed of dam.
[b] Deviation based on marbling score 400 = small[00]

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GENETIC CORRELATIONS OF COMPONENT CARCASS TRAITS WITH RETAIL PRODUCT PERCENTAGE IN SIMMENTAL CATTLE

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ABSTRACT: The objective of this study was to estimate genetic parameters required for genetic evaluation of retail product percentage (**PRP**) in Simmental cattle. Carcass weight (**HCW**, n = 6,558), fat thickness (**FAT**, n = 6,188), longissimus muscle area (**REA**, n = 6,527), and kidney, pelvic, and heart fat (**KPH**, n = 6,434) were available from steers (n = 5,171) and heifers (n = 1,400) in the American Simmental Association carcass database. Animals with carcass records were sired by 561 Simmental bulls and out of 5,889 crossbred dams, with percent Simmental breed composition ranging from 50 to 94%. Approximately three ancestral generations were used to construct the inverse relationship matrix among 49,766 animals. Genetic parameters were estimated using an animal model and REML with fixed harvest contemporary group (harvest date × sex × percentage Simmental [50, 62, 75, 94%], n = 244), random animal genetic effects, and a linear covariate for age at harvest (455 d, SD = 50). A five-trait model including all component carcass traits and PRP failed to converge due to linear dependencies of PRP with FAT and REA. Two three-trait models were then used to estimate parameters among HCW, REA, and PRP (**M1**), and among FAT, KPH, and PRP (**M2**). Heritability estimates (± 0.05) from M1 were 0.51, 0.46, and 0.41 for HCW, REA, and PRP, respectively, and were 0.36, 0.18, and 0.41 for FAT, KPH, and PRP, respectively, from M2. Estimated genetic correlations of PRP with HCW, FAT, REA, and KPH were -0.16 ± 0.08, -0.83 ± 0.03, 0.68 ± 0.05, and 0.01 ± 0.12, respectively. Based on these estimates, PRP is strongly associated with genetic potential for muscle and fat deposition, but essentially independent of carcass weight and body cavity fat. Genetic evaluation of PRP would therefore be straightforward using multiple trait index methods to decrease the numbers of mixed model equations to be solved, and to avoid a genetic (co)variance matrix among PRP and its components that is not positive definite.
Key Words: Beef Cattle, Carcass, Genetics, Simmental

Introduction

Several national beef breed associations maintain carcass databases which are used in their national cattle evaluation systems for carcass merit. Heritability estimates for most carcass traits have generally been reported to be moderate (Koots et al., 1994a), and therefore expected to respond to selection, given a sufficiency of data and selection intensity. The typical traits recorded and maintained in carcass databases include those components used to compute composite carcass merit traits, including USDA yield grade, retail product percentage, and USDA quality grade. To varying extent, the genetic and statistical properties of composite carcass traits have also been summarized (Koots et al., 1994a,b).

Genetic evaluation of composite traits requires model development and estimation of necessary genetic parameters. However, increasing the numbers of traits to be evaluated with a multivariate model greatly increases the numbers of equations to be solved with large field data sets (Crews et al., 2003). Problems with convergence may also occur when composite traits are linear functions of components evaluated in the same model, or when composite and(or) component traits share part-whole relationships.

The development of multiple trait carcass models for genetic evaluation of retail product percentage in field populations have been rarely reported in the literature. Therefore, the objectives of this study were to develop an appropriate model and estimate genetic parameters required for multiple trait genetic evaluation of retail product percentage in Simmental cattle.

Materials and Methods

Carcass records, including hot carcass weight (HCW, kg, n = 6,558), subcutaneous fat thickness (FAT, mm, n = 6,188), longissimus muscle area (REA, cm^2, n = 6,527), and kidney, pelvic and heart fat (KPH, %, n = 6,434), were available from 5,171 steers and 1,400 heifers in the American Simmental Association database. Animals with carcass data were sired by 561 Simmental bulls and out of 5,889 crossbred dams. Retail product percentage (PRP) was calculated for the 6,051 steers and heifers for which all component carcass measurements were non-missing, according to the standard formula: PRP = 51.34 – (5.78 × FAT) – (0.0093 × HCW) – (0.462 × KPH) + (0.740 × REA). For this calculation, component carcass traits were expressed in imperial units (i.e., HCW, lb,, FAT, in, and REA, in^2).

Approximately three ancestral generations, beginning with animals with records, were used to construct the inverse additive relationship matrix among 49,766 animals. Sires had from 1 to 406 progeny (average = 20.7) with carcass data whereas dams had from 1 to 7 progeny (average = 1.45) with carcass data. The fixed effects portion of the model for all traits included the main effect of harvest contemporary group (harvest date × sex ×

percentage Simmental [50, 62, 75, 94%], n = 244) and a linear covariate corresponding to age at harvest (455 d, SD = 50). It is noteworthy that the inclusion of harvest date in the contemporary group definition reduced the impact of the harvest age covariate effect. Random effects in the model, also assumed constant across traits, included only direct genetic (animal) effects. In matrix notation, the animal model can be represented as: $\mathbf{y} = \mathbf{Xb} + \mathbf{Zu} + \mathbf{e}$, where design matrices **X** and **Z** relate observations in the vector **y** to vectors of fixed (**b**) and random (**u**) effects, respectively, and **e** is a vector of residuals, specific to animals. (Co)variance components, resulting genetic parameters, and their associated standard errors were estimated using ASREML (Ver. 1.10, VSN International, Ltd., Hemel Hempstead, UK) which employs an average information REML algorithm.

An initial five-trait model with all component carcass traits plus PRP was fit, but failed to converge due to an apparent linear dependency among FAT, REA, and PRP. This dependency most likely resulted in a genetic (co)variance matrix that was not positive definite. Subsequently, two models that separated the component traits into two groups were employed. Model 1 (M1) included HCW, REA, and PRP, whereas model 2 (M2) included FAT, KPH, and PRP. A third model (M3), including only the four component carcass traits (i.e., HCW, FAT, REA, and KPH) was used to estimate (co)variance components and genetic parameters. From these three models, a complete genetic (co)variance matrix for a five-trait model could be assembled. However, the resulting system of mixed model equations would be dramatically increased compared to a more reduced model genetic evaluation model. Therefore, to avoid a genetic (co)variance matrix that is not positive definite, and to reduce the size of the mixed model equation system, multiple trait index methods (e.g., Mrode, 2005) were used to solve for PRP breeding values. The equations to be solved can be represented in matrix notation as:

$$\mathbf{u} = \mathbf{aG^{-1}P}$$

where **u**, the n × 1 vector of PRP breeding values was the product of **a**, the n (n = numbers of animals) × t (t = numbers of predictor traits) matrix of breeding values for the component carcass traits, $\mathbf{G^{-1}}$, the t × t matrix of inverse genetic (co)variances among the component carcass traits, and **P**, the t × 1 vector of genetic covariances of each component carcass trait with PRP. In this application, t = 4 and n = 49,766. Elements of the matrix **a** were from the solution to M3, and elements of **G** were the genetic (co)variance components from M3. Genetic covariances of HCW, FAT, REA, and KPH with PRP from M1 and M2 were the four elements of **P**. Matrix properties were verified using OCTAVE, an interpreted matrix language component of the Linux (Red Hat Enterprise Linux Workstation Ver. 4.2, Research Triangle Park, NC). Specifically, the symmetry of **G** was checked, as well as the existence of a positive definite inverse, $\mathbf{G^{-1}}$. The matrix and vector products were obtained using the Animal Breeder's Tool Kit (ABTK Ver. 2.1.2, Golden et al., 2000). Summary statistics for the resulting PRP breeding values were also computed. Comparisons with PRP breeding values from M2, M3, and the genetic regression were also made.

Results and Discussion

Summary statistics for the component carcass trait and PRP phenotypes in the sample are reported in Table 1. Further details on a subset of these data were given in Crews et al. (2003, 2004). Percent retail product phenotypes ranged from 42.1 to 56.9%.

Table 1. Summary statistics for component carcass traits and retail product percentage

Trait[a]	N	Mean	SD
HCW, kg	6,558	347.8	41.5
FAT, mm	6,188	9.91	4.06
REA, cm^2	6,537	85.8	10.7
KPH, %	6,434	2.18	0.51
PRP, %	6,051	50.77	1.67

[a] HCW = hot carcass weight, FAT = subcutaneous fat thickness, REA = longissimus muscle area, KPH = kidney, pelvic and heart fat, PRP = retail product percentage.

(Co)variance components from M3 were used to derive genetic parameters among the component carcass traits, which are summarized in Table 2.

Table 2. Phenotypic SD and genetic parameters[a] among component carcass traits[b]

	HCW	FAT	REA	KPH
σ_P[c]	31.75	3.45	8.37	0.38
HCW	0.51 ± 0.05			
FAT	0.03 ± 0.09	0.36 ± 0.05		
REA	0.51 ± 0.06	-0.43 ± 0.08	0.46 ± 0.05	
KPH	-0.02 ± 0.11	-0.07 ± 0.12	0.08 ± 0.11	0.18 ± 0.04

[a] Heritability (± SE) estimates are on the diagonal and genetic correlations (± SE) are below the diagonal.
[b] HCW = hot carcass weight, FAT = subcutaneous fat thickness, REA = longissimus muscle area, KPH = kidney, pelvic and heart fat.
[c] Phenotypic SD.

Heritability estimates were generally moderate to high (0.18 to 0.51) for the component carcass traits, with the exception of KPH. Koots et al. (1994a) reported weighted average heritabilities from a meta-analysis of published parameter estimates of 0.45, 0.43, and 0.43 for HCW, FAT, and REA. The estimates in the present study were similar to the weighted averages in that summary. The heritability estimate of 0.18 for KPH in this study was the lowest in magnitude among the component traits. Few heritability estimates for KPH have been published from field populations, however, Pariacote et al. (1998) reported that heritability of KPH in Shorthorns was 0.45 ± 0.19, which is considerably higher than in the present study. Genetic correlation estimates among the component carcass traits were largest between HCW and REA (0.51 ± 0.06) and between REA and FAT (-0.43 ± 0.08). These estimates generally reflect the negative genetic association between deposition of fat versus lean, and that genetic effects for increasing muscle were positively associated with those for

increasing carcass weight. Although HCW and FAT intuitively share a part-whole relationship, their genetic correlation was near zero.

Models M1 and M2 were used to estimate genetic (co)variances and correlations of the four component carcass traits with PRP. The traits included in these models were grouped according to their general description as being lean-related (M1) or fat-related (M2). Consequently, heritability estimates were obtained for PRP from both M1 and M2. From both models, the estimated heritability for PRP was 0.41 ± 0.05. Koots et al. (1994a) reported weighted heritability estimates of 0.47 for cutability, 0.63 for lean:bone ratio, and 0.55 for carcass lean percentage which are traits similar to PRP. Table 3 contains estimates of genetic covariances and correlations involving PRP.

Table 3. Genetic covariances (σ_g) and correlations (r_g) of retail product percentage with component carcass traits

		Retail product percentage	
Component[a]	Model	σ_g	r_g
HCW	M1	-3.166	-0.16 ± 0.08
FAT	M2	-1.560	-0.83 ± 0.03
REA	M1	3.477	0.68 ± 0.05
KPH	M2	0.001	0.01 ± 0.12

[a] HCW = hot carcass weight, FAT = subcutaneous fat thickness, REA = longissimus muscle area, KPH = kidney, pelvic and heart fat.

The genetic correlation estimates reported in Table 3 reflect the very strong associations of PRP with FAT (r_g = -0.83 ± 0.03) and REA (r_g = 0.68 ± 0.05). However, PRP was not significantly correlated with either HCW (r_g = -0.16 ± 0.08) or KPH (r_g = 0.01 ± 0.12). The magnitude of the genetic correlations of PRP with FAT and REA also allude to the problem of forming a positive definite genetic (co)variance matrix that would be required for multivariate genetic evaluation of component carcass traits plus PRP. Combining results in Tables 2 and 3 also suggest that KPH may not be an important component for genetic evaluation of PRP. In general, KPH had a low heritability, and was essentially uncorrelated with the remaining component carcass traits and with PRP. Removal of KPH, leaving a reduced model including only HCW, FAT, REA, and PRP, however, did not alleviate the convergence failure in estimating variance components.

From these results, the challenge remains to obtain breeding values for PRP without fitting a model that simultaneously includes PRP and its components. Standard multiple trait index equations of the form $\mathbf{u} = \mathbf{aG^{-1}P}$ could be solved which would give the PRP breeding values, with the added advantage that fewer equations would be solved than if PRP were included as a separate trait. From Table 2, the t × t inverse genetic (co)variance matrix ($\mathbf{G^{-1}}$) in these equations can be represented as

$$\mathbf{G^{-1}} = \begin{bmatrix} 516.0 & & & \text{Symm.} \\ 1.483 & 4.237 & & \\ 64.17 & -4.97 & 32.05 & \\ -0.06 & -0.02 & 0.068 & 0.026 \end{bmatrix}^{-1}$$

if all four component traits were considered predictors. Further, from Table 3, the t × 1 vector of genetic covariances of the component traits with PRP can be represented as

$$\mathbf{P} = \begin{bmatrix} -3.166 \\ -1.560 \\ 3.477 \\ 0.001 \end{bmatrix}$$

which relates the predictors to PRP. Pre-multiplication of the product $\mathbf{G^{-1}P}$ by the matrix **a** (n × 4) could be termed genetic regression, with the resulting (n × 1) vector **u** containing PRP breeding values. In this data set, where n = 49,766 animals, the reduction in numbers of equations was less important, however, in routine national cattle evaluation involving up to millions of animals, the reduction in iteration and other computing time would be considerable. In general, reducing the system to four traits from five by removing PRP would decrease the numbers of equations to be solved by approximately 20%.

The mean, minimum, maximum, and SD for PRP breeding values (data not presented in tabular form) were 0.01, -3.37, 2.37, and 0.29, respectively. Compared to the PRP breeding values predicted with M1 and M2, those obtained by solving the above regression equations had a slightly larger range and therefore slightly larger SD. Whereas PRP breeding values from M1 and M2 had a correlation of 0.93, correlations of PRP breeding values from the regression approach described here with those from M1 and M2 were below 0.90.

Implications

National cattle evaluation of composite carcass traits such as retail product percentage typically involves multiple trait systems including component carcass traits such as hot carcass weight, subcutaneous fat thickness, longissimus muscle area, and kidney, pelvic, and heart fat percentage. Problems associated with the numbers of equations to be solved with models with more traits, and with linear dependencies of composite with component traits can be minimized using an application of index methods. This approach would significantly reduce computing requirements in large national cattle evaluation of carcass merit.

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PARAMETER ESTIMATES AND BREEDING VALUES FOR DAYS TO A CONSTANT FAT ENDPOINT

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ABSTRACT: Genetic predictions for carcass traits are typically calculated for a constant age endpoint. However in the feedlot industry, cattle are rarely fed and harvested at a constant age. Additionally, typical carcass EPD do not reflect costs of feedlot production. These two deficiencies may lead to inappropriate selection decisions. To address the deficiency in EPD representing costs of feedlot production, carcass data was linearly adjusted to a constant fat thickness, rather than a constant age, with the outcome variable being days to reach that fat endpoint**.** Heritability was estimated and breeding values subsequently calculated for days to finish. Data from the American Gelbvieh Association included 16,376 pedigree animals, 6,672 animals with carcass records of which 2,138 also had weaning weight observations. Contemporary groups (CG) were formed using breed association CG code, harvest date, producer and sex of animal. Weaning weight direct and maternal effects were included in a multi-trait model. Estimates of genetic variances were 645 $days^2$, 451 kg^2 and 75 kg^2 for days to fat endpoint, weaning weight direct and weaning weight maternal respectively. Residual variances were 775 $days^2$ and 253 kg^2 for days to endpoint and weaning weight direct respectively. Heritabilities (SE) were 0.45 (0.05) for days to constant fat endpoint, 0.58 (0.07) for weaning weight direct and 0.10 (0.03) for weaning weight maternal. The genetic correlation between weaning weight direct and days to constant fat endpoint was -0.29, indicating that genetically heavier cattle at weaning require fewer days to reach a constant fat endpoint. Aligning genetic predictions with industry practices is necessary to facilitate accurate genetic progress through selection and to begin to address costs of production.

Key words: Beef cattle, Days to finish, Genetic prediction

Introduction

The number of breed with genetic predictions for carcass characteristics has increased greatly over the past five years. Today a majority of cattle breeds publish some type of carcass genetic evaluation. As with the growth traits, carcass traits are adjusted to a constant age endpoint. However, feedlot management practices do not allow cattle to be fed for a set number of days prior to harvesting. Typically, cattle are sorted into groups or pens based on visual appraisal of their condition/degree of finish. It has been shown that as cattle increase in subcutaneous fat their feed efficiency decreases thus diminishing profit (Pyatt et al., 2005).

An effective management tool for sorting cattle into optimal harvest groups is ultrasound backfat measure during the growing phase (Hassen et al., 1999). Other technologies such as cameras and computer algorithms have been developed to sort cattle on the basis of their optimum endpoints (Peck, 2000). Many different optimized or profit maximizing endpoints such as a defined amount of backfat, weight range or age ranges have been studied. Feeding past the market defined optimum endpoint can decrease the profit of an individual. The amount of the time spent in the feedlot directly impacts the profitability of an animal through daily yardage and feed costs. However no matter the method used to sort cattle, degree of finish or fat thickness has a large impact in all management systems. Decreasing the number of cattle which are not fed long enough or past optimum fat thickness is of economic importance. The National Beef Quality Audit (McKenna et al., 2002) found 11.7% of carcasses yield grade 4 and greater indicating too much time on feed and 6.5% with less than select quality grades**.**

Producers selling weaned calves are not typically rewarded when their cattle are expected to have superior feedlot performance. A growing trend for producers is retaining ownership of calves through the feeding phase. Retaining ownership would make the number of days spent in a feedlot an economically relevant trait. Economically relevant traits (Golden et al., 2000) describe those genetic traits which have a direct impact on profitability. From the point of view of either a feedlot manager or a producer retaining ownership, the amount of time it takes to get an animal to their optimum endpoint is economically important. Selecting sires whose offspring will spend less time on feed has the potential to reduce costs and increase profit, and also to allow feedlot managers to sort calves into more homogeneous groups. The objective of this study was to develop a days to finish endpoint EPD from data pre-adjusted to a constant fat thickness.

Materials and Methods

Data supplied by American Gelbvieh Association (AGA) consisted of a total of 1,030,570 pedigree records and 599,087 individuals with weaning observations. Carcass data, including harvest age, carcass weight, rib-eye area and marbling score, pre-adjusted to a constant backfat thickness was available on 7,309 individuals. Data was considered usable if the age range of slaughter was 360 to 800 days and within four standard deviations of the mean for each trait. This data filter reduced the total number of useable records to 6,672. Carcass contemporary groups

were formed using the AGA supplied contemporary group, producer code, sex of the animal and harvest date. Formation of contemporary groups in this manner yielded a total of 329 unique contemporary groups with an average size of 20.3 animals. Contemporary groups were restricted to only those with greater than 5 individuals and those with variation for variance component estimation.

Weaning weight was included in the two-trait analysis to account for selective reporting and sequential culling. Entire weaning contemporary groups were included if any animal belonging to the group possessed a valid carcass observation. Including animals in this manner added 2,012 individuals with weaning weight but without carcass data to the analysis. The 6,672 animals with carcass observations included 2,138 with weaning data. Weaning contemporary groups were formed using Gelbvieh weaning work order, percentage (high 100 to 87.5 or low 87.5 to 50) Gelbvieh and sex of animal, resulting in 293 unique weaning contemporary groups.

A linear adjustment of slaughter age was undertaken to achieve a common fat endpoint of 0.4 inches. Adjustments were made using actual carcass backfat measurement and carcass weight as predictors. The age of the animal at the common fat endpoint was used as data. Heritability for the number of days to reach constant fat thickness was estimated in conjunction with weaning weight. These resulting variance components were then used in the calculation of EPD for days to finish.

Estimation of variance components:

Variance components were obtained from a multiple trait, multiple component animal model. Fixed effects for each trait included contemporary group and weaning age as covariate for weaning weight. Random effects in the model included direct and maternal components of weaning weight along with a direct genetic effect for days to the constant fat endpoint. The two trait model is represented below in matrix form.

$$\begin{bmatrix} y_{WWT} \\ y_{DAYS} \end{bmatrix} = \begin{bmatrix} X_{WWT} & 0 \\ 0 & X_{DAYS} \end{bmatrix} \begin{bmatrix} b_{WWT} \\ b_{DAYS} \end{bmatrix} +$$

$$\begin{bmatrix} Z_{WWD} & Z_{WWM} & 0 \\ 0 & 0 & Z_{DAYS} \end{bmatrix} \begin{bmatrix} u_{WWD} \\ u_{WWM} \\ u_{DAYS} \end{bmatrix} + \begin{bmatrix} e_{WWT} \\ e_{DAYS} \end{bmatrix}$$

Where y is a vector of response variables for weaning weight (WWT) and days to constant backfat (DAYS), X_{WWT} and X_{DAYS} are known incidence matrices relating fixed effects in b to observations in y and Z_{WWD}, Z_{WWM} and Z_{DAYS} are known incidence matrices relating the random effects in u to observations in y. The vector of random residual errors was e. Variance components were estimated for WWD, WWM and DAYS using ASREML (Gilmour et al., 2002).

Results and Discussion

Heritability, phenotypic, genetic, and residual variance component estimates are shown below in Table 1. The heritability estimate of days to finish, 0.45, is moderate to high. Literature estimates for heritability of days to finish in beef cattle are lacking for comparison purposes. The phenotypic standard deviation was 38 days.

The genetic correlation between weaning weight direct and days to finish was estimated to be -0.29. The phenotypic correlation between weaning weight and days to constant backfat was -0.17. Biologically this relationship is intuitive, as an animal increases in lean growth, deposits of adipose tissue also increase similar to the results found within breed types (British or Continental) of the Germplasm Evaluation Project, (Cundiff et al., 2004) where the heaviest breeds at weaning also had greatest fat thickness and most pounds of carcass fat. Heritability of weaning weight direct is on the high side however the estimate of 0.58 obtained is within one standard error of the Gelbvieh breed estimates summarized by Koots et al. (1994). Conversely the heritability estimate for weaning weight maternal is lower than the summarized Gelbvieh estimate

Breeding values were calculated using the Animal Breeders Toolkit (Golden et al., 1995) using the previously described two-trait model. Breeding values ranged from -33.5 to 69.0 d with an average of 3.9 d. The genetic trend of animals by birth year is shown in Figure 1. Average EPD show as fairly constant increase from the mid-1970's to a peak in 1997. Individuals born since 1998 demonstrate a sharp decrease in days to constant endpoint EPD.

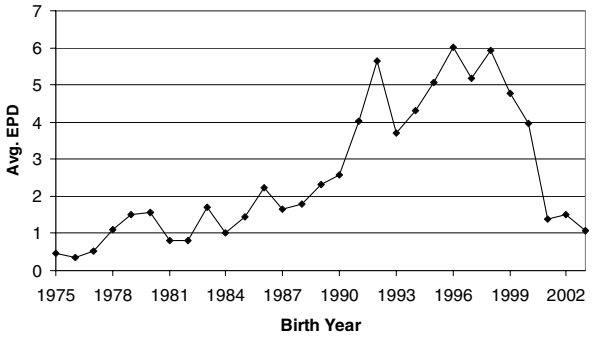

Figure 1. Average expected progeny difference (EPD) by year of birth.

Implications

The ability to select animals with a propensity to grow and finish in a shorter amount of time reduces costs for the industry. Genetic prediction of days to a finish endpoint will enable selection to include this economically relevant trait along with others such as value at finish and feed to finish. Matching genetic evaluation to industry practices will lead to more accurate and faster response to selection for traits such as days to finish.

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Table 1. Heritability and variance component estimates.

	h^2 (SE)	σ^2_p	σ^2_g	σ^2_r
Days to Constant Fat Thickness (days)	0.45 (0.05)	1,420	645	775
Weaning Wt. Direct (kg)	0.58 (0.07)	779	451	253
Weaning Wt. Maternal (kg)	0.10 (0.03)	-	75	-

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POTENTIAL RE-RANKING OF SIRES FOR WEANING WEIGHT IN ABOVE- AND BELOW-AVERAGE ENVIRONMENTS

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ABSTRACT: Heritability estimates for maternal weaning weight have been shown to be higher in environments with restricted cow feed intake as opposed to environments with less limiting feed resources. Sires evaluated in better than average environments may re-rank in poor environments. The purpose of this study was to determine the magnitude of sire re-rankings when accounting for different heritabilities in different environments. Data from the Red Angus Association of America consisting of 91,061 cow weight observations and 23,243 calf weaning weight observations was used. In the first analysis, weaning weights were analyzed with a single trait model including random direct (D), maternal (M) and permanent environmental effects. In a second analysis, weaning weights were classified as occurring in a good (g) or poor (p) environment, depending upon their dam's weight change since the previous year, and then analyzed using a two trait model with random direct (Dg and Dp), maternal (Mg and Mp) and permanent environmental effects for both traits. Spearman rank correlation coefficients were calculated between breeding values from the single trait and the multiple trait model for all animals and for the 50 most accurate sires. For all animals, correlations were 0.96 (D and Dg), 0.97 (D and Dp), 0.94 (M and Mg), 0.96 (M and Mp), 0.99 (Dg and Dp) and 0.97 (Mg and Mp). Correlations between the 50 most accurate sires were above 0.96 for all traits. These data have shown that while accounting for heterogeneous variance estimates for weaning weights in differing environments may be technically more appropriate, there was insignificant re-ranking of sires.

Key words: Beef Cattle, Heritability, Weaning Weight, Heterogeneous Variance

Introduction

An assumption often made in most national beef cattle genetic evaluations is constant genetic and residual variance structures across differing herds, years and production levels. We know differing environmental conditions can result in heterogeneous genetic and residual variance structures for both dairy and beef cattle (Butts et al., 1971; Koger et al., 1979; Burns et al., 1979; Pahnish et al., 1983; Pahnish et al., 1985; Wade and VanVleck 1989; Speidel et al., 2006).

Selection of animals based on genetic predictions calculated under the improper assumption of homogeneous (co)variances may in-appropriately rank animals and cause decreased economic returns (Nunez-Dominguez et al., 1995). Garrick et. al., (1989) showed that in the absence of selection, ignoring heterogeneous variance in genetic evaluations will increase prediction error variance, with the estimated predictors remaining unbiased. However, the regression of predicted merit on actual merit will not be unity resulting in the under- or over-evaluation of individuals.

Weaning weight maternal heritability estimates have been shown to be higher in environments where feed resources are limited (Speidel et al., 2006). Using assumed homogeneous variance structures for weaning weight, sires evaluated in better than average environments may re-rank in poor environments. Therefore, the purpose of this study was to determine the magnitude of sire re-rankings when accounting for heterogeneous variances across differing environmental conditions.

Materials and Methods

Data obtained from the Red Angus Association of America (RAAA) consisting of 91,061 cow weight and 23,243 weaning weight observations were used. Details of data preparatory procedures were presented by Speidel et al. (2006). Weaning weight EPD were estimated using two models. In the first model, weaning weight was conventionally analyzed using a single trait multiple component animal model represented by:

$$y = Xb + \begin{bmatrix} Z_w & Z_m & Z_p \end{bmatrix} \begin{bmatrix} u_w \\ u_m \\ u_p \end{bmatrix} + e$$

where **y** was a vector of weaning weight observations, **X** was an incidence matrix relating fixed effects in **b** to observations in **y**, $\mathbf{Z_w}$ $\mathbf{Z_m}$ and $\mathbf{Z_p}$ were incidence matrices relating random effects in $\mathbf{u_w}$, $\mathbf{u_m}$ and $\mathbf{u_p}$ to observations in **y** for direct, maternal and permanent environmental effects respectively. Random effects were assumed to have means of 0 and variances represented as follows:

$$\text{var}\begin{bmatrix} u_w \\ u_m \\ u_p \\ e \end{bmatrix} = \begin{bmatrix} A\sigma^2_w & 0 & 0 & 0 \\ 0 & A\sigma^2_m & 0 & 0 \\ 0 & 0 & I_D\sigma^2_p & 0 \\ 0 & 0 & 0 & I_N\sigma^2_e \end{bmatrix}$$

where **A** was Wright's numerator relationship matrix, $\mathbf{I_D}$ and $\mathbf{I_N}$ were identity matrices with lengths equal to the number of dams with data and the number of weaning weight observations respectively. Weaning weight (co)-variances for direct, maternal, permanent environmental effects due to the dam and residual weaning weight were 97.4 kg^2, 50.3 kg^2, 76.6 kg^2 and 288.8 kg^2 respectively (Speidel et al., 2006).

In model 2, weaning weight observations were analyzed using a multiple trait multiple component animal model where the weights were treated as separate but genetically related traits according to the quality of environment using the model:

$$\begin{bmatrix} y_{w_g} \\ y_{w_b} \end{bmatrix} = \begin{bmatrix} X_{w_g} & 0 \\ 0 & X_{w_b} \end{bmatrix}\begin{bmatrix} b_{w_g} \\ b_{w_b} \end{bmatrix} +$$

$$\begin{bmatrix} Z_{w_g} & Z_{m_g} & Z_{p_g} & 0 & 0 & 0 \\ 0 & 0 & 0 & Z_{w_b} & Z_{m_b} & Z_{p_b} \end{bmatrix}\begin{bmatrix} u_{w_g} \\ u_{m_g} \\ u_{p_g} \\ u_{w_b} \\ u_{m_b} \\ u_{p_b} \end{bmatrix} + \begin{bmatrix} e_{w_g} \\ e_{w_b} \end{bmatrix}$$

where, **y** is a vector of weaning weight observations classified as good ($\mathbf{w_g}$) and bad ($\mathbf{w_b}$) respectively. **X** are an incidence matrices that relate the good and bad weaning observations to their respective fixed effects in **b**. **Z** are known incidence matrices relating good and bad observations to their respective random effects in **u**. The vector **u** represented random additive effects for direct, maternal and permanent environmental effects for both good and bad weaning weight respectively; and **e** was a vector of good and bad weaning weight random residuals unique to each observation. The random effects were assumed to have means of zero, genetic variances represented by

$$\text{var}\begin{bmatrix} u_{w_g} \\ u_{m_g} \\ u_{w_b} \\ u_{m_b} \end{bmatrix} = \begin{bmatrix} \sigma^2_{w_g} & \sigma_{w_g,m_g} & \sigma_{w_g,w_b} & \sigma_{w_g,m_b} \\ \sigma_{m_g,w_g} & \sigma^2_{m_g} & \sigma_{m_g,w_b} & \sigma_{m_g,m_b} \\ \sigma_{w_b,w_g} & \sigma_{w_b,m_g} & \sigma^2_{w_b} & \sigma_{w_b,m_b} \\ \sigma_{m_b,w_g} & \sigma_{m_b,m_g} & \sigma_{m_b,w_b} & \sigma^2_{m_b} \end{bmatrix} \otimes A$$

and uncorrelated permanent environmental effects represented by

$$\text{var}\begin{bmatrix} u_{p_g} \\ u_{p_b} \end{bmatrix} = \begin{bmatrix} \sigma^2_{p_g} I_{D_g} & 0 \\ 0 & \sigma^2_{p_b} I_{D_b} \end{bmatrix}$$

and residual variances as

$$\text{var}\begin{bmatrix} e_{w_g} \\ e_{w_b} \end{bmatrix} = \begin{bmatrix} \sigma^2_{e_{w_g}} I_g & 0 \\ 0 & \sigma^2_{e_{w_b}} I_b \end{bmatrix}.$$

In the above equations, **A** denotes Wright's numerator relationship matrix. Subscripts $\mathbf{w_g}$, $\mathbf{m_g}$, $\mathbf{p_g}$, $\mathbf{w_b}$, $\mathbf{m_b}$ and $\mathbf{p_b}$ refer to weaning "good" direct, maternal, permanent environment, weaning "bad" direct, and maternal permanent environment, respectively. The $\mathbf{I_{D_g}}$, $\mathbf{I_{D_b}}$, $\mathbf{I_g}$ and $\mathbf{I_m}$ are identity matrices with the length of the number of dams whose offspring have good weaning observations, the number of dams whose offspring have poor environment weaning observations, the total number of good observations and the total number of poor observations respectively. Residual covariances not relevant 0 because no individuals had both good and poor observations recorded. Genetic (co)-variances used in the analysis are shown below in table 1. Residuals used were 292.4 kg^2 and 240.8 kg^2 for WW_g and WW_b respectively (Speidel et. al., 2006).

Fixed effects included in both models were weaning contemporary group of the calf and a sex by age of dam interaction. EPD estimates were obtained for the two weaning weight models using ASREML (Gilmour et al., 2002), and were compared with rank correlations between all animals, all sires, and the top 50 most reliable sires for each trait (from models 1 and 2) on the basis of EPD accuracy. All correlations were obtained using the RANK and CORR procedures of SAS (SAS Inst. Inc., Cary, NC).

Results and Discussion

Weaning weight EPD were obtained from both models 1 and 2. Summary statistics for EPD obtained from model 1 are shown below in table 2 for all animals and for sires.

Table 2. EPD Summary statistics from model 1 for all animals and for sires.

	N	Mean	SD	Min	Max
WWd_{all}	40,769	1.27	2.58	-10.98	13.70
WWm_{all}		0.35	1.76	-12.29	8.66
WWd_{sires}	3,173	1.00	2.53	-10.98	13.70
WWm_{sires}		0.28	1.71	-12.29	8.66

Mean EPD for both WW_d and WW_m was slightly lower for sires than for all animals. The sire group did contain the minimum and maximum EPD for both WW_d and WW_m.
EPD summary statistics for model 2 are shown below in table 3. Mean EPD for the direct components of weaning weight in the two environments were the same for all individuals (1.36) and for sires (1.09). Mean maternal EPD

was higher in the poor (0.59 for all animals and 0.46 for sires) environments than in the good environments (0.13 for all animals and 0.12 for sires).

Table 3. EPD Summary statistics from model 2 for all animals and for sires.

	N	Mean	SD	Min	Max
$WWdg_{all}$	40,769	1.36	2.61	-11.02	14.29
$WWmg_{all}$		0.13	2.31	-16.01	10.25
$WWdb_{all}$		1.36	2.57	-10.70	13.83
$WWmb_{all}$		0.59	2.80	-18.34	12.70
$WWdg_{sires}$	3,173	1.09	2.60	-10.79	14.29
$WWmg_{sires}$		0.12	2.25	-16.01	10.11
$WWdb_{sires}$		1.09	2.58	-10.61	13.83
$WWmb_{sires}$		0.46	2.68	-18.32	12.02

Rank correlations between model 1 and model 2 for all animals are shown below in table 4. These correlations are all very high (>0.95) between the direct components of weaning weight. Rankings between the maternal EPD are slightly lower. Animals tended to rank more similarly in the poor environment than they do in the good environment, which may be attributed to the higher weaning weight maternal heritability estimate found in the good environment as opposed to the poor environment.

Table 4. Rank correlations between Model 1 and Model 2 for all animals.

	WWdg	WWdb	WWmg	WWmb
WWd[a]	0.96	0.97		
WWdg[a]		0.99		
WWm[a]			0.94	0.96
WWmg[a]				0.97

[a]Rank correlations on all animals between Model 1 WWd, WWm and Model 2 WWdg, WWdb, WWmg, WWmb.

Table 5 below shows the rank correlations for all sires. Similar trends are seen for the sires as were shown above for all animals, but the gap between maternal EPD in the good and poor environments increased slightly.

Tables 6 and 7 below contain the rank correlations between the top 50 most reliable sires for each EPD based on accuracy. In table 6 rank correlations between the direct components of weaning weight are shown. No matter which accuracy was used to choose individuals to compare, all rank correlations are 0.96 and greater. Table 7 makes similar comparisons to that of table 6, but for the maternal traits. These correlations are slightly higher (0.97 vs. 0.96) than their direct counterparts. High rank correlations indicate minimal re-ranking which were similar to those results seen by Rodriguez-Almeida et al. (1995).

Table 5. Rank correlations between Model 1 and Model 2 for sires.

	WWdg	WWdb	WWmg	WWmb
WWd[a]	0.95	0.95		
WWdg[a]		0.99		
WWm[a]			0.93	0.96
WWmg[a]				0.96

[a]Rank correlations on all animals between Model 1 WWd, WWm and Model 2 WWdg, WWdb, WWmg, WWmb.

While these rank correlations are not unity, they are still extremely high. With rank correlations on high accuracy individuals 0.97 and higher, the additional information gained by accounting for these heterogeneous variance components across environments may not out weigh the additional complexity introduced into national cattle evaluations. Often times relaxing heterogeneous variance assumptions is necessary when using field data to reduce computational requirements for estimation of breeding values (Garrick and Van Vleck, 1987).

Implications

Not properly accounting for heterogeneous variances across herds from differing environments can lead to inaccurate ranking of animals and consequently leading to incorrect selection decisions. Although heritability estimates of weaning weight maternal are higher in poor environments than in good environments, in-significant sire re-ranking results. Even though accounting for these differences in variance components may be more technically appropriate, the additional layers of complexity added to beef cattle genetic evaluations by accounting for this may not be warranted.

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Table 1. Additive genetic (co)variances, and genetic correlations among both weaning weight (WW) traits (kg).

	WWg_d[a]	WWg_m[a]	WWb_d[a]	WWb_m[a]	PEDg[a]	PEDb[a]
WWg_d[a]	**115.4**	-33.2	109.2	-11.9		
WWg_m[a]	-0.31	**98.7**	-28.0	109.2		
WWb_d[a]	0.94	-0.26	**116.3**	-15.9		
WWb_m[a]	-0.10	0.99	-0.13	**124.3**		
PEDg[a]					**53.9**	
PEDb[a]						**26.0**

[a] Genetic variances are shown on the diagonal, genetic correlations are below the diagonal, and additive genetic covariances are above the diagonal for both direct (d) and maternal (m) components of weaning weight in good (g) and bad (b) environments.

Table 6. Rank correlations between the most reliable sires for the direct components of weaning weight for models 1 and 2.

	WWdg[a]	WWdb[a]	WWdg[b]	WWdb[b]	WWdg[c]	WWdb[c]
WWd	0.97	0.97	0.97	0.97	0.98	0.97
WWdg		0.96		0.96		0.96

[a]The top 50 most reliable sires for WWd.
[b]The top 50 most reliable sires for WWdg
[c]The top 50 most reliable sires for WWdb.

Table 7. Rank correlations between the most reliable sires for the maternal components of weaning weight for models 1 and 2.

	WWmg[a]	WWmb[a]	WWmg[b]	WWmb[b]	WWmg[c]	WWmb[c]
WWm	0.98	0.97	0.98	0.98	0.97	0.97
WWmg		0.98		0.98		0.98

[a]The top 50 most reliable sires for WWm.
[b]The top 50 most reliable sires for WWmg
[c]The top 50 most reliable sires for WWmb.

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BREED COMPARISONS AND TRENDS FOR EWE PRODUCTIVITY AND LAMB GROWTH TRAITS IN SHEEP MANAGED AS CONTEMPORARIES IN A WESTERN RANGE SYSTEM

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ABSTRACT: Ewe productivity and lamb growth traits are economically important for commercial sheep production systems; thus our objectives were to utilize retrospective data to characterize trends in performance and quantify breed differences for these trait types. Data were from purebred Columbia, Polypay, Rambouillet, and Targhee ewes and lambs from 28 yr of production beginning in 1978 at the U.S. Sheep Experiment Station near Dubois, ID. All breeds were managed for spring (shed) lambing, summer mountain grazing, and 120-d weaning. Generic selection practices throughout generally emphasized increased litter weight weaned. Data were analyzed using general linear and mixed models to test for fixed effects of breed, age of dam, year, types of birth and rearing, lamb gender, and breed×year interactions and the random effect of band (summer grazing). Breed least squares means (± SE) from 1978 for Columbia, Polypay, Rambouillet, and Targhee were, respectively: number born alive per ewe lambing: 1.33 ± 0.04, 1.75 ± 0.06, 1.46 ± 0.03 and 1.35 ± 0.03; birth weight (kg) of live lambs: 4.3 ± 0.07, 3.6 ± 0.09, 4.1 ± 0.05, and 4.2 ± 0.06; number weaned per ewe lambing: 1.19 ± 0.05, 1.47 ± 0.06, 1.31 ± 0.04, and 1.24 ± 0.05; litter weight (kg) weaned: 44.4 ± 1.6, 46.1 ± 2.2, 39.3 ± 1.4, and 40.3 ± 1.6. Breed least squares means (± SE) from 2005 for Columbia, Polypay, Rambouillet, and Targhee were, respectively: number born alive per ewe lambing: 1.54 ± 0.04, 1.70 ± 0.04, 1.52 ± 0.03 and 1.49 ± 0.03; birth weight (kg) of live lambs: 4.8 ± 0.08, 4.2 ± 0.04, 4.6 ± 0.05, and 4.6 ± 0.07; number weaned per ewe lambing: 1.48 ± 0.06, 1.58 ± 0.05, 1.43 ± 0.05, and 1.42 ± 0.05; litter weight (kg) weaned: 64.1 ± 1.8, 60.9 ± 1.6, 55.7 ± 1.6, and 56.8 ± 1.8. Coefficients for regression of trait least squares means on year were positive and different from zero ($P \leq 0.05$) for these traits in most breeds. Results of these analyses document progress in ewe productivity and lamb growth traits and provide Western range producers with the data necessary to make statistically valid breed comparisons.
Key Words: Sheep, Maternal, Genetics

Introduction

In Western range sheep production systems that market weaned lambs, profitability is largely determined by ewe productivity (Ercanbrack and Knight, 1998). Litter weight weaned per ewe is generally regarded as the primary measure of ewe productivity and is a composite trait influenced by ewe fertility, number of lambs born, lamb survival, and lamb growth potential. The lowly heritable nature of ewe productivity traits (Okut et al., 1999) limits the rate of progress that can be attained strictly from traditional selection. Variation exists among Western white-faced breeds for traits of ewe productivity and lamb growth and this variation offers the potential for rapid genetic progress. Variation also exists among the breeding objectives of commercial producers. Appropriate breed utilization has significant economic implications and requires that producers have the data available to make objective breed comparisons.

The objectives of this study were to 1) compare purebred Columbia, Polypay, Rambouillet, and Targhee sheep managed as contemporaries in a Western-range production system for traits of ewe productivity, lamb survival, and lamb growth and 2) report phenotypic trends for these breeds over 28 yr of production. Results of this study are intended to provide producers with statistically valid breed comparisons from which they can objectively identify the breed most appropriate for their breeding objectives.

Materials and Methods

Data were from purebred Columbia, Polypay, Rambouillet, and Targhee ewes and lambs collected over 28 yr of production beginning in 1978 at the U.S. Sheep Experiment Station near Dubois, ID. All breeds were managed as contemporaries for spring (shed) lambing, summer mountain grazing, and 120-d weaning as previously described (Ercanbrack and Knight, 1998). Ewe traits analyzed included total number of lambs born (**TNB**), number of lambs born alive (**NBA**), litter size at weaning (**NW**), litter weight weaned (**LWW**), ewe body weight (**EBW**) measured in late May, subjective milk score (**MILK**), and annual ewe fleece weight (**EFW**). Records of breeding ewes that did not lamb were excluded from the analyses. For NW and LWW, all records affected by cross-fostering were excluded from the analyses and orphaned lambs were considered to have died after birth (not reared). Only litter records in which at least one lamb was weaned were included in the analysis of LWW. The method to evaluate MILK has been described elsewhere (Snowder et al., 2001). Lamb traits analyzed included live birth weight (**LBW**) and 120-d weaning weight (**WW**). Summary statistics for traits by breed are reported in Table 1.

Statistical Analyses. Ewe traits (NB, NBA, NW, EBW, EFW, and MILK) were analyzed as repeated measures of ewes using mixed model methodology in SAS (SAS Inst. Inc., Cary, NC). Fixed effects included breed, year, breed × year, and the linear and quadratic effects of ewe age (in months). Grazing band (nested within year) was included as a random effect for NW. Number of lambs born (nested within breed) was included as a fixed effect for MILK. Litter weight weaned was fitted to a model that

Table 1. Number of observations, mean, standard deviation, and range (by breed) for each trait

Trait[a] (unit)	Breed[b]	Records	Mean	SD	Range
TNB	COL	9,183	1.7	0.6	1 to 4
(lamb)	POL	11,182	2.0	0.7	1 to 5
	RAM	12,576	1.7	0.6	1 to 4
	TAR	12,362	1.7	0.6	1 to 4
	Total	45,303	1.8	0.7	1 to 5
NBA	COL	9,183	1.5	0.7	0 to 4
(lamb)	POL	11,182	1.8	0.8	0 to 5
	RAM	12,576	1.6	0.7	0 to 4
	TAR	12,362	1.5	0.7	0 to 4
	Total	45,303	1.6	0.7	0 to 5
LBW	COL	13,080	5.0	1.0	1.5 to 8.4
(kg)	POL	18,286	4.0	0.8	1.1 to 7.8
	RAM	18,061	4.7	0.8	1.6 to 8.4
	TAR	17,729	4.9	0.9	1.3 to 8.7
	Total	67,156	4.6	1.0	1.1 to 8.7
NW	COL	7,143	1.4	0.6	0 to 3
(lamb)	POL	8,285	1.6	0.6	0 to 3
	RAM	9,849	1.4	0.6	0 to 3
	TAR	8,768	1.4	0.6	0 to 3
	Total	34,045	1.4	0.6	0 to 3
WW	COL	9,735	38.1	7.1	12 to 65
(kg)	POL	13,046	34.4	5.7	12 to 55
	RAM	13,145	34.7	5.8	14 to 61
	TAR	11,650	33.2	6.3	10 to 62
	Total	47,576	35.0	6.4	10 to 65
LWW	COL	6,646	55.8	18.5	17 to 114
(kg)	POL	8,091	55.5	17.2	14 to 117
	RAM	8,862	51.4	16.9	15 to 108
	TAR	8,073	48.0	16.2	13 to 125
	Total	31,672	52.5	17.5	13 to 125
EBW	COL	9,512	72.0	12.8	34 to 139
(kg)	POL	10,312	65.3	11.5	31 to 113
	RAM	12,318	66.2	11.0	32 to 106
	TAR	12,667	67.6	12.7	28 to 120
	Total	44,809	67.6	12.2	28 to 139
MILK	COL	7,946	3.2	0.9	0 to 5
	POL	9,266	2.8	0.9	0 to 5
	RAM	10,658	3.0	0.9	0 to 5
	TAR	10,861	2.9	0.9	0 to 5
	Total	38,731	3.0	0.9	0 to 5
EFW	COL	8,792	5.0	1.0	1.6 to 9.8
(kg)	POL	9,972	3.4	0.8	1.2 to 7.6
	RAM	11,391	4.4	0.8	1.4 to 9.2
	TAR	11,752	4.5	0.9	1.4 to 9.0
	Total	41,907	4.3	1.0	1.2 to 9.8

Table 1. (continued)

[a] TNB = total number born; NBA = number born alive; LBW = live birth weight; NW = number weaned; WW = weaning weight; LWW = litter weight weaned; EBW = ewe body weight; MILK = subjective milk score; EFW = ewe fleece weight

[b] COL = Columbia; POL = Polypay; RAM = Rambouillet; TAR = Targhee

included fixed effects of breed, year, breed × year, linear and quadratic effects of ewe age (in months), and litter age at weaning (covariate) and random effects of sire and grazing band (nested within year). The range in weaning ages was 70 d (from d 90 to 160).

Data for lamb traits (LBW and WW) were fitted to mixed models that included fixed effects of breed, year, gender, breed × year, linear and quadratic effects of ewe age (in months), and the random effect of sire. Number of lambs born (nested within breed) was included as a fixed effect for LBW. Number of lambs reared (nested within breed) and age at weaning (covariate) were included as fixed effects for WW.

Phenotypic trends were estimated by regressing breed least-squares means on year. Breed differences in fertility of ewe lambs (number of ewes lambing at ~1 yr of age ÷ total number of ewe lambs exposed to breeding) were tested using a chi-square analysis.

Results and Discussion

Breed least-squares means and pooled standard errors for the years of 1978 and 2005 are reported in Table 2. Additionally, averaged least-squares means for the five most recent years of production (2001 through 2005) are reported to resemble current breed production levels while removing some year-to-year variation that could impact breed rankings. Variation across years was more pronounced for traits affected by vibriosis (i.e. NBA), which was prevalent within the flock as recently as 2005.

Polypay ewes gave birth to approximately 0.30 more live lambs per lambing compared with the other breeds and maintained a litter size advantage of approximately 0.18 lambs through weaning (Table 2). While Polypay lambs were the lightest of all breeds at birth ($P < 0.05$), their weights at weaning were higher than Rambouillet lambs and not different from Targhee lambs ($P < 0.05$). Columbia sheep were the heaviest of all breeds at birth, weaning, and as mature ewes ($P < 0.05$). The superior growth rate of the Columbia lambs combined with their intermediate litter size at weaning resulted in higher LWW compared with the other breeds ($P < 0.05$). Fleece weights differed among all breeds ($P < 0.05$), with Columbia ewes having the heaviest fleeces followed by Rambouillet, Targhee, and Polypay ewes, respectively.

Phenotypic trends for all traits within all breeds were different from zero ($P < 0.05$) with the exception of NBA in Polypays. The absence of a significant phenotypic trend for NBA in Polypay sheep is likely due to the large effect of vibriosis on this breed observed in 2005. Phenotypic trends for all trait types, with the exception of

Table 2. Breed least-squares means (SE) by year and phenotypic trends

Trait[a] (unit)	Breed[b]	1978	2005	5-yr avg.[c]	SEM	b[d]
TNB (lamb)	COL	1.44	1.77^{z}	1.78	0.03	0.013***
	POL	1.87	2.18^{x}	2.21	0.03	0.016***
	RAM	1.55	1.83^{y}	1.79	0.03	0.012***
	TAR	1.48	1.75^{z}	1.78	0.03	0.012***
NBA (lamb)	COL	1.33	1.54^{y}	1.55	0.04	0.010**
	POL	1.75	1.70^{x}	1.85	0.04	0.010^{NS}
	RAM	1.46	1.52^{y}	1.57	0.03	0.008*
	TAR	1.35	1.49^{y}	1.56	0.03	0.009**
LBW (kg)	COL	4.26	4.79^{x}	4.70	0.08	0.025***
	POL	3.58	4.23^{z}	4.09	0.06	0.019***
	RAM	4.14	4.63^{y}	4.54	0.05	0.021***
	TAR	4.23	4.58^{y}	4.58	0.06	0.019***
NW (lamb)	COL	1.19	1.48^{y}	1.44	0.05	0.013***
	POL	1.47	1.58^{x}	1.62	0.05	0.006**
	RAM	1.31	1.43^{y}	1.42	0.04	0.009***
	TAR	1.24	1.42^{y}	1.46	0.05	0.012***
WW (kg)	COL	31.8	42.1^{x}	41.4	0.41	0.368***
	POL	29.3	38.5^{y}	37.7	0.37	0.289***
	RAM	28.6	37.2^{z}	36.4	0.35	0.305***
	TAR	29.9	38.1^{y}	36.8	0.45	0.264***
LWW (kg)	COL	44.4	64.1^{x}	62.7	1.61	0.843***
	POL	46.1	60.9^{y}	60.5	1.71	0.528***
	RAM	39.3	55.7^{z}	54.1	1.51	0.665***
	TAR	40.3	56.8^{z}	55.7	1.61	0.619***
EBW (kg)	COL	61.1	81.2^{x}	80.4	0.51	0.863***
	POL	56.2	69.9^{z}	68.3	0.45	0.479***
	RAM	58.9	69.4^{z}	68.8	0.39	0.470***
	TAR	59.4	73.8^{y}	71.3	0.47	0.497***
MILK	COL	2.75	3.19^{x}	3.14	0.08	0.013***
	POL	2.72	3.04^{y}	3.03	0.05	0.015***
	RAM	2.89	3.16^{x}	3.00	0.06	0.011**
	TAR	2.91	3.06^{y}	3.05	0.07	0.007*
EFW (kg)	COL	5.66	4.57^{w}	4.60	0.05	-.043***
	POL	4.10	3.19^{z}	3.12	0.04	-.037***
	RAM	4.93	4.24^{x}	4.25	0.03	-.031**
	TAR	5.10	4.03^{y}	4.11	0.04	-.039***

[a] TNB = total number born; NBA = number born alive; LBW = live birth weight; NW = number weaned; WW = weaning weight; LWW = litter weight weaned; EBW = ewe body weight; MILK = subjective milk score; EFW = ewe fleece weight

[b] COL = Columbia; POL = Polypay; RAM = Rambouillet; TAR = Targhee

[c] Average of years 2001 through 2005

[d] Regression coefficient of trait least-squares mean on year

[wxyz] Numbers within a trait with different superscripts are different ($P < 0.05$)

Table 2. (continued)
*** = P < 0.001; ** = P < 0.01; * = P < 0.05; ^{NS} = regression coefficient in not different from 0 at P = 0.05

fleece weight, were positive. Utilizing data from the same populations as the current study, Bromley et al. (2001) suggested a genetic independence between traits of ewe productivity and fleece traits. Generic selection practices throughout the 28 yr of production represented in this study have generally favored increasing LWW, with no direct emphasis on fleece characteristics, and have been consistent across breeds. Specific selection experiments utilizing the U.S. Sheep Experiment Station populations that impact the current data are outlined elsewhere (Ercanbrack and Knight, 1998).

Results of a chi-square analysis to test for differences in fertility of ewe lambs are provided in Table 3. These data clearly identify Polypay sheep as being superior (81% fertility) to the other breeds (~ 50% fertility) for breeding to lamb at 1 yr of age.

Table 3. Breed comparison of ewe lamb fertility

	Breed			
	Columbia	Polypay	Rambouillet	Targhee
Number Lambed	1,737	3,401	2,837	2,455
Number Open	2,065	783	1,985	2,535
Number Exposed	3,802	4,184	4,822	4,990
Fertility	45.7%	81.3%	58.8%	49.2%

χ^2 = 1,330.85, 3 df, P < 0.001

Implications

Variation exists among Western white-faced breeds for traits of ewe productivity and lamb growth. Similarly, breeding objectives differ among commercial flocks. The matching of breed strengths with flock breeding objectives has strong economic implications. Results of this study are intended to provide statistically valid comparisons among Columbia, Polypay, Rambouillet, and Targhee sheep managed as contemporaries in a Western range production system. Additionally, phenotypic trends are documented over 28 yr of production. From these comparisons, producers have the tools to objectively identify the most appropriate ewe breed given their breeding objectives.

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ANALYSIS OF SCROTAL CIRCUMFERENCE ADJUSTED FOR AGE OR WEIGHT IN CHAROLAIS FIELD DATA

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ABSTRACT: Records from 7,410 Charolais bulls were analyzed to determine if adjusting yearling scrotal circumference (**SC**) for weight or age results in different genetic parameters, ranking of animals, or genetic trends. Scrotal circumference was analyzed with direct genetic effects and residual as random effects and year and contemporary group as fixed effects. Contemporary group included percent Charolais (<25, 25-50, 50-75, 75-94, and >94%), breeder defined yearling management group, breeder defined yearling pasture, and breeder. A linear and quadratic covariate was included as an additional fixed effect to adjust for either age at measure (**AGE**) or yearling weight (**YGW**), depending on the model. Age was measured in days with bulls having to be between 320 and 410 days of age and yearling weight being recorded the same day as SC. Genetic parameters between the two models did not differ with estimates of direct heritability being 0.39 (0.04) and 0.38 (0.04) for AGE and YGW adjusted models, respectively. The Spearman Rank correlation for the EBV on the 26,117 animals in the pedigree was 0.90 (P > 0.01). Genetic trends were similar for both models with SC increasing at an average rate of 0.004 cm and 0.005 cm per year for AGE and YGW, respectively. Initial analysis of SC data shows that there is negligible difference if SC is adjusted to an age or yearling weight basis.

Keywords: Adjustments, Scrotal Circumference, Yearling Weight

Introduction

Beef cattle producers use scrotal circumference as a selection tool because it has been shown to be favorable associated with female fertility (Brinks et al., 1978; Morris et al., 1992; and Vargas et al., 1998) and age at puberty (Smith et al., 1989). However, in order for selection for scrotal circumference to be the most effective, accurate estimates of breeding values must be calculated.

Currently scrotal circumference is adjusted to a constant 365-d basis when analyzed in genetic evaluations, but there has been some discussion as to whether age is the correct adjustment to use. The objective of this study was to compare analyses of scrotal circumference data, adjusting for age or weight, to determine if there is a difference in the ranking of animals between these two models.

Materials and Methods

Scrotal circumference (**SC**) field data were obtained from the American-International Charolais Association and contained records on 7,410 bulls. In order to be included in the dataset, bulls had to be between 320 and 410 d old when SC was measured and weight had to also be measured on the same day.

Bulls were placed into contemporary groups based on percent Charolais (<25, 25-50, 50-75, 75-94, and >94%), breeder, and breeder defined codes for yearling management group and yearling pasture.

Data was analyzed using two different models. One model adjusted data for age at measure (**AGE**) and a second model adjusted data for weight at measure (**YGW**). The adjustment was included in the model as a linear and quadratic covariate.

Random effects included in the model were only direct genetic effects and residual so that the model was:

$$\mathbf{y} = \mathbf{X\beta} + \mathbf{Z_a a} + \mathbf{e}$$

where:

- **y** is a vector of observed scrotal circumferences;
- **β** is a vector of fixed effects including contemporary group and year and a linear and quadratic covariate of adjustment, based on the model;
- **a** is a vector of direct genetic effects;
- **e** is a vector of random error effects;
- **X** is a known incidence matrix associating fixed effects with records in **y**; and
- $\mathbf{Z_a}$ is a known incidence matrix associating random genetic effects with records in **y** with zero columns associated with animals in the pedigree that do not have records.

Furthermore,

$E[\mathbf{y}] = \mathbf{X\beta}$; and

$$\text{Var}\begin{bmatrix}\mathbf{a}\\ \mathbf{e}\end{bmatrix} = \begin{bmatrix}\mathbf{A}\sigma_a^2 & 0\\ 0 & \mathbf{I}\sigma_e^2\end{bmatrix}$$

Variance components and EBV were estimated using the MTDFREML program (Boldman, et al., 1995) with the adjustment made by Dodenhoff et al. (1998) to calculate the standard errors for certain models. Spearman rank correlations of the EBV between the two models were analyzed using the CORR procedure of SAS.

Results and Discussion

The estimates of heritability from the two models did not differ with estimates of 0.39 (0.04) and 0.38 (0.04) for AGE and YGW models, respectively. These estimates are similar to those found in literature (i.e., Keeton et al., 1996; Martinez-Velazquez et al., 2003; Rumph et al., 2005), but are less than the estimate of 0.53 reported by Kriese et al. (1991) and the estimate of 0.71 reported by Evans et al. (1999).

The regression estimated for AGE was:

$$0.026816x - 0.000118x^2$$

which results in bulls receiving a larger adjustment at older ages than at younger ages for this dataset (320 to 410 d). This result cannot be explained biologically and is opposite of what would be expected.

For YGW, the regression was estimated to be :

$$0.009797x - 0.000002x^2$$

which results in bulls receiving a larger adjustment at smaller weights than bulls at larger weights for this dataset.

Estimated breeding values were calculated for the 26,117 animals in the pedigree for each model. The Spearman Rank correlation of the EBV was 0.90 ($P > 0.01$) indicating that, in general, animals are not reranking based on the endpoint that SC is adjusted to.

Genetic trends for animals born from 1976 to 2004 are shown in Figure 1 for each model. Regardless of model, SC increased at an average of 0.004 cm* yr^{-1} for AGE 0.005 cm*yr^{-1} for YGW, indicating a positive, but very slight increase in SC. However, from 1990 through 2004 EBV for SC increased by 0.16 and 0.19 for each adjustment, respectively, which is more than twice the prediction based on the genetic trend. This later part of the trend is steeper in slope than the earlier part. The slight slope prior to 1990 and an unexplainable decrease in EBV in 2001are responsible for the small estimate of genetic trend.

Implications

Based on the results from this analysis, there appears to be no obvious differences between using age or weight as the adjustment factor for yearling SC. However, further research is necessary to determine if one model better predicts progeny performance.

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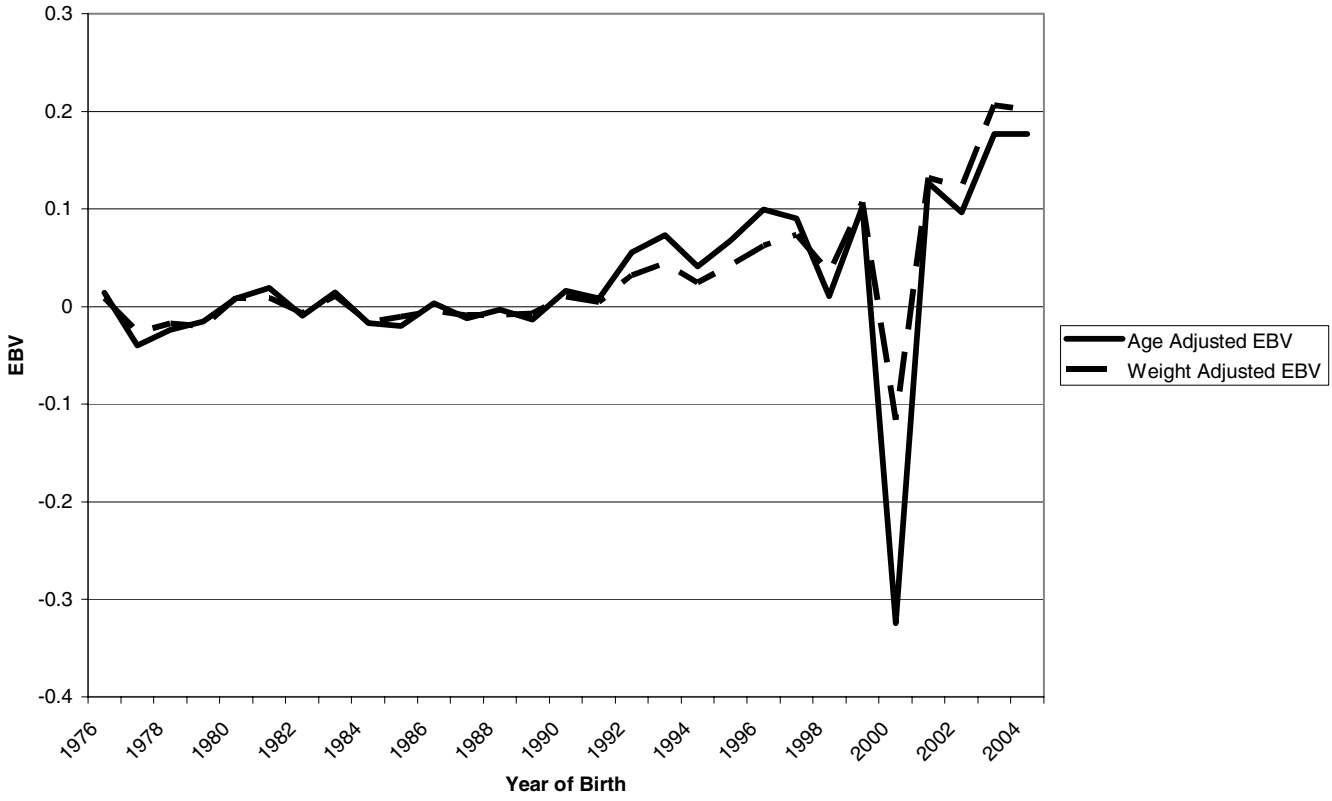
Figure 1. Genetic trends of scrotal circumference for age- or weight-adjusted data



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GENETIC PARAMETERS FOR STAYABILITY AND BODY CONDITION SCORE IN BEEF FEMALES

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ABSTRACT: Stayability (ST) is an economically relevant trait in most cow/calf production systems and body condition score (BCS) is a potential indicator of ST. Stayability, defined as a binary trait in most published genetic evaluations, is achieved when females calve at both two and six years of age. The objective of this research was to estimate genetic parameters for BCS and ST and determine whether a genetic relationship exists that would allow BCS to be used as an early indicator of ST. Early indicators of ST could be incorporated in the genetic evaluation of ST to improve accuracy of EPD at earlier ages. Data and pedigree information came from the Red Angus Association of America (RAAA). Stayability and body condition score were analyzed as continuous traits. Three separate linear analyses were performed. Each contained fixed effects of body condition score (BCSCG) and stayability (STCG) contemporary groups. REML procedures were used to estimate random direct genetic and residual variances for BCS and ST from a two trait animal model for stayability to 2, 3, and 4 years of age.. Separate bivariate analyses were conducted for ST to 6 years and BCS at two (AGE2), three (AGE3), or four years of age (AGE4). Estimates of heritability (SE) for BCS were 0.15 (0.03), 0.12 (0.03), and 0.16 (0.04) for AGE2, AGE3 and AGE4 and for ST were 0.19 (0.05), 0.15 (0.04) and 0.08 (0.04) for each of the subsets of the data, respectively. Genetic correlations between BCS and ST were -0.14 (0.17), -0.12 (0.18), and -0.22 (0.27) for AGE2, AGE3 and AGE4.

Key words: Red Angus, Reproduction, Genetic correlation

Introduction

Stayability is a complex trait, reflective of a beef females fertility, maternal ability and health (Martinez et al., 2003). The measure of lifetime success of a female is profit driven, based on her ability to avoid culling. Females who remain in the herd longer reduce the number of replacements kept and the cost associated with their development, as well as increasing productivity as more females remain in higher-producing age groups (Martinez et al., 2004).

Difficulties encountered when analyzing stayability (ST) are the result of the binary nature of the trait, which increases computational demand. Also, females with stayability observations have been culled (failure) or are in the later stages of there life (success), making accurate predictions and selection more challenging.

Some studies have investigated traits associated with stayability for a better understanding of the underlying process involved. Rogers et al. (2004) found that early indicators of longevity such as age at first calving and calf birth weight were not useful predictors of subsequent longevity. Dystocia and larger maternal breeding values for pre-weaning gain were found to significantly increase the risk of a female being culled.

The objective of this study was to estimate genetic parameters for BCS and ST for females ages two, three and four and to determine the magnitude of the genetic relationship between these with the goal to use BCS as an early indicator of ST.

Materials and Methods

Description of Data

Body condition scores and stayability observations, corresponding pedigrees, and other pertinent performance information were obtained from the Red Angus Association of America (RAAA). Individuals within body condition score contemporary groups (BCSCG) and stayability contemporary groups (STCG) for BCS and ST, respectively, with more than two observations, and in contemporary groups where more than one sire was represented were used in the analyses. Three separate analyses for ST and BCS at two (AGE2), three (AGE3), and four years of age (AGE4) included 6,647, 5,219 and 4,179 BCS observations, and 2,904, 2,682 and 2,515 ST observations for the three age groups, respectively. A two-generation pedigree information was assembled for the three analyses resulting in 22,036, 21,044 and 18,744 animals total for each trait combination, respectively.

The binary trait ST was defined as dams with calving observations at two years of age, and then again at six years of age. Dams meeting the criteria were allocated a score of 1, for success, and dams failing to calve at two and six years of age were assigned a zero. Body condition scores (BCS) are used to indicate the nutritional status of beef females. Scores of 1 through 9, obtained at weaning, represent a scale from emaciated to very fat, respectively.

The Models

Genetic parameters were estimated using linear two-trait animal models. Three separate bivariate analyses were conducted for ST and BCS at two (AGE2), three (AGE3), and four years of age (AGE4). Stayability and body condition scores were analyzed and variance components estimated with the following animal model

$$\begin{bmatrix} y_B \\ y_S \end{bmatrix} = \begin{bmatrix} X_B & 0 \\ 0 & X_S \end{bmatrix} \begin{bmatrix} b_B \\ b_S \end{bmatrix} + \begin{bmatrix} Z_B & 0 \\ 0 & Z_S \end{bmatrix} \begin{bmatrix} u_B \\ u_S \end{bmatrix} + \begin{bmatrix} e_B \\ e_S \end{bmatrix}$$

where
$\mathbf{y_B}$ and $\mathbf{y_S}$ are N × 1 vectors of observations for BCS and ST, respectively;
$\mathbf{b_B}$ and $\mathbf{b_S}$ are vectors of fixed effects (BCSCG and STCG, respectively);
$\mathbf{u_B}$, and $\mathbf{u_S}$ are vectors of direct genetic effects for BCS and ST, respectively;
$\mathbf{e_B}$ and $\mathbf{e_S}$ are vectors of residual effects for BCS and ST, respectively;
$\mathbf{X_B}$, $\mathbf{X_S}$, $\mathbf{Z}_B$ and $\mathbf{Z}_S$ are known incidence matrices relating BCS and ST observations to their respective fixed and random effects.
The (co)variance structure of the random effects in the two models

$$\mathrm{V}\begin{bmatrix} u_B \\ u_S \\ e_B \\ e_S \end{bmatrix} = \begin{bmatrix} A\sigma^2{}_B & A\sigma_{BS} & 0 & 0 \\ A\sigma_{BS} & A\sigma^2{}_S & 0 & 0 \\ 0 & 0 & I\sigma^2{}_{eB} & I\sigma_{eB,eS} \\ 0 & 0 & I\sigma_{eB,eS} & I\sigma^2{}_{eS} \end{bmatrix}$$

where
A is the numerator relationship matrix;
σ^2_B is the additive direct genetic variance for BCS;
σ^2_S is the additive maternal genetic variance for ST;
σ_{BS} is the additive direct genetic covariance between BCS and ST;
σ^2_{eB} and σ^2_{eS} are the residual variances due to BCS and ST, respectivley;
$\sigma^2_{eB,eS}$ is the residual covariance between BCS and ST; and
I represents identity matrices.

Estimation of Variance Components

Fixed effects included body condition score contemporary group (BCSCG), defined by calf weaning contemporary group and dam breed composition, and stayability contemporary group (STCG) defined as cow breeder and breeder of her calf. Analyses included 688, 786 and 708 BCSCGs for the AGE2, AGE3 and AGE4, respectively, as well as 206, 239 and 302 STCGs, respectively for each subset of data.

Correlations between BCS and ST were estimated to determine the magnitude of their genetic relationship. The direct genetic correlation between BCS and ST; and the residual correlation between BCS and ST were estimated as follows

$$r_{BS} = \frac{\sigma_{BS}}{\sqrt{\sigma^2{}_B \sigma^2{}_S}}$$

$$r_{eB,eS} = \frac{\sigma_{eB,eS}}{\sqrt{\sigma^2{}_{eB} \sigma^2{}_{eS}}}.$$

Variance Components were estimated with ASREML (Gilmour et al., 2002) which fits linear mixed models using Residual Maximum Likelihood (REML). This program was used to obtain the solutions to the mixed-model equations and the log-likelihood values. The maximum number of iterations was set to 20 for all three analyses and convergence criterion was met at the sixth iteration for each bivariate analyses. Convergence was presumed when the REML log-likelihood changed less than 0.002 from the current iteration number and the individual variance parameter estimate changed less than 1% (Gilmour et al., 2002).

Results and Discussion

Results of this study suggest that BCS does not provide information about ST. Heritability estimates and residual correlations for BCS and ST are reported in Table 1.

Table 1. Parameter [a] estimates for BCS and ST in AGE2, AGE3 and AGE4 females estimated with the program ASREML

Parameter Estimates				
Model	h^2_B	h^2_S	r_{BS}	$r_{eB,eS}$
AGE2	.15±.03	.19±.05	-.14±.17	.01±.03
AGE3	.12±.03	.15±.04	-.12±.18	-.04±.03
AGE4	.16±.04	.08±.04	-.22±.27	-.01±.04

[a] h^2_B = direct heritability for BCS; h^2_S = direct heritability for ST; r_{BS} = genetic correlation between traits BCS and ST; $r_{eB,eS}$ = residual correlation between BCS and ST.

Estimates of heritability (SE) for BCS were 0.15 (0.03), 0.12 (0.03), and 0.16 (0.04) for AGE2, AGE3 and AGE4. These estimates were similar to those reported in the literature. Heritability estimates for cow body condition score (0.16) and repeatability estimates (0.30) using a linear animal model were reported by Aarango et al. (2002). Meyer (1995) reported BCS heritability estimates for Hereford and Wokalups ranging from 0.12 to 0.16 and repeatability from 0.20 to 0.25. Naphawe et al. (2004) observed a low heritability estimate of 0.16 for BCS using bivariate linear analyses.

The low heritability estimates for BCS indicate genetic improvement through direct selection of body condition scores would be difficult.

Heritability estimates (SE) for ST were 0.19 (0.05), 0.15 (0.04) and 0.08 (0.04) for AGE2, AGE3 and AGE4 analyses. Estimates produced in this study were also similar to results from the literature. Using a sire-threshold model, Martinez et al. (2004a) reported stayability estimates for Hereford cows ranging from 0.09 to 0.17.

Selection for increased longevity of a beef female is possible given the moderate estimates from these analyses.

Genetic correlations between BCS and ST were -0.14 (0.17), -0.12 (0.18), and -0.22 (0.27) for AGE2, AGE3 and AGE4. Low correlations associated with extreme variation in standard errors, suggest BCS in young females is not an effective indicator of the ability of a female to remain in the herd to a specific age.

Implications

The discrete nature of both BCS and ST increase the difficulty in estimation of genetic differences for each trait. The method of body condition scoring is subjective, measured at different times of the reproductive cycle, or are not recorded at all. Although stayability was found to be moderately heritable, it is not expressed until later in life.

The small correlations and large standard errors associated with the genetic correlation estimates imply any benefit from using BCS to predict ST may be small.

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PERFORMANCE OF EARLY WEANED (~80 D) VS NORMAL WEANED (~215 D) COWS IN THE NORTHERN GREAT PLAINS [1]

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ABSTRACT: Our objective was to determine effects of early weaning at the start of breeding on cow reproductive performance following AI with a 50-d cleanup breeding season among cows in the Northern Great Plains. Angus (n = 199) and Angus x Simmental (n = 158) cows stratified within breed by age, postpartum interval, calf sex, and AI sire were assigned within strata to one of two weaning treatments. Cows (n = 232) receiving early weaning (EW ≈ 80 d) had calves permanently removed at the time of prostaglandin (PGF) injection and start of AI breeding. Cows (n = 125) receiving normal weaning (NW) were suckled by calves until weaning at approximately 215 d of age. Estrous cycles of all cows were synchronized for AI using a protocol including 14 d progesterone insert (CIDR) + PGF 16 d following CIDR removal (primiparous cows) or a CIDR insert for 7 d with gonadotropin releasing hormone (GnRH) at CIDR insertion and PGF at CIDR removal (multiparous cows). Cows detected in estrus within 72 h after PGF were inseminated approximately 12 h later. Cows not detected in estrus by 72 h after PGF received timed AI with GnRH at 80 h after PGF (d 0). Bulls were placed with cows beginning 2 wk after AI for the remainder of a 50-d breeding season. Pregnancy rates from AI were higher ($P < 0.05$) for early weaned cows (66%) compared to normal weaned cows (54%). Cow age and age by weaning treatment had no effect ($P > 0.10$) on AI pregnancy rates. Breeding season pregnancy rates tended ($P = 0.12$) to favor cows that were early weaned (94%) compared to normal weaned (89%). Date of conception was 7 d earlier ($P < 0.05$) for early weaned cows compared to normal weaned cows. Early weaned cows gained more weight during the grazing period and were 36 kg heavier than normal weaned cows at the time of normal weaning ($P < 0.01$). Primiparous early weaned cows were 65 kg heavier than primiparous normal weaned cows. We conclude early weaning at the start of a synchronized breeding season increased AI pregnancy rates and cow weights at the time of normal weaning. Early weaning may be a viable alternative to culling cows during periods of low forage production in the Northern Great Plains.

[1] Mention of a proprietary product does not constitute a guarantee or warranty of the product by USDA, Montana AES, or the authors and does not imply its approval to the exclusion of other products that may also be suitable. USDA, ARS, Northern Plains Area, is an equal opportunity/ affirmative action employer. All agency services are available without discrimination.

Key Words: Early weaning, AI pregnancy rates,

Introduction

Lactation places additional nutritional demands on beef cows, which are especially evident during drought conditions and when forage availability is limiting. Suckling delays the onset of estrus in beef cows (Short et al., 1972), and early weaning before the breeding season has been reported to shorten the postpartum anestrous period and increase conception rates (Bellows et al., 1974; Lusby et al., 1981).

Synchronization of estrus using protocols that include an intravaginal progesterone insert (**CIDR**) induced estrous cycles in postpartum anestrous beef cows (Lamb et al., 2001; Perry et al., 2005). Pregnancy rates were similar for estrous cycling and anestrous cows synchronized with gonadotropin releasing hormone (**GnRH**) injection at CIDR insertion, prostaglandin (**PGF**) at CIDR removal and fixed time insemination with a second injection of GnRH (Lamb et al., 2001). Use of 48-h temporary calf removal from the time of PGF to GnRH + fixed time AI among cows receiving GnRH 7 d before PGF increased AI pregnancy rates among both cyclic and anestrous cows (Geary et al., 2001). The objective of this study was to determine effects of early and permanent weaning at the start of breeding on cow reproductive performance following AI with a 50-d cleanup breeding season among cows in the Northern Great Plains.

Materials and Methods

Angus (n = 199) and Angus x Simmental (n = 158) cows stratified within breed by age, postpartum interval, calf sex, and AI sire were assigned within strata to one of two weaning treatments. Cows (n = 232) receiving early weaning (**EW**) had calves permanently removed at the time of PGF injection and start of AI breeding when calves were approximately 80 d of age. These calves were fed one of two rations in drylot (Waterman et al., 2006). Cows (n = 125) receiving normal weaning (**NW**) were suckled by calves until weaning at approximately 215 d of age. Initial body weight of all cows was recorded at assignment of treatment. Estrous cycles of all cows were synchronized for AI using a protocol including 14 d CIDR treatment + PGF 16 d following CIDR

removal (primiparous cows) or a CIDR insert for 7 d with GnRH at CIDR insertion and PGF at CIDR removal (multiparous cows). Cows were observed for estrus continuously during daylight hours from PGF injection until 72 h after PGF. Cows detected in estrus were inseminated approximately 12 h later. Cows not detected in estrus by 72 h after PGF received timed AI with GnRH at 80 h after PGF.

Bulls were placed with cows 2 wk after AI and remained with cows until the end of a 50-d breeding season. Primiparous cows remained in a single breeding pasture for the duration of this study regardless of weaning treatment. Multiparous cows were pastured in two adjacent breeding pastures according to weaning treatment. Predominant grass species in these pastures included crested wheatgrass (*Agropyron cristatum*), green needlegrass (*Nassella viridula*), and needle-and thread (*Hesperostipa comata*) with slighter amounts of alfalfa (*Medicago sativa*), blue grama (*Bouteloua gracilis*), bluebunch wheatgrass (*Pseudoroegneria spicatum*), junegrass (*Koeleria pyramidata*), kentucky bluegrass (*Poa pratensis*), slender wheatgrass (*Agropyron trachycaulum*), and western wheatgrass (*Pascopyrum smithii*). Other less dominate perennial grasses and annual forbs were present in relatively low abundance.

Pregnancy was diagnosed by transrectal ultrasonography using a 5 MHz linear probe (Aloka, Wallingford, CT) 85 d after PGF. Weight and BCS were collected from all cows at the time of pregnancy diagnosis and weight collected at normal weaning (d 85 and 133 after early weaning, respectively). Cow weight gain was calculated for d 0 (EW) to d 85, d 85 to 133, and d 0 to 133.

Statistical Analysis. Data were analyzed using the MIXED procedure in SAS (SAS Inst. Inc., Cary, NC). Measures of reproductive performance (AI pregnancy rate, breeding season pregnancy rate, estimated date of conception) and cow individual performance (weight, gain, and body condition score) were analyzed using a model that included weaning treatment, cow age, and the interaction of weaning treatment and cow age as dependent variables. Least squares means were used to compare differences between significant variables.

Results and Discussion

Pregnancy rates from AI were greater ($P < 0.05$) for early weaned cows (66%) compared to normal weaned cows (54%; Figure 1). Laster et al. (1973) reported increased conception rates following AI during a 42-d breeding season among 2 and 3-yr old cows. Temporary calf removal for 48 h beginning at PGF injection of similar estrous synchronization protocols improved AI pregnancy rates (Smith et al., 1979; Kiser et al., 1980; Geary et al., 2001), but the magnitude of improvement was less than observed in the current study, indicating that perhaps permanent calf removal also improved maintenance of pregnancy. Cow age and age by weaning treatment had no effect ($P > 0.10$) on AI pregnancy rates. Similar improvements in AI pregnancy rate for EW cows were realized across each age group (Figure 1).

Estimated date of conception was 7 d earlier ($P < 0.05$) for early weaned cows compared to normal weaned cows. Assuming that early weaned cows calve an average of 7 d earlier and that these calves would gain 1.2 kg/d, this difference in calf age at weaning would be worth approximately $1,985 per 100 calves from early weaned cows (Table 1).

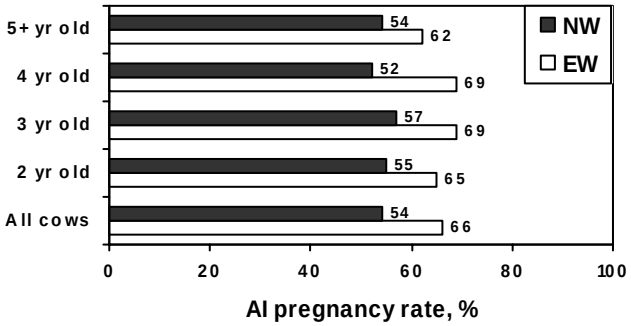

Figure 1. Pregnancy rates from AI for cows whose calves were early weaned (EW) at the PGF injection of a synchronized breeding season (~ 80 d of age) or normal weaned (NW) at approximately 215 d of age.

Pregnancy rates from the entire 50-d breeding season tended ($P = 0.12$) to be greater for cows that were early weaned (94%) compared to normal weaned (89%). A similar tendency for improvement in breeding season pregnancy rate has been observed previously (Myers et al., 1999). Among primiparous cows, Lusby et al. (1981) reported 38% greater pregnancy rates. It is possible that the synchronization protocol used in cows in the present study masked some of the beneficial effects because these protocols have been reported to induce estrous cycles (Lamb et al., 2001; Lucy et al., 2001; Larson et al., 2006) Maintaining herd size would require purchase of five pregnant replacement heifers for the normal weaned herd on a per 100 cow basis. Replacement heifers of similar genetics last year in Montana were valued at approximately $1,200 (Table 1).

Initial weight of cows did not differ ($P > 0.10$) between treatments. Early weaned cows gained more weight during the grazing period and were 36 kg heavier than normal weaned cows at the time of normal weaning ($P < 0.01$). The difference in weight gain between early and normal weaned cows was greatest among 2-yr olds and decreased with increased age (Figure 2). Similar improvements in weight gain for early weaned compared to normal weaned primiparous cows grazing summer pastures have been reported previously (Lusby et al., 1981). Myers et al. (1999) reported improved weight gain for early weaned cows compared to normal weaned cows even when calves were weaned at 158 to 177 d compared to 213 to 231 d of age. Early weaned cows would be expected to have consumed 1/3 animal unit month (**AUM**) less forage than normal weaned cows during the grazing period. Grazing leases averaged $15.90 per AUM in the area where this study was conducted. Thus, during the 133 d (4.43 mo) interval from early weaning to normal weaning, grazing costs were $4,933 greater for normal weaned cows compared to early weaned cows.

This difference in cost is equivalent to $2,128 per 100 cows (Table 1).

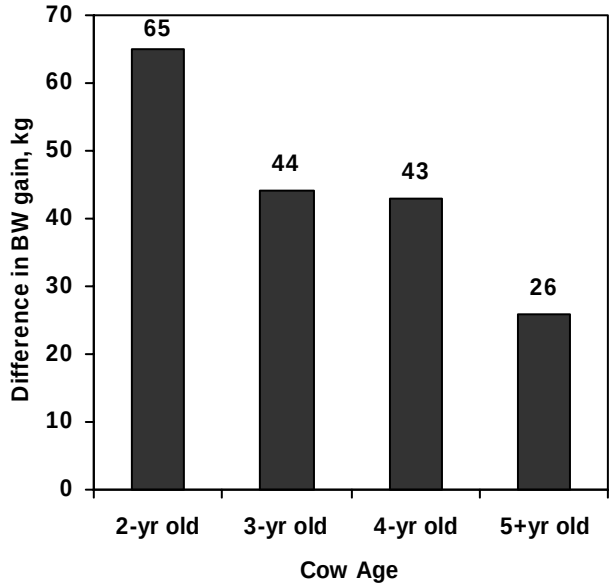

Figure 2. Advantage in weight gain (from early to normal weaning) that early weaned cows (weaned at ~80 d after calving) had over normal weaned cows (weaned at ~215 d after calving) for different aged cows grazing summer pastures.

Others have reported that 34 kg of weight difference in cattle of similar genetics is equivalent to one body condition score (Corah et al., 1991). Thus early weaned cows were approximately 1.0 BCS greater at the time of normal weaning. Feeding early and normal weaned cows to the same BCS at calving suggests early weaned cows should require approximately 152 kg less feed (ex. barley hay with 0.58 Mcal/lb, DM basis, @ $70/T) during the winter to be maintained sufficiently to calve in the same BCS as normal weaned cows. Alternatively, normal weaned cows, being 1.0 BCS lower going into winter, would need 152 kg additional feed (ex. barley hay) to be at the same BCS at calving as early weaned cows. Estimated cost difference of winter supplemental feed for early and normal weaned cows is $11.71 per cow (Table 1).

Implications

We conclude early weaning at the start of a synchronized breeding season increased AI pregnancy rates, tended to increase breeding season pregnancy rates, and increased cow weight at the time of normal weaning. Similar improvements in pregnancy rates were observed across all age groups. The magnitude of improvement in AI pregnancy rate is greater than has been reported with temporary calf removal (48 h) indicating permanent calf removal may improve pregnancy maintenance. The greatest increase in weight gain was among 2-yr old cows. Early weaning may be a viable alternative to culling cows and/or maintaining high levels of reproductive performance among young cows during periods of low forage production in the Northern Great Plains.

Table 1. Estimated financial return on a per 100 head of early weaning (EW) compared to normal weaning (NW) cows grazing summer pasture in the Northern Great Plains

Item	**EW**	**NW**	**EW-NW Value**
Grazing cost[a]	$4,177	$7,049	$2,128
Older calves at subsequent weaning[b]	$70,846	$68,861	$1,985
Replacement heifer cost[c]	$0	$6,000	$6,000
Additional winter feed required to calve in same BCS	$0	$1,171	$1,171
Total			**$11,284**

[a]Grazing cost calculated at average lease value per AUM.
[b]Estimated additional weaning weight in subsequent year due to 7-d earlier conception date. Calf gain estimated at 1.23 kg/d of age and price estimated at $2.31/kg ($1.05/lb).
[c]Purchase of five additional pregnant replacement heifers valued at $1,200/hd.

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PERFORMANCE OF EARLY WEANED (≈ 80 D) VS NORMAL WEANED (≈ 215 D) CALVES IN THE NORTHERN GREAT PLAINS [1]

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ABSTRACT: Early weaning, in spring calving production systems, has intrigued many producers to consider this alternative management practice especially during extended droughts and for young developing cows. The objective of the present study was to evaluate performance and cost of production of early-weaned calves (≈ 80 d of age) fed one of two diets (Diets were isonitrogenous and isocaloric but differed in ruminal degradable and undegradable protein (RDP and RUP, respectively)) compared to normal weaned calves (≈ 215 d of age). Three hundred sixty-seven Simmental × Angus calves (108.2 ± 1.07 kg) were randomly allocated to one of three treatments: 1) Weaned and fed a 33:67 forage:concentrate diet containing 17.5 % CP (31 % RUP) and 1.80 Mcal of NEm/ kg (EW1); 2) Weaned and fed a 33:67 forage:concentrate diet containing 17.5 % CP (43 % RUP) and 1.84 Mcal of NEm/kg (EW2); or 3) suckling and grazing range forage until normal weaning (NW). Calf weight and age were similar at time of early weaning for all treatments ($P > 0.10$). At the time of normal weaning, BW was heavier ($P < 0.01$) for EW vs. NW steers and a tendency for EW2 steers to be heavier ($P = 0.15$) than EW1 steers was observed. Similarly, EW heifers were heavier ($P < 0.01$) when compared to NW heifers; however, BW at normal weaning did not differ between EW treatments ($P = 0.62$). Total cost●calf^{-1}● d^{-1} was greater ($P < 0.01$) for EW treatments than NW; furthermore, calves receiving EW2 had a higher cost●calf^{-1}●d^{-1} than calves receiving EW1. Value of calves at time of normal weaning were greater ($P < 0.01$) for all EW treatments when compared to NW calves ($817.32, $823.24, and $785.51, for EW1, EW2, and NW steers, respectively and $711.96, $717.06 and $686.75, for EW1, EW2, and NW heifers, respectively). Calf value did not differ between EW treatments ($P > 0.10$). This study demonstrates that early weaning may be an effective management option when forage is limited or removal of production pressures from young cows is desired; however, the additional calf value alone was not enough to overcome cost of EW diets.

Key Words: Calf performance, Early weaning, Protein Supplementation

[1] Mention of a proprietary product does not constitute a guarantee or warranty of the product by USDA, Montana AES, or the authors and does not imply its approval to the exclusion of other products that may also be suitable. USDA, ARS, Northern Plains Area, is an equal opportunity/ affirmative action employer. All agency services are available without discrimination.

Introduction

Economic and herd sustainability may be optimized by early weaning calves during times when forage quantity and/or quality are insufficient to meet cow requirements (e.g., drought) or when there is concern about cow body condition going into winter to enhance reproductive success for the subsequent year (especially, young 2 and 3-yr old cows). Consequences of extended drought often lead to extensive liquidation of cowherds, which may result in loss of genetic diversity and recent herd advancements. Early weaning can ease the pressure to liquidate cowherds, simply by reducing the nutritional demands of lactation, thereby reducing forage consumption and optimizing the opportunity for a cow to rebreed. However, early weaning will raise initial cash cost for production and increase reliance on harvested or purchased feeds, labor, and management. Calves weaned at 70 to 150 d of age often exhibit improved ADG and are subsequently heavier at more traditional weaning or 205 d of age (Neville and McCormick, 1981; Myers et al., 1999b; Story et al., 2000). In addition, early weaned steer calves have been shown to grade higher than traditionally weaned calves on similar diets (Myers et al., 1999a). Therefore, livestock producers may be able to recover the initial cash cost due to early weaning, and possibly receive a premium for their calves. The objective of the present study was to evaluate performance and cost of production of early-weaned calves (≈ 80 d of age) fed one of two diets (Diets were isonitrogenous and isocaloric but differed in ruminal degradable and undegradable protein (RDP and RUP, respectively)) compared to normal weaned calves (≈ 215 d of age).

Material and Methods

Study area. The study was conducted in the Northern Great Plains of Central Montana, approximately 5 km northeast of Judith Gap, Montana, at an average elevation of 1,270 m. Annual precipitation for this region is 383 mm with the majority of that moisture accumulating from April through September (Figure 1). Predominant grass species in pastures used in study include crested wheatgrass (*Agropyron cristatum*), green needlegrass (*Nassella viridula*), and needle-and thread (*hesperostipa comata*) with slighter amounts of alfalfa (*Medicago sativa*), blue grama (*Bouteloua gracilis*), bluebunch wheatgrass (*Pseudoroegneria spicata*), junegrass

(*Koeleria pyramidata*), kentucky bluegrass (*Poa pratensis*), slender wheatgrass (*Agropyron trachycaulum*), and western wheatgrass (*Pascopyrum smithii*). Other less dominate perennial grasses and annual forbs were present in relatively low abundance.

Animals, management, and measurements. Approximately 10 d before initiating the early weaning study, all calves had access to creep feed (9.5 mm commercial pellet) that was identical to those incorporated into early wean diet 1. Three hundred sixty-seven Simmental × Angus calves (108.2 ± 1.07 kg) were randomly allocated to one of three treatments at approximately 80 d of age. Calves were stratified within age of dam, age of calf, calf sex, calf birth weight, and AI sire and assigned within strata to one of three weaning treatments: 1) Early weaned and fed a 33:67 forage:concentrate diet containing 17.5 % CP (31 % ruminally undegradable protein (**RUP**) and 1.80 Mcal of NEm/kg (**EW1**); 2) Early weaned and fed a 33:67 forage:concentrate diet containing 17.5 % CP (43 % RUP) and 1.84 Mcal of NEm/kg (**EW2**); or 3) remained with dam and grazed range forage until normal weaning (**NW**; ≈ 215 d of age). Calves in the early weaning treatments were allocated by sex to two pens within each early weaning treatment. Normal weaned calves were allocated to one of two pastures separate from the non-lactating cows. Early weaning diets (i.e., EW1 and EW2; Table 1) were fed ad-libitum and adjusted daily by previous day's intake. Average monthly rates (kg●calf^{-1}●d^{-1}) of diet delivery are presented in Table 2.

Calves were individually weighed May 9, August 2, and September 19, 2005 corresponding to 0, 85, and 133 d of the study. Calf weaning weights were evaluated on an actual and adjusted 205-d basis using formulas provided by the Beef Improvement Federation with age of dam adjustment (BIF, 2002). The economic measurements in the present study are based on actual feed and management costs and assume that all calves were sold at time of early weaning. Cash values used in the analysis are based on the Montana weekly auction summary (USDA-AMS, 2005) for the week in which normal weaning occurred.

Statistical Analysis. Performance data was analyzed for a randomized block design using Mixed procedures of SAS (SAS Inst., Inc., Cary, NC) with pen/pasture as the experimental unit. Model effects included dietary treatment, cow age and their interaction. Two preplanned contrast statements were constructed to separate least squares means when no interaction was detected: 1) NW vs. EW1 + EW2 to evaluate dietary influences between normal weaned vs. early weaned calves; 2) EW1 vs. EW2 to evaluate early weaning diets differing only in the proportions of ruminal degradable (RDP) to RUP protein and not total CP. Differences between means were considered significant if $P \leq 0.10$.

Results and Discussion

Calving date (48.5 ± 1.14 d), birth (38.3± 0.95 kg) and pre-test weights (107.6 ± 2.20 kg), and age at early (78.5 ± 0.22 d) and normal (211.8 ± 0.28 d) weaning for steer and heifer calves did not differ ($P \geq 0.10$) between treatments (Table 3). Weights obtained on d 85 of the study revealed lighter weights ($P < 0.01$) for NW vs. EW steers (228.0, 241.9, and 239.9 kg for NW, EW1, and EW2, respectively), but no differences ($P = 0.67$) between EW steer treatments. However, heifer weights remained similar ($P = 0.34$) after 85 d for NW and EW treatments (Table 3).

Inadequate precipitation during active growing seasons in the Northern Great Plains (early spring to mid-summer) reduces forage availability for livestock. The 5 yr preceding this investigation was below the 55 yr average for precipitation (Figure 1) whereas during the current study year it was above that 55 yr average.

Older cows had heavier calves ($P < 0.01$) at time of early and normal weaning. In addition, calves from 2-yr-old cows were older ($P < 0.01$) by approximately 20 d at early and normal weaning (Data not presented).

Weaning wt at 113 d from inception of early weaning treatments until time of normal weaning revealed that calves in the NW treatment weighed less ($P < 0.01$) than those early weaned, however, no differences ($P > 0.40$) in weaning wt were observed between EW treatments (Table 3). This agrees with previous studies that showed early weaning allowed for heavier calves at time of normal weaning or around 205 d of age (Lusby et al., 1981; Neville and McCormick, 1981; Fluharty et al., 2000).

There was a trend ($P \leq 0.13$) for heifers receiving EW treatments to have a higher ADG than NW heifers from 85 to 133 d and 0 to 133 d, but no differences ($P = 0.40$) between EW treatments (Table 3). A treatment × cow age interaction was observed for ADG from 0 to 85 d ($P < 0.01$) and 0 to 133 d ($P = 0.06$) as well as overall weight gain ($P = 0.06$) for steers. The interaction was a result of changing ranks within early weaning treatment among steers from different aged cows (Table 4).

Table 5 illustrates the economic inputs and returns for early and normal weaned calves. As expected early weaning increases the initial cost of producing beef steers and heifers and intensifies management obligations to construct facilities or make accommodations to manage young calves. The average price($)/kg of calves at time of normal weaning was greater ($P < 0.01$) for NW steers and similar for heifers ($P > 0.10$) with no observed differences ($P > 0.10$) between EW treatments for either steers or heifers. However, the average overall value of steers was lower ($P \leq 0.08$) for NW than EW ($785.51, $817.32, and $823.24 for NW, EW1 and EW2, respectively). This observation held true for heifers as well with NW heifers valued less ($P < 0.01$) than EW heifer ($686.75, $711.96, and $717.06 for NW, EW1 and EW2, respectively). The extra value from early-weaned calves was not sufficient to overcome the initial cost for the early weaning diets, therefore the additional expenses need to be recovered from other facets of production. A potential outcome of the present study may be indicative of the lack of drought conditions during this investigation. Above average precipitation observed in this study most likely improved the quality of range forage consumed by normal weaned calves and potentially had a greater

influence on calf gains than one would expect during more intensive drought conditions.

Implications

Early weaning beef calves at or before breeding will increase initial cash costs and management responsibilities for production. In addition, the increased value of early-weaned calves alone at time of normal weaning may not offset the cost of early weaning diets as observed in the present study. The value of early weaning may however, be derived from improved feedlot gain and carcass improvements, increased conception rates for not only the year early weaning occurred, but for the subsequent year as well. Early weaning may prove to be a valuable alternative to traditional management practices in the Northern Great Plains once all facets of production have been fully assessed, especially during times of reduced forage production.

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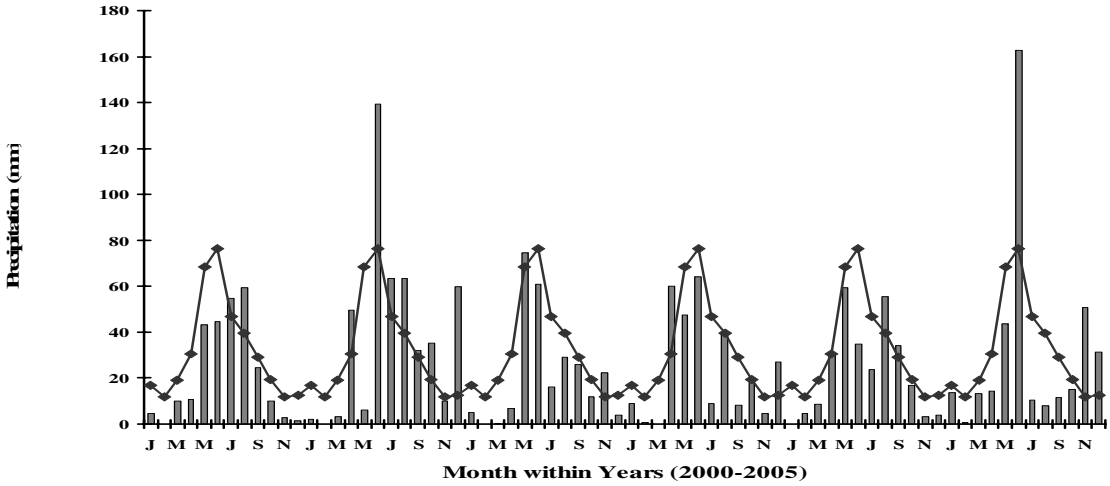

Figure 1. Monthly precipitation within years (bars; 2000-2005) and 55-year average (line) for Judith Gap, MT. Annual precipitation was 160, 278, 357, 301, 365, and 391 mm for 2000, 2001, 2002, 2003, 2004, and 2005, respectively with the 55-year annual precipitation being 383 mm. Information obtained from Western Regional Climate Center, (WRCC, 2006). The study was conducted May – September 2005.

Table 1. Ingredients and nutrient composition of diets fed to early-weaned calves

Item	Diet[a] EW 1	EW 2
Ingredient	------- % of DM -------	
Barley hay	32.78	32.72
Soybean hulls	14.62	20.46
Corn, ground	16.80	20.18
Dried distillers grains	10.59	14.80
Canola meal 34%	12.10	0.67
Wheat middlings	8.91	2.52
Hydrolyzed feather meal	--	4.04
Molasses, cane	3.36	3.36
Dicalcium phosphate	0.25	1.00
Selenium	0.35	0.35
Potassium chloride	0.03	0.205
Calcium carbonate	0.50	0.15
Trace mineral premix[b]	0.065	0.065
Aureo 198 g/kg[c]	0.056	0.056
Zinc sulfate	0.007	0.007
Vitamin premix[d]	0.002	0.002
Nutrient Composition	------- Mcal/kg -------	
NEm	1.80	1.84
NEg	1.17	1.21
	---------- % ----------	
DM	87.58	87.75
TDN	75.30	75.14
CP	17.50	17.48
RDP (% of CP)	61.19	50.84
RUP (% of CP)	31.28	42.66

[a]Diets formulated to be isocaloric and isonitrogenous
[b]Contains 7.82% Ca and supplied the following amounts/kg in premix: 2000 mg Co; 120,000 mg Cu; 10,600 mg I; 35,000 mg Fe; 170,000 mg Mg; and 400,000 mg Zn
[c]Manufactured by Alpharma Animal Health (Alpharma Inc. Fort Lee, NJ 07024)
[d]Contains the following amounts/kg in premix: 180,000 KIU, Vitamin A; 18,000 KIU, Vitamin D; and 353,000 IU, Vitamin E

Table 2. Average monthly delivery (kg●calf^{-1}●d^{-1}) of early weaning diets

Item	Month (days)[a] May (30)	June (30)	July (31)	Aug – Sept (41)
Early wean 1				
Steers	3.31	5.87	7.42	8.32
Heifers	3.03	5.33	6.52	7.92
Early wean 2				
Steers	3.36	5.71	7.56	8.40
Heifers	3.08	4.98	6.41	7.67

Table 3. Effects of calf performance in response to normal (NW) and early weaning (EW)

Item	Weaning NW	EW1	EW2	SEM	*P* - value	Contrast[a] 1	2
Steer Calves, n	64	68	67	--	--	--	--
Wt, d 0, kg	111.1	111.8	113.7	2.10	0.66	0.53	0.51
Wt, d 85, kg	228.0	241.9	239.9	3.53	0.01	< 0.01	0.67
Weaning Wt, d 133, kg	298.1	316.3	323.3	4.48	0.09	0.06	0.36
Adjusted weaning Wt, kg[b]	304.6	321.1	328.1	4.03	0.10	0.06	0.32
Gain d 85-133, kg/d	1.42	1.56	1.73	0.10	0.28	0.21	0.31
Heifer Calves, n	57	55	55	--	--	--	--
Wt, d 0, kg	100.4	102.8	105.9	2.04	0.16	0.11	0.28
Wt, d 85, kg	204.7	210.4	210.1	3.17	0.34	0.14	0.95
Gain, d 0-85, kg/d	1.22	1.26	1.22	0.05	0.74	0.76	0.52
Weaning Wt, d 133, kg	266.3	280.1	283.9	3.69	< 0.01	< 0.01	0.46
Adjusted weaning Wt[d]	271.6	284.4	287.4	3.51	< 0.01	< 0.01	0.54
Gain, d 85-133, kg/d	1.28	1.45	1.54	0.06	0.15	0.10	0.39
Gain, d 0-133, kg/d	1.24	1.33	1.33	0.03	0.34	0.13	0.96
Overall gain, kg	165.6	177.1	177.4	3.42	0.33	0.13	0.96
% calf weaned/cow exposed	0.50	0.54	0.54	0.01	0.20	0.14	0.91

[a]Contrasts 1) Normal vs. Early wean; 2) Early wean 1 vs Early wean 2
[b]Adjusted for age of dam using formulas provided by Beef Improvement Federation (BIF, 2002)

Table 4. Effects of steer performance in response to normal (NW) and early weaning (EW) treatment and cow age

	Weaning				
Item	NW	EW1	EW2	SEM	*P* - value
2-yr-old cows	n =14	n = 16	n = 18		
Gain, d 0-85, kg/d	1.18	1.54	1.48	0.06	< 0.01
Gain, d 0-133, kg/d	1.24	1.55	1.54	0.05	0.06
Overall Gain, kg	164.9	206.4	204.6	7.29	0.06
% calf weaned per cow exposed	0.57	0.68	0.69	0.02	< 0.01
3-yr-old cows	n =11	n = 9	n = 9		
Gain, d 0-85, kg/d	1.37	1.51	1.48	0.06	< 0.01
Gain, d 0-133, kg/d	1.46	1.50	1.57	0.06	0.06
Overall Gain, kg	194.5	199.7	208.5	7.84	0.06
% calf weaned per cow exposed	0.54	0.59	0.62	0.02	< 0.01
4-yr-old cows	n =12	n = 13	n = 14		
Gain, d 0-85, kg/d	1.45	1.52	1.52	0.06	< 0.01
Gain, d 0-133, kg/d	1.46	1.57	1.66	0.06	0.06
Overall Gain, kg	194.7	208.7	220.9	8.00	0.06
% calf weaned per cow exposed	0.53	0.60	0.62	0.02	< 0.01
5+ yr-old cows	n =27	n = 30	n = 27		
Gain, d 0-85, kg/d	1.47	1.55	1.43	0.04	< 0.01
Gain, d 0-133, kg/d	1.43	1.53	1.50	0.04	0.06
Overall Gain, kg	190.1	203.4	199.6	5.75	0.06
% calf weaned per cow exposed	0.53	0.52	0.53	0.02	< 0.01

Table 5. Economic assessment for normal (NW) and early weaning (EW) steers and heifers

	Steers			Heifers		
Item	NW	EW1	EW2	NW	EW1	EW2
n	64	68	68	57	55	55
Barley hay, kg	--	21,490.34	21,539.74	--	15,956.47	15,465.50
Cost[a], $	--	$1,658.23	$1,662.05	--	$1,231.23	$1,193.35
Concentrate feed, kg	--	43,631.91	43,732.20	--	32,396.47	31,399.66
Cost[b], $	--	$9,859.67	$10,605.43	--	$7,320.76	$7,614.68
Total kg delivered	--	65,122.25	65,271.94	--	48,352.94	46,865.16
Avg. kg feed delivered●hd●d^{-1}	--	7.31	7.35	--	6.62	6.49
Feed:Gain	--	4.83	4.75	--	5.05	4.86
Grazing fee, @ 0.3 AUM[c]	$1,352.39	--	--	$1,204.47	--	--
Pen or Pasture days	8368	8910	8878	7581	7300	7219
Yardage $0.25●calf●day^{-1}	--	$2,227.50	$2,219.50	--	$1,825.00	$1,804.75
Total feed cost, $/d	$0.16	$1.54	$1.63	$0.16	$1.42	$1.47
Cost per kg gain	$0.12	$1.01	$1.05	$0.13	$1.08	$1.10
Morbidity %, (ratio)	0.0, (0/64)	2.94, (2/68)	0.0, (0/68)	0.0, (0/57)	3.64, (2/55)	0.0, (0/55)
Mortality %, (ratio)	3.13, (2/64)	2.94, (2/68)	2.94, (2/68)	0.0, (0/57)	1.82, (1/55)	1.82, (1/55)
Avg. Price/kg of calves at Normal Weaning	$2.64[d]	$2.59[e]	$2.56[e]	$2.60	$2.56	$2.54
Avg. Value of calves at Normal Weaning	$785.51[f]	$817.32[g]	$823.24[g]	$686.75[d]	$711.96[e]	$717.06[e]
Treatment value of calves at Normal Weaning[h]	$48,341.75	$53,795.20	$54,438.00	$39,233.05	$38,484.10	$38,884.35
Return after expenses	$46,989.36	$40,006.8	$41,923.02	38,028.58	28,068.11	28,243.57
Net income difference	--	$-6,952.56	$-5,066.34	--	$-9,960.47	$-9,785.01

[a]Barley hay $77.16/ metric ton ($70.00/ ton)
[b]EW1 = $225.97/ metric ton ($205.00/ ton); EW2 = $242.51/ metric ton ($220.00/ ton)
[c]$15.90 AUM for 4.43 months
[d,e]Within sex and row, means with unlike superscripts differ ($P < 0.01$)
[f,g]Within sex and row, means with unlike superscripts differ ($P < 0.08$)
[h]Value of live calves at normal weaning

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GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF LAMBS FED CARNIVAL OR FORAGER FIELD PEAS[1]

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ABSTRACT: Twenty-four black faced lambs (24 ± 0.4 kg initial BW) were used in a randomized complete block designed experiment to determine the effects of feeding 2 varieties of field peas on growth performance and carcass characteristics. Lambs were blocked by BW and assigned randomly to 1 of 4 pens within each block (2 lambs/pen). Diets (formulated to be isonitrogenous) included a conventional corn-soybean meal supplement (Control) or either Carnival or Forager field peas (approximately 33% of dietary DM) fed in place of corn and soybean meal. Periods included a growing phase (56% roughage, 44% concentrate), a transition phase (36% roughage, 64% concentrate), and a finishing phase (14% roughage, 86% concentrate). Lambs were weighed (unshrunk) on 2 consecutive d at the start of each period and immediately before slaughter (14 h shrink). Lambs fed Forager peas tended to have greater (P = 0.06) ADG than lambs fed Carnival peas, with lambs fed Control being intermediate during the growing phase. Lambs fed Forager peas had greater (P < 0.001) ADG during the transition phase; however, G:F did not differ (P = 0.31) among treatments because lambs fed Forager peas had greater (P = 0.01) DMI. No differences (P = 0.33) in DMI occurred among dietary treatments during the finishing phase, but ADG (P = 0.06) and G:F (P = 0.10) tended to be greater for lambs fed Carnival peas than lambs fed Forager peas, with Control lambs being intermediate. Overall (d 1 to slaughter), greater (P = 0.01) ADG for lambs fed Forager peas may have been due to an increase in gut fill because these lambs tended (P = 0.09) to have the greatest DMI and G:F was not affected (P = 0.31) by dietary treatment. Shrunk BW at slaughter was greatest (P = 0.03) for lambs fed Forager peas, but carcass characteristics (P = 0.19 to 0.86) did not differ among dietary treatments. Thus, feeding lambs Carnival field peas at approximately 33% of dietary DM does not influence overall feedlot performance or carcass characteristics. Although carcass characteristics of lambs fed Forager field peas were comparable to that of lambs fed Carnival field peas and the Control diet, greater DMI was necessary to achieve those endpoints.

Key Words: Field peas, Lambs

Introduction

Production of field peas has increased in recent years because this cool-season legume can be incorporated into crop rotations and the grain can be used to diversify farm income. Field pea production in the United States, for example, has increased from 214,483 ha in 2004 to 326,986 ha in 2005 (NASS, 2006). Field peas are marketed as a dry, shelled product for either human consumption or livestock feed (Sell and Aakre, 1993). The Carnival pea variety is classified by the USDA (1999) as a yellow grain pea and can be sold at current market price, whereas the Forager pea is classified under the U.S. sample grade miscellaneous category and may be subject to discount due to its darker seed coat. Darker seed coats may be discounted because they are presumed to be less nutritious; however, previous research by our laboratory (Wolf et al., 2005) demonstrated that either Carnival or Forager field peas could replace a portion of corn and soybean meal in diets fed to finishing hogs. Although previous research has demonstrated that field peas were an acceptable substitute for cereal grains and protein supplements in diets fed to growing and finishing lambs (Purroy and Surra, 1990; Purroy et al., 1992; Loe et al., 2004), comparisons with different field peas varieties in diets of growing and finishing lambs have not been reported. Therefore, our objective was to compare growth performance and carcass characteristics of lambs finished on either Forager or Carnival field peas.

Materials and Methods

General

The University of Wyoming Animal Care and Use Committee approved all procedures for the following study. Twenty-four (12 Suffolk and 12 Hampshire) lambs (24 ± 0.4 kg initial BW) were weighed on 2 consecutive d, blocked by BW, and assigned randomly to 1 of 4 pens within each block (1 Suffolk and 1 Hampshire/pen). The experiment consisted of a growing phase (d 1 to d 31), a transition phase where lambs were adjusted to a finishing diet (d 31 to d 64), and a finishing phase (d 65 to slaughter).

Diets

Lambs were fed one of three total mixed rations throughout the experiment. Dietary treatments included a conventional ground corn-soybean meal supplement (Control) or either ground Carnival or Forager field peas incorporated at approximately 33% of dietary DM in place of ground corn and soybean meal (Table 1). Diets were formulated to be isonitrogenous and meet nutrient requirements of an early weaned lamb with moderate to rapid growth potential (NRC, 1985). During the growing phase, lambs were offered a 56% roughage diet daily at 0700. Beginning with the transition phase, lambs were offered 75% of their daily ration at 0700 and 25% of their daily ration at

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1500. Lambs were adjusted to an 86% concentrate finishing diet during the transition phase by offering various amounts of the growing phase and finishing phase diets: 100% growing phase diet during wk 1; 75% growing phase diet plus 25% finishing phase diet during wk 2; 50% growing phase diet plus 50% finishing phase diet during wk 3; 25% growing phase diet plus 75% finishing phase diet during wk 4; 100% of the finishing phase diet for the last 6 d. Average roughage:concentrate ratio during the transition phase was 36:64. Daily rations were offered at 5 to 10% above ad libitum consumption throughout the experiment. Feed refusals were collected and weighed daily at 0630, and daily rations were adjusted accordingly.

Sampling

Lambs were weighed (unshrunk) at 0600 on 2 consecutive d at the beginning and end of each phase of the experiment. On d 111, lambs were shorn then ultrasonic images were collected (Aloka SSD-500 ultrasound machine with a 12 cm transducer, Aloka Co., Lt., Wallingford, CT) and interpreted (Ovine Image Analysis software, Designer Genes Technologies, L. L. C.) to estimate the date at which lambs would accumulate 5 mm of fat over the 12th rib. Fleece weights were recorded and added back to BW at the end of the finishing phase. Two blocks of lambs were slaughtered on d 131, and the remaining lambs were slaughtered 145 d after initiating the experiment. For both slaughter groups, lambs were fasted for 14 h before being hauled (8 km) to the University of Wyoming Arbitoir where BW was determined immediately before slaughter. Other than HCW, carcass measurements were collected after an overnight chill. Dressing percentage was estimated from HCW after adjusting for overnight shrinkage (Boggs and Merkel, 1993). Back fat thickness over the 12th rib, body wall thickness 13 cm from the backbone, and 12th rib LM area were the average of measurements collected on both sides of each carcass. Areas of the LM were estimated using a 20 dots/inch^2 grid, which was then converted to cm^2. Yield grade, boneless retail cut percentage, and final quality grade were estimated using methods described by Boggs and Merkel (1993).

Grab samples (~35.0 g) of each total mixed ration were taken daily from 3 random locations in respective feed bins. After compositing within sample type, feed samples were ground through a Wiley Mill (Thomas Hill and Sons, Philadelphia, PA) to pass a 1-mm screen. Ground samples were analyzed for DM (AOAC, 1990), NDF and ADF (ANKOM 200 fiber analyzer, ANKOM Technology Fairport, NY), N (LECO model FP-528 Nitrogen Determinator, LECO, St. Joseph, MO), and IVDMD (ANKOM Daisy^{II} Incubator, ANKOM Technology Fairport, NY).

Statistical Analysis

Lamb growth performance within each collection period and carcass characteristics were analyzed as a randomized complete block design using the GLM procedure of SAS (SAS Institute, Cary, NC). Body weight block served as the blocking factor and pen was used as the experimental unit. Means were separated using the LSD procedure of SAS ($\alpha = 0.05$) when the F-test was $P < 0.10$.

Results and Discussion

Feedlot Performance

Growing Phase. Initial BW of lambs did not differ ($P = 0.75$) among dietary treatments; however, BW of lambs fed Forager peas tended to be greater ($P = 0.07$) than lambs fed Carnival peas at the end of the growing phase (Table 2). Lambs fed Forager peas tended to have greater ($P = 0.06$) ADG than lambs fed Carnival peas because lambs fed Forager peas consumed 40.3% more ($P = 0.01$) DM than lambs fed Carnival peas. However, a 20.0% increase ($P = 0.01$) in DMI by lambs fed Forager peas did not result in greater ADG compared to lambs fed the Control diet. The difference in DMI by lambs fed the Forager pea diet vs. the other diets may be related to dietary fiber content (Table 1). In a review of the literature on forage-based diets, Jarrige et al. (1986) inferred that a diet's "fill value" was related inversely with the diet's fiber content. Although less fiber seemed to result in an increase in diet digestibility (Table 1), the increase in diet digestibility for the Forager pea diet did not improve nutrient utilization because G:F did not differ ($P = 0.34$) among dietary treatments.

Transition Phase. As in the growing phase, lambs fed Forager peas had the greatest ($P = 0.005$) DMI during the transition from the growing diet to the finishing diet. Similarly, ADG was greatest ($P < 0.001$) for lambs fed the Forager pea diet. Growth performance and DMI did not differ between lambs fed Carnival peas and the Control diet. Gain efficiency also did not differ ($P = 0.31$) among dietary treatments during the transition phase.

Finishing Phase. No differences ($P = 0.33$) in DMI occurred among dietary treatments during the finishing phase. In contrast to the growing and transition phases, however, ADG tended to be greater ($P = 0.06$) for lambs fed Carnival peas compared with lambs fed Forager peas. This response may be attributable to improved nutrient utilization by lambs fed the Carnival pea diet because diet digestibility (Table 1) and G:F tended to be greater ($P = 0.10$) for this diet compared with the Forager pea diet. Similar DMI, ADG, and G:F for lambs fed the Control diet compared to lambs fed diets containing field peas at approximately 33% of DM was consistent with previous reports wherein field peas were included in finishing lamb diets at 24.5% (Purroy and Surra, 1990; Purroy et al., 1992), 39% (Lanza et al., 2003), and up to 45% (Loe et al., 2004) of dietary DM.

Overall. Overall (d 1 to slaughter), DMI tended to be greater ($P = 0.09$) for lambs fed the Forager pea diet than lambs fed the Carnival pea diet but no differences in DMI were noted between the Control diet and the diets containing field peas. As in the transition phase, lambs fed the Forager pea diet had the greatest ($P = 0.01$) ADG but G:F was similar ($P = 0.31$) among dietary treatments. Greater ($P = 0.01$) total BW gain for lambs fed the Forager pea diet may be attributable to gut fill because HCW was similar ($P = 0.19$) among treatments.

Carcass Characteristics

Hot carcass weight ($P = 0.19$), dressing percentage ($P = 0.25$), LM area ($P = 0.39$), fat thickness over the 12th rib ($P = 0.71$), yield grade ($P = 0.39$), flank streaking ($P = 0.75$), maturity ($P = 0.24$), body wall thickness ($P = 0.25$), conformation score ($P = 0.67$), percentage of boneless retail cuts ($P = 0.21$), and quality grade ($P = 0.86$) did not differ among dietary treatments (Table 3). Our results are in agreement with previous reports in which field peas replaced corn at 15 to 45% of dietary DM (Loe et al., 2004) or soybean meal at 18 and 39% of dietary DM (Lanza et al., 2003). Purroy et al. (1992) noted that lambs fed field peas at 24.5% of dietary DM deposited more pelvic and internal fat and had a greater degree of fatness than lambs fed a barley-based diet. Nevertheless, other carcass characteristics were not affected by incorporating field peas into the diets of lambs at 24.5% of DM (Purroy and Surra, 1990; Purroy et al., 1992).

Implications

Lambs may be fed Carnival field peas at approximately 33% of the diet without effect on feedlot performance and carcass characteristics. Although carcass characteristics of lambs fed Forager field peas were comparable to that of lambs fed Carnival field peas and the Control diet, lambs fed Forager peas consumed more feed to achieve those endpoints. Forager peas would not be an acceptable replacement for Carnival peas in diets of feedlot lambs unless the Forager peas are priced less than Carnival peas.

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Table 1. Composition of diets fed to lambs throughout the experiment[1]

	Growing phase			Transition phase			Finishing phase		
	Control	Carnival	Forager	Control	Carnival	Forager	Control	Carnival	Forager
Ingredient	% DM								
Ground bromegrass hay[2]	56.31	56.05	56.23	35.82	35.63	35.75	14.02	13.90	13.98
Ground corn	22.54	-	-	42.57	20.00	20.12	63.89	41.28	41.53
Ground Carnival peas	-	33.20	-	-	33.08	-	-	32.95	-
Ground Forager peas	-	-	32.79	-	-	32.67	-	-	32.54
Soybean meal	13.48	3.18	3.37	13.39	3.16	3.27	13.30	3.13	3.15
Liquid molasses	5.62	5.57	5.60	5.61	5.56	5.60	5.60	5.55	5.59
Limestone	0.64	0.57	0.58	1.42	1.37	1.38	2.24	2.22	2.23
Ammonium chloride	0.51	0.50	0.50	0.50	0.50	0.50	0.50	0.49	0.50
Dicalcium phosphate	0.43	0.43	0.43	0.22	0.22	0.22	-	-	-
Mineralized salt[3]	0.22	0.25	0.25	0.24	0.25	0.26	0.24	0.25	0.26
Magnesium chloride	0.13	0.13	0.13	0.11	0.11	0.11	0.10	0.10	0.10
ADE premix[4]	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Rumensin 80	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Analyzed composition									
DM, %	91.87	90.97	88.89	90.25	90.13	88.40	88.54	89.23	87.88
		% DM			% DM			% DM	
NDF	50.98	51.01	46.15	37.93	38.63	36.65	24.09	25.50	26.57
ADF	27.25	28.82	25.79	18.87	20.00	19.16	9.99	10.65	12.12
CP	14.24	14.14	12.12	15.77	15.05	14.20	17.39	16.02	16.41
IVDMD	77.00	77.14	80.75	85.21	86.08	85.84	93.92	95.57	91.23

[1]The experiment consisted of a growing phase (d 1 to d 31), a transition phase where lambs were adjusted to a finishing diet (d 31 to d 64), and a finishing phase (d 65 to slaughter).

[2]Mean particle length = 2.54 cm.

[3]Contained 13% NaCl, 10% Ca, 10% P, 2% K, 1.5% Mg, 0.28% Fe, 0.27% Zn, 0.12% Mn, 0.01% I, 35 ppm Se, and 20 ppm Co.

[4]Contained 110,000 IU/kg vitamin A, 27,500 IU/kg vitamin D, and 660 IU/kg vitamin E.

Table 2. Feedlot performance of lambs fed field peas[1]

Item	Dietary treatment			SE[2]	*P*-value[3]
	Control	Carnival	Forager		
Growing phase					
Initial BW, kg	24.2	23.9	23.7	0.4	0.75
ADG, g/d	87.6[c,d]	59.8[d]	108.8[c]	11.1	0.06
DMI, g/d	781.1[b]	668.5[b]	937.6[a]	41.6	0.01
G:F	0.11	0.09	0.12	0.3	0.34
Transition phase					
Initial BW, kg	29.4[c,d]	27.5[d]	30.2[c]	0.7	0.07
ADG, g/d	116.0[b]	116.3[b]	166.4[a]	5.3	<0.001
DMI, g/d	1,298.0[b]	1,136.3[b]	1,623.9[a]	66.0	0.005
G:F	0.09	0.10	0.10	0.006	0.31
Finishing phase					
Initial BW, kg	37.3[b]	35.4[b]	41.6[a]	0.8	0.004
ADG, g/d	121.8[c,d]	128.5[c]	112.2[d]	3.7	0.06
DMI, g/d	1,715.7	1,624.2	2,073.0	204.4	0.33
G:F	0.07[c,d]	0.08[c]	0.06[d]	0.006	0.10
Final BW, kg	55.4[b]	54.5[b]	58.2[a]	0.7	0.02
Overall					
DMI, kg	195.3[c,d]	178.6[d]	233.5[c]	14.7	0.09
Gain, kg	15.6[b]	15.3[b]	17.2[a]	0.3	0.01
G:F	0.08	0.09	0.08	0.004	0.31
ADG g/d	113.0[b]	110.4[b]	124.9[a]	2.5	0.01

[1]The experiment consisted of a growing phase (d 1 to d 31), a transition phase where lambs were adjusted to a finishing diet (d 31 to d 64), and a finishing phase (d 65 to slaughter). Carnival or Forager field peas replaced a conventional corn-soybean meal supplement at approximately 33% of dietary DM.
[2]n = 4.
[3]*P*-value of F statistic.
[a,b]Means within a row lacking a common superscript differ ($P < 0.05$).
[c,d] Means within a row lacking a common superscript differ ($P < 0.10$).

Table 3. Carcass characteristics of lambs fed field peas[1]

Item	Dietary treatment			SE[2]	*P*-value[3]
	Control	Carnival	Forager		
Live BW[4], kg	53.9[b]	53.0[b]	56.6[a]	0.8	0.03
HCW, kg	30.9	30.2	31.8	0.6	0.19
Dressing percentage	55.8	55.4	54.7	0.4	0.25
LM area, cm^2	18.7	18.0	18.0	0.6	0.39
12th rib fat thickness, mm	6.2	4.4	6.2	1.0	0.71
Yield grade	2.8	2.1	2.8	0.4	0.39
Flank streak[5]	203.8	220.0	200.0	19.2	0.75
Maturity, A	40.0	45.0	50.0	3.7	0.24
Body wall thickness, cm	2.4	2.3	2.5	0.1	0.25
Conformation score	11.8	12.0	12.0	0.2	0.67
Boneless retail cuts, %	46.9	47.3	46.3	0.4	0.21
Quality grade[6]	10.5	10.3	10.5	0.4	0.86

[1]Carnival or Forager field peas replaced a conventional corn-soybean meal supplement at approximately 33% of dietary DM.
[2]n = 4.
[3]*P*-value of F statistic.
[4]Shorn BW after a 14-h fast.
[5]Slight = 100, small = 200, moderate = 300.
[6]10 = high choice (Control = 75.0%, Carnival = 87.5%, and Forager = 75.0%); 12 = low prime (Control = 25.0%, Carnival = 12.5%, and Forager = 25.0%).
[a,b]Means within a row lacking a common superscript differ ($P < 0.05$).

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GROWTH AND REPRODUCTIVE PERFORMANCE OF BEEF HEIFERS FED CARNIVAL OR FORAGER FIELD PEAS[1]

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ABSTRACT: Our objective was to evaluate Carnival or Forager field peas as a replacement for a conventional corn-soybean meal supplement in diets of peripuberal beef heifers. Beginning 60 d before estrous synchronization, 90 Angus × Gelbvieh rotationally crossed heifers (330 ± 1.0 kg initial BW) were stratified by BW and allotted randomly within each BW block to 1 of 3 pens (10 heifers/pen). Bromegrass hay was offered daily at 6.30 kg of DM/heifer for the first 30 d whereas heifers had access to 7.35 kg/d of bromegrass hay (DM basis) for the second 30 d. Dietary treatments (formulated to be isonitrogenous) included a 62.6% ground corn and 37.4% soybean meal (DM basis; Control) supplement fed daily at 1.36 kg of DM/heifer, ground Carnival peas fed daily at 1.41 kg of DM/heifer, and 90.7% ground Forager peas and 9.3% soybean meal (DM basis) fed daily at 1.41 kg of DM/heifer. Data were analyzed as a randomized complete block design, and dietary treatments were compared using the orthogonal single degree of freedom contrast of Control vs. field peas and Carnival vs. Forager peas. Heifers fed field peas tended (P = 0.08) to have greater ADG and G:F than heifers fed the Control supplement during the first 30 d. Growth performance was not affected (P = 0.18 to 0.19) by dietary supplement during the second 30 d, but over the course of the 60-d feeding period, ADG and G:F were greater (P = 0.04) for heifers fed field peas compared with heifers fed the Control supplement. Variety of field peas did not influence (P = 0.18 to 0.47) growth performance of heifers throughout the experiment. Likewise, AI pregnancy rate (confirmed at calving) was 43.3% for all dietary treatments. We conclude that field peas can replace conventional corn-soybean meal supplements fed to peripuberal beef heifers for 60 d before estrous synchronization. Moreover, Forager peas are comparable to Carnival peas as a dietary supplement for beef heifers consuming forage-based diets.

Key Words: Beef Heifers, Field Peas, Supplementation

Introduction

Integrated dryland crop and livestock agroecosystems represent a potential ecologically and economically sustainable form of agriculture (Krall and Schuman, 1996). Agroecosystems that utilize grain legumes, such as dryland peas, to integrate cereal and livestock production have gained popularity in the Great Plains. Reed et al. (2004a,b), for example, noted that based on NDASS (2003) statistics field pea (*Pisum sativum*) grain production in North Dakota increased nearly 10-fold from 1994 to 2003. Green and yellow cotyledon types are the primary classes of grain peas (McKay et al., 2003). Carnival is a variety with smooth whitish yellow seed coats, and is representative of the yellow market class. In contrast, the recently released Forager variety has a dimpled seed coat with a green-brown color (Krall et al., 2004). We hypothesized that the feeding value of the dryland green-brown pea variety Forager would be comparable to a common dryland yellow pea variety Carnival. Although field peas have been evaluated as a source high-protein grain in the diets of lactating dairy cows (Petit et al., 1997), suckling calves (Gelvin et al., 2004), growing steers (Reed et al., 2004a,b; Soto-Navarro et al., 2004) and heifers (Anderson, 1998), and finishing steers and heifers (Flatt and Stanton, 2000), we are not aware of reports published on feeding field peas to developing replacement heifers. Therefore, our objective was to evaluate Carnival or Forager field peas as a replacement for a conventional corn-soybean meal supplement in diets of peripuberal beef heifers.

Materials and Methods

General

The University of Wyoming Animal Care and Use Committee approved all procedures for the following experiment. Beginning 60 d before estrous synchronization, 90 Angus × Gelbvieh rotationally crossed heifers (330 ± 1.0 kg initial BW) were stratified by BW and allotted randomly within each BW block to 1 of 3 pens (10 heifers/pen). Heifers had free access to water and mineralized salt [Nutrena® 12:12 Mineral Block; Cargill, Inc., Nutrena Feed Division, Minneapolis, MN; guaranteed analysis (DM basis): 11.5 to 13.5% Ca; 12.0% P;6.5 to 7.5% NaCl; 2.6 to 3.12% Na; 2.5% Mg; 3,500 ppm Zn; 2,000 ppm Cu; 900 ppm Mn; 250 ppm I; 18 ppm Se] throughout the experiment. Individual BW was obtained on 2 consecutive d at the beginning and termination of the 60-d feeding period, and an interim BW was obtained on d 30. Initial and final BCS (9-point scale) was the average of BCS determined by three independent evaluators.

Supplements

Brokaw et al. (2002) demonstrated that replacement heifers from the University of Wyoming beef herd should be between 60 and 65% of mature BW before breeding, which would be comparable to between 342 and 371 kg average BW after the 60-d feeding period. Therefore, heifers were fed diets formulated to achieve 0.67 kg/d ADG (NRC, 2000). Bromegrass hay was offered daily at 6.30 kg of DM/heifer for the first 30 d, whereas heifers had access to 7.35 kg/d of bromegrass hay (DM basis) for the second

[1]Research supported by a grant from the USDA-CSREES Sustainable Agriculture Research and Education (SW03-008).

30 d. Any hay left in the bunk after 24 h was collected, weighed, and analyzed for DM (AOAC, 1990) to obtain an accurate estimate of DMI. A conventional supplement consisting of 62.6% ground corn and 37.4% soybean meal (DM basis) fed daily at 1.36 kg of DM/heifer served as the control supplement (**Control**). Ground Carnival peas fed daily at 1.41 kg of DM/heifer or 90.7% ground Forager peas and 9.3% soybean meal (DM basis) fed daily at 1.41 kg of DM/heifer were formulated to be isonitrogenous replacements for the conventional corn-soybean meal supplement.

Reproduction

At the conclusion of the 60-d experimental feeding period, heifers were combined into one large group. Heifers had free access to water, mineralized salt, and bromegrass hay, and were synchronized for estrus using a melengestrol acetate-$PGF_{2\alpha}$ protocol. The 14 to 17 d melengestrol acetate-$PGF_{2\alpha}$ treatment followed the protocol recommended by Patterson et al. (2000) for synchronizing estrus of replacement beef heifers. Estrous activity was evaluated twice daily. Heifers showing estrus were bred via AI 12 h after standing heat. After a 42-d AI period, heifers were placed with a bull. Pregnancy was detected by palpation per rectum at approximately 60 d after the conclusion of the AI period. Conception via AI was confirmed at parturition.

Diet Sampling and Analyses

Core samples from 10% of the baled hay were collected before feeding, and grab-samples of supplements were collected daily. Samples were composited within respective sample type before grinding in a Wiley Mill (Thomas Hill and Sons, Philadelphia, PA) to pass a 1-mm screen. Ground samples were analyzed in duplicate for DM and ash (AOAC, 1990), CP (Leco FP-528; Leco Corp., St. Joseph, MO), ADF and NDF (non-sequential methods; Ankom 200 fiber analyzer, Ankom Technology, Fairport, NY), and in triplicate for IVDMD (Daisy II Incubator; Ankom Tech. Corp., Fairport, NY). Nitrogen associated with NDF and ADF was used to estimate rumen undegraded protein and the B_3 fraction (Sniffen et al., 1992). An additional IVDMD experiment was conducted in triplicate to evaluate digestibility of the hay and supplements when the ingredients were included in dietary proportions determined during the first 30 d of the heifer feeding period.

Statistical Analyses

Growth performance data were analyzed as a randomized complete block design using GLM procedures whereas categorical data were analyzed using CATMOD procedures of SAS (SAS Inst., Inc., Cary, NC). Dietary treatments were compared using the orthogonal single degree of freedom contrast of Control vs. field peas and Carnival vs. Forager peas.

Results and Discussion

Diet Composition

Pre-experimental analysis of CP indicated that Carnival peas had 25.1% CP and Forager peas had 22.4% CP (DM basis). Results of analyses conducted on samples composited over the course of the experiment (Table 1) indicated that the supplements were not isonitrogenous because the soybean meal used in the Control and Forager pea supplements had greater CP content than initially analyzed. Crude protein values for the pea varieties used in our experiment are comparable to values of 23.4 and 28.1% reported by Reed et al. (2004a) and Petit et al. (1997), respectively. Whereas fiber content of Carnival peas was within the range (5.9 to 7.2% for ADF; 9.1 to 14.2% for NDF) reported by Petit et al. (1997), fiber values for Forager peas were greater than those reported by Anderson (1998) for field peas (7.5% ADF; 15.16% NDF). Our IVDMD value for Carnival peas was less than the value for in vitro OM digestibility (95.7%) reported by Reed et al. (2004a), but was within the range (85.2 to 88.6%) of effective DM degradability values reported by Petit et al. (1997). Olaisen et al. (2003) noted that apparent ruminal DM disappearance was 73.9 to 76.4% for field peas, which is comparable to our estimate of IVDMD for Forager peas after accounting for the soybean meal contribution to the Forager pea supplement. Although effective ruminal degradation estimates of field pea CP have ranged from lows of 67.7% (Rotger et al., 2005) to 86.4% (Olaisen et al., 2003), our values of rumen degradable protein based on neutral detergent soluble N are similar to effective ruminal degradation estimates (88.9 to 96.0% of total CP) presented by Petit et al. (1997) and Soto-Navarro et al. (2004). Overall, nutritive values for Carnival and Forager peas were comparable to values commonly reported in the literature.

Growth Performance

Heifers fed field peas tended ($P = 0.08$) to have greater ADG and G:F than heifers fed the Control supplement during the first 30 d, which contributed to greater ($P = 0.04$) ADG and G:F for heifers fed field peas compared with heifers fed the Control supplement over the course of the 60-d feeding period. Dietary supplement did not influence ($P = 0.71$ to 0.92) heifer BCS. Growth performance was not affected ($P = 0.18$ to 0.19) by dietary supplement during the second 30 d, and variety of field peas did not influence ($P = 0.18$ to 0.47) growth performance of heifers throughout the experiment. Lower G:F by heifers in the present experiment compared with heifers fed similar diets in our past experiments (Whitney et al., 2000; Brokaw et al., 2002) likely reflects slower rate of gain by heifers in the present experiment. Nevertheless, the 8.4% average improvement in ADG and G:F for heifers fed field peas observed in the present experiment was more than expected based on results of a demonstration trial in which Anderson (1998) reported an 7.5% improvement in ADG and 1.5% greater G:F for weaned heifers fed field peas versus heifers fed wheat middlings.

We postulated that the greater than expected improvement in growth performance by heifers fed field

peas in our study was related to inclusion level of peas in the diet. Heifers in our experiment consumed field peas at 16.1 to 18.3% of DMI, whereas the weaned heifers in the trial of Anderson (1998) were fed field peas at 32.0% of dietary DM. According to data presented by Soto-Navarro et al. (2004), ruminal in situ disappearance rate of DM and fiber from grass hay and soybean hulls was virtually unaffected and rate of DM disappearance from field peas increased from 5.0 to 8.4%/h by including field peas at 15% of DM in forage-based diets fed to beef steers. Including field peas at 30 and 45% of diet DM, however, resulted in a linear decrease in ruminal in situ disappearance rate of DM and fiber from grass hay and soybean hulls (Soto-Navarro et al., 2004). Supplementing field peas at less than 1.62 kg/d (approximately 20% of DMI) seemed to be optimal for beef steer given ad libitum access to native prairie grass hay (Reed et al., 2004a).

Results of our IVDMD evaluation indicated that the potential negative associative effect was less for field peas than for the Control supplement. Values for IVDMD were 54.4, 56.2, and 54.4% for the Control, Carnival pea, and Forager pea diet, respectively. Based upon IVDMD (Table 1) and DMI (Table 2), the Control diet should have had an IVDMD of 59.8%, the Carnival pea diet should have had 59.9% IVDMD, and the Forager pea diet should have had 58.4% IVDMD. Thus, the difference in observed versus expected digestibility was nearly 4 units greater for the Control diet compared with the diets containing field peas.

Reproductive Performance

Pregnancy rate to AI was 43.3% for heifers fed each of the three dietary supplements. Lack of differences among dietary treatments for AI pregnancy rates was not surprising because heifers fed each diet achieved the target BW set at the onset of the experiment.

Implications

Field peas can replace a conventional corn-soybean meal supplement fed to peripuberal beef heifers for 60 d before estrous synchronization. Forager peas are comparable to Carnival peas when included at 16.1 to 18.3% in forage-based diets consumed by developing replacement beef heifers.

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Table 1. Composition of hay and supplements fed to beef heifers for 60 days before estrous synchronization

Item	Bromegrass hay	Supplement[1]		
		Control	Carnival	Forager
DM, %	89.3	85.4	89.0	88.6
	----------% of DM----------			
Ash	9.3	4.0	4.9	4.3
ADF	40.1	9.3	5.4	9.5
NDF	68.9	20.1	11.3	21.8
IVDMD	54.3	85.1	85.3	76.7
CP	10.7	28.4	25.3	27.8
RDP[2], % of CP	63.4	89.5	95.4	90.0
B_3, % of CP	28.9	8.3	3.3	8.8

[1]Control was 62.6% ground corn and 37.4% soybean meal (DM basis), Carnival consisted of ground Carnival peas, and Forager was comprised of 90.7% ground Forager peas and 9.3% soybean meal (DM basis).
[2]Rumen degradable protein (RDP) and the B_3 fraction were estimated from NDF and ADF insoluble N (Sniffen et al., 1992).

Table 2. Growth and reproductive performance of beef heifers fed field pea supplements for 60 days before estrous synchronization

Item	Supplement[1]			SE[3]	Contrast[2]	
	Control	Carnival	Forager		Control vs. Peas	Carnival vs. Forager
Initial BW, kg	331.1	328.7	329.3	1.0	0.15	0.74
Initial BCS, 1-9 scale	5.2	5.3	5.2	0.09	0.81	0.71
1st 30-d hay DMI, kg/d	6.3	6.3	6.3	-	-	-
1st 30-d ADG, kg/d	0.57	0.64	0.68	0.03	0.08	0.47
BW after 30 d, kg	348.3	348.1	349.7	1.0	0.64	0.34
First 30-d G:F, kg:100 kg	7.5	8.9	8.4	0.4	0.08	0.40
2nd 30-d hay DMI, kg/d	7.35	7.35	7.35	0.03	0.74	0.78
2nd 30-d ADG, kg/d	0.67	0.73	0.65	0.04	0.73	0.19
2nd 30-d G:F, kg:100 kg	7.8	7.4	8.3	0.4	0.83	0.18
Final BW, kg	368.4	369.9	369.1	1.3	0.53	0.68
60-d BCS change	0.16	0.12	0.18	0.03	0.86	0.21
Overall ADG, lb/d	0.62	0.68	0.66	0.01	0.04	0.35
Overall G:F kg:100 kg	7.6	8.1	8.4	0.2	0.04	0.34
Final BCS, 1-9 scale	5.4	5.4	5.4	0.06	0.79	0.92
Pregnancy rate to AI[4], %	43.3	43.3	43.3	-	-	-

[1]Supplements included a 62.6% ground corn and 37.4% soybean meal (DM basis) supplement fed daily at 1.36 kg of DM/heifer (Control), ground Carnival peas fed daily at 1.41 kg of DM/heifer (Carnival), and 90.7% ground Forager peas and 9.3% soybean meal (DM basis) fed daily at 1.41 kg of DM/heifer (Forager).
[2]*P*-value of single degree of freedom contrasts comparing the Control supplement to supplements with peas and then with either Carnivalor Forager peas.
[3]n = 3.
[4]Pregnancy rate to AI was confirmed by cross referencing breeding records with calving date.

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THE EFFECTS OF TIMBER HARVEST, HERBIVORY, AND SEASON OF USE ON DIET SELECTION OF STEERS GRAZING FORESTED RANGELANDS.

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ABSTRACT: The objectives of this study were to document the effects of timber harvest and herbivory on the botanical composition of steer diets in grand fir (*Abies grandis*) and ponderosa pine (*Pinus ponderosa*) forests. Three grand fir and ponderosa pine sites were established in 1986. Grand fir sites were arranged as a split-plot design and timber harvest treatments: [1) no harvest (CON), 2) thinning (TH), 3) clearcut (CL)] were whole plots and herbivory treatments [1) cattle and big game grazing (GR), 2) big game grazing (BG), and 3) exclusion of cattle and big game grazing (EX)] were the sub-plots. Ponderosa pine sites were arranged as a split-plot design and timber harvest [1) CON, 2) TH] were whole plots and herbivory treatments [1) GR, 2) BG, and 3) EX] were sub-plots. Diet samples were collected using four ruminally cannulated steers in June and August of 2001 and 2002. Microhistological analysis of ruminal masticate was used to determine the botanical composition of diets. Results from the grand fir sites revealed that graminoids were the major constituent in the diet ranging from 65 to 91%, forbs were intermediate ranging from 8 to 31%, and shrubs were least ranging from 0.2 to 3.5%. Season of use did not affect ($P > 0.10$) the composition of diets. Results from the ponderosa pine sites revealed that graminoids were the major constituent in the diet ranging from 83 to 88%, forbs were intermediate ranging from 10 to 14%, and shrubs were least ranging from 2 to 3%. Again, season of use did not affect ($P > 0.10$) the composition of diets. This study suggests that timing of grazing did not influence botanical composition of diets and that grasses were preferred by cattle grazing forested rangelands.

Key Words: Botanical composition, Grand fir, Ponderosa pine

Introduction

Grazing cattle and timber harvest are common practices associated with forested rangelands in North America. These areas comprise a significant portion of the public lands in the west and are productive in producing habitat and forage for livestock and wildlife, as well as wood products for human use. However, over the past 100 years many areas with the potential for high forage production have low outputs due to dense canopy cover (Hedrick et al. 1969). Therefore, it may be necessary to open the canopy to return the understory productivity of these lands.

Timber harvest on forested rangelands sets back succession and, in most cases, increases understory forage production (McConnell and Smith 1970; Young et al. 1967). This results in an increased opportunity for cattle/wildlife to forage and obtain a higher quality diet and subsequently increase productivity. Typically, cattle select a diet that is predominantly grass with limited forbs and shrubs (Holechek et al. 1982). However, cattle diets vary throughout the grazing season, with woody vegetation becoming a greater part of the diet as the grazing season progress (Holechek et al. 1982).

The combined effects of timber harvest and previous herbivory (wild and/or domestic ungulates) on diet quality and botanical composition of diets have not been documented. Therefore, the objectives of this study were to determine how timber harvest, previous herbivory and season of use affect the quality and botanical composition of diets obtained from forested rangelands.

Materials and Methods

The study area is located at the Eastern Oregon Agriculture Research Center's Hall Ranch, which is approximately 16 km east of the city of Union in the Wallowa Mountains of northeastern Oregon. Elevation ranges from 1050 to 1250 m and annual precipitation averages 56 cm with about 65% coming in the winter; whereas summers are usually dry. Cattle have been grazing the area since mid-1880. Elk (*Cervus elaphus* L.) and mule deer (*Odocoileus hemionus* Raf.) are indigenous to the area and can be found throughout the year; however, heaviest use occurs in spring and fall.

The study was conducted as a replicated split-plot design. Three *Abies grandis* (Dougl. ex D. Don) Lindl. / *Pachistima myrsintes* (Pursh) Raf. (grand fir), 22.5 ha each in size, and three *Pinus ponderosa* P.& C. Lawson / *Symphoricarpos albus* (L.) Blake (Ponderosa pine), 15 ha each in size, sites were selected to analyze the effects of herbivory and overstory canopy cover on botanical composition of diets and diet quality. Sites were selected within areas of relatively homogeneous stand structure. The grand fir sites had three timber harvest treatments applied: 1) clear cut, 2) crown thinning and 3) uncut (Control; Figure 2). Crown thinning consisted of removing co-dominant and some dominant trees. Timber harvest began in 1985 and was completed in 1986. The grand fir clearcuts were replanted in the spring of 1988 with Ponderosa pine, Douglas-fir (*Pseudotsuga menziesii*

(Mirbel) Franco var. *glauca* (Beissn.) Franco), and western larch (*Larix occidentalis* Nutt.). Whereas, the ponderosa pine sites had two timber harvest treatments applied: 1) commercial thinning and 2) uncut (Control; Figure 3). Thinning within the Ponderosa pine sites was done to achieve a tree basal area of 24 m^2/ha (tree spacing of approx. 8 m). Timber harvest began in 1985 and was completed in 1986.

The following herbivory treatments were applied within all timber harvest treatments for both grand fir and ponderosa pine sites: 1) grazing by cattle and big game to achieve 60 percent utilization (Grazed), 2) big game grazing only (Cattle exclosure), and 3) exclusion of cattle and big game grazing (Total exclosure). Sixty percent utilization is considered heavy relative to current recommendations (Holechek 1995), but was used because it was considered a typical utilization level for industrial forests within the area. Cattle and total exclosures were approximately 0.5 ha in size. Grazing by cattle was done in conjunction with allotment grazing from mid-August through October for the grand fir sites. Whereas, ponderosa pine sites were grazed in a deferred rotation grazing system. Even years were grazed from mid-June to mid-July and odd years were grazed from beginning of July to mid-August. Grazing by cattle in ponderosa pine sites was removed from 2001 and 2002 to allow for diet collections in mid-August.

Vegetation on these sites was varied but the dominant grasses were elk sedge (*Carex geyeri* Boott), pinegrass (*Calamagrostis rubescens* Buckl.), and Kentucky bluegrass (*Poa pratensis* L.). Numerous forbs were also found which include heartleaf arnica (*Arnica cordifolia* Hook.), western yarrow (*Achillea millefolium* L. var. *occidentalis* DC.), cinquefoil species (*Potentilla* spp.), and lupine species (*Lupinus* spp.). Several shrub species were typically found which include mallow ninebark (*Physocarpus malvaceus* (Greene) Kuntze), common snowberry, Oregon grape (*Berberis repens* Lindl.), and spirea (*Spiraea betulifolia* Pallas). Overstory of the grand fir sites within the controls and thinned timber harvest treatments were dominated by grand fir, whereas, dominant overstory species within clearcuts was ponderosa pine, Douglas-fir, and western larch, however, grand fir saplings were numerous. Overstory of the ponderosa pine sites was dominated by ponderosa pine and interspersed with western larch.

Four ruminally cannulated steers were used to determine diets in June and August of 2001 and 2002. Steers were allowed to graze pastures for several weeks before collections to become familiar with plant communities. Prior to the grazing bout, steers were transported to site and ruminally evacuated as described by Lesperance et al. (1960), except rumen walls were rinsed with a sponge to remove as much material as possible. Steers were allowed to graze for 20 min. and grazed masticate samples were removed immediately following the grazing bout. Multiple collections were made by each steer within a day, both morning and evening collections. Launchbaugh et al. (1990) reported no differences in cattle diets between morning and evening collections, therefore only considerations for possible effects from an empty rumen were considered. To minimize possible effects of an empty rumen on forage selectivity by steers, we randomized the order that sites were grazed within each block. Following collection of masticate samples, original rumen contents were replaced. Masticate samples were completely dried at 50°C in a forced air oven and were ground through a Wiley Mill (Thomas Scientific, Sweedesboro, NJ) using a 1 mm screen. Composite samples were created for each experimental unit by combining 50 g sub-sample of each steers masticate sample. Livestock were handled according to the protocol approved by the Institutional Animal Care and Use Committee at Oregon State University.

Botanical composition of steer diets was determined using microhistological analysis. Composite samples were soaked in sodium hydroxide and mounted using techniques described by Holechek (1982). Three slides for each sample collected from grand fir sites and four slides for each sample collected from ponderosa pine sites were prepared and then dried at 55°C in a forced air oven, for a minimum of 48 hours, prior to analysis. Twenty fields per slide were systematically observed at 100x magnification. Plant fragments were identified by comparing epidermal characteristics with plant species reference slides and recorded as frequency counts. Dry weight composition of each sample was determined by dividing the frequency of each species by the total number of frequencies for all species (Holechek and Gross 1982).

Herbaceous production was collected in 2003 by clipping 0.5 m x 1.0 m rectangular plots placed randomly within each experimental unit. Plots were clipped by species to a 2 cm stubble height. Production clips were completely dried in a forced air oven at 50°C and weighted to the nearest tenth gram.

All data were analyzed as a split-plot design within a randomized complete block design with three replications using MIXED procedures in SAS (SAS Inst. Inc., Cary, NC) with the block (site replication) effect considered random. The whole-plot experimental unit was timber harvest treatment and the sub-plot experimental unit was herbivory within timber harvest treatments. Treatment means were separated using LSmeans procedures of SAS (SAS Inst. Inc., Cary, NC) and were considered significant at $P < 0.05$.

Results and Discussion

Grand Fir Sites

Botanical composition of steer diets did not exhibit season of use x timber harvest x herbivory treatment interactions ($P \geq 0.70$). However, graminoids and forbs exhibited a timber harvest x herbivory treatment interaction ($P < 0.05$). Graminoids, elk sedge, and pinegrass were affected by season of use. June diets had greater ($P = 0.03$) amount of graminoids than August diets (83.5% and 80.4%, respectively), and June diets had greater ($P < 0.01$) amount of pinegrass than August diets (23.4% and 19.8%, respectively). However, June diets had lower ($P < 0.01$) amounts of elk sedge than in August diets (17.9% and 21.8%, respectively). Skovlin (1967) reported that elk sedge was able to maintain higher quality throughout the grazing season and that it was an important forage for grazing ungulates. The amount of shrubs consumed was not

affected ($P \geq 0.11$) by either season of use, timber harvest or herbivory treatments.

Consumption of graminoids was least ($P \leq 0.02$) in controls, across all herbivory treatments, compared to clearcuts and thinned treatments (Table 1). In addition, total exclosures within the controls, had the lowest amount of graminoids in steer diets compared to grazed and cattle exclosures. However, across all treatments the percent of graminoids in steer diets was greater than their percent of production. Conversely, consumption of forbs was greatest ($P \leq 0.04$) in controls, across all herbivory treatments, compared to clearcuts and thinned treatments. The composition of elk sedge, pinegrass and Kentucky bluegrass in diets was similar to their availability on the rangeland. Composition of elk sedge and pinegrass within diets varied from a low of 36% to a high of 48.0% of the diets. Kentucky bluegrass only contributed a significant component to the diet within the clearcuts which was related to the greater production of Kentucky bluegrass within the clearcuts.

Total understory production and graminoid production in 2003, 18 years post-harvest, was only affected ($P \leq 0.05$) by timber harvest treatments (Table 1). Only the production of Kentucky bluegrass, as a percent of total production, was affected ($P < 0.05$) by timber harvest and herbivory treatments. Greater percent of production occurred within the cattle and total exclosures of clearcuts as compared to all other treatments.

The seasonal effects of graminoids in diets was likely due to the declining forage quality and increasing dry matter content (Darambazar, 2003). In results similar to our study, Stout and Quinton (1986) noted that pinegrass was more palatable to cattle in the beginning of the grazing season and as pinegrass matures and senesces it becomes less palatable. The reduction in pinegrass from the diets is similar in amount to the increased consumption of elk sedge. Skovlin (1967) concluded that elk sedge would be an important forage for ungulates grazing forested rangelands late season because of its greater forage quality when compared to other forage species.

Ponderosa Pine Sites

There were no interactions ($P \geq 0.21$) among season of use, timber harvest and herbivory treatments on the botanical composition of diets. Percent of elk sedge and Kentucky bluegrass in diets were affected ($P < 0.05$) by a timber harvest and herbivory interaction. Consumption of elk sedge was greatest in the cattle and total exclosures of the control timber harvest treatments. Unlike the grand fir sites, the proportion of elk sedge in the diets was less than the proportion of elk sedge in total understory production. Alternatively, Kentucky bluegrass composition of diets was greater than available on the pasture, and this was especially true for the control timber harvest treatments. The botanical composition of steer diets was not affected ($P \geq 0.40$) by season of use, but the amount of graminoids, forbs and pinegrass in the steer diets was affected ($P \leq 0.04$) by herbivory treatments. Greater than 80% of the steer diets (Table 2) was graminoids, however, the diets from cattle exclosures contained 5.2% and 4.3% more ($P \leq 0.04$) graminoids than the grazed and total exclosures, respectively. Composition of forbs in the diets was greater ($P = 0.01$) in the grazed pasture than in the cattle exclosure, and the total exclosure tended to be greater ($P = 0.08$) than the cattle exclosure.

Total understory production in 2003 was ($P < 0.05$) greater in thinned treatments compared to controls (Table 2). Only the percent pinegrass, Kentucky bluegrass, and shrubs of total understory production were affected ($P < 0.05$) by herbivory. Percent Kentucky bluegrass was greater in grazed and cattle exclosures compared to total exclosures. Whereas, percent pinegrass was reduced by in grazed pastures compared to cattle and total exclosures. Stout and Quinton (1986) observed that pinegrass was most susceptible to damages from grazing at the time when growth is slowing down and summer dormancy is setting in, which typically occurs in late-June through July. Percent shrubs was less in the grazed and cattle exclosures compared to total exclosures. Therefore, indicating that big game browsing is capable of altering the understory vegetation dynamics.

Implications

Cattle grazing forested rangelands in northeastern Oregon preferred a diet that was dominated by graminoids. However, as graminoid production decreases, such as in heavily timbered areas, cattle will increase consumption of forbs. Shrubs occurred considerably less in the diets and forbs occurred of similar proportion as available on the rangeland. As a result, when forage availability/palatability is not limiting, cattle prefer a grass based diet..

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Table 1. The effects of timber harvest* and herbivory† on diet composition and percent understory production in a ponderosa grand fir forest in northeastern Oregon.

		Clearcut			Thinned			Control			SE
		Graze	CExc	TExc	Graze	CExc	TExc	Graze	CExc	TExc	
Elk sedge	% in diet	21.0^{acde}	18.5^{abcde}	19.7^{abcde}	11.8^{bc}	14.0^{ce}	21.0^{ae}	19.3^{ef}	27.0^{a}	26.1^{a}	3.8
	% of prod	20.7	14.7	29.4	12.8	13.4	20.9	22.6	33.0	25.8	6.3
Pinegrass	% in diet	19.1	19.4	19.8	24.5	22.4	21.8	24.1	21.9	20.8	2.8
	% of prod	24.7	6.3	11.3	24.0	27.0	29.5	24.5	11.3	12.2	8.0
Kentucky bluegrass	% in diet[1]	15.2^{a}	14.9^{a}	18.0^{a}	6.5^{b}	5.3^{b}	7.6^{b}	5.8^{b}	3.7^{b}	2.3^{b}	2.5
	% of prod	8.6^{a}	19.7^{b}	20.9^{b}	5.0^{a}	4.7^{a}	4.9^{a}	0.8^{a}	2.5^{a}	1.2^{a}	3.9
Graminoids	% in diet	88.3^{ab}	91.5^{a}	90.3^{a}	82.7^{ab}	88.0^{a}	79.4^{b}	76.1^{b}	75.8^{b}	65.4^{c}	3.2
	% of prod	65.9	59.0	68.8	64.4	66.3	67.5	53.7	53.6	47.7	7.3
Forbs	% in diet	10.7^{ab}	8.3^{a}	9.3^{a}	15.6^{ac}	10.7^{a}	19.6^{bc}	22.5^{c}	21.1^{c}	31.1^{d}	3.1
	% of prod	16.8	18.4	14.9	14.7	20.5	10.3	23.5	17.7	21.9	6.9
Shrubs	% in diet	0.9	0.2	0.4	1.7	1.3	0.9	1.3	3.1	3.5	1.0
	% of prod	17.3	22.5	13.6	20.9	13.2	22.2	22.7	28.7	30.9	5.9
Total Understory Production (kg/ha)		1598^{a}	1320^{bc}	1385^{c}	1124^{bcdg}	1185^{bcdg}	1031^{bdfg}	757^{ef}	901^{eg}	769^{ef}	114

* Timber harvest treatments: Clearcut; Thinned – removal of co-dominant trees; Control – no timber harvest.

† Herbivory treatments: Graze – cattle and big game grazing; CExc – cattle exclosure, big game grazing only; TExc – total exclosure, exclusion of cattle and big game grazing.

^{abcdefg} values with different superscripts are different ($P < 0.05$).

[1] Timber harvest treatment main effect only ($P < 0.05$)

Table 2. The effects of timber harvest* and herbivory† on diet composition and percent understory production in a ponderosa pine forest in northeastern Oregon.

		Thinned			Control			SE
		Graze	CExc	TExc	Graze	CExc	TExc	
Elk sedge	% in diet	10.0^{a}	13.0^{ab}	14.7^{b}	13.2^{ab}	22.9^{c}	26.4^{c}	2.4
	% of prod.	30.2	29.7	35.5	29.6	47.6	42.8	7.4
Pinegrass	% in diet [1]	5.4a	8.5^{ab}	11.7^{b}	8.4^{a}	9.8^{ab}	11.2^{b}	1.4
	% of prod. [1]	4.5^{a}	9.3^{b}	11.5^{b}	5.8^{a}	14.9^{b}	9.4^{b}	3.3
Kentucky bluegrass	% in diet	15.7^{a}	18.4^{b}	15.1^{a}	15.0^{a}	13.7^{a}	10.1^{c}	1.4
	% of prod. [1]	10.7^{a}	11.6^{a}	6.7^{b}	6.8^{a}	4.0^{a}	3.2^{b}	3.2
Graminoids	% in diet [1]	82.5^{a}	87.5^{b}	84.7^{a}	83.8^{a}	89.3^{b}	83.5^{a}	3.1
	% of prod.	63.1	64.9	56.8	67.7	74.5	62.8	6.3
Forbs	% in diet [1]	15.3^{a}	10.8^{b}	12.6^{ab}	13.4^{a}	9.1^{b}	13.5^{ab}	2.9
	% of prod.	28.1	25.4	24.9	23.5	15.0	14.8	4.3
Shrubs	% in diet	2.1	1.8	2.7	2.9	3.0	1.7	0.6
	% of prod. [1]	8.8^{a}	9.7^{a}	18.3^{b}	8.8^{a}	10.7^{a}	22.2^{b}	5.1
Total Understory Production (kg/ha) [2]		979^{a}	1061^{a}	1165^{a}	753^{b}	848^{b}	776^{b}	239

* Timber harvest treatments: Thinned – commercial thinning; Control – no timber harvest.

† Herbivory treatments: Graze – cattle and big game grazing; CExc – cattle exclosure, big game grazing only; TExc – total exclosure, exclusion of cattle and big game grazing.

^{abc} values with different superscripts are different ($P < 0.05$).

[1] Herbivory treatment main effect only ($P < 0.05$).

[2] Timber harvest treatment main effect only ($P < 0.05$).

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EFFECTS OF EARLY WEANING ON COW PERFORMANCE, GRAZING BEHAVIOR, AND WINTER FEED COSTS IN THE INTERMOUNTAIN WEST

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ABSTRACT: Our objective was to determine the influence of early weaning (EW) and traditional weaning (TW) on cow performance and grazing behavior in a 2 yr study. In addition, cow winter feed costs were compared. Each year, 156 cow/calf pairs (78 steer calves and 78 heifer calves) were used in a randomized complete block design. Cows were stratified by calf sex, BCS, and age and assigned randomly to one of two treatments (TRT) and one of three 810-ha pastures. Two cows from each TRT and pasture were fitted with global positioning system collars each year (6 cows/TRT/yr) to evaluate grazing behavior. The EW calves were removed from dams at approximately 130 d, while TW calves grazed with their dams until approximately 205 d of age. All cows were removed from pastures following TW and placed in six separate 25 ha pastures. The same cow groups (blocks) remained intact; however, EW and TW cows were separated and randomly allotted to pastures. All cows were fed to attain a similar BCS (minimum of 5) by approximately 1 mo prior to calving. The TW cows lost 0.8 BCS and 40 kg while the EW cows gained 0.1 BCS and 8 kg from EW to TW ($P < 0.01$). After winter feeding (approx. 110 d), there was no difference between EW and TW cow BCS ($P = 0.52$). However, winter feed costs were $29 greater ($P < 0.01$) for TW compared with EW cows. Grazing time, distance traveled, and number of visits to water were unaffected ($P > 0.10$) by TRT. However, the proportion of each pasture visited by EW cows tended to be greater than that of TW cows ($P = 0.08$). Results indicate that EW improves cow BCS entering the winter feeding period, thereby, decreasing winter feed costs. Cow grazing behavior was minimally affected by weaning treatment.

Key words: Alternative, Economics, Management

Introduction

Early weaning (**EW**) spring born calves can yield heavier calves compared with calves left alongside their dams on sagebrush-bunchgrass range until mid-October (Wallace and Raleigh, 1961). Other benefits include: 1) the cow does not have the additional nutrient demand of lactation and shouldn't lose as much body condition; 2) the total number of animal units on the range is decreased, thereby extending the number of days cows can remain on range without hay feeding; and 3) dry-gestating cows may cover more range and be better distributed over the grazing area.

In a recent Cattle-Fax® survey of 500 producers in 41 states (Cattle Fax®, 2005), the annual cost to carry a cow averaged $315. When cow cost was compared by region, the northwest had the highest. The annual costs by region were southwest - $270, southeast - $282, southern plains - $317, midwest - $326, and northwest - $379. The primary reason for the greater expense was winter feed costs. This represents an expense of somewhere between $75 and $180 per cow. This is a major disadvantage for northwest ranchers compared with other areas of the country. Consequently, the ability to compete with other regions of the United States may depend on how effectively northwest cow/calf producers can reduce winter-feed costs while maintaining acceptable levels of performance.

Winter feed costs normally include the cost of harvested forage and supplement necessary to sustain, or increase, cow BCS prior to calving. This is necessary to optimize conception rate and to maintain a 365-d calving interval (Herd and Sprott, 1986). The objective of this study was to compare the effects of early weaning and traditional weaning (**TW**) on cow performance, grazing behavior, and subsequent winter feed costs.

Materials and Methods

Experimental Sites

Grazing research was conducted in 2004 and 2005 using three 810-ha pastures at the Northern Great Basin Experimental Range, 52 km west-southwest of Burns, OR. Vegetation has been described previously (Ganskopp, 2001).

Both years, winter feeding of cows was conducted at the Eastern Oregon Agricultural Research Center, 6 km south of Burns, OR, in six 25-ha native flood meadow pastures that had been harvested for hay the previous summer.

Available standing crop in each pasture at the Northern Great Basin Experimental Range was measured at the beginning and conclusion of the grazing period each year by clipping 20 randomly (randomized from pasture UTM coordinates) placed 1-m^2 quadrats in each pasture. Clipped herbage was dried at 55° C for 48 h and weighed for determination of standing crop.

Experimental Design

One hundred fifty-six spring-calving Angus x Hereford cows (78 with steer calves and 78 with heifer calves; cow age 6 ± 0.1 yr) were used each year. Experimental design was a randomized complete block and was approved by the Institutional Animal Care and Use Committee at Oregon State University. The study was initiated on 2 August 2004 and 3 August 2005 and

concluded 15 February 2005 and 10 February 2006 (approximately 1 month prior to calving) for year 1 and 2, respectively. One wk prior to EW, cows were stratified by calf sex, BCS, and age and assigned randomly to one of two weaning treatments and one of three pastures. All animals were then managed in common pastures as a single group until the date of EW. Early-weaned calves (39 steers/yr; 39 heifers/yr) were 130 ± 1 d of age at EW (early August of each year) and traditional-weaned calves (39 steers/yr; 39 heifers/yr) were 207 ± 1 d of age at TW (late October of each year). All cows were weighed and evaluated for BCS following an overnight shrink (16 h) at EW and TW. Also, calves were weighed at EW and TW following a 16-h shrink (overnight).

Early-weaned calves were removed from dams at EW. Early-weaned cows and TW cows and calves were returned to their respective pastures at the Northern Great Basin Experimental Range approximately 1 wk after EW. In 2004 and 2005, each pasture had 26 EW cows and 26 TW cow/calf pairs. Water and mineral/salt placement within each pasture were maintained in the same location throughout both years. A mineral/salt mix (7.3% Ca, 7.2% P, 27.8% Na, 23.1% Cl, 1.5% K, 1.7 % Mg, .5% S, 2307 ppm Mn, 3034 ppm Fe, 1340 ppm Cu, 3202 ppm Zn, 32 ppm Co, 78 ppm I, 85 ppm Se, 79 IU/kg vitamin E, and 397 kIU/kg vitamin A) was available free choice.

Six cows from each treatment each year (2 cows•pasture^{-1}•treatment^{-1}•year^{-1}) were fitted with global positioning system (**GPS**) collars (Lotek GPS_2200 Collars; Lotek, 115 Pony Drive, Newmarket, Ontario, Canada, L3Y7B5) to obtain data related to grazing behavior. Collars are equipped with head fore/aft and left/right motion sensors, a temperature sensor, and a GPS unit. The collars were programmed to take position readings at 5-min intervals for three 7-d periods evenly distributed between EW and TW dates each year to estimate grazing time (h/d), distance traveled (m/d), frequency of visits to water (visits/wk), maximum distance from water (m/d), and cow distribution (percentage of ha occupied•pasture^{-1}•wk^{-1}). Collar data were retrieved after each 7-d period, downloaded to a computer, and converted from latitude/longitude to Universal Transverse Mercator as described by Ganskopp (2001). Grazing time was estimated through generation of a prediction model for each cow. Each collared cow was visually observed for 8-12 h. Activities monitored included: grazing, resting (standing or lying down), and walking. Prediction models for estimating grazing time were developed via forward stepwise regression analysis for each cow (S-Plus 2000, Mathsoft Inc., Seattle, WA). The dependent variable was grazing time (min/5 min interval) and the independent variables from GPS collar data included: head fore/aft and left/right movement sensor counts, their sum, ambient temperature, and the distance traveled (m) by the cow within each 5-min interval. Distance traveled (used for predicting grazing time and distance traveled/d) is likely underestimated because straight-line pathways were assumed between successive coordinates. Cow distribution within pastures was estimated with Geographic Information System software (Idrisi32 For Windows, Clark Univ., Worcester, MA) using 1-ha grids.

All cows were removed from the three Northern Great Basin Experimental Range pastures following weaning of the TW calves, palpated for determination of pregnancy, and pregnant cows placed in the six separate pastures at the Eastern Oregon Agricultural Research Center. The same cow groups (blocks) were maintained from the Northern Great Basin Experimental Range pastures to the Eastern Oregon Agricultural Research Center pastures; however, EW and TW cows were separated and randomly allotted (by previous blocking structure) to pastures. The amount of hay, alfalfa, and inputs specifically associated with each cow group were recorded daily. The EW and TW cows were fed to attain a similar BCS (minimum of 5) by mid-February (approximately 1 mo prior to calving).

The winter feed costs associated with each weaning treatment were compared for economic analysis. The costs used in 2003-2004 were: 1) meadow hay - $60/ton; 2) alfalfa - $90 ton; 3) diesel fuel - $2.00/gallon; 4) labor - $7.25/hr. The costs used in 2005-2006 were: 1) meadow hay - $60/ton; 2) alfalfa - $90 ton; 3) diesel fuel - $2.50/gallon; 4) labor - $7.50/hr. The amount of fuel and labor used was determined as 1 gallon and 0.75 h per each hay feeding or supplementation event.

Before the study, calves were vaccinated with Vira Shield® 5 and Clostri Shield® 7 (Novartis Animal Health US, Inc.) at approximately 30 d of age. Two weeks prior to weaning calves were vaccinated with Vira Shield® 5 + Somnus and a Clostri Shield® 7 booster. At weaning, calves received a booster of Vira Shield® 5 + Somnus.

Approximately 1 mo prior to calving, all cows were vaccinated with Vira Shield® 5 and Clostri Shield® 7. Also, all cows were vaccinated with Vira Shield® 5 + VL5 (Novartis Animal Health US, Inc.) at TW.

Statistics

Available standing crop, cow and calf performance data, and cow and calf economical data were analyzed as a Randomized Complete Block using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC). The model included treatments (EW and TW), pasture (n = 3), and year (n=2). A Fisher's protected LSD ($P \leq 0.05$) was used for mean separations (Fisher, 1966).

The experimental design for cow behavioral data (grazing time, distance traveled, frequency of visits to water, maximum distance from water, and cow distribution) was a randomized complete block with 2 yr, three replications/yr (pastures) and two factors: treatments (EW and TW) and sampling periods (n = 3). Data were analyzed as a split-split-plot using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC) with the effects of year and year*treatment analyzed using treatment*year*pasture as the error term and the effect of treatment was analyzed using pasture*treatment as the error term (Petersen, 1985). A Fisher's protected LSD was used as previously to separate treatment means.

Results and Discussion

Standing Forage and Forage Quality

Initial and final standing crop at the Northern Great Basin Experimental Range was unaffected (P > 0.30) by pasture. However, sampling date (beginning or end of grazing period) and year had an effect (P < 0.01) on standing crop, with herbage in August averaging 362 kg/ha compared with 242 in November. In addition, standing crop in 2005 averaged 366 kg/ha compared with 239 in 2004. There were no year*pasture or year*sampling date interactions (P > 0.74). The increase in standing forage in 2005 was expected due to increased precipitation. Precipitation for the crop year (September through June) in 2004 and 2005 was 81% (219 mm) and 95% (259 mm) of the 21-year average (272 mm; Burns, OR; NCDC, 2006), respectively.

Standing crop CP was greater (P < 0.01) in 2004 than 2005 (4.2% vs, 3.3%; DM basis) but not affected by sampling date or pasture (P > 0.05). In addition, there were no year*pasture or year*sampling date interactions (P > 0.05). This agrees with other research demonstrating that annual forage quality is improved with below average compared with normal to above average crop year precipitation (Ganskopp and Bohnert, 2001).

Behavior

Weaning treatment did not influence time spent grazing, resting, or walking by cattle ($P > 0.25$; Table 1). In addition, distance traveled (m/d), average distance to water (m/d), and weekly visits to water were similar for EW and TW cows ($P > 0.20$). However, the percentage of the pasture occupied each week tended to be greater ($P = 0.08$) for EW than cow/calf pairs. The greater pasture distribution for EW cows agrees with the 1 hr numerical increase observed in their daily grazing time. We are not aware of other research evaluating the effects of weaning on grazing behavior of beef cows. Nevertheless, Rosiere et al. (1980) reported that forage intake of 2-yr old heifers grazing blue grama summer range was 67% of the intake of 2-yr old lactating cows with calves at their side. To increase intake, the heifers had to either consume a higher digestibility diet or graze longer and, potentially, a larger proportion of the pasture. This agrees with the numerical increase in grazing time and tendency for increased pasture distribution by EW cows in the current study.

Cow Performance

During the grazing period between EW and TW, BCS of EW cows increased 0.1 while TW cows lost 0.8 ($P < 0.01$; Table 2). Similarly, weight change during the same period was 8 and -40 kg for EW and TW cows, respectively ($P < 0.01$). These results agree with other research that has demonstrated increased cow weight and/or BCS with EW compared with TW (Short et al., 1996; Story et al., 2000). During the winter feeding period, TW cows gained 0.8 more BCS and 31 kg compared with EW cows ($P < 0.01$).

Total cow BCS change tended (P = 0.07) to be greater, and overall weight change was greater (P < 0.01) for EW compared with TW cows, but the differences were not deemed physiologically important (0.1 BCS and 17 kg, respectively).

Total feed costs for EW cows during the winter feed period were $136.66 compared with $165.52 for TW cows ($P < 0.01$; data not shown). The greater cost associated with TW cows was due to the alfalfa (and related costs) needed to attain a similar BCS (minimum BCS of 5) to EW cows by 1 mo prior to calving.

Implications

Early weaning calves of spring calving cows at approximately 130 days of age will improve cow body condition score entering the winter feeding period and decrease winter feed costs compared with cows traditionally weaned at approximately 205 days of age in the Intermountain West. However, the overall economic effect of early weaning is dependent on a number of factors including timing and amount of precipitation, calf performance during the late summer and early fall, seasonal disparities of calf prices, and costs associated with winter feeding (feedstuffs, labor, and fuel).

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Table 1. Influence of weaning treatment on grazing behavior of cows pastured on sagebrush-bunchgrass range in southeastern Oregon[a]

Item	Early-Weaned	Traditional-Weaned	SEM	P-value
Grazing Time, h/d	9.57	8.68	0.240	0.37
Resting Time, h/d	13.62	14.68	0.240	0.26
Walking Time, h/d	0.77	0.73	0.041	0.49
Distance Traveled, m/d	6032	5630	132.3	0.21
Avg. Distance to water, m/d	1245	1173	52.7	0.25
Weekly visits to water	5.7	6.1	0.34	0.53
Distribution, %[b]	21	18	0.7	0.08

[a] Early- and traditional-weaned calves were weaned at 130 ± 1 d and 207 ± 1 d of age, respectively. Grazing behavior was measured from early weaning to traditional weaning; therefore, only traditional-weaned cows had calves at their side.
[b] Percentage of ha occupied per pasture each week

Table 2. Influence of weaning treatment on cow performance[a]

Item	Early-Weaned	Traditional-Weaned	SEM	P-value
Grazing Period[b]				
Initial BCS	5.0	5.1	0.02	0.14
Final BCS	5.1	4.3	0.04	< 0.01
BCS Change	0.1	-0.8	0.04	< 0.01
Initial Wt., Kg	499	499	2.4	0.96
Final Wt., Kg	507	459	3.1	< 0.01
Wt. Change, Kg	8	-40	1.9	< 0.01
Hay Feeding Period[c]				
Initial BCS	5.1	4.3		
November BCS	5.3	4.8	0.03	< 0.01
December BCS	5.6	5.1	0.05	< 0.01
January BCS	5.4	5.1	0.08	0.06
February BCS	5.3	5.3	0.06	0.52
Hay Feeding BCS Change	0.2	1.0	0.07	< 0.01
Initial Wt., Kg	507	459		
November Wt., Kg	550	511	2.5	< 0.01
December Wt., Kg	569	536	3.4	< 0.01
January Wt., Kg	576	549	6.6	0.03
February Wt., Kg	584	567	4.0	0.02
Hay Feeding Wt. Change, Kg	77	108	2.4	< 0.01
Total BCS Change	0.3	0.2	0.04	0.07
Total Wt. Change, Kg	85	68	1.9	< 0.01

[a] Early- and traditional-weaned calves were weaned at 130 ± 1 d and 207 ± 1 d of age, respectively. Grazing behavior was measured from early weaning to traditional weaning; therefore, only traditional-weaned cows had calves at their side.
[b] The initial BCS and weights occurred at early weaning (early August) and Final BCS and weights occurred at traditional weaning (Late October).
[c] Hay feeding began in late October following traditional weaning and concluded in mid-February each year, with BCS and weights obtained approximately every 28 d. Initial BCS and weights were obtained at traditional weaning (same as grazing period final BCS and weights above). The early-weaned cows received only meadow hay (13.9 kg/hd daily; DM basis) while the traditional-weaned cows received meadow hay (13.6 kg/hd daily; DM basis) plus alfalfa (3.55 kg/hd three days a week; DM basis).

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Vitamin D Supplementation in Fall Born Rambouillet Lambs Raised on Small Grain Pastures

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SUMMARY

During preliminary data collection it was determined that lambs grazing lush small grain fields during the winter months are deficient in total vitamin D plasma concentrations. Should deficient conditions exist it could impede proper bone growth and formation. Therefore, this study was designed to determine if vitamin D supplementation shortly after birth would prevent vitamin D deficiencies in lambs grazing small grain pasture during the winter months in West-Central Texas. Forty Rambouillet lambs, born between October 15 and December 1, were blocked by sex and randomly assigned to 1 of 3 treatment groups. Treatment 1 received no vitamin D supplementation (placebo), Treatment 2 received 250,000 IU injections of vitamin D at day 14 and 42; Treatment 3 received 500,000 IU injection of vitamin D at d42. Weights and plasma vitamin D were measured at d14, 42, 68, and 90 after birth. There were no differences in weight gains, plasma vitamin D_3 or total plasma vitamin D concentrations on d14 ($P>0.05$). However, lambs supplemented on d14 had higher ($P<0.05$) total plasma vitamin d concentrations on d 42 than both the control and treatment 3 lambs. Both supplementation treatments were higher ($P<0.05$) than the control on d 68 and 90. Data suggests that supplementing with vitamin D will correct vitamin D deficiencies in fall born lambs grazing small grain fields.

Key Words: Rambouillet, Vitamin D, Bent Leg Syndrome

INTRODUCTION

The Rambouillet breed of sheep makes up the largest portion of sheep raised in West Texas. Rambouillet sheep are suitable to West Texas environments because they are adaptable to the changing weather conditions and are heat tolerant. Typically ewes are bred so they lamb in the spring (February – May) of the year, but approximately 25% are born in the fall (October – December). When lambs are born in the spring, there is a greater abundance of forage and the nutritional management of the flock is less intensive. However, lambs born in the fall of the year require additional feed or cultivated fields usually planted with some type of small grain (wheat, rye, barley or oats), because these plants will grow when the ambient temperatures are low. A commercial producer that chooses to have lambs born in the fall is producing lambs that will be available when supplies are typically low and prices are higher. However, the majority of the lambs that are born in the fall of the year are purebred lambs that are used for seedstock and sold to commercial producers as replacement ewes and breeding rams (SID, 1996).

Ewes and lambs grazing small grain fields are consuming adequate protein and energy in their diet and when commercially available mineral supplements are provided, they consume adequate amounts of their essential minerals. However, vitamins are not normally supplemented to animals grazing lush fields because it is assumed that they are receiving adequate amounts of vitamins to meet their nutrient requirements. A vitamin that has been ignored in most management plans is vitamin D, because it is available in all sun dried forages and is activated at the skin's surface from the sun. When considering the fact that small grains do not have any vitamin D in their plant material when it is growing, and that shortly after fall born lambs are born the day lengths are at their shortest along with the fact that young lambs are covered in wool, lambs may not be able to consume enough vitamin D or activate the required amounts at the skin's surface. In addition, during the fall and winter months in San Angelo, Texas, it is not uncommon for there to be extended periods of cloudy or overcast conditions that may last more than five days, which limits the amount of sunshine available to growing animals and compounding the problem of the lack of sunlight.

Vitamins are organic substances that are essential in small amounts for the maximum performance of animals. Vitamins must be included in the diet since they either cannot be synthesized at all or cannot be synthesized in sufficient quantities in the body (Ensminger et al., 1990). Vitamin D is required for metabolism by affecting calcium absorption, deposition, and metabolism of bone. Vitamin D promotes intestinal absorption of calcium and phosphorus and influences the process of bone mineralization (Ensminger et al., 1990). Vitamin D can be absorbed in the small intestine from the diet or can be synthesized in the skin by activation from ultraviolet light. However, sheep are poor synthesizers of vitamin D and their skin is predominantly covered with wool during most parts of the year. A deficiency of calcium and phosphorus in growing animals may result in rickets. The "bent leg syndrome" resembles a mild case of rickets with the front legs bowing out. Animals experiencing the "bent leg syndrome" are generally adequate in calcium and phosphorus ingestion and plasma levels are at normal levels, but lambs still experience the "bent leg syndrome" (Salisbury, unpublished preliminary data). Preliminary

research also shows that about 33% of lambs that are raised on winter small grain fields exhibit the "bent leg syndrome," while none of the lambs raised on pasture showed the malformation of bone. Plasma vitamin D levels revealed that all fall born lambs were low in vitamin D, according to normal levels reported by Horst et al, (1982). Because of the lack of vitamin D and limited activation, coupled with increased requirements for growth, it is possible that fast growing lambs are deficient in vitamin D and thus, lacking the ability to utilize available calcium and phosphorus for proper bone development. Therefore, a study was designed to determine if strategic vitamin D supplementation could be incorporated into a management program to prevent vitamin D deficiencies in fall born Rambouillet lambs grazing small grain fields following birth.

MATERIALS AND METHODS

This study was conducted at the Angelo State University Management, Instruction, and Research Center, located in Tom Green County north of San Angelo, Texas. Forty Rambouillet lambs born October 15 – December 1 were blocked by sex and randomly assigned to one of three treatment groups at birth. Treatments consisted of a control (Treatment 1) which received only an intramuscular injection of the placebo at d 14 and d 42 of the experiment, treatment two received an intramuscular injection of 250,000 IU of vitamin D at d 14 and d 42, and treatment three received an intramuscular injection of the placebo on d 14 and 500,000 IU of vitamin D on d 42 (Table 1). The placebo consisted of the carrier oil and preservative used to suspend the vitamin D.

All ewes were brought to the lambing facilities two weeks prior to expected parturition and allowed to lamb in confinement. At birth all lambs were identified, tails docked and vaccinated against enterotoximia and soremouth. On d 14, 42, 68, and 90 of the experiment lamb body weights were taken. On d 14 following treatment application and weighing, lambs and their mothers were taken to a small grain (oat) field where they would remain for the entirety of the experiment. The field consisted of minimal native grasses to prevent the consumption of sun cured forage that may contain vitamin D. Fresh clean water, commercial sheep mineral, and a 16% crude protein creep feed was available free choice. The mineral and creep feed did not contain any vitamin D. Lambs were inspected a minimum of three times per week for health and the incidence of the "bent leg syndrome".

On the days that body weights were taken, blood samples were also taken to measure for plasma concentrations of total vitamin D (Animal Disease Laboratory, Ames, IA). Blood samples were collected via jugular viena puncture in sodium heparin tubes. Tubes were centrifuged at 1500 x gravity and the plasma was decanted into small scintillation vials, labeled and frozen at -80^{o}C until analysis.

The first observed case of the "bent leg syndrome" was recorded on d 90 of the experiment. Therefore, d 90 became the end of the experiment because the lambs used in the trial were to be sold as replacement rams and ewes and could not be allowed to continue to deteriorate in their leg condition. At weaning, any lamb exhibiting the start of the "bent leg syndrome" was placed on a complete diet balanced to meet all NRC (1985) requirements for weaned lambs with additional vitamin D to help stop the bending of the front legs.

Table 1. Treatment design of fall born Rambouillet lambs receiving no vitamin D supplementation or supplemented with vitamin D on d 14 and/or d 42.

	Treatments[a]		
Day	1	2	3
d14	Inj[b], Bld, & BW	Inj, Bld, & BW	Inj, Bld, & BW
d42	Inj, Bld, & BW	Inj, Bld, & BW	Inj, Bld, & BW
d68	Bld & BW	Bld & BW	Bld & BW
d90	Bld & BW	Bld & BW	Bld & BW

[a]Treatment 1 received placebo vitamin D supplementation of d 14 and d 42, treatment 2 received 250,000 IU vitamin D supplementation on d 14 and d 42, and treatment 3 received the placebo on d 14 and 500,000 IU vitamin D supplementation on d 42.
[b]Inj = injection, either placebo or vitamin D; Bld = blood sample taken; BW = body weight taken.

Statistical Analysis

Each lamb will be considered an experimental unit because treatments were applied to each individual lamb. Variables included initial (d 14), d 42, d 68 and d 90 body, body weight change, and plasma vitamin D concentrations. General linear models of SAS (SAS Inst. Inc.,Cary, NC) were used to determine treatment differences and the model included sex as a block. Means were separated using Duncan's Least Significant Difference (pdiff option in SAS) and treatments were considered different at $P \leq 0.05$.

RESULTS AND DISCUSSION

Differences in body weights or body weight gain were not found ($P > 0.05$, Table 2). These results were in contrast to those found by McDowell (1989), who reported that one of the clinical signs of rickets is decreased performance. However, these lambs were not allowed to progress beyond a mild case and probably a decreased performance would have been recognized if allowed to progress further.

No differences ($P > 0.05$) were found in vitamin D_3 concentration among treatments (Table 3). However, Horst et al. (1982) reported that vitamin D_3 is found in extremely low concentrations and differences are difficult to detect. Therefore, differences were not expected.

However, when D_2 and D_3 were measured together as total vitamin D differences are easier to detect. In the initial (d 14) blood samples, concentrations were

similar ($P > 0.05$, Table 4), which was expected since Bonniwell et al. (1988) reported that lambs are born with adequate levels of vitamin D until they are six weeks of age. Yet, at d 42 the lambs receiving 250,000 IU of vitamin D at d 14 were higher ($P < 0.05$) in plasma vitamin D concentration, but even the lambs not receiving vitamin D supplementation were still at normal (21.1 ng/ml) levels. Since d 42 is at six weeks of age, lambs not receiving any supplement would not be expected to be deficient yet. Nonetheless, on d 68, lambs not receiving vitamin D were lowest ($P < 0.05$) in plasma concentrations and their levels were below normal levels according to that reported by Horst et al. (1982). The differences ($P < 0.05$) remained the same for d 90, where the nonsupplemented lambs were below normal and those lambs receiving vitamin D were well above normal levels.

Table 2. Body weights and gain in fall born Rambouillet lambs receiving no vitamin D supplementation or supplemented with vitamin D on d 14 and/or d 42.

	Treatments[a]			
Days	1	2	3	SE[b]
d 14, initial	8.91	9.42	9.41	0.544
d 42	17.40	18.44	18.86	0.882
d 68	26.91	28.59	28.82	1.150
d 90, weaning	37.05	38.97	39.32	1.282
Weight gain	28.14	29.55	29.90	0.882

[a]Treatment 1 received placebo vitamin D supplementation of d 14 and d 42, treatment 2 received 250,000 IU vitamin D supplementation on d 14 and d 42, and treatment 3 received the placebo on d 14 and 500,000 IU vitamin D supplementation on d 42.
[b]SE = most conservative standard error of the least squares mean.

Table 3. Plasma concentration of vitamin D (pg/ml) in fall born Rambouillet lambs receiving no vitamin D supplementation or supplemented with vitamin D on d 14 and/or d 42.

	Treatment[a]			
Item	1	2	3	SE[b]
D_3	76.3	63.2	63.9	4.86

[a]Treatment 1 received placebo vitamin D supplementation of d 14 and d 42, treatment 2 received 250,000 IU vitamin D supplementation on d 14 and d 42, and treatment 3 received the placebo on d 14 and 500,000 IU vitamin D supplementation on d 42.
[b]SE = most conservative standard error of the least squares mean.

Table 4. Plasma concentration of total vitamin D (D_2 and D_3) concentrations (ng/ml) in fall born Rambouillet lambs receiving no vitamin D supplementation or supplemented with vitamin D on d 14 and/or d 42.

	Treatment[a]			
Days	1	2	3	SE[b]
14 d	36.0[a]	28.3[a]	29.2[a]	5.17
42 d	23.6[a]	79.1[b]	22.2[a]	5.17
68 d	17.9[a]	92.2[b]	101.1[b]	5.17
90 d	16.1[a]	77.9[b]	75.4[b]	5.17

[a]Treatment 1 received placebo vitamin D supplementation of d 14 and d 42, treatment 2 received 250,000 IU vitamin D supplementation on d 14 and d 42, and treatment 3 received the placebo on d 14 and 500,000 IU vitamin D supplementation on d 42.
[b]SE = most conservative standard error of the least squares mean.

Treatment 2 received supplementation on both d 14 and d 42 and their levels remained fairly constant throughout the trial, but treatment 3 received supplementation only on d 42 and their concentration made a dramatic increase following supplementation. Additionally, treatment 3 lambs were only slightly above normal levels when they received their large dose of vitamin D at d 42, which was followed by the spike in concentrations. Should supplementation occur at an earlier age, levels just above normal may not have ever occurred and their concentrations may have been more even as seen in treatment 2.

The incidence of the "bent leg syndrome" was only used to determine the time at which the lambs should be weaned. Therefore, differences were impossible to detect and data were not analyzed, because it was impossible to determine how many would actually exhibit the condition. Should the lambs have been allowed to progress further, there may have been an observable difference in the condition.

CONCLUSIONS

It appears that supplementing lambs with vitamin D will prevent deficiencies either supplemented with one-half a dose at d14 and 42 or supplemented with the entire dose at d42. Therefore, the data suggests that a vitamin D deficiency is present in fall born lambs grazing small grain fields, and supplementation will correct the deficiency.

There is however, a critical time between day 14 and day 42 that should be examined more closely to determine the most appropriate time to give single massive dose injections. Treatment 3 had two lambs that exhibited the "bent leg syndrome", and this could be because the lambs were deficient prior to the time at which they received their supplementation and the supplementation occurred too late.

It appears from the data that the deficiency can be corrected by supplementation, but the correct timing of supplementation is not thoroughly understood. Other researchers have reported that lambs are born with enough vitamin D to last six weeks, but should supplementation occur at the six week point as in treatment 3 of the current

study, or a few days earlier? Treatment 2 had a more even concentration of vitamin D, but could the supplementation have been postponed to accommodate a single supplementation time for easier management practices?

In the current study, lambs were not allowed to progress to a point where the "bent leg syndrome" was visible. Deficiency were corrected in the lambs by supplementing vitamin D, but it was inconclusive as to whether the supplementation prevented the "bent leg syndrome." Therefore, additional work needs to be done to determine if the current levels of supplementation would actually prevent the condition. Furthermore, is the critical timing of supplementation necessary in preventing deficiencies which could lead to the onset of the "bent leg syndrome?"

Once the correct level of supplementation has been determined it must be investigated to determine which mode of administering a vitamin D supplement is the most efficient and easiest to administer. Ideally, a feed or mineral supplement with vitamin D could be developed to provide the appropriate level to young growing lambs that are grazing small grain pastures.

Since small grain pastures are an efficient and easy way to manage fall born lambs, it is vital that research determine a method to prevent the "bent leg syndrome" and reduce the economic loss purebred producers incur when potential replacement rams and ewes develop the "bent leg syndrome".

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FENCELINE WEANING AND FORAGE BARLEY TO EXTEND THE GRAZING SEASON FOR REPLACEMENT HEIFERS.

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ABSTRACT: In a 3-yr study an average of 47 heifers/year were allotted to two weaning treatments in early October to evaluate fenceline weaning on pasture and forage barley as an alternative to drylot weaning. The pasture-weaned group (**P**) was separated from their dams and grazed grass pasture across the fence from their dams for 2 wk. Then, until early December, they grazed Robust barley that was planted into oat stubble in early August. The drylot-weaned group (**DL**) was transported to a drylot and received grass hay, corn and protein supplement that provided .73 kg CP and 14.5 Mcal ME/day. All heifers were managed as one group from December to April. The impact of treatment on weight gain was dependent on year ($P < 0.05$). In year 1, P gained more than DL during the first 2 wk after weaning ($P < 0.10$). In year 2, DL out gained P at 2 and 4 wk after weaning ($P < 0.05$). Gain from weaning to December and April was not affected by treatment in year 1 or 2. In year 3, P gained less than DL from weaning to early December ($P < 0.05$). In April, P weighed 23 kg less than DL ($P = 0.05$). Typical weaning behavior (walking the fence and bawling) was observed for DL. The P group appeared to be less stressed. No disease symptoms were observed for either group. Response to weaning vaccination was measured by IBR and BVD type 1 and 2 titers at 2 and 4 wk after weaning. There was a year x treatment interaction ($P = 0.06$) for BVD type 1 titer at 2 wk. In year 2, DL had a higher mean BVD type 1 titer than P (136.9 versus 73.1; $P = 0.06$). Titer values were similar at 4 wk. BVD type 2 and IBR titers were not affected by treatment. The P heifers had less rib fat ($P < 0.001$), smaller rib eye area ($P < 0.001$), and lower %IMF ($P = 0.02$) as measured by ultrasonography in April. Fenceline weaning on pasture combined with small grain pasture is a feasible alternative for managing replacement heifers compared to traditional drylot weaning. Weaning management has potential to impact response to vaccination.

KEYWORDS: weaning, heifers, barley

Introduction

Weaning calves on pasture across the fence from their dams or allowing contact while preventing nursing has been shown to reduce the behavioral signs of stress associated with weaning (Haley et al., 2005; Price et al., 2003). Reduction in stress has potential to improve the health of weaned calves and possibly the acquisition of immunity from vaccination. It is common in southern areas of the United States to graze calves on small grain pasture in the fall and winter. In South Dakota, combining pasture weaning and an extended grazing season has potential to reduce cost and labor associated with feeding, maintaining drylot facilities, and manure management. Small grains such as wheat, oats, rye, barley, and triticale are potential sources of high quality forage for calves. The objectives of this study were to: 1) evaluate fenceline weaning on pasture compared to traditional drylot weaning for calves and 2) evaluate forage barley for pasture to extend the grazing season of weaned calves.

Materials and Methods

In each of 3 yr, heifer calves averaging 198 d of age were allotted by breed and weight to 2 weaning treatments in early October. On weaning day the heifers in the pasture-weaned group were separated from their dams and allowed to graze grass pasture across the fence from their dams for 2 wk. Two weeks after weaning they grazed 12.1 ha of forage barley until early December. The pasture consisted of "Robust" barley (forage type) that had been no-till planted into oat stubble in early August. They had access to a free choice mixture of salt, phosphorous, and trace minerals. The heifers in the drylot-weaned group were transported to pens 3.2 km from their dams and bunk fed a diet of corn, protein supplement, and grass hay (Table 1). Beginning in early December, all heifers were fed and managed as one group until yearling weights were recorded in April.

Prior to weaning (64 d the first year, 58 d the second year, and 43 d the third year) all heifers were administered a modified live virus vaccine containing IBR, BVD type 1, BVD type 2, PI_3, BRSV, as well as a Haemophilus somnus bactrin (Resvac 4/Somubac from Pfizer Animal Health). On the day of weaning, heifers were weighed and re-vaccinated with the same vaccine. At weaning and 2 and 4 wk after weaning, a blood sample was collected from each heifer by jugular venipuncture. Titers for IBR, BVD type 1, and BVD type 2 were determined using serum neutralization by the South Dakota Animal Disease Research and Diagnostic Laboratory, Brookings, SD. At 2 and 4 wk after weaning and again in early December, all heifers were weighed following removal from feed and water overnight. For 28 d following weaning, heifer health was determined by observing for signs of depression, gauntness, eye or nose discharge, increased respiratory rate, coughing, diarrhea, or lameness. In April, heifers were weighed after receiving the same diet and being managed as one group since December.

In April, heifers were weighed after receiving the same diet and being managed as one group since December. Ultrasound images were recorded by a Centralized Ultrasound Processing Lab (CUP) certified technician.

Images were interpreted by the CUP Lab, Ames, Iowa, for rib fat, intramuscular fat and rib eye area.

Data were analyzed using the GLM procedure of SAS (SAS Institute, Inc, Cary, NC) and means were separated using the PDIFF option. For average daily gain and weight the statistical model included weaning treatment, year, and weaning treatment x year. The logarithm base 2 of blood titers for IBR, BVD type 1, and BVD type 2 were analyzed with weaning treatment, year, and weaning treatment x year in the statistical model. The logarithm base 2 of blood titers at weaning was included as a covariate to analyze titers at 2 and 4 wk after weaning. The least square means were transformed back to titers for Table 4. The percentage of calves with positive titers by treatment was analyzed by the FREQ procedure of SAS with chi-square to determine significant differences.

Results & Discussion

The impact of weaning management on weight gain for the 4 wk after weaning was dependent on year ($P < 0.05$ for the treatment x year interaction; Table 2). In the first year, pasture-weaned heifers gained more than the drylot group during the 2 wk after weaning ($P < 0.10$). Gains during other periods were similar, resulting in similar weights in April. Due to less favorable pasture conditions in the second year, the drylot group outgained the pasture-weaned group for 2 and 4 wk after weaning ($P < 0.05$). Gains from weaning to December and April were not affected by management in either of the first 2 yr. During the third year, quality and quantity of barley pasture limited gains from weaning to early December ($P < 0.05$). Heifers did not compensate from December to April, resulting in 23 kg lower weight in April ($P = 0.05$) for heifers that grazed forage barley. It is not surprising that year affects weight gains of grazing cattle more than cattle fed grain and hay in drylot. Haley et al. (2005) also found that the effect of weaning management on calf weight gain on pasture was influenced by yearly variation in forage quality.

Similar weight gain from weaning to December and to April during the first 2 yr indicate that weaning on pasture followed by grazing small grains is a feasible alternative for developing replacement heifers. Based on their performance, it would have been advisable to provide supplemental feed to heifers grazing barley during the third year to achieve weight gain similar to the drylot group. An important difference in year three was that heifers were slightly younger and almost 27 kg lighter at weaning. The pasture group was not able to make up for lower gains early after weaning. Supplementation early after weaning is likely more important for lighter calves, particularly when forage quality and quantity limits performance. This could be important when calves are weaned earlier than 7 mo of age.

The drylot-weaned group exhibited typical weaning behavior by walking the fence and bawling for about 1 wk following weaning. The pasture-weaned group appeared to be less distressed. No bawling or walking the fence was observed. This agrees with the reduction of behavioral signs of distress observed by Price et al (2003). Weather conditions were near ideal to minimize stress each year, and no disease symptoms were observed for either group.

Management treatment did not affect IBR or BVD type 2 titer at any of the three sampling times (Table 3). There was a year x weaning treatment interaction ($P = 0.06$) for BVD type 1 titer at 2 weeks after weaning. During the second year the drylot group had a higher mean BVD type 1 titer than the pasture group (136.9 versus 73.1; $P = 0.06$). By 4 wk, titer values were similar. It is possible that weaning management affected acquisition of immunity following vaccination. But after analyzing 3 yr of data, the effect was not consistent. Table 4 shows the same information expressed as the percentage of heifers with positive titers. There was no effect of treatment when analyzed in this manner.

Body composition measured by ultrasonography in April is presented in Table 5. Heifers weaned on pasture had less rib fat ($P < 0.001$), smaller rib eye area ($P < 0.001$), and lower %IMF ($P = 0.02$). In a second analysis when rib fat was included in the statistical model as a covariate, the differences for rib eye area and % IMF were still important. Although it was not expected that the small difference in diets for less than 3 mo would affect body composition as yearlings, this difference was consistent across years. This may not be important for developing replacement females but could be a factor to consider when backgrounding calves intended for harvest.

Implications

Fenceline weaning on pasture followed by grazing small grain pasture is an alternative to drylot weaning for developing replacement heifers. It appears to be less stressful without detrimental affects on immunity following vaccination. Yearly differences that affect forage quality and quantity will influence gain. Calf weight at weaning and forage conditions may be important when determining the need for supplementation.

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Tables

Table 1. Average DMI of drylot heifers from weaning to early December.

Grass hay, kg	3.32
Cracked corn, kg DM	1.86
Protein supplement, kg [a]	.55
Monensin supplement, kg [b]	0.41
Crude protein, kg	.73
ME, Mcal	14.5

[a]Provided 27.4% CP and Ca, P, and trace minerals to exceed NRC (1996) requirements.
[b]To provide 100 mg monensin per head daily.

Table 2. Weaning management and heifer performance

Year	2002		2003		2004		
Weaning treatment	Drylot	Barley Pasture	Drylot	Barley Pasture	Drylot	Barley Pasture	SE[f]
No. heifers	23	23	21	21	26	26	
Age, d	200	203	201	201	193	193	
Weaning weight, kg	265	262	262	260	237	236	
Average daily gain after weaning, kg[a]							
First 2 ws	-0.24[b]	0.05[c]	0.18[d]	-0.37[e]	0.10	0.28	0.14
First 4 wk	0.27	0.32	0.57[d]	-0.04[e]	0.49	0.32	0.08
To December	0.62	0.68	0.67	0.65	0.73[d]	0.45[e]	0.04
To April	1.96	1.96	1.87	1.78	1.98[d]	1.75[e]	0.03
April weight, kg	422	419	432	423	436[d]	413[e]	9

[a] There was a year x treatment interaction for ADG during all periods ($P < 0.05$).
[b,c] Within year, means with uncommon superscripts differ ($P < 0.10$).
[d,e] Within year, means with uncommon superscripts differ ($P < 0.05$).
[f] Average SE of the year x treatment mean.

Table 3. Effect of weaning management on IBR and BVD titers

Management treatment	Drylot		Pasture		Treatment P =	Treatment x year P =
No. heifers	70		70			
Age at weaning, d	198		197			
IBR titer						
Weaning	8.8	±1.1	8.1	±1.1	0.60	0.74
2 wk after weaning[a]	106.4	±1.1	111.6	±1.1	0.78	0.85
4 wk after weaning[a]	85.1	±1.1	86.4	±1.1	0.94	0.29
BVD type 1 titer						
Weaning	46.9	±1.2	44.3	±1.2	0.81	0.68
2 wk after weaning[a, b]	77.8	±1.2	80.3	±1.2	0.87	0.06
4 wk after weaning[a]	83.8	±1.2	84.4	±1.2	0.98	0.28
BVD type 2 titer						
Weaning	5.6	±1.1	6.0	±1.1	0.55	0.85
2 wk after weaning[a]	7.2	±1.1	6.9	±1.1	0.69	0.54
4 wk after weaning[a]	7.0	±1.1	7.4	±1.1	0.64	0.55

[a] The statistical model for titers at 2 and 4 wk after weaning included the titer at weaning as a covariate.
[b] In the year 2 BVD type 1 titer at 2 wk was greater for the drylot group than the pasture group (136.9 vs 73.1; P = 0.08).

Table 4. Weaning treatment and percentage of positive titers for IBR and BVD

	Drylot	Pasture	P =
IBR titer, % positive (> 4)			
Weaning	62.9	57.1	0.49
2 wk after weaning	98.6	95.7	0.31
4 wk after weaning	94.3	92.9	0.73
BVD type 1 titer, % positive (> 8)			
Weaning	84.3	81.4	0.65
2 wk after weaning	90.0	87.1	0.60
4 wk after weaning	90.0	85.7	0.44
BVD type 2 titer, % positive (> 8)			
Weaning	12.9	15.7	0.63
2 wk after weaning	28.6	28.6	1.00
4 wk after weaning	15.7	25.7	0.14

Table 5. Weaning treatment and yearling ultrasound measurements

Weaning Treatment	Drylot		Pasture		Treatment P =	Treatment x Year P =
No. heifers	70		68			
Average age, d	408		408			
Rump fat, cm	0.74	±0.02	0.74	±0.02	0.61	0.64
Rib fat, cm	0.61	±0.02	0.56	±0.02	0.02	0.78
Ribeye area, cm^2 [a]	73.5	±0.84	69.7	±0.84	0.00	0.84
% Intramuscular fat[a]	4.27	±0.08	3.98	±0.08	0.00	0.96

[a] When rib fat was included in the model, treatment effect was still important ($P < 0.06$).

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CORN GERM AS A SOURCE OF SUPPLEMENTAL FAT FOR COWS IN LATE GESTATION

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ABSTRACT: To evaluate corn germ as a source of supplemental fat, cows at one location in year 1 and two locations in year 2 were allotted by age, breed and projected calving date to two treatments. Starting approximately 50 d prior to the first expected calving, cows received grass hay free choice and were supplemented with either corn germ (1.25 kg DM) or soybean meal (0.36 kg DM) to provide an equal amount of CP. Within 24 hr after calving, cows were individually removed from treatment and managed as a single group (within location) until weaning in the fall. Within location, cows grazed a common pasture, from approximately 14 d prior to the breeding season until weaning. Treatment did not affect cow weight change. Corn germ did not improve any measure of reproduction. Calf performance, calf health, or measures of colostrum absorption (total serum protein or IgG of blood samples collected 24 to 48 hr after birth) were not influenced by treatment. The results were similar whether all age groups were included in the analysis or when data for only 2- and 3-yr old cows were included in the data set. Under the conditions of this study there was no advantage to feeding supplemental fat from corn germ during late gestation.

KEYWORDS: beef cows, corn germ, reproduction, calf health

Introduction

Providing supplemental fat during late gestation has been shown to affect reproductive performance, cow weight change and improve calf vigor, cold tolerance, and weaning weight (Bellows et al, 2001; Funston, 2004; Lammoglia et al., 1999; Rush, 2001). The response to fat supplementation has not been consistent in all studies and may be dependant on the source of fat or the base diet. Wittum and Perino (1995) found that calves with low plasma protein and serum IgG concentrations at 24 hr had higher morbidity and mortality than calves with adequate concentrations. The objective of this study was to evaluate corn germ as a source of supplemental fat for beef cows in late gestation and determine its effect on cow performance, calf health and calf performance.

Materials and Methods

The study was conducted during 2 yr at location 1 and 1 yr at location 2. Within location and year, pregnant cows from 2 to 12 yr of age were allotted by age group (2, 3, 4 and greater than 4 years old), breed and projected calving date to 2 treatments starting approximately 50 d prior to the first expected calving. At location 1, 2-yr-olds had been bred to start calving 21 d prior to the rest of the cowherd so they started on trial prior to the rest of the cowherd. At location 2 all age groups were bred to start calving on the same day and started on trial the same day. During the treatment period, all cows received grass hay free choice (Table 1 and 2). Cows on the corn germ treatment received 1.25 kg of corn germ dry matter per head daily and cows in the control group received 0.36 kg of soybean meal dry matter per head daily to provide an equal daily amount of crude protein as the corn germ treatment.

At the beginning of each trial and prior to the first scheduled calving, cows were weighed on 2 consecutive days following an overnight shrink away from feed and water. Fat thickness between the 12^{th} and 13^{th} rib was measured by ultrasonography and cows were assigned a body condition score (1 – 9 with 1 being extremely thin and 9 being obese; Pruitt and Momont, 1988) by 2 people. Within 24 hr of calving, cows were assigned condition scores by the same 2 people, weighed, removed from the treatments and managed as 1 group (within location) through the breeding season until weaning in the fall. Cows grazed a common pasture, within location, starting approximately 14 d prior to the breeding season until weaning time.

Starting 4 wk prior to the breeding season blood samples were collected by jugular veni-puncture weekly and analyzed for serum progesterone by radioimmunoassay. Onset of cyclicity was defined as: 1) the date of the first of two consecutive weekly samples with > 1 ng progesterone/mL; 2) the date of a sample >1 ng progesterone/mL followed by an observed estrus within 14 d; or 3) the date of the first observed estrus without a preceding sample >1 ng progesterone/mL. At the beginning of the breeding season cows were observed for estrus at least twice daily for 7 d and artificially inseminated (AI) approximately 12 h after standing estrus. Cows not inseminated were then administered an injection of prostaglandin $F_{2\alpha}$ to synchronize estrus. At location 1, heat detection and AI continued for 30 d and then cows were exposed to a bull for 30 d. At location 2, heat detection and AI continued for 7 d and then cows were exposed to a bull for 45 d. Pregnancy was determined by transrectal ultrasonography. Conception date was determined using a combination of breeding records, calving date and ultrasonography (when calving date was not available).

Calves were weighed within 24 hr of birth, at weaning and at about a 1 yr of age. Calves were observed daily for symptoms of disease and treatments were recorded.

Blood samples were collected from the calves by jugular veni-puncture between 24 and 48 hr after birth. Serum was separated the following day after centrifuging at 1500x g for 25 min and frozen. Total serum protein was measured by refractometry, which is closely related to the amount of immunoglobulin in serum. These have been used to determine the transfer of passive immunity to the newborn calf (Odde, 1988; Wittum and Perino, 1995)

Statistical analysis. Since cows were fed as a group within each location, treatment and year, feeding group was defined as: 1) year 1, location 1; 2) year 2, location 1; and 3) year 2, location 2. Cows producing twins were deleted from the data set and only cows that weaned a calf were included in the analysis.

Cow weight, average daily gain, condition score, rib fat, calving date and days from calving to onset of cycling and conception were analyzed using PROC GLM of SAS (SAS Institute, Cary, NC). Independent variables in the statistical model included treatment (corn germ and soybean meal), feeding group and treatment x feeding group. Treatment x feeding group served as the error term. Means were separated by the PDIFF option of SAS.

Percentage cycling in the first 21 d of the breeding season, percentage conceiving in the first 21 d of the breeding season and overall pregnancy rate were analyzed with PROC GENMOD of SAS. Independent variables were treatment, cow age group and treatment x cow age group.

The first set of analyses included all cows. Since young, thin cows are more likely to show a reproductive response to nutritional treatments, a second analysis was performed with only 2 and 3 yr old cows in the data set.

Calf weights, average daily gain, total serum protein and IgG were analyzed using Proc GLM of SAS. Independent variables included: treatment (corn germ and soybean meal), feeding group, treatment x feeding group, percentage Angus of the dam and calf sex. The error term to test treatment effects was treatment x feeding group. Means were separated using the PDIFF option of SAS.

Results and Discussion

Cow weight and average daily gain were not affected by supplement treatment (Table 3). The higher fat content of corn germ makes it a higher energy feed than soybean meal. Similar weight gains between the treatment groups indicate that the total energy available to each of the treatment groups was similar.

Cows receiving soybean meal before calving had a higher percentage conceiving in the first 21 d of the breeding season than those receiving corn germ (Table 4). No other measure of reproductive performance was affected by treatment.

Bellows et al. (2001) reported inconsistent responses to supplemental fat fed in late gestation to first calf heifers. They concluded that when pasture forage quality and quantity prior to and during the breeding season was limited, supplemental fat in late gestation resulted in a beneficial response to reproduction. When weather conditions resulted in abundant high quality forage, they found no reproductive response to supplemental fat in late gestation. In our study pasture forage prior to and during the breeding season was not limiting. Funston (2004) concluded that response to supplemental fat depends on body condition score, age (parity), nutrients available in the diet, and type of fat supplemented.

Supplemental treatment did not affect calf birth weight (Table 5). Similar mean values for total serum protein and IgG of calves from blood samples taken 24 to 48 hr after birth indicate that corn germ did not increase passive immunity of the calf. Analysis of health records indicate a very low incidence of calf disease symptoms and there was no effect of supplement treatment on the percentage of calves requiring treatment prior to weaning or from weaning to yearling time. Typically 2 and 3-yr old cows are thinner at the beginning of the breeding season, require more days from calving to the first postpartum estrus and have lower pregnancy rate. Management that has potential to improve reproductive performance is more likely to affect young cows than mature cows. When only 2 and 3 yr old cows were included in the analysis, the results were the same as when all age groups were analyzed together.

Implications

Under the conditions of this study supplemental fat in the form of corn germ during late gestation did not have a beneficial effect on cow reproductive performance or calf performance. Under these conditions, additional expense to provide supplemental fat during late gestation would not be justified.

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Tables

Table 1. Feed analysis

	Corn germ	Soybean meal	Grass hay
Location 1, Year 1			
% dry matter	93.7	89.2	84.9
% crude protein[a]	12.4	49.4	9.4
% crude fat[a]	38.6	2.0	2.2
% NDF[a]			63.4
% ADF[a]			42.1
Location 1, Year 2			
% dry matter	92.9	89.1	89.4
% crude protein[a]	12.4	49.3	9.4
% crude fat[a]	47.6	1.4	
% NDF[a]			62.8
% ADF[a]			41.4
Location 2, Year 2			
% dry matter	92.9	89.1	83.6
% crude protein[a]	12.4	49.3	10.4
% crude fat[a]	47.6	1.4	
% NDF[a]			62.0
% ADF[a]			40.2

[a]dry matter basis

Table 2. Feed intake.

		Dry matter disappearance, kg per cow daily				Supplemental fat	
Treatment	No. cows	Grass hay	Corn germ	Soybean meal	Total	kg per cow daily	% of daily dry matter
Location 1, Year 1							
Corn germ	52	8.8	1.25		10.1	0.48	4.82
Soybean meal	50	9.2		0.36	9.6	0.01	0.08
Location 1 Year 2							
Corn germ	49	9.3	1.25		10.6	.60	5.61
Soybean meal	50	11.0		0.36	11.4	0.01	0.04
Location 2, Year 2							
Corn germ	37	9.5	1.24		10.7	0.60	5.50
Soybean meal	37	11.4		0.37	11.8	0.01	0.04

Table 3. Cow performance.

	Corn Germ	SE	Soybean Meal	SE	Probability
No. of females	127		128		
Avg. days on treatment	56.8		56.0		
Avg. calving date	3/20		3/20		
Weight, kg					
Initial	625	14	630	14	0.79
Prior to the start of calving	638	10	635	10	0.87
Post-calving	602	5	603	5	0.90
Cow ADG from initial weight, kg					
Prior to the start of calving	0.35	0.13	0.16	0.13	0.16
To post-calving	-0.51	0.19	-0.55	0.18	0.41
To weaning	-0.01	0.10	-0.02	0.11	0.42
Condition score					
Initial	6.2	0.1	6.2	0.1	0.99
Prior to the start of calving	6.2	0.1	6.2	0.1	0.87
Post-calving	6.1	0.1	6.1	0.1	0.94
Ribfat, cm	0.56	0.05	0.53	0.05	0.70

Table 4. Reproductive performance.

	Corn Germ	SE	Soybean Meal	SE	Probability
No. of females	127		127		
Cycling before the start of the breeding season, %	36.2		38.1		0.76
Cycling by d 21 of the breeding season, %	92.9		94.5		0.61
Calving to cycling, d	66.9	8.9	68.4	9.1	0.91
Conception in first 21 d of breeding season, %	62.2		74.2		0.04
Calving to conception, d	88.4	2.3	88.1	2.3	0.97
% pregnant	92.6		94.3		0.58

Table 5. Calf performance and health.

	Corn Germ	SE	Soybean Meal	SE	Probability
No. of calves	129		130		
Birth weight, kg	39.8	1.4	39.0	1.4	0.71
Age at weaning, d	189	8	191	8	0.89
ADG birth to weaning, kg	1.14	0.05	1.13	0.05	0.90
Weaning weight, kg	564	38	562	38	0.97
Total serum protein 24-48 h after birth, g/dl	6.6	0.2	6.6	0.2	0.95
No. of calves[a]	88		86		
IgG, 24-48 h after birth, mg/dl	4951	323	5444	335	0.38
No. of calves	127		127		
Calves treated from birth to weaning, %	2.4		2.4		1.00
Calves treated from weaning to yearling, %	5.7		5.1		0.85
Calves treated from birth to yearling, %	7.6		6.8		0.82
No. of yearlings	117		122		
ADG from weaning to yearling, kg	1.16	0.01	1.18	0.01	0.53

[a]Calves at location 1 only.

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An Evaluation of Western Whiteface Lamb Loss on the Range

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ABSTRACT: The objective of the three year study at the New Mexico State University Corona Range and Livestock Research Center was to identify the periods at which reproductive wastage is greatest. Western Whiteface Ewes were randomly divided into four similar pastures in 2003, 2004, and 2005. Rams were randomly applied to each treatment at a rate of less than 25 ewes per ram for a breeding season of 34 to 40 d. In 2005, ovulation rates were measured in eight randomly selected ewes from each pasture via mid-ventral laparotomies 28 d after the breeding season began. Each year, one week before expected lambing half of the ewes from each pasture were randomly selected and brought in the corrals to be shed lambed in order to estimate the number of lambs born per ewe. Lambs born to the shed lambing ewes were ear tagged, weighed, and returned to their original pasture within 24 h of birth. Approximately 55 d after onset of lambing, lambs were docked, castrated, weighed, and ear tagged (pasture born lambs). Lambs were weaned at about 150 d after lambing began and all lamb IDs' and weights were recorded. Across all pastures and years potential lamb survival averaged 134, 121, and 113 percent of ewes exposed to rams for birth (shed lambing), marking, and weaning rates, respectively. Shed lamb survivability at birth was greater ($P < 0.001$) than shed lamb survivability at marking and weaning. Lamb survivability was similar from marking to weaning for both pasture ($P > 0.5$) and shed lambs ($P > 0.10$). Ovulation rates (1.75 CLs per ewe) were greater ($P < 0.01$) than birth, marking, and weaning rates for 2005. Assuming ovulation rates represent potential lambs, combining prenatal and pre-marking lamb loss a total of 31 percent potential lambs were absent at weaning.

Keywords: sheep, western white face, reproductive wastage, lamb survivability

Introduction

Willingham et al. (1986) conducted a 10 year study with Rambouillet sheep on Texas rangelands and showed 152, 118, 117, 103, and 101 percent ovulation, viable embryos (> 20 d post breeding), lambing, marking, and weaning rates, respectively. Their greatest reproductive losses were from ovulation to presence of viable embryos and from lambing to marking.

Reasons for early reproductive loss can include fertilization failure, embryonic death, and failure to maintain the corpus luteum. Willingham et al. (1986) also showed that 95.1 % of ewes were pregnant at greater than 20 days post mating, which alludes to the fact that most early reproductive failures are due to the inability of the embryo to survive. Moreover, Kleemann et al. (1990) stated that high ovulating ewes have higher percentages of embryonic mortalities than single ovulating ewes. Improving survival of embryos in sheep has been successfully accomplished by the administration of progesterone post mating (Parr et al., 1987, Kleemann et al., 1991, and Nephew et al., 1994) but uneconomic for a range operation.

The second area of high concern for range reproductive loss is the time between lambing and marking. Rowland et al. (1992) showed that 8.2 to 12.2 % of lambs die within 24 hours of parturition and 85 % of the lambs lost were born to ewes having two or more lambs. Moreover, the leading causes of perinatal lamb loss were starvation, dystocia, stillbirth, and infectious disease.

Since the major income for sheep producers depends on the pounds of weaned lamb, knowing what time period that reproductive loss is the greatest could be very beneficial to the New Mexico sheep producer.

Material and Methods

In 2003, 2004, and 2005, Western white face ewes (n=102, 110, and 216, respectively) were divided equally into four pastures at the Corona Range and Livestock Research Center. Each pasture consists of approximately 223 ha and was comparable in forage production. Suffolk or Rambouillet sires were randomly assigned to each pasture (three rams per pasture) and ewes were exposed to the rams for 34-40 days.

One week prior to the onset of lambing (day 0 is onset of lambing) half the ewes from each pasture were randomly selected to be penned and lambed in confinement (shed). Birth weights were recorded and lambs were ear tagged for identification purposes. Within 24 h post parturition, these ewes and lambs were returned to their original pastures. Birth weights and type of birth were recorded from the confinement lambed group. On day 55 (marking), all the lambs were ear tagged, docked, males castrated, and body weights recorded. On day 150 (weaning), all lambs were weaned and body weights were recorded.

In 2005, surgical laporotomies were conducted twenty days into the breeding season on eight ewes from each pasture to estimate ovulation rates. All procedures were approved by the NMSU, Institutional Animal Care and Use Committee (2004-028).

Data were analyzed as a completely random design to test the effects of lamb survivability among periods of production (PROC GLM of SAS; SAS Inst., Inc. Cary, NC).

Results and Discussion

Confinement lambing data pooled over three years showed 134, 111, and 101 percent lambs alive per ewe exposed to rams for birth, marking, and weaning, respectively. Lamb survival was greater ($P < 0.05$) at birth than marking or weaning and no difference ($P > 0.10$) between marking and weaning was detected (Table 1). Ewes showed very few instances of dystocia and/or lambs dead upon arrival, suggesting that the greatest lamb loss was due to starvation and predation. Pasture born birth rates were not collected but 131 and 126 percent lambs per ewe were present at marking and weaning, respectively. Similarly, no difference ($P > 0.5$) was detected for lamb survival between marking and weaning (Table 1). All sheep were guarded by livestock guard dogs to minimize predation, yet confirmed coyote kills (2005) were found.

Assuming ewes had similar lambing rates, pasture born lambs had greater ($P < 0.05$) lamb survivability at marking than did confinement born lambs at marking. Higher marking survival rates for the pasture born lambs carried over to greater ($P < 0.05$) weaning rates for the pasture born lambs as compared to confinement born lambs. We attribute this depression in lamb survivability to human interaction with flight prone ewes during the return of ewes and lambs to pasture after birth.

In 2005, lamb crop percentages were determined to be 175, 124, 110, and 103 lambs per ewe exposed for ovulation, birth, marking, and weaning, respectively (Table 1). Assuming ovulation rate represents potential lambs, ovulation rates were greater ($P < 0.05$) than birth, marking, and weaning rates in both shed and pasture born groups.

Similar to Willingham et al. (1986), range lamb loss is greatest from ovulation to birth. Secondly birth to marking lamb loss was high, which may have been increased by human involvement during the bonding period. Rowland et al. (1992) stated that most perinatal lamb loss occurred 24 h after parturition, and starvation attributed for most of this lamb loss.

Implications

Our data clearly shows that the greatest reproductive wastage occurs from ovulation to birth and from birth to marking. Outside of proper nutrition, little is known to efficiently improve range lamb survival between ovulation and birth. However, good animal husbandry may improve lamb survivability between lambing and marking.

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Table 1. Range lamb survivability (lambs present per ewe exposed to rams) when born to Western whiteface ewes in the pasture or confinement setting and reared on central New Mexico rangelands.[1,2]

	Shed Lambing					Pasture Lambing		
Year	Ovulation	Birth	Marking	Weaning	SE	Marking	Weaning	SE
2003		138	118	109		145	139	
2004		139	116	105		128	117	
2005	175[a]	124[b]	99[c]	92[c]	5.3	120[b]	113[b]	5.3
Avg[3]		**134[a]**	**111[b]**	**101[b]**	**4.5**	**131**	**126**	**6.6**

[1] Ewes were divided into four pastures and pasture was the experimental unit.

[2] Births were recorded from the shed born lambs, and half of each pasture was shed lambed. Ewes and shed born lambs were returned to their pasture on the day of birth (d 0), all lambs were marked on d 55, and weaned on d 150.

[3] Means were averaged from pastures and years as replications to evaluate lamb survivability (n=9).

[abc]Row means (% lamb survivability) with different superscripts differ ($P < 0.05$).

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EFFECTS OF WEANING DATE AND RETAINED OWNERSHIP ON CATTLE PERFORMANCE AND FORAGE DISAPPEARANCE IN SPRING CALVING BEEF SYSTEMS

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ABSTRACT: Weaning calves early from spring calving cows can have multiple impacts on beef systems. The objective of this two-year three-state study was to evaluate the effects of mid-August (AW) versus early-November weaning (NW) on cow and calf production traits, forage utilization, and economic return. Five hundred-five cow-calf pairs from the NDSU-Dickinson Research Extension Center (**DREC**; n=176), SDSU-Antelope Research Station (**ANT**; n=136) and the University of Wyoming Beef Unit (**UW**; n=193) were stratified by BW and body condition score (BCS) and assigned to either **AW** (August Wean - weaned at approx. 140 d of age) or **NW** (November Wean - weaned at approx. 215 d of age). Cows grazed native range between the two weaning dates. At AW date, a subset of cows from each treatment at DREC were randomly assigned to six 20-ha. pastures (n=3/treatment) to measure biomass disappearance between AW and NW dates. Steer calves at ANT and DREC were weaned and backgrounded 7.4 wk and finished in a commercial feed yard. Steers at UW were backgrounded 42 d and finished on site. Treatment by location interactions were detected for cow BW change, BCS change, calf ADG, and gain:feed. At each location, AW cows lost less weight (P<0.01) than NW cows. Similarly, cow BCS change was improved (P<0.01) for AW vs. NW at DREC (0.91 and -0.55), and ANT (0.34 and -0.02). At UW BCS change did not differ (0.22 and 0.47). Forage biomass disappearance, between weaning dates, was reduced by 27.7% (P=0.15) when calves were AW. AW steers at DREC had higher (P<0.01) ADG during backgrounding than NW; AW steers at DREC and ANT were more feed efficient (P<.01). During finishing, AW steers grew slower (P<.01), but were more efficient (P<.01). On average, at all locations, NW steers entered the feedlot heavier (P<0.01) and required less days (P<0.01) on feed to harvest; however, AW steers were 46 days younger at harvest. Weaning regime lowered feedlot cost/calf and regression analysis of carcass characteristics and weaning treatment suggests a positive effect on annualized rate of return. Weaning spring-born calves early reduced forage utilization, improved cow BW and BCS, improved backgrounding performance and finishing FE, reduced the number of days from birth to harvest, yielded similar finishing performance, and increased annualized rate of return.

Key Words: Early Weaning, Cow Performance, Forage Disappearance, Annualized Return

Introduction

Profit margins in cow/calf production are slim due to high production costs (Taylor and Field, 1995) and lost opportunity to capture value from marketable ranch products (NASS, 1999). Development of systems that lower production costs while adding value to calves would be beneficial to sustaining and improving rural communities in the drier regions of the Western United States. The majority of costs in cow/calf businesses are for harvested feed (Taylor and Field, 1995). Systems that rely more on grazing and less on harvested and purchased feedstuffs have a higher potential to be profitable (Adams et al., 1994).

Body condition of cows at time of calving has been shown to influence subsequent pregnancy rates (Richards et al., 1986), and the body condition score of spring calving cows grazing winter range is influenced by body condition score in the fall (Adams et al., 1987). Lamb et al. (1997) showed spring calving cows grazing native range lost 0.4 of a body condition score if nursing a calf from September to November, whereas cows that had their calves weaned in September maintained condition from September to November. Management of body condition score by weaning early can improve subsequent reproduction and/or reduce the requirements for non-grazed feed inputs that would be required for thin cows.

The Beef Cattle NRC (1996) predicts a spring calving cow lactating in August will have a 9% greater daily intake of range forage than a dry cow. Weaning calves early may allow standing forage to be spared, reducing late season supplemental feed requirements.

Performance of early-weaned calves during the backgrounding and finishing phase is important. Research has shown calves weaned at 100 to 150 days of age were heavier and younger at slaughter than normal weaned (weaned at 225-250 days) calves (Peterson et al., 1987). Meyers et al. (1999) reported that 40% more early weaned steers graded average choice or higher than their normal weaned counterparts. Carcass quality improvement in early weaned calves managed for maximum economic yield parallels value-based marketing trends (Cattle-Fax, 2003).

The objective of this multi-state investigation is to evaluate the impact of early weaning and retained ownership decisions on the relationship between weaning date and herbage availability, cattle performance, and economic returns.

Materials and Methods

Over a two-year period, cow herds from the SDSU Antelope Range and Livestock Research Station (136 cows), the NDSU Dickinson Research Extension Center (176 cows) and the UW Beef Unit (193 cows) were used in the study. At each location, spring-born calves were weaned from cows at approximately 140 days (mid-August, **AW**) or 215 days of age (early-November, **NW**). Cow body weight and body condition score changes were monitored between the August and November weaning dates to determine the impacts of weaning on cow performance. During the second year of the study, the cow herd at the Antelope Station became compromised with persistently infected BVD virus and did not participate.

Calf weaning weights were recorded at each location. The steer calves from Antelope Station (Yr. 1) and Dickinson were transported immediately after weaning to the NDSU Hettinger Research Extension Center for backgrounding. The steers were backgrounded an average 52 days, using a diet consisting of locally grown forage and a commercial co-product pellet. Two-to-four weeks prior to each weaning date, calves were immunized against calfhood diseases and were administered a booster vaccination at weaning.

Following the 7.4 week backgrounding phase, Antelope and Dickinson steers were transported to Decatur County Feed Yard, Oberlin, Kansas, for finishing using electronic cattle management and fat depth end point of 10 mm. Steers were slaughtered at a commercial plant and carcass data were collected.

Steers and heifers at the UW were managed in a similar manner, but backgrounded at the UW, Laramie, Wyoming, for an average 50.1 days. Following backgrounding, the cattle were finished at the UW Beef Unit. Harvest endpoint was determined based on ultrasound backfat depth and percent intramuscular fat measured between the 12^{th} and 13^{th} ribs. Cattle were slaughtered at a commercial plant and carcass data were collected.

Grazing, backgrounding, and finishing performance were analyzed by ANOVA using a PROC GLM of SAS (SAS Inst. Inc., Cary, NC). Since treatment by location interactions were identified, treatment means were compared within location.

Vegetation samples were collected at the Dickinson to determine the magnitude of biomass disappearance among cows suckling calves from August to November (NW; n=3 pasture groups) versus dry cows grazing from August to November (AW; n=3 pasture groups). A 240 ha pasture was subdivided into 12 20-ha pastures in a wagon-wheel configuration with central watering. A subset of cattle from each treatment at the Dickinson, were rotated into six previously ungrazed pastures at the August weaning date (3 pastures/treatment; 8 cows/pasture).

Clipped forage samples were obtained in the six pastures just prior to the AW date and again at the end of grazing when all cows were removed from the pastures in November. Samples (0.25 m^2) were cut to ground level, using battery-powered electric shears. Samples were oven dried. Forage disappearance was calculated as the difference between pre- and post-grazing estimates.

Analysis of variance was used to evaluate weaning treatment effect on biomass disappearance.

Dickinson steers (n = 55) were used to evaluate the economics of early weaning on the decision to retain ownership from feedlot placement to final harvest. Analysis of variance was used to separate means for feedlot performance, carcass measurements, and effect of calf age. Annualized rate of return from feedlot placement to harvest was determined using regression analysis. The annualized rate of return is regressed on carcass characteristics at harvest and a weaning effect variable.

Results and Discussion

In this multi-state weaning date study, early weaning improved cow body weight ($P<0.01$) and ending body condition score ($P<0.01$) at each location (Table 1). Body condition score change from AW to NW was improved ($P < 0.01$) for Antelope and Dickinson cows but did not differ for UW cows ($P > 0.10$).

The AW system utilized 72% of the available biomass when compared to the NW system. Forage disappearance for cows that had calves weaned early was estimated to be 803 kg per ha, whereas forage disappearance among cows that continued to nurse their calves for an additional 75 days was estimated to be 1109 kg per ha ($P = 0.15$). The difference in forage utilization was attributed to calf removal and less trampling.

Weaning weights for NW steers at Antelope and Dickinson were heavier ($P < 0.01$), but at the UW weaning weight did not differ ($P = 0.29$).

Postweaning backgrounding performance for Antelope, Dickinson, and UW steers is shown in Table 2. Normally weaned steers were heavier at the end of the backgrounding phase ($P<0.01$) at each location. Average daily gain was greater for AW steers at Dickinson, but not at the other locations ($P< 0.01$). Average daily feed intake was greater for NW steers ($P<0.01$) at Dickinson and Antelope, but did not differ at UW. Early weaned steers were more efficient ($P<0.01$) at Antelope and Dickinson, but did not differ at the UW ($P =0 .99$).

Finishing performance for the two management systems is shown in Table 3. Normally weaned steers were an average 87 kg heavier on arrival ($P<0.01$) for all locations and were heavier at harvest for the Dickinson steers. However, harvest weight for Antelope and UW steers did not differ ($P > 0.10$). On average, and overall, AW steers was 32 days younger ($P < 0.01$) at harvest than NW steers. On average, when backgrounding and finishing days are combined, AW steers required 51 more

days on feed in the feedlot ($P<0.01$). August weaned steers were more feed efficient ($P < 0.01$) at Antelope and Dickinson, but did not differ at the UW ($P = .22$).

Hot carcass weight did not differ for Antelope and UW steers, however, Dickinson NW steer carcasses were heavier ($P <0.01$). Rib-eye area was greater for Dickinson and UW steers ($P < 0.05$). Fat depth at Dickinson and Antelope did not differ, but was greater ($P < 0.01$) for AW steers at the UW. Yield grade did not differ at Dickinson and Antelope, but was greater ($P < 0.01$) for AW steers at UW. Quality grade was improved ($P < 0.01$) at Dickinson and UW, but did not differ at Antelope ($P = 0.69$). The number of steers grading Choice was low for Dickinson and Antelope steers suggesting the steers needed to be fed longer.

August weaned steers had a higher level of production efficiency and lower average cost of production, but AW steers, on average, had a lower return on investment. Regression analysis; however, suggests that, when other finishing variables are held constant, early weaning increases annualized net return by 29% (P = 0.01) ($R^2 = 0.68$).

Implications

These data suggest that weaning spring-born calves 75 days early (140 versus 215 days) can reduce late summer native forage utilization, improve cow body condition, improve calf backgrounding performance, and improve annualized net return.

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Table 1. Body weight and condition score change among early and normally weaned cows located at the NDSU-Dickinson REC, SDSU-Antelope Station and UW-Beef Unit (2003; 2004).

	NDSU Dickinson REC		SDSU Antelope Station[a]		UW Beef Unit	
	Weaning Period		Weaning Period		Weaning Period	
	Early	Normal	Early	Normal	Early	Normal
August Cow Wt., kg[z]	589	606	609	603	562	567
November Cow Wt., kg[x]	596	544	624	582	615	579
Cow Wt. Change, kg[x]	7	-62	15	-21	50	12
August BCS[z]	5.18	5.26	5.63	5.65	5.53	5.60
November BCS[x]	6.09	4.71	5.97	5.63	5.75	5.14
BCS Change[y]	0.91	-0.55	0.34	-0.02	0.22	-0.46
August Calf Wt., kg[z]	180	183	185	183	212	211
November Calf Wt., kg	-	212	-	264.	-	297

[a]Antelope Station means are for year one only.
[x]Treatments at each location differ ($P<.01$)
[y]Treatments at Dickinson and Antelope locations differ ($P < 0.01$)
[z]Treatments at all locations did not differ ($P > 0.10$)

Table 2. Summary of backgrounding performance for early and normally weaned steers at the NDSU-Dickinson REC, SDSU-Antelope Station and UW-Beef Unit (2003; 2004)

	NDSU Dickinson REC		SDSU Antelope Station[a]		UW Beef Unit	
	Early	Normal	Early	Normal	Early	Normal
No. Steers	68	66	36	35	46	46
Days on Feed	52.5	52.5	49	54	50	51.3
Start Wt., kg[x]	187	262	188	272	221	311
End Wt., kg[y]	269	337	258	347	273	372
ADG, kg[z]	1.56	1.43	1.43	1.39	1.03	1.21
DM Intake, kg[x]	7.57	9.62	7.28	8.96	6.11	8.35
F:G[x]	4.85	6.72	5.09	6.45	5.93	6.90

[a]Antelope Station means are for year one only.
[x]Treatments at Dickinson and Antelope locations differ (P<.01)
[y]Treatments at Dickinson and Antelope locations differ (P<.01); UW differs (P < 0.10)
[z]Treatments at Dickinson differ (P<.01)

Table 3. Feedlot finishing performance and carcass measurements. (Decatur County Feed Yard, Oberlin, Kansas, and UW Livestock Center, Laramie, Wyoming) (2003; 2004)

	NDSU Dickinson REC		SDSU Antelope Station[b]		UW Beef Unit	
	Early[a]	Normal	Early	Normal	Early	Normal
Receiving Wt., kg[u]	260	335	255	338	269	372
Harvest Wt., kg[x]	504	546	504	533	534	549
Kill Age[u]	366	421	371	405	414	421
Days at Feed Yard, da[u]	167	137	183	133	198	117
ADG, kg[v]	1.49	1.55	1.36	1.47	1.34	1.53
F:G[w]	5.13	5.86	5.18	5.86	7.55	7.11
G:F, kg/100kg[w]	19.50	17.07	19.31	17.06	13.24	14.06
Hot Carcass Wt., kg[x]	318	327	319	329	330	336
Rib-eye Area, sq. cm.[y]	79.4	82.5	78.4	80.1	76.8	81.9
Fat Depth, mm.[w]	.12.07	12.18	.53	.48	12.7	9.65
Yield Grade,[w]	2.57	2.64	2.68	2.7	2.71	2.34
Quality Grade[y]	3.29	4.91	3.00	2.8		
Marbling Score[z]					447	408
Percent Choice, %	33.0	40.0	13.9	23.5	67.7	32.4

[a]Two steers died of bloat during finishing.
[b]Antelope Station means are for year one only.
[u]Treatments at each location differ (P<.01)
[v]Treatments at Dickinson differ (P < 0.05); at Antelope and UW locations differ (P < 0.01)
[w]Treatments at UW Beef Unit differ (P<.10)
[x]Treatments differ at Dickinson location (P < 0.01)
[y]Treatments at Dickinson and UW differ (P < 0.05)
[z]Treatments at the UW Beef Unit differ (P<.05)

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ALTERNATIVE SUPPLEMENTATION STRATEGIES FOR REPLACEMENT BEEF HEIFERS GRAZING DRY CALIFORNIA FOOTHILLS ANNUAL RANGE OR IRRIGATED PASTURE DURING SUMMER

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ABSTRACT: California's foothill rangelands make up the primary forage source for the state's range livestock industry and are characterized by marked seasonal variations in forage availability and quality. Feed supplementation to correct deficiencies in protein, energy and minerals is essential to maintain adequate growth rates and achieve early reproductive maturity. The objective of this research was to evaluate different types of supplementation for weaned heifer calves grazing dry range or irrigated pastures. The supplements were: a commercial molasses-based tub supplement (COM-DR; 20% CP), or a low-cost protein/energy/mineral formulation (UCD-DR; 58% CP) for dry range; and trace mineral salt (TMS-IP; 0% CP) or a protein/energy/mineral supplement (UCD-IP; 20% CP), for irrigated pasture. One hundred twenty weaned replacement Angus-Hereford heifers (259 ± 4.2 kg BW) were stratified by BW and allocated randomly to 12 groups in a 2 x 2 x 3 design: two pasture types (irrigated, IRR) or dry range (DRY) and two supplement types for each pasture type, with three replicate groups of 10 heifers for each treatment. Heifers were given supplements weekly (TMS), every 3 d (UCD-DR and UCD-IP) or every 20 d (TUB) for 70 d. Supplement intakes averaged 740, 350, 30 and 950 g/d for the COM-DR, UCD-DR, TMS-IP and UCD-IP groups, respectively. Heifers' ADG were 121, 274, 440 and 611 g/d for the COM-DR, UCD-DR, TMS-IP and UCD-IP groups, respectively ($P < 0.05$). Providing protein supplementation to heifers improved ADG on both low-quality (dry) and high-quality (irrigated) forage. On dry range the UCD-DR supplement was superior (>2X, $P < 0.05$) to a commercial tub supplement, at much lower (1/3) cost. With appropriate feeders the UCD supplements can be fed free choice to improve calf performance and reduce costs of production.

Keywords: beef heifers, grazing, annual range supplementation

Introduction

California's foothill rangelands make up the primary forage source for the state's range livestock industry. Optimal livestock production on these annual rangelands requires strategies that meet cattle's nutritional requirements throughout the year at minimal cost. Due to qualitative and quantitative seasonality of forage production, animal productivity may be limited by the effects of forage quality on digestibility, dry matter intake, and nutrient supply (George et al., 2001a,b). Dry residual forage from the previous growing season is commonly available for grazing and provides energy but is low in crude protein (**CP**) and other vital nutrients. The leaching of nutrients by precipitation further decreases the nutritional quality of this dry residual forage. Therefore, range supplementation may be necessary to maintain cattle performance. Providing supplements with relatively high CP concentrations to ruminants consuming low-quality forages has been shown to enhance forage use and livestock performance (McCollum and Galyean, 1985; Bodine et al., 2000)

The objective of this research was to evaluate different types of supplementation (containing high CP with regular or high ruminally undegradable protein) for weaned heifer calves grazing dry range or irrigated pastures.

Materials and Methods

Site Description

This study was conducted at UC Sierra Foothill Research and Extension Center (SFREC), located at Marysville district, California. The region is located at 39°16' N and 121°18' W.

Experimental Design

The trial was conducted in the summer of 2005, during 70 days from July to September. One hundred twenty weaned replacement Angus-Hereford heifers (259 ± 4.2 kg BW) were stratified by BW and allocated randomly to 12 groups in a 2 x 2 x 3 design. Two pasture types, irrigated (**IRR**) or dry range (**DRY**) were used. The dry pastures were composed of 6 fields of similar size and once allocated, the animals stayed in same field until the end of the experiment. The irrigated pastures were composed of 8 similar sized fields, managed under a rotational system in which six fields were being grazed and two were being rested at any point in time. Heifers were rotated among the fields with a seven-day grazing period, in order to avoid field effects among treatments. Fields were irrigated every 14 days.

Two supplement types were given to cattle on each pasture type. Supplements evaluated were: a commercial molasses-based tub supplement (**COM-DR**; 20% CP), or a low-cost protein/energy/mineral formulation (**UCD-DR**; 58% CP) for DRY; and trace mineral salt (**TMS-IP**; 0% CP) or a protein/energy/mineral supplement (**UCD-IP**; 20% CP), for IRR. Both UCD supplements were formulated to meet the estimated requirements of the heifers (NRC, 2000) based on pasture composition (Table 1). The COM-DR supplement was fed according to the

manufacturer's directions every 20 days. Other supplements were given weekly (TMS) or every 3 days (UCD-DR and UCD-IP). Feeders were 3.5 m long with access on both sides to minimize dominance and extreme differences in consumption between heifers. Daily consumption was estimated by weekly weighing of the refusals. Average daily gain (ADG) was calculated based on three weights taken in the morning without feed and water restriction at the beginning, middle and end of the trial. All procedures were approved by the UC Davis Animal Use and Care Committee.

Statistical Analyses

Statistical analysis of data was performed using one-way ANOVA, with each pasture x supplement treatment included as a separate effect (Minitab Statistical Software, Release 13, Minitab, Inc., College Station, PA, USA). Because all 30 heifers in each treatment group were fed in three fields (n = 10 heifers/field), all data were analyzed considering the field as the experimental unit.

Results and Discussion

Table 2 shows the initial and final body weights and weight gains for the four treatment groups. For the purposes of this discussion, supplements will be compared within pasture type, or pasture types will be compared generally. Final body weights and ADG were generally greater in heifers grazing IRR than those on DRY ($P < 0.05$). For heifers grazing IRR, the UCD-IP supplement produced greater ADG and final weights than the TMS-IP ($P < 0.05$; Table 3). For heifers grazing DRY, the UCD-DR supplement produced greater ADG ($P < 0.05$) and tended to produce greater final weights ($P < 0.10$) than COM-DR. On dry range, the greater ADG obtained with UCD-DR as compared to COM-DR may have been a result of improved forage digestibility (Bodine et al., 2000).

Supplement intakes averaged 740, 350, 30 and 950 g/d for the COM-DR, UCD-DR, TMS-IP and UCD-IP groups, respectively (Table 4). Taking into account the costs of each supplement, the daily costs per head of each supplement were $0.45, $0.16, $0.01 and $0.37 for the COM-DR, UCD-DR, TMS-IP and UCD-IP groups, respectively. Therefore, on dry range use of a formulated high CP supplement increased ADG by 153 g/d while reducing supplement cost by $0.29 per day. For the irrigated pasture, use of a protein/energy/mineral supplement improved ADG by 171 g/d over trace mineralized salt alone, but at an increased cost of $0.36/day. The marginal cost:benefit works out to $2.11/kg additional gain, which appears to be unfavorable under present market conditions. However, this calculation might be different if one were to factor in the earlier onset of puberty and improved conception obtained with heavier heifers.

Conclusions

Providing protein supplementation to heifers improved ADG on both low-quality (dry) and high-quality (irrigated) forage. On dry range the UCD-DR supplement was superior (>2X, $P < 0.05$) to a commercial tub supplement, at much lower (1/3) cost. With appropriate feeders the UCD supplements can be fed as a free choice to improve calf performance and reduce costs of production.

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Table 1. Irrigated and dry pasture composition

Component	Units	Irrigated pasture[1]	Dry range[2]
Crude protein	%	22.7	5.0
TDN	%	66.7	55.0
NDF	%	48.8	60.0
Calcium	%	0.46	0.85
Phosphorus	%	0.360	0.075
Magnesium	%	0.27	--
Potassium	%	2.55	1.00
Sodium	%	0.388	0.030
Cobalt	mg/kg	--	--
Copper mg	mg/kg	11.0	6.0
Iodine	mg/kg	--	--
Iron	mg/kg	216.0	--
Manganese	mg/kg	175.0	--
Selenium	mg/kg	--	--
Zinc	mg/kg	31.0	--

[1]Sampled and analyzed at the beginning of the trial.
[2]Taken from: George et al., 2001b.

Table 2. Supplement compositions

Component	Units	COM-DR	UCD-DR	TMS	UCD-IP
TDN	%		60	-	72
Crude protein	%	20	58	-	20
Calcium	%	1.0	0.15	-	3
Phosphorus	%	1.0	3	-	2
Magnesium	%	1.0	1	-	1.6
Potassium	%	2.5	1	-	1
Sulfur	%	1.0	1	-	0.64
Sodium	%	0.7	4.5	37	0.6
Chlorine	%	11.0	4.2	58	0.5
Cobalt	mg/kg	6.6	2	70	1
Copper	mg/kg	460	500	400	100
Iodine	mg/kg	45	9	70	5
Manganese	mg/kg	665	500	2800	100
Selenium	mg/kg	8.5	3	-	2
Zinc	mg/kg	665	1500	3500	1000
Vitamin A	IU/kg	165,000	350,000	-	100,000

Table 3. Initial and final weights and weight gains on dry or irrigated pastures and different types of supplement

	Dry range		Irrigated pasture			
Supplement	COM-DR	UCD-DR	TMS	UCD- IP	Pooled SD	P[1]
Initial wt, kg	262.9	255.1	258.3	262.4	4.59	0.200
Final wt, kg	271.2[c]	273.9[bc]	288.6[b]	304.6[a]	4.53	< 0.001
Average daily gain, g/d	121[d]	274[c]	440[b]	611[a]	50.0	< 0.001

[1]Probability of a Type I error.

[abcd]Means within the same row not sharing a superscript are different (P < 0.05)

Table 4. Supplement costs and intakes

Supplement	COM-DR	UCD-DR	TMS-IP	UCD-IP
Daily intake, g	740	350	30	950
Cost, $/ton	$550	$420	$310	$350
Daily cost per head	$0.45	$0.16	$0.01	$0.37

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CASE STUDY: A FIVE YEAR SUMMARY OF CARCASS DATA FROM CALVES ENROLLED IN THE MONTANA BEEF NETWORK

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ABSTRACT: The Montana Beef Network (MBN) is a cooperative effort between Montana State University Extension Service and Montana Stockgrowers Association. A project with Certified Angus Beef and Colorado State University was implemented to summarize carcass data (17,306 animals) for the years of 1999 through 2003. The carcass characteristics analyzed were: yield grade (YG); quality grade (QG); hot carcass weight (HCW); ribeye area (REA); back fat (BF); marbling score (MB); and kidney, pelvic, heart fat (KPH). Correlation coefficients were developed from these data. The hot carcass weights averaged 356 kg (range 156 to 527 kg), while average QG for the calves was 66.6% which was higher than the national average of approximately 51%. Thirty five percent of the carcasses were average choice or better. Average YG was 3.10 (range 0.0 to 6.81) but the 10.1% YG 4s and 5s were higher than expected. Ribeye area per hundred pounds (REA/cwt) averaged 1.64 with a range of 0.91 to 3.34. Back fat averaged 1.3 cm and suggested the cattle were harvested at the correct weight. Correlation coefficients showed a slightly positive relationship with back fat (0.274) and yield grade (0.289), but no correlation with carcass weight (-0.08). The ratio of REA/cwt was nearly twice as important (0.764) as back fat (-0.314) or carcass weight (0.47) to final YG. These results suggest that these cattle did not have the muscling to be 386 to 409 kg carcasses. Results also suggested that calves had the genetic potential to grade at least low choice but over feeding to a heavier carcass weight would result in a yield grade discount.

Key words: Beef cattle, Carcass, Extension

Introduction

The National Beef Quality Audit (NBQA, 2000) was published to establish baselines for product-quality shortfalls and identify targets for quality levels for the future of beef cattle production. The first NBQA (1991) determined that US beef was too inconsistent to remain competitive. Since then, beef producers have clearly focused on meeting the demands of the market-place.

In 2000 through a series of surveys and questionnaires, seedstock and cow/calf producers were asked to identify quality challenges they had experienced. According to top ten aggregated responses, low quality grade was ranked number three, low cutability was ranked number six and excessive fat cover was ranked number seven. To address these concerns, the NBQA (2000) provided industry goals for producers. Among these were to eliminate USDA standard-grade carcasses and yield grade 4s and 5s. Ultimately, the continuous improvement of the eating quality of beef remains the underlying tone for these objectives.

The purpose of the Montana Beef Network (MBN) is to provide producers carcass data on their calves so that breeding and feeding decisions can be made to minimize the outliers. This case study was designed to summarize for MBN participants how their calves compared to the national goals outlined by the NBQA (2000).

Materials and Methods

For this study, 17,306 carcasses were selected from the Montana Beef Network database using the years of 1999, 2000, 2001, 2002 and 2003. Table 1 describes the distribution over years of the population analyzed. The carcass characteristics analyzed were: yield grade (YG); quality grade (QG); hot carcass weight (HCW); ribeye area (REA); back fat (BF); marbling score (MB); and kidney, pelvic, heart fat (KPH). Simple means of the selected carcass traits were calculated, along with the range for each trait (Table 2). To better illustrate relationships between specific carcass characteristics of the cattle enrolled in MBN correlation coefficients were calculated.

Results

The years of largest enrollment were 2000 and 2003 (5,190 and 4,990 carcasses, respectively). In 2001 the lowest participation was reported at 1,806.

The average hot carcass weight (Table 2) was slightly below national levels and may be attributed to the influence of predominately English breeding genetics across MT. The range in carcass weights were between 156 and 527 kg; a 371 kg spread.

The back fat thickness average of 1.29 (Table 2) cm suggested the cattle were harvested at the appropriate weight. This average is comparable to the national average of 1.24 cm but the range of 0.25 to 3.9 cm did show a wide variation. Again, this may be due to differences in cattle genetics; or there could have been some instances where cattle were kept in the feedlot too long.

The average REA was 82.7cm^2 which fell below the reported national average and the range of 48 to 118 cm^2 suggested differences in muscling. Although ribeye area per 100 lb cwt. (1.64) was closer to the targeted national average (1.66), the large range (0.91 to 3.34) was indicative that a change in bull genetics should be considered by some ranchers.

Thirty three percent of the cattle had a calculated YG of 2 and 4.33% had a YG of 1 (Figure 1). An average of 10.1% of the cattle had a YG of 4 or 5. This 10.1% rate was higher than expected, and could result in serious grid discounts. Efforts to decrease these outlier cattle should be considered in future breeding plans.

The distribution of QG (Figure 2) showed that approximately 35% of the cattle were at a premium-choice level. This is more than double the national average. Many of these animals would qualify for a premium program such as Certified Angus Beef. At 66.6% choice or higher, these cattle are much higher than the national average of approximately 51%.

The correlations among the carcass measurements are shown in Table 3. There was a slightly positive relationship between QG and BF (0.274) and yield grade (0.289), but no correlation with carcass weight. This would imply that as QG increased, so did BF and YG. A strong relationship between QG and marbling (0.854) confirmed the assumption that intramuscular fat deposition was greater in higher quality grade carcasses.

A strong positive correlation between BF and YG (0.822) showed that as BF increased, the body condition of these cattle increased and tended to produce higher yielding carcasses.

The ratio of REA/100 lb cwt. was nearly twice as important (-0.764) as BF (-0.314) or carcass weight (-0.47) to final YG. This suggests that the cattle in this study did not have the muscling to achieve heavy weight carcasses (386 kg). Added carcass weight might mean more value, but because of the potential to increase YG there was the chance that carcass value would be discounted on a grid pricing structure.

Implications

With approximately 90% of the cattle in this study producing YG carcasses of 3 or better and nearly two thirds grading choice or better suggests that these cattle were quickly approaching industry goals. Quality grade standards exceeded the national average reported at 51%.

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Table 1. Distribution of cattle carcass data analyzed for the years 1999-2003

Year	# Observations	% Observations
1999	2841	16.42
2000	4990	28.83
2001	1806	10.44
2002	2479	14.32
2003	5190	29.99
TOTAL	17,306	100

Table 2. Averages and ranges for carcass measurements for MBN cattle: 1999-2003

Variable	Mean	Range	# Missing values
HCW, kg	355.4	156-527	95
Marb. score	4.46	1.0-8.9	5483
BF[a], cm	1.29	0.25-3.86	3487
KPH[b]	2.17	0.39-4.50	7856
REA, cm^2	82.71	47.74-118.84	3251
YG	3.1	0.00-6.81	4349
REA/100 lb cwt	1.64	0.91-3.34	3341

[a]Carcasses with back fat of less than 0.25 cm and one carcass with back fat of 9.14 cm were deleted from the calculations
[b]Carcasses with KPH greater than 10% were deleted from the calculations

Table 3. Correlation coefficients for selected carcass traits for MBN cattle: 1999-2003

Variable	QG	HCW	BF	REA	KPH	YG	MB	REA/cwt
Quality Grade	1.0	0.080	0.274	0.120	0.060	0.289	0.854	0.212
Hot carcass weight		1.0	0.151	0.425	0.086	0.247	0.114	-0.470
Back fat			1.0	0.191	0.156	0.822	0.326	-0.314
Ribeye area				1.0	0.062	0.565	0.125	0.591
KPH					1.0	0.167	0.796	-0.021
Yield grade						1.0	0.320	-0.794
Marbling score							1.0	-0.222
REA/cwt								1.0

Figure 1. Distribution of calculated USDA Yield Grades for MBN cattle: 1999-2003

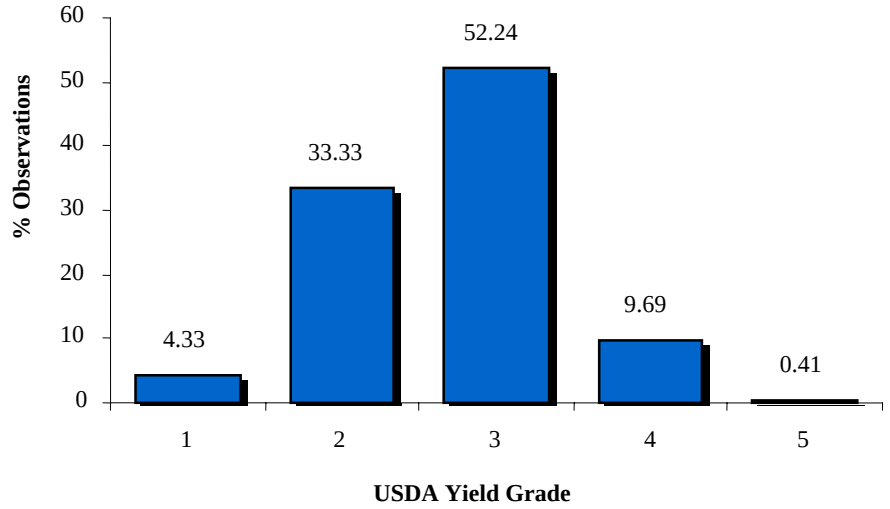
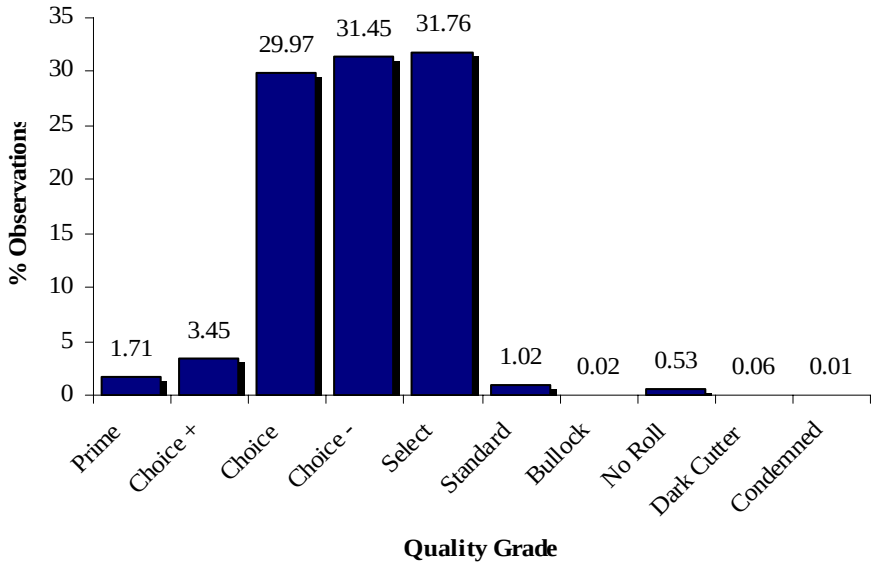


Figure 2. Distribution of Quality Grade for MBN cattle: 1999-2003



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EFFECT OF DECREASING TEMPERATURE ON THE READABILITY OF SIX DIFFERENT RADIO FREQUENCY ELECTRONIC IDENTIFICATION TRANSPONDERS SCANNED BY FIVE DIFFERENT TRANCEIVERS

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ABSTRACT: The objective of this study was to determine if different sources of commercially available electronic ear tags (transponders) and readers (transceivers) were influenced by decreasing ambient temperatures. Read ranges of six commercially available, [five full-duplex (FDX) and one half-duplex (HDX)] radio frequency identification (RFID) ear tags were evaluated using five handheld stick readers at three temperatures (20°C, 2°C and -19°C). Fifty ear tags from each company were randomly selected and scanned by each reader to determine if the coldest temperature decreased tag read range and the scanners ability to read tags. Tags and readers were exposed to selected temperatures for 22 h prior to the initiation of the experiment. The distance of the tag from the reader when the reader scanned the tag was then recorded. The tags were read with the orientation that best maximized the read range. There was a tag x temperature and reader x temperature interaction ($P<0.05$) confirming that both ear tags and readers did not behave the same as temperature decreased. Overall, as the temperature became colder, tag read rang decreased slightly (~0.07 cm, $P<0.05$). The HDX tag had an average read distance of 23.7 cm, while one FDX tag had an average read distance of 12.2 cm with the remaining tags being intermediate. There were differences ($P<0.05$) in the average read range among the scanners as well. The average read distance was 25.5 cm from one reader compared to a distance of 8.6 cm from another reader. The HDX (half-duplex) tag consistently had the longest read range compared to the FDX (full-duplex) tags. All readers tested read the different sources of tags in the study with a read range between 8.6 and 25.5 cm. Further research in this area will focus on retention and readability of these RFID transponders in cows over several years.

Keywords: Ear Tag, Electronic Identification, Temperature

Introduction

Few issues in the US livestock industry in recent years have been more controversial than the national animal identification legislation proposed by the US Department of Agriculture (Agweb, 2006). Coe (2004) stated that the tools and resources that technology providers offer to the industry will be vital to the successful implementation of the National Animal Identification System (NAIS). Individual animal identification will be used in the future to facilitate collection and analysis of production data; and it will become increasingly important that identification systems are reliable and efficient to use for disease traceback purposes (Coe, 2003). The use of radio frequency identification devices (RFID) is currently considered the automatic information and data capture technology that will be used for the NAIS (Bryant et al., 2006 unpublished).

However, there are various minimal standards that animal identification tools must meet if they are to be used under this proposed NAIS legislation. Artman (1999) emphasized that RFID tags and reader technologies must comply with the International Organization for Standardization (ISO). This non-governmental organization documents standards in agreements containing technical specifications to be used as rules and guidelines to ensure that materials, products, processes and services are fit for their intended purpose (ISO, 2006).

There are two main types of electronic tags used in the industry today, half-duplex (HDX) and full-duplex (FDX). "Duplex" means data is able to be sent and received from the same device. Half-duplex devices allow for the sending and receiving of data, but only one-way at a time (i.e. walkie-talkies). Full-duplex transmission can occur in both directions at the same time (i.e. a phone conversation). Unlike HDX technology, power is not stored in FDX tags and relies on being within the electromagnetic field to maintain sufficient voltage to operate (Allflex, 2006).

Most commercially available RFID systems operate at frequencies between 120 and 132.2 kKz. This frequency range easily penetrates wood, body tissues or plastic, but will not broadcast through metal chutes or handling systems (McAllister et al., 2000). Artman (1999) also noted that metal objects in the vicinity of a transceiver antenna or the transponder can influence the reading range due to electromagnetic interference.

Livestock are often subjected to a variety of conditions including low temperatures and frequent temperature fluctuations. It is important to determine if environmental temperatures influence tag read ranges as the beef industry moves toward an increased use of electronic technology. The objectives of this study were to: (1) compare the read ranges of five different readers; and (2) determine if six different sources of electronic ear tags and readers were influenced by decreasing temperatures.

Materials and Methods

General

Five commercially available hand-held readers (A, B, C, D, E) were evaluated for their ability to read six commercially available transponders (1, 2, 3, 4, 5, 6) at three controlled and static temperatures. Both half-duplex

(1) and full-duplex (2, 3, 4, 5, 6,) ear tag designs were included in this study. Temperatures evaluated were room temperature (22°C), 2°C and -19°C. Measurements were recorded 22 h after the tags and readers were placed in the 2°C and -19°C environments. The tags were scanned with the orientation that best maximized the read range of the transceivers: front scanning (A, B, C) or side scanning (D, E). In each trial, two groups of two people each, measured the distance of the tag from the reader using a measuring ruler. One member of each group held the transceivers at the end of the measuring ruler (0 cm), while the other person progressively moved the ear tag along the measuring device, toward the reader. A successful interrogation of the 15-digit number was recorded by an audible beeper. The distance (read range) of the tag from the transceiver was then manually recorded.

To prevent metal and electromagnetic interferences, caution was taken as to the location and positioning of the study to assure that no metal objects were in the read zone of the transceivers.

Statistical Analysis

The dependent variable, read range, was evaluated based on ear tag, reader and temperature interactions using analysis of variance (SAS 9.1, 2003). The three-way interaction of tag x reader x temperature was determined. In addition, the two-way interactions of tag x reader, tag x temperature, and reader x temperature were calculated to determine if temperature influenced read range.

Results and Discussion

A three-way interaction of ear tag x temperature x reader (Table 1, Fig. 1, 2, 3, 4) was measured ($P<0.05$). There were also two way interactions of tag x reader, tag x temperature and reader x temperature ($P<0.05$) suggesting that both ear tags and readers did not behave the same as temperature decreased. Additionally, it can be concluded that temperature had an effect on the read range of both ear tags and readers. However, readability was not affected as all the tags were successfully interrogated by all the readers at all temperatures. This data agrees with Ribo´ et al. (2001) which suggest that cold temperatures do not affect the reading ability of electronic ear tag and reader identification systems. Furthermore, the authors found that the functioning of the electronic identification devices were not affected when used at different temperatures.

A significant difference ($P<0.05$) between read range for the five readers was measured (Figure 3). Reader A recorded the longest average read range (25.5 cm) followed by reader B with an average read range of 18.3 cm. The shortest average read range was measured with reader E at a distance of 8.6 cm. As Figure 1 illustrates, the read range of the readers inconsistently fluctuated as temperature decreased. Still these read range variations were statistically significant ($P<0.05$). However, the read range of B decreased 47.6% ($P<0.05$) as temperature decreased from 22°C to 2°C. Temperature did not have an effect ($P>0.05$) on the read range of the remaining transceivers. A similar study conducted by Ribo´ et al. (2001) and Nehring et al. (1994) obtained results similar to the decreasing read range of R2. Nehring et al. (1994) found a 25% reduction on the reading distance was when temperatures during testing were between -5 to +5°C. A 60% reduction in read range was measured on the reading distance at -30°C, when both transponder and reader were placed inside a freezer. The author did not find a reduction in reading distance from 5 to 140°C.

There was a significant difference ($P<0.05$) between read range for all six tag designs (Figure 4), as well as between temperatures. Figure 2 illustrates the results of the read range by ear tag interactions at decreasing temperatures. The HDX tag consistently had the greatest read range with an average of 23.7 cm. The five FDX tags had an average read range of 15.77 cm with a variation from 18.76 to 12.15 cm.

This agrees with research conducted by Bryant et al. (2006, unpublished) where a significant difference ($P<0.05$) between tag read ranges as well as reader performance was found. It was concluded that not one average read range for any particular tag design was similar between any particular reader. Also in agreement with Bryant et al. (2006, unpublished), these results could be due to the varying tag designs and frequencies of each manufacturer's product.

Implications

This study should provide more data to support performance standards in the event that the National Animal Identification System becomes mandatory in 2009.

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Table 1: The effects of decreasing ambient temperature as influenced by handheld reader and RFID ear tag on read range (cm)[a,b,c,d]

	Reader						
Tag Source	**A**	**B**	**C**	**D**	**E**	**Average**	
Temperature, 22C							
1	36.25	29.63	22.83	22.58	9.88	**24.23**	
2	26.55	27.35	18.20	17.18	8.83	**19.62**	
3	27.05	28.58	19.70	18.10	9.03	**20.49**	
4	19.75	19.75	14.78	12.55	7.15	**14.80**	
5	26.10	23.40	18.33	15.65	8.53	**18.40**	
6	19.93	18.20	12.85	11.10	6.10	**13.64**	
Average, 22C	**25.94**	**24.48**	**17.78**	**16.19**	**8.25**	**18.53**	
Temperature, 2C							
1	36.83	29.33	21.10	17.60	10.48	**23.07**	
2	26.85	13.80	18.40	17.43	9.13	**17.12**	
3	27.03	15.00	20.03	18.53	9.55	**18.03**	
4	22.08	9.15	15.08	12.45	7.13	**13.18**	
5	25.70	11.03	17.83	15.58	8.50	**15.73**	
6	19.53	8.08	13.08	11.25	6.23	**11.63**	
Average, 2C	**26.33**	**14.40**	**17.58**	**15.47**	**8.50**	**16.46**	
Temperature, -19C							**Average for RFID tags**
1	35.60	29.38	21.90	20.85	10.93	**23.73**	**1 23.68**
2	23.93	16.63	18.35	16.85	9.38	**17.03**	**2 19.62**
3	23.88	17.63	19.40	17.55	10.30	**17.75**	**3 18.76**
4	20.30	9.78	13.18	12.40	7.73	**12.68**	**4 13.55**
5	23.23	12.93	16.33	14.90	9.38	**15.35**	**5 16.49**
6	18.70	9.00	10.68	10.70	6.88	**11.19**	**6 12.15**
Average, -19C	**24.27**	**15.89**	**16.64**	**15.54**	**9.10**	**16.29**	
Average for Scanners	**25.11**	**18.26**	**17.33**	**15.73**	**8.26**	**17.09**	

[a]Tag x Reader x Temperature, P<0.05
[b]Tag x Reader, P<0.05
[c]Tag x Temperature, P<0.05
[d]Reader x Temperature, P<0.05

Figure 1: The effect of decreasing ambient temperature on the read range of five available commercially reader (RFID)

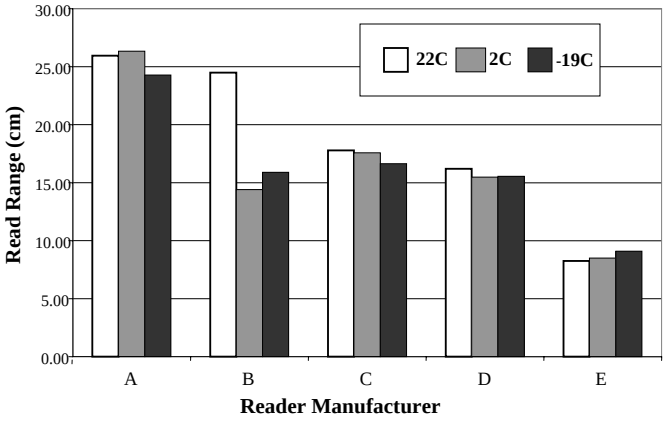


Figure 2: The effect of decreasing ambient temperature on the read range of six commercially available electronic ear tags (RFID)

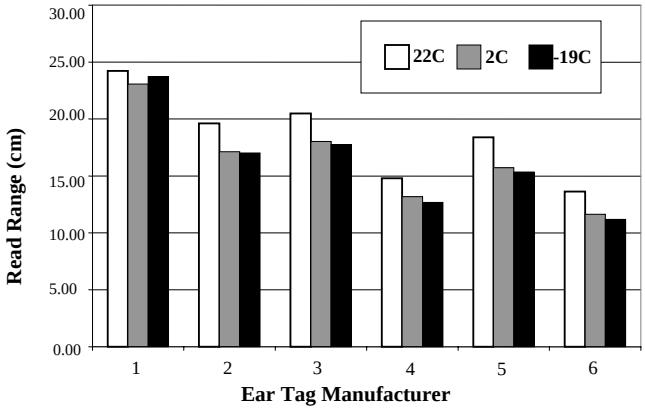


Figure 3: Comparison of read range of five different commercially available handheld readers (RFID)[a,b,c,d,e]

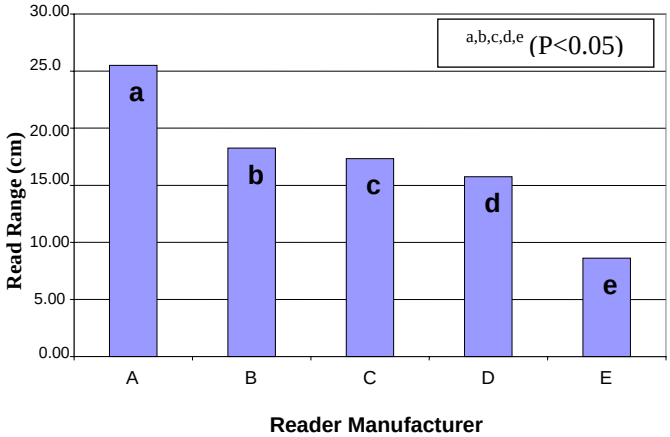
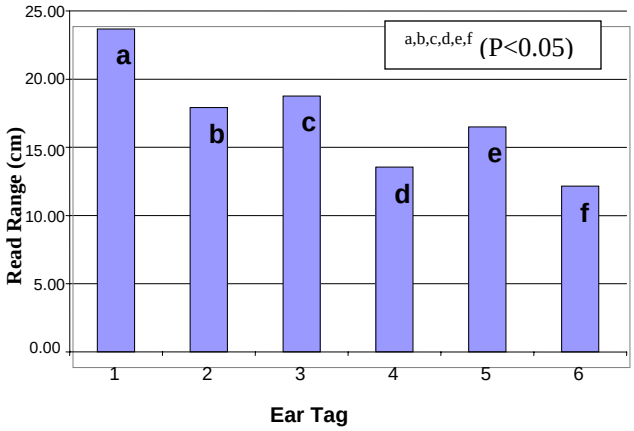


Figure 4: Comparison of read range of six different commercially available electronic ear tags (RFID)[a,b,c,d,e,f]



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READABILITY AND RETENTION RATES OF RADIO FREQUENCY IDENTIFICATION (RFID) EAR TAGS WHEN TRACKING THE MOVEMENT OF CALVES USING THREE SCANNING METHODS

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ABSTRACT: Calves from three commercial ranches in MT were tagged with Allflex half duplex (HDX) electronic identification (RFID) ear tags. Readability of tags was evaluated by three different methods; 1) handheld-stick reader, 2) walk through reader, and 3) fence mounted panel reader. At weaning, calves from Ranch A (491 head) were transported to wheat pasture in OK followed by sale through an auction market and then shipped to a feedlot and finally to a packing plant in NE. Tags were scanned at each movement with a stick reader with read rates between 98.1% to 100%. Tag retention after approximately 240 d was 97.1%. Calves from Ranch B (164 head) were weaned and grazed on a summer USDA Forest Service permit in MT and then transported to a NE feedlot followed by harvest in NE. The tags were scanned as the calves were moved onto the grazing permit with the walk-through reader and had a read rate of 92.1%. The tags were scanned again when the calves were removed from the summer grazing permit prior to entering the feedlot with the panel reader. The read rate was 93.4%. Tag retention after approximately 190 d was 100%. Calves from Ranch C (555 head) were born in ID, wintered in MT, summered in ID and then transported to a KS feedlot and finally harvested in NE. Tags were scanned with the handheld reader when entering MT and had a read rate of 100%. Calves were scanned when moved back to ID with both the handheld and walk through readers and had read rates of 100% and 73.6%, respectively. When moved to the KS feedlot, tags were scanned with the panel reader fitted to the loading chute. The read rate was 98.5%. Tag retention after approximately 125 d was 98.0%. This data suggests that the handheld reader read the highest percentage of tags while the walk through device read the lowest percentage. The panel reader was intermediate in its ability to read tags. Metal panels in corrals appeared to have negative effects on the stationary readers. Tag retention of RFID tags among these three ranches was much higher than with traditional plastic dangle eartags.

Key Words: Electronic Identification, Eartag Retention, Animal Traceability

Introduction

Recent animal health and food borne illness scares in all parts of the world are creating a demand for source verification, food safety and supply chain identification of food products (Coe, 2003); (Smith et al., 2005). Even though the US has historically set the operating standard for international food handling, the US food industry may currently be lagging with regards to traceability. There is currently not a standard process that identifies a traceable product, nor is a brand or social equity of a traceable product currently established in many end-user markets (Sparks, 2002). Domestically and internationally, it has become essential that producers, packers, distributors, retailers, and governments assure that livestock and meat are identified, and that traceability through all of the life-cycle of an animal can be verified and authenticated (Smith et al., 2005).

The US beef industry has been challenged to create a workable National Animal Identification System (NAIS) to address these issues (http://animalid.aphis.usda.gov/nais/index.shtml). The only way that a beef cattle traceability system can be implemented without slowing the speed of commerce is by the use of RFID tags. These tags can be scanned and data recorded simultaneously as opposed to individual animal restraint and writing down individual numbers which can be error ridden, cumbersome, and time consuming (DEFRA, 2005).

Many cattle producers have raised questions about the retention of RFID tags as well as their readability under different production scenarios. The objectives of these demonstration projects were to compare three different scanning methods (handheld, walk through, and panel readers) under three production scenarios to measure the readability of RFID tags and secondly to evaluate the retention of the tags over time.

Materials and Methods

General Calves from three different MT ranches were fitted with Allflex® half duplex (HDX) eartags. Each time the calves were moved (changed premise) until harvest, they were scanned with at least one of three scanning methods. The first was a handheld (stick) reader made by Allflex® of Dallas, TX. Second was a walk-through reader made by Agricultural Technology Limited (ATL) of England, with the third method by a fence mounted panel reader also made by Allflex®.

Exp. 1 On this ranch (Ranch A) located in central MT, 491 calves (spring born) were tagged with HDX tags on d 0 and scanned with the handheld reader approximately 30 d prior to weaning. At the time of weaning (d 30), the calves were transported to wheat pastures in north central OK. The calves were processed there, and were again scanned with the handheld reader. At 240 d, the calves were transported to an auction market near Cherokee, OK where they were again scanned with the handheld reader. Unfortunately, the buyer of these calves was unwilling to allow the experiment to continue through the feedlot or

packing plant phases which is a problem with a voluntary NAIS system.

Exp. 2 One hundred sixty-four calves (fall born) from Ranch B located in SW MT were tagged at weaning (d 0) with pre-scanned HDX tags that were scanned with the handheld reader. On d 34 the calves were trailed to a USDA Forest Service permit for summer grazing. Upon arrival at the grazing pastures, all tags were scanned by the use of the walk through reader set up at the end of a narrow alley. At 160 d (end of summer grazing), the calves were gathered and the tags were scanned by the fence mounted panel reader. The panel reader was fitted to the loading chute to scan the steers as they were loaded onto semi-trailers prior to being transported to the feedlot. The panel reader was also fitted to a narrow working alley to scan the steers that were not transported to the feedlot. At 190 d, these calves were transported to the feedlot and the tags were scanned when the calves walked down a portable alleyway fitted with two panel readers.

Exp. 3 Five hundred fifty-five calves (fall born) from Ranch C were born in ID and were transported to a SW MT ranch at approximately 45 d of age to be wintered and weaned. HDX tags were applied and scanned with a handheld reader on d 0 in MT. The calves were transported back to southeast ID for summer grass on d 32 and the tags were scanned as the cattle were being unloaded. One half of the tags were scanned with the walk through reader and one half of the tags were scanned with the handheld reader. Upon shipment to a north central KS feedlot at 125 d, the calves were scanned with the panel reader as they were being loaded onto the trucks. These steers were harvested at 258d, 265d, 273d, and 293d of the exp. at a NE packing plant and all tags were scanned with a handheld reader.

Each time the calves were processed, the missing tags were counted to determine the retention rates.

Results and Discussion

USDA-APHIS (2006) released performance standards for animal identification tags to be used for the NAIS. Included in these standards were: the tag must function and remain affixed to the animal for the expected lifetime of the animal, on average, not more than one percent of the tags applied may be lost in years following application, and the animal identification number (AIN) must be readable at a distance of 76.2 cm (http://animalid.aphis.usda.gov/nais/index.shtml). In all experiments, tags could not be read with the handheld reader at a distance of 76.2 cm. In all experiments, tags could be read with the panel reader at this distance. In Exps. 1 and 3, 97.1% and 98% of the tags were retained for the duration of the trials which would not meet the requirements for retention. In Exp. 2, 100% of the tags were retained for 190 d. which would meet the requirements for retention. Our findings agree with Ribo et al (2001) who reported that RFID tags had higher retention rates and readability values than other conventional livestock identification methods (dangle eartags, tattoos, etc.).

We believe that the environment that the cattle are exposed to (fencing, vegetation, etc.) could definitely have an effect on tag retention, and are variables that are impossible to keep constant. Environment can also affect readability because it appeared that metal fences made the use of panel and walk through readers inconsistent.

Each method of scanning presented its own challenges. With the handheld reader, the calves had to be confined so that a person could get close enough to scan the tag. This presents a challenge when the cattle are not being worked through a squeeze chute. If the cattle are worked through a squeeze chute, or single file alley then it is very easy to achieve a read rate of 100%. The problem was that cattle are not always worked in this manner such as the calves from Ranch A at the auction market. We were only able to use a handheld reader there and were not able to run the cattle through a squeeze chute or single file alley. The read rate of 98.1%, the lowest achieved with a handheld, was due to not being able to get close enough to the cattle in a working alley.

With the two stationary but portable scanning methods (walk through and panel readers), it was important that the calves moved past the reader in single file. If more than one tag entered the read field at the same time, then only one of the two tags would be recorded. This was especially an issue when loading or unloading cattle from semi-trailers. The success of the reading depended on the width of the loading chute compared to the size of the cattle. If more than one animal could fit in the read field at one time, then tags were missed. On Ranch B when the first set of calves was transported from the forest permit to the feedlot, the loading chute was approximately 1.5 m wide. This allowed more than one calf to enter the read field at the same time and thus contributed to the read rate of only 89.5%. The read rate of 98.5% achieved on Ranch C demonstrates what was possible when the alley was narrowed enough to prevent multiple animals in the read field.

It is still unclear why higher read rates were not achieved with the walk through reader. A read rate of only 92.1% causes concern under proposed NAIS guidelines.

Implications

Scanning RFID tags with the handheld reader provided the greatest read rate compared to either a walk through or panel reader. Results also suggest that the panel reader had a higher read rate than the through reader. These experiments show that approximately 98% of RFID tags should be retained if applied properly.

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Figure 1. Read rates achieved on Ranch A using a handheld reader (491 calves).

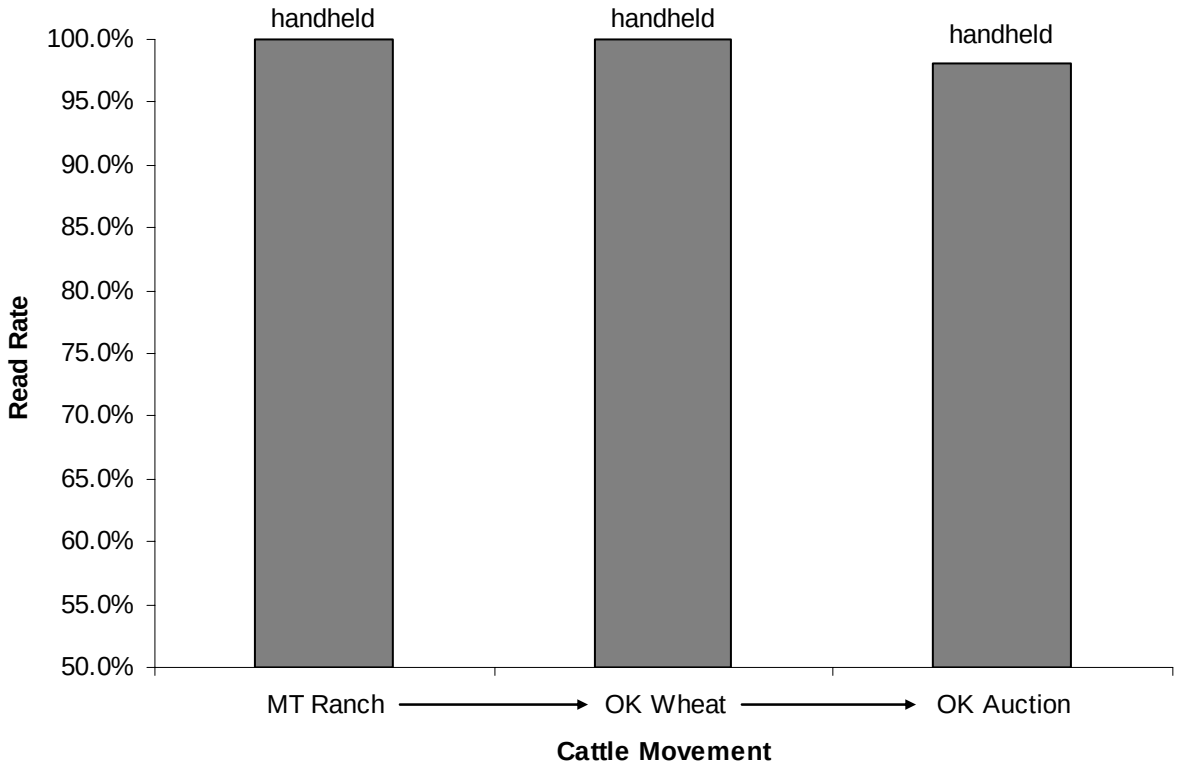


Figure 2. Read rates achieved on Ranch B using handheld, walk through, and panel readers (164 calves).

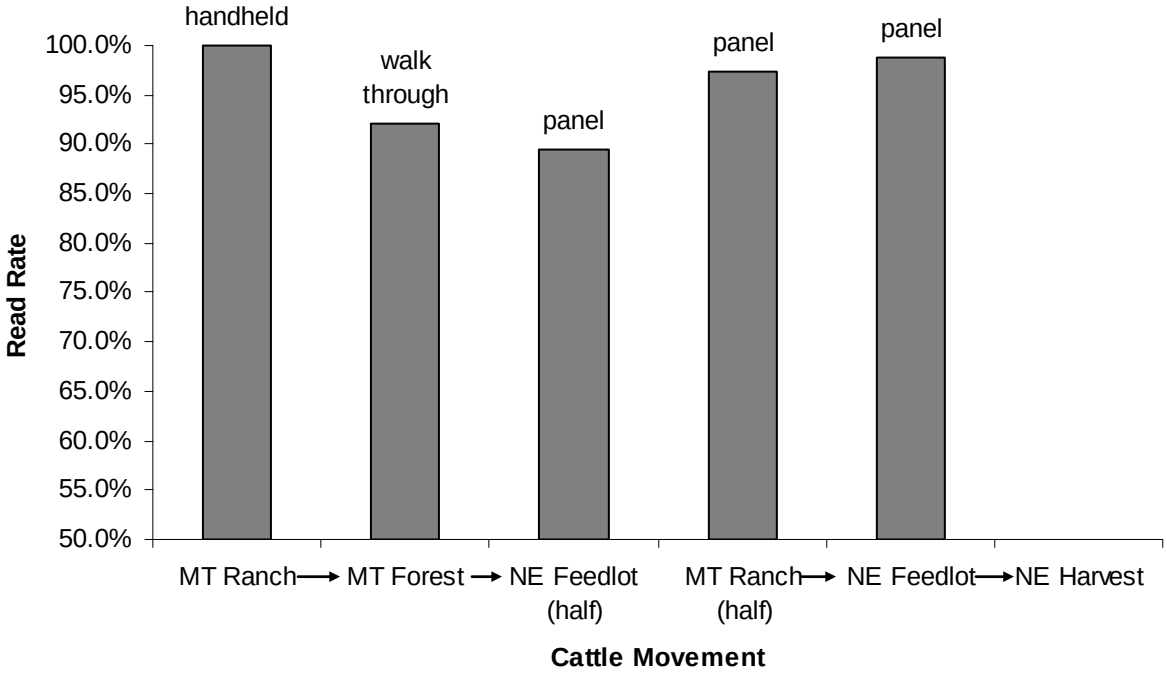
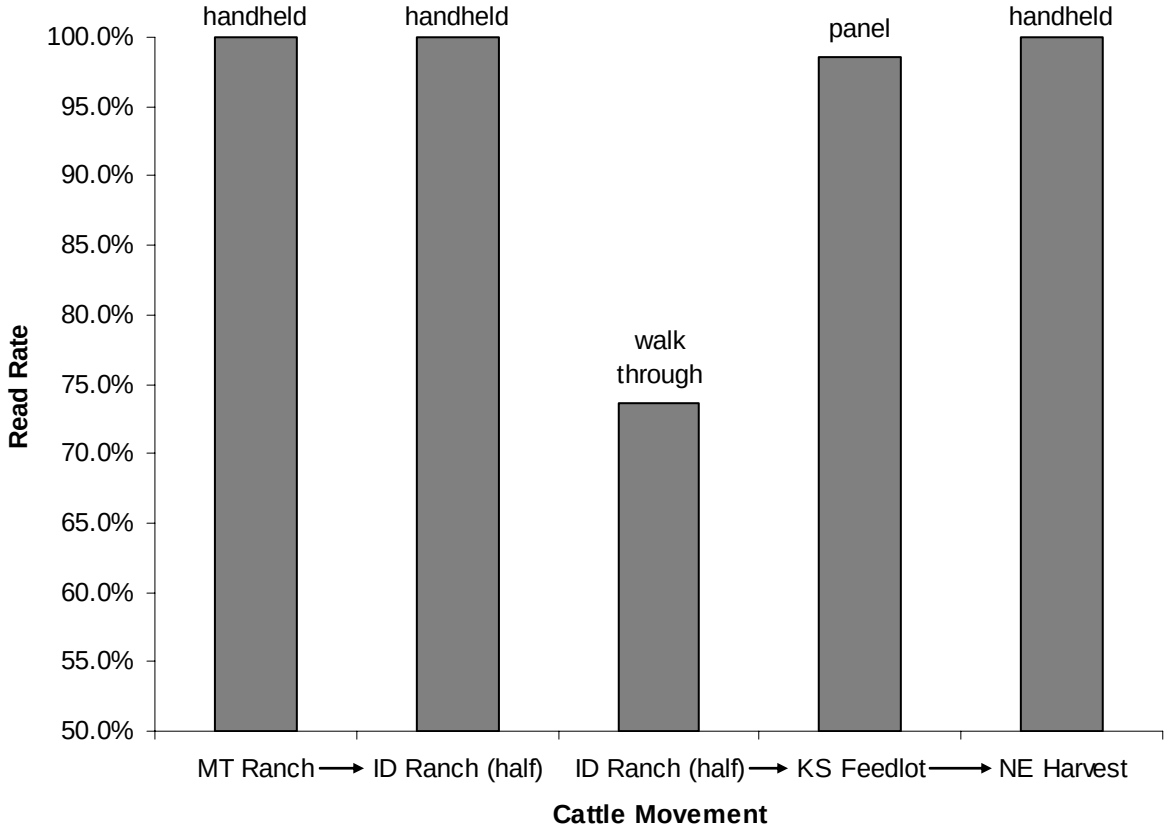


Figure 3. Read rates achieved on Ranch C using handheld, walk through, and panel readers (555 calves).



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EFFECTS OF PROPHYLACTIC ADMINISTRATION OF CEFTIOFUR CRYSTALLINE FREE ACID ON HEALTH AND PERFORMANCE OF NEWLY RECEIVED BEEF CALVES[1]

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ABSTRACT: One-hundred six newly received crossbred beef steers (198.2 ± 0.7 kg BW) were used to evaluate effects of ceftiofur crystalline free acid (CCFA; EXCEDE™, Pfizer Animal Health) on health and performance during a 28-d receiving period. Calves were transported 1440 km from Missouri the Clayton Livestock Research Center (CLRC) in Clayton, NM. At arrival, steers were individually processed and assigned to one of two treatments: 1) control (CON) no ceftiofur equivalent (CE), or 2) 6.6 mg/kg BW CE (s.c., ear). Alternate steers through the chute were assigned to CE treatment, stratified by BW, and assigned to pens (8 to 9 steers/pen; 6 pens/treatment). All steers had free access to a 70% concentrate diet. Steers were observed once daily after feeding (0800) for visual signs of respiratory disease (BRD). Steers with a rectal temperature greater than or equal to 39.7°C received additional antibiotic therapy for BRD. No steers died from BRD during the experiment. Prophylactic treatment with CE reduced the number of steers treated, at least once, for BRD over the 28-d period from 85.1% of CON to 35.8% of those receiving CE ($P < 0.01$). Of steers treated a first time for BRD, 50.0 and 15.8 % of CON and CE calves, respectively, received a second treatment ($P = 0.08$). Calves receiving CE had greater ($P = 0.02$) DMI compared with CON. Steers treated with CE tended ($P = 0.09$) to gain more (1.22 vs. 0.99 ± 0.08 kg/d) than CON over 28-d. Prophylactic use of CE improves health and performance of newly received feedlot calves.

Key Words: Antibiotic, Bovine Respiratory Disease, Cattle

Introduction

Annually, the U.S. feedlot industry faces enormous losses attributed to bovine respiratory disease (BRD; Martin et al., 1989). Approximately 75% of the morbidity and up to 70% of the mortality observed in U.S. feedlot cattle is linked to BRD (Edwards, 1996; USDA-APHIS, 1994). Economic losses attributed to BRD include, but are not limited, death loss, therapeutic treatment cost (Martin et al., 1982; Perino, 1992), performance loss (Bateman et al., 1990; Morck et al., 1993), and reduced carcass value (McNeill et al., 1996; Larson, 2005).

Calves experiencing extended periods of transportation (Swanson and Morrow-Tesch, 2001), nutrition (NRC, 1996), and/or climate (Hahn, 1999) stress commonly lack immunocompetence to viral and bacterial pathogens causing BRD. Light-weight (BW<200kg), recently weaned calves that are co-mingled at auction facilities and shipped to backgrounding/growing facilities typically experience multiple management and climatic stressors in a short time period. These types of calves have an increased susceptibility to BRD (Gaylean et al, 1992).

Design and evaluation of health and nutrition protocols that aid in the prevention and control of BRD in calves at high-risk for contracting BRD has been a focal point at the Clayton Livestock Research Center (CLRC) since the late 1970's. Previous work from the CLRC has demonstrated prophylactic administration of antibiotics to high stress calves effectively reduces the incidence of BRD (Lofgreen, 1983; Gaylean et al., 1995; Duff et al. 2000).

In 2004, ceftiofur crystalline free acid (CCFA), a broad spectrum antibiotic, was commercially released with Federal Drug Administration (FDA) labeled-use for the control and treatment of BRD. Uniquely, this antibiotic is administered subcutaneously in the ear and is sustained at therapeutic levels for seven days. The literature has not reported the effectiveness of CCFA as a prophylactic measure to reduce the incidence of BRD in newly received calves, classified as "high-stress." Therefore, the objective of this study was to define the effectiveness of CCFA as a prophylactic medication, administered at arrival, to high-stressed, newly-received beef calves.

Materials and Methods

One-hundred six crossbred steers and bull calves (198.2 ± 0.7 kg BW) originating from multiple sale barn facilities in Missouri were transported 1440 km to the Clayton Livestock Research Center in Clayton, NM. Upon arrival, newly received calves were individually tagged, hot-iron branded, as well as castrated and dehorned as necessary. Calves were treated for external and internal parasites with a commercial pour-on (22.5 ml./steer). Additionally, calves were administered a 7-way chlostridial, and a modified-live vaccine for the prevention of IBR, BVD, BRSV, and PI_3. Steers were assigned to one of two treatments during processing: 1) control (CON) no ceftiofur equivalent (CE), or 2) 6.6 mg/kg BW CE (s.c., ear; ceftiofur crystalline free-acid (EXCEDE®; Pfizer, Inc, NY, NY)). Alternate steers through the chute were assigned to CE treatment, stratified by BW, and assigned to pens (8 to 9 steers/pen; 6 pens/treatment).

After processing and pen assignment, steers were delivered to pens and provided ad libitum access to wheat hay for five days and fresh water. During the first five

days a receiving diet consisting of 70% concentrate and 30% roughage was delivered once daily (0800) as a total mixed ration and top-dressed over the wheat hay. After five days, additional wheat hay was not added to the feedbunk and only the 0800 delivery of the receiving diet was offered.

Steers were observed once daily following morning feed delivery for visual signs commonly associated with BRD. Steers with visual signs of BRD and a measured rectal temperature greater than or equal to 39.7°C received antibiotic therapy to BRD. Intial pull and treatment for BRD involved a single s.c. injection (12.5 mg/kg BW) of enerofloxacin (Baytril®; Bayer HealthCare, LLC, Animal Health Division, Shawnee Mission, KS). Steers pulled and treated a second time were administered a single s.c injection (40 mg/kg BW) of florfenicol (Nuflor®; Schering-Plough Animal Health,). If required, a third treatment for BRD involved a single i.m. injection (19.9 mg/ kg BW) of oxytetracycline (Agrimycin-200®; Agri Laboratories, St. Joseph, MO) and a single i.v. injection of sulfadimethoxine (Di-Methox®; Agri Laboratories, St. Joseph, MO). After treatment for BRD, steers were returned to home pen.

Data was analyzed as a completely randomized design using the GLM procedures of SAS (SAS Inst. Inc., Cary, NC). When significant ($P < 0.05$) F-statistics were noted means were separated using the method of least significant difference.

Results and Discussion

The effectiveness of CCFA as an arrival prophylactic in high-stressed, newly-received calves has not been documented in the literature. The incidence of calves diagnosed and treated for BRD, in the current study, are shown in Figure 1. Neither CON nor CE treatments experienced death loss during the 28-d receiving period. Fewer (49.3% less; $P<0.01$) calves administered the prophylactic CE (35.8%) at arrival were pulled at least once for BRD during the 28-d trial compared to CON (85.1%). Ninety-five percent of the CON calves treated at least once occurred between d 0 and d 7 (Table 1). By d 7, 29.5 and 2.2% of CON calves initially diagnosed and treated for BRD, were re-treated for clinical symptoms of BRD a second and third time, respectively. In accordance with labeled-use of the CE product used in this study, no calves were pulled and treated for BRD in the CE treatment during the first week. However, following the 7-d "no-pull" period of CE treated calves, 28.3% of CE calves were diagnosed and therapeutically treated for BRD. Through d 21, 50% of CON calves were retreated compared to 15.7% of CE calves.

Nutritional stress, coupled with other stressors experienced during weaning and marketing increase the susceptibility of newly-received calves to BRD. Timely adaptation to the feeding environment and processed diets is critical to achieve adequate feed intake to meet nutrient requirements and reduce nutritional stress in newly-received calves (Gaylean et al., 1999). Dry matter intake for the 28-d receiving trial is displayed in Figure 2. Calves administered the CE upon arrival had greater ($P<0.01$) DMI during the 28-d period. The difference between CON and CE in DMI was most pronounced ($P<0.0009$) during the first two weeks of the receiving trial, where CE calves consumed 0.73 kg/d more than CON. In two independent experiments, Duff et al. (2000) also observed an increase in DMI early in the receiving period in calves administered antibiotics at arrival, compared to non-treated control calves. These data concur with the data of Hutcheson and Cole (1986), who have demonstrated the inverse relationship between BRD and DMI in calves fed energy-dense diets under confined, dry lot conditions. In general, our data and the literature support the concept that morbid calves eat less than calves that remain healthy. Furthermore, this concept would support a positive performance response (i.e. ADG). Gain performance is shown in Figure 3, Average daily gain between CON and CE calves followed a similar trend as DMI. Over the 28-d receiving period, CE calves numerically ($P=0.09$) outperformed CON calves by 0.22 kg/d, with the largest numerical ($P=0.16$) advantage during the first two weeks. Results from experiments using tilmicosin phosphate as prophylactic antibiotic at arrival (Galyean et al., 1995; Duff et al., 2000) described similar numerical gain advantages in calves during the first two weeks after arrival.

Prophylactic administration of antibiotics is a proven management tool, extensively documented in the literature, to reduce the incidence of BRD in high-stressed, newly-received calves. Antibiotic cost and anticipated health and performance response are important factors for producers to weigh when considering the use of antibiotics as a prophylactic to minimize the incidence of BRD in calves most susceptible to the disease. In our study, the average initial cost for the CE treatment at arrival was $10.50 per calf. Accounting for the initial cost of the CE product and the associated cost of the other antibiotics used to treat diagnosed cases of BRD in the present study (Table 2), prophylactic treatment of calves with the CE resulted in an actual $2.23 savings in medicine cost compared to CON calves. This figure does not include the additional labor for each pulled calf to treat BRD, nor does it account for the increase in performance observed in calves administered the CE.

Implications

Prophylactic administration of CE at arrival in newly-received calves at high risk of contracting BRD decreased the incidence of BRD, improved DMI, and decreased medicine cost during the 28-d receiving period. Our results suggest CCFA can be a cost-effective, prophylactic measure to reduce the susceptibility of newly received calves to BRD.

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Figures and Tables

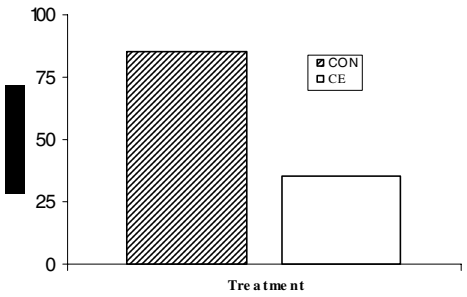

Figure 1. Percentage of one-hundred six newly received beef calves pull and treated for bovine respiratory disease that either received no ceftiofur equivalent (CON) or 6.6 mg/kg BW of a ceftiofur equivalent (CE; s.cu., ear) upon arrival ($P < 0.0001$).

Table 1. Number of treatments for bovine respiratory disease per week that either received no ceftiofur equivalent (CON) or 6.6 mg/kg BW of a ceftiofur equivalent (CE; s.cu., ear) upon arrival.

Group	No. of Treatments	Week of Trial				Total
CON (54)						
	1[a]	44	2	0	0	46
	2[b]	13	10	0	0	23
	3[c]	1	3	2	0	6
CE (53)						
	1[a]	0	15	4	0	19
	2[b]	0	1	2	0	3
	3[c]	0	1	0	0	1

[a] A single s.c. injection (12.5 mg/kg BW) of enrofloxacin (Baytril®; Bayer HealthCare, LLC, Animal Health Division, Shawnee Mission, KS) was administered as the first treatment for BRD.

[b] A single s.c. injection (40 mg/kg BW) of florfenicol (Nuflor®; Schering-Plough Animal Health,) was administered as the second treatment for BRD.

[c] A single i.m. injection (19.9 mg/ kg BW) of oxytetracycline (Agrimycin-200®; Agri Laboratories, St. Joseph, MO) and a single i.v. injection of sulfadimethoxine (Di-Methox®; Agri Laboratories, St. Joseph, MO) were administered as the third treatment for BRD.

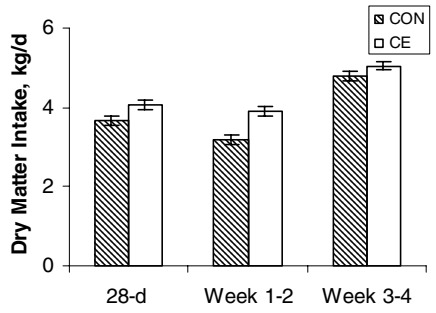

Figure 2. Dry matter intake of one-hundred six newly received beef steers during the first 28-d (28-d trial, $P < 0.01$; Week 1-2, $P < 0.0009$; Week 3-4, $P < 0.26$) after arrival to the Clayton Livestock Center. Steers either received no ceftiofur equivalent (CON) or 6.6 mg/kg BW of a ceftiofur equivalent (CE; s.cu., ear) upon arrival.

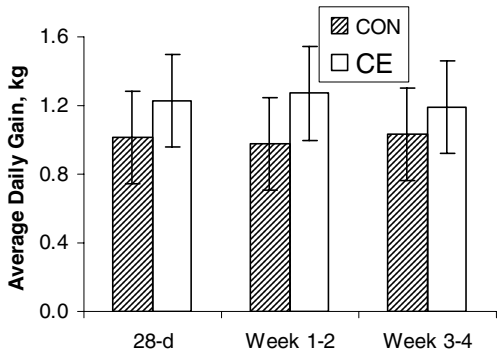

Figure 3. Average daily gain of one hundred six newly received beef steers during the first 28-d (28-d, $P = 0.09$; Week 1-2, $P = 0.16$; Week 3-4, $P = 0.49$) after arrival at the Clayton Livestock Research Center. Steers either received no ceftiofur equivalent (CON) or 6.6 mg/kg BW of a ceftiofur equivalent (CE; s.c., ear) upon arrival.

Table 2. Therapeutic medicine costs administered to control and treat bovine respiratory disease (BVD) in one-hundred six newly received beef steers during the first 28-d at the Clayton Livestock Research Center.

Group	Treatment Number	Steers Treated	Antibiotic Cost $	Group Cost $	Steer Cost $
CON (54)					
	1[a]	46	684.48	1021.37	18.91
	2[b]	23	316.25		
	3[c]	6	20.64		
CE (53)					
	Prophylactic[d]	53	556.50	883.91	16.68
	1[a]	19	282.72		
	2[b]	3	41.25		
	3[c]	1	3.44		

[a] A single s.c. injection (12.5 mg/kg BW) of enrofloxacin (Baytril®; Bayer HealthCare, LLC, Animal Health Division, Shawnee Mission, KS) was administered as the first treatment for BRD.

[b] A single s.c. injection (40 mg/kg BW) of florfenicol (Nuflor®; Schering-Plough Animal Health,) was administered as the second treatment for BRD.

[c] A single i.m. injection (19.9 mg/ kg BW) of oxytetracycline (Agrimycin-200®; Agri Laboratories, St. Joseph, MO) and a single i.v. injection of sulfadimethoxine (Di-Methox®; Agri Laboratories, St. Joseph, MO) were administered as the third treatment for BRD.

[d] A single s.c. injection in the ear (6.6 mg/kg BW) of ceftiofur crystalline free-acid (EXCEDE®; Pfizer, Inc, NY, NY) was administered at arrival for the control of BRD.

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WORKING TOGETHER TO ACHIEVE NATURAL RESOURCE SUSTAINABILITY IN CENTRAL OREGON

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ABSTRACT: Understanding natural resource management objectives is often confusing and daunting to livestock producers who are not intimately familiar with Government regulations and standards. In order to help livestock producers and natural resource management personnel understand these regulations and standards the Oregon State University Crook County Extension office worked collaboratively with the Crook County Soil and Water Conservation District and the Crooked River Watershed Council to provide annual educational workshops focusing on livestock management strategies aimed at improving and sustaining our natural resources in Central Oregon. These educational programs were called "Cows and Creeks, Managing for Healthier Watersheds" and were held over a three year period focusing on different natural resource management issues relating to sustainable use or our natural resources. Following these programs many local producers and land owners stopped in our respective offices requesting technical and financial assistance in implementation and installation of various management techniques that were discussed during the workshops. Collaboratively we were able to work together providing both the requested technical and financial assistance that the producers requested while implementing many resource conservation practices totaling over $50,000 in on the ground practices.
Key Words: Natural Resource Management, Conservation Practices, Sustainability

Introduction

In order to help livestock producers and natural resource management personnel better understand current conservation practices aimed at improving and sustaining the natural resource base of Central Oregon the Oregon State University Crook County Extension office along with the Crook County Soil and Water Conservation District (**CC-SWCD**) and the Crooked River Watershed Council (**CRWC**) teamed up to provide annual informal educational workshops. These workshops were titled "Cows and Creeks, Managing for Healthier Watersheds" and were designed to be a one day in-depth workshop focusing on current, up to date, conservation practices that could be implemented by the participants to help improve and maintain the natural resources associated with their operations. These workshops were held in Prineville, Oregon during the winter of 2003, 2004 and in Prineville and Beatty Oregon during the winter of 2005 with over 400 total individuals participating. Approximately half of the participants were private land owners with the other half being State and Federal natural resource agency personnel.

When possible we utilized local experts and resources to present and educate, but when necessary we invited outside experts in. During the three workshops we relied upon experts from Oregon, California, Montana, Idaho, Nevada and Utah, with employment backgrounds in University Extension and research, Public land management and private consulting. We solicited funds from outside businesses, organizations, Crook County Court, and State and Federal agencies to assist with travel, lodging and meals during the programs.

Following the workshops many producers stopped in our offices and requested financial and technical assistance in implementing selected practices they had learned about during our programs. The CC-SWCD and the CRWC served as the grant writing leads in securing funds to assist the producers when possible. The Crook County Extension office served as technical advisor when possible, relying upon outside experts when needed. Conservation practices consisted of stream bank stabilization, spring box (infiltration gallery) development, solar powered off stream watering facilities and riparian area fencing.

Another factor that led us to develop these programs was the introduction of the Senate Bill 1010 plans in Oregon, also known as Agriculture Water Quality Management Plans. These plans were written by local producers under the supervision of local Oregon Department of Agriculture 1010 planners and focused on management strategies aimed at decreasing the amount of water quality degradation due to agricultural practices. The CC-SWCD along with the Crook County Extension office conducted annual neighborhood meetings focusing on helping producers, both large and small, identify and address any water quality problems on their operations. We would later visit these operations and provide technical advice and assist with financial needs when needed.

Materials and Methods

Three 1 day Cows and Creeks workshops were held in Prineville, Oregon during the winters of 2003, 2004 and 2005 and one in Beatty, Oregon during the winter of 2005. We received over $6,000 from various sources to assist with program design, delivery and evaluation. Following these workshops the CC-SWCD and the CRWC along with the Crook County Extension Office applied for multiple grants written to the Oregon Watershed Enhancement Board asking for financial assistance in

applying conservation practices learned during the workshops. Over $50,000 in grants were received that provided cost share funds to assist producers with installation and implementation of recommended practices.

Three 1 day neighborhood meetings were held each year during 2002, 2003, 2004, and 2005 focusing on the Agriculture Water Quality Management Plans and helping producers better understand their local plan and make appropriate changes to their agricultural practices when needed.

Results and Discussion

The first Cows and Creeks program focused on grazing behavior of free ranging livestock, with emphasis on grazing effects on water quality and watershed response. We had 145 participants at this first workshop.

The next year, Cows and Creeks II, we changed topics and focused on livestock grazing behavior, why they eat what they eat and management strategies aimed at modifying their grazing behavior. We also discussed funding sources that were available to assist land owners in implementing sustainable natural resource conservation practices. We had 78 participants at this workshop.

The third year of this program Cows and Creeks III was held in two locations to better serve the clientele of Central Oregon. This year we focused on the use of annual indicators, such as stubble height, bank trampling and woody species utilization, and had 125 participants in Prineville and 55 in Beatty.

Following our successful grant applications we were able to assist local producers in implementing improved natural resource management practices, all aimed at minimizing the potential negative impacts of grazing livestock on water quality.

Eight kilometers of McKay Creek north of Prineville were corridor fenced through two neighboring operations. This reduced the amount of access that 500 head of cattle had to McKay Creek during the winter feeding months. Along with the corridor fencing, water gaps were installed to provide focused watering sites to the livestock. Eight geothermal heated off stream water troughs were also installed along these stream reaches, providing ice free water during the cold winter feeding months. One of these operations contains 80 acres of crop aftermath. Due to the remoteness of this sight we installed an infiltration gallery along side McKay creek and used a 160 watt, 13.3 liters per minute solar powered system to provide water for 60 dry beef cows.

Eight kilometers of the Lower Crooked River were stabilized and corridor fenced through two operations. The Lower Crooked River is comprised of a fine silt loam soil and in some areas is deeply incised. Bank rehabilitation along these areas included bank sloping and excavation, incorporating of soil holding ground cloth and herbaceous vegetation seeding along with woody vegetation transplants. These areas were later corridor fenced making it necessary for the creation of off stream watering facilities. Due to the remoteness of these areas electrical power was not available, making it necessary for the use of solar powered systems. On one facility we designed and installed a 160 watt solar pumping system designed to pump 13.3 liters per minute (Figure 1). This system cost approximately $2,000 for materials and labor. On the other facility we needed to provide water for 400 pair of beef cattle during a 6 month grazing season. This system (Figure 2) was a 600 watt, 95 liters per minute and cost approximately $8,000 for materials and labor.

Another more involved project was undertaken south of Prineville in the area of Little Bear Creek. This is a private ranch that leases grass to a neighboring producer to graze yearling cattle. This area has abundant forage available but limited watering sites. The landowner and producer worked with the Extension office and the CRWC to identify potential sites they would like to make available upland watering sites. The only issue was once again access to electricity. We contracted with a local solar energy consultant and designed a portable solar powered pumping system that could be installed and utilized in meeting the desired conservation practices that had been developed.

Conclusions

We were able to provide off stream water to 1200 pair of grazing beef cattle, 400 yearlings, 45 horses and 65 sheep, protecting stream side vegetation and water quality along 24 kilometers of stream in Central Oregon. With out the collaboration between the Crook County Extension office, the Crook County Soil and Water Conservation District and the Crooked River Watershed Council none of this would have been possible.

Figure 1. A 160 watt solar array powering a 13.3 liter per minute pump providing off stream water to 25 horses and 35 sheep.

Figure 2. A 600 watt solar array running a 95 liter per minute pump to provide off stream water to 400 pair of beef cattle in a rotational grazing system.

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DUTCHWOMAN BUTTE REVISITED: EXAMINING PARADIGMS FOR LIVESTOCK GRAZING EXCLUSION

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ABSTRACT: In 2000, a collaborative rangeland monitoring program was established with the University of Arizona, Gila County Cattlegrowers, and the Tonto National Forest. Dutchwoman Butte (DWB) is an isolated, ungrazed 40 ha mesa with relict vegetation. Our objective was to contrast the vegetation of DWB to that of a grazed site, Whiskey tank (WT), across multiple years (2001, 2003, 2004, and 2005). Data were collected for plant frequency, botanical composition (dry weight rank procedure), ground cover, and distance to the nearest perennial plant base (fetch). In 2001, DWB had 42% composition from perennial grasses. In 2003, the total species composition from perennial grasses was 2.0% and in 2004 and 2005, 6.5% and 2.1%, respectively. On WT, the composition from perennial grasses was 57% in 2001, 19% in 2003, 45% in 2004, and 37% in 2005. The dominant grass species present on DWB in 2001 was green sprangletop (*Leptochloa dubia*; 24% frequency) and sideoats grama (*Bouteloua curtipendula*; 22% frequency). The dominant grass species present on WT in 2001 was curly mesquite (*Hilaria belangeri*; 37% frequency) and sideoats grama (20% frequency). Hairy grama frequency (*Bouteloua hirsuta*) in 2001 was similar ($P > 0.05$) on both sites (14% on DWB and 13% on WT), decreased ($P < 0.05$) at both sites in 2003, but recovered ($P < 0.05$) at WT in 2004 to 19% while remaining less than 1% at DWB. In 2005, hairy grama frequency was still greater ($P < 0.05$) at WT than at DWB (10 vs. 1%). Sideoats grama was similar on both sites in 2001 ($P > 0.05$) but decreased ($P < 0.05$) at both sites in 2003 and never increased above 6% during the trial. Curly mesquite frequency at WT in 2005 was similar ($P > 0.05$) to that observed in 2001, being 40% in 2005 and 37% in 2001. Green sprangletop on DWB was less ($P < 0.05$) in 2005 than in 2001 (3 vs. 24%). Fetch was less ($P < 0.05$) on DWB than on WT in 2001 (10.9 ± 0.71 vs. 13.0 ± 0.89 cm), but was greater ($P < 0.05$) than at WT from 2002 to 2005. The WT site appeared more resilient to drought than DWB and the greater presence of low growing sod forming species like curly mesquite could have aided in drought recovery at WT.

Key Words: Cooperative Extension, Rangeland Monitoring, Grazing

Introduction

In 2000, a collaborative range monitoring program was established with the University of Arizona Cooperative Extension in Gila County, the Gila County Cattle Growers, and the Tonto National Forest. The Dutchwoman Allotment was selected as one of four ranches in Gila County to participate in the "Reading the Range" program.

Dutchwoman Butte (DWB) is an isolated land form supporting relict vegetation on the 40 ha on top of the butte. As reported previously (Ambos et al., 2000), elevations at the top of DWB range from approximately 1,441 m at lower levels to just over 1,527 m at the extremity, tilting to the southeast on a 20% slope. The top of the butte has never been grazed by domestic livestock, though deer and bear ascend its heights periodically. The Butte is located at the southern extremity of the Sierra Ancha Mountains just north of Roosevelt Lake in central Gila County, Arizona. One of the key areas selected for the allotment was located on DWB (1,479 m) paired with a grazed companion site immediately across the canyon. The Whiskey Tank Companion Site (WT) is situated approximately 182 m lower (1,287 m) than DWB on a mesa with a 10% slope and a similar southeastern aspect. Over geologic time, it is theorized that DWB separated from the Companion Site across the canyon.

Materials and Methods

The 726 ha pasture enclosing WT was grazed lightly (less than 40%) from September 15, 2000 to May 1, 2001 the first year of data collection by 150 cows (70% of the permitted livestock numbers). In 2002, a severe drought occurred and cattle were removed from the allotment in July 2002. The cattle removal continued until May 2004. Lower cattle numbers (30% of permitted numbers) returned to the Whiskey Pasture on September 15, 2005 and grazed this pasture until April 1, 2006. At the time of monitoring in 2005 (November 8), utilization at WT was 15%.

Range Monitoring Data Collection. Range monitoring data reported here were collected from 2001 to 2005, excluding 2002. Data were not collected in 2002 due to drought and livestock removal. Range monitoring data were collected annually in October or November, except for 2001, when data were collected in February. Data collection (Sampling Vegetation Attributes: Interagency Technical Reference, 1996) on the top of DWB consisted of six transects encompassing three hundred 0.16 m^2 quadrats for plant frequency and dry weight rank for plant species composition. Cover point data for litter, gravel (2 mm to 1.9 cm), rock (> 1.9 cm), live perennial basal vegetation, litter, persistent litter (> 1.27 cm deep and persistent), and bare ground were collected at two points on each quadrat. From the center point

in a 360° arc, the distance to the nearest perennial plant base (fetch) was measured for each quadrat.

Data collection at WT was identical to that collected on DWB, except that we only collected frequency, cover, fetch, and dry weight rank data from 200 quadrats placed along four transects. Fewer transects were used due to space limitations.

Statistical Analyses. Treatment means for cover and fetch data were separated using paired t-tests with pooled variance for the two means. Frequency data means were separated using 95% confidence intervals for binomial populations (Owen, 1962).

Results and Discussion

Climate During the Period of this Study. Precipitation in central Arizona typically occurs in a bimodal fashion, with a very dry May and June. Winter moisture is influenced by Pacific oceanic temperatures and air streams and summer moisture is influenced by the North American monsoon. Summer moisture generally occurs from July through September. It should be recognized that summer rainstorms exhibit considerable variability in their location and intensity. For the purpose of this study, winter moisture is defined as that occurring from November through June and summer moisture from July through October.

Winter and summer precipitation at the Roosevelt weather station (Arizona Climate Summaries, 2006) is shown in Table 1. Average annual precipitation is 40.34 cm. Precipitation recorded in 2002 was the driest in Arizona recorded history (since 1905). The *total* 2002 precipitation was less than Southwestern tree ring estimated (Ni et al., 2002) *cool season* (November to April) precipitation for all years since A. D. 1000 except possibly 1904, 1773, 1685, 1664, and 1150.

Table 1. Precipitation data at Roosevelt [1], cm

Year	Winter (Nov. to July)	Summer (July to Nov.)	Total
Nov. 2000 to Nov. 2001	21.34	17.93	39.27
Nov. 2001 to Nov. 2002	5.00	4.78	9.78
Nov. 2002 to Nov. 2003	21.26	14.25	35.51
Nov. 2003 to Nov. 2004	19.46	10.80	30.26
Nov. 2004 to Nov. 2005	45.34	11.35	56.69
Long Term Average	**25.48**	**14.86**	**40.34**

[1]Arizona Climate Summaries, Available at: http://www.wrcc.dri.edu/

Species Composition. Figure 1 shows the total composition of perennial grasses at each site preceding and through the drought. Due to the drought, the perennial grasses on DWB were mostly replaced by annuals. Though perennial grasses dropped precipitously at WT, they were not reduced to the same levels as they were on DWB. Recovery of perennial grasses following the brief respite from the ongoing drought occurred at WT in 2004, but not at DWB.

Cover Data. Cover data for the two key areas preceding and following the brief respite from drought showed some changes (Table 2). Due to the much larger sample size for the fetch data compared to the bare ground and live vegetation cover data (200 to 300 individual measurements vs. 4 to 6 transects), only the fetch data changed in a statistically significant way during the trial. At the beginning of the trial, plants were closer together on the top of DWB. Through the drought, plants were closer together at WT. By the fall of 2004, WT had recovered sufficiently to have plant spacings comparable to what was observed at the onset of the trial. However, due to the poor monsoon moisture received at WT in 2005, plant spacings increased again in 2005.

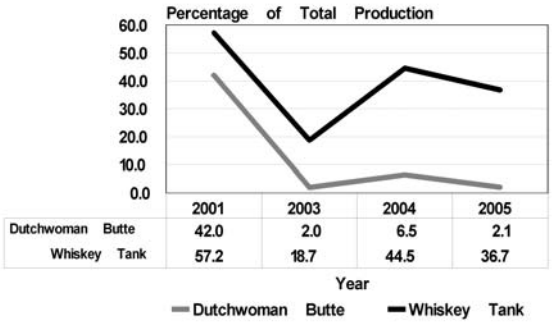

Figure 1. Percentage of total production from perennial grasses as estimated by dry weight rank. Grasses included in totals are listed in Table 3.

Frequency Data. Perennial grass frequency varied prior to and through the drought at both monitoring sites (Table 3). Prior to the drought, DWB had a much greater abundance of green sprangletop (*Leptochloa dubia* [H. B. K.] Nees) and WT had a much greater abundance of curly mesquite (*Hilaria belangeri* [Steud.] Nash). The sites were comparable with respect to sideoats grama (*Bouteloua curtipendula* [Michx.] Torr.), hairy grama (*Bouteloua hirsuta* Lag.), and threeawn (*Aristida* spp.). The Companion Site also had a greater frequency of cane beardgrass (*Bothriochloa barbinodis* [Lag.] Herter) than did DWB at the beginning of the trial.

Surprisedly, the grass species most impacted on both sites was sideoats grama. At the end of the study, sideoats grama had not recovered on either site. It would be expected for the more shallow rooted hairy grama species to suffer more plant mortality during the drought, but on WT this species had recovered to pre-drought levels by the end of the study. Curly mesquite, a shallow rooted, sod forming grass, rebounded fairly quickly from the effects of the drought on WT. Given the proper moisture and temperature regime, curly mesquite has the ability to anchor new plants from stolons. The frequency of curly mesquite on DWB did not demonstrate such a recovery.

Much has been written and said about the influence of livestock grazing upon the increased presence of more grazing resistant plants like curly mesquite in the Southwest.

While it is true that livestock grazing may increase the competitive advantage of curly mesquite to other bunch grasses, in this study curly mesquite may have actually aided in the drought recovery for WT.

Why did the perennial grass population decline on DWB and not on WT? Soils were taxonomically the same with nearly identical diagnostic attributes and vegetation was similar. Several possibilities exist: 1) The same mechanisms or genetic mutations which make plants resistant to grazing may also make them more resistant to drought (Cheplick et al., 2000; Cheplick and Chui, 2001; Smith, 1998); 2) Grazing may result in a more diverse age classification of plants due to seed dispersal and seed implantation by grazing herbivores, thus making grazed plant communities more resistant to environmental stress than more even-aged plant communities (Holechek, 1981); 3) Grazing removes senescent plant material, and if not extreme, helps open up the basal plant community for photosynthesis and rainfall interception (Holechek, 1981); 4) Beneficial mychorrizae for plant health may be contributed into ecological sites by grazing herbivores (in this case, cattle) in a truly symbiotic relationship; 5) Shading and rainfall infiltration could have been greater at WT due to the greater abundance of the sod forming grass, curly mesquite; and/or 6) The Sites in question are examples of state and transition models (Briske et al., 2005), wherein each site is independently different from the other following different trajectories (grazed vs. ungrazed) from a common original state.

Additional possibilities in comparing grazed vs. excluded sites are suggested by Holechek et al. (2006). In their study, they reported that livestock grazing at light to moderate intensities can have positive impacts for plant survival on rangelands in the Southwest (Arizona and New Mexico). Courtois et al. (2004) found similar results between grazed and excluded sites in Nevada. Two paradigms that have become dogma need to be reexamined. First, grazing tolerant native grasses should not be viewed only as an indication of degraded ecological systems. They may in fact be part of an ecological site that is functioning effectively and contributing to a healthy ecosystem under adverse climatic conditions. The second paradigm that needs to be reevaluated is that removing livestock from ecological systems will always lead us to "Nirvana".

Climate is the biggest influence of ecological systems, followed distantly by management. Poor management can exacerbate the effects of drought, while effective management can help temper and ease drought recovery. On WT, effective management has been practiced for over 25 years.

The timing of this study was especially fortuitous since it preceded and followed the 2002 drought. Will DWB recover? The authors of this study are divided on this question. Some feel that Arizona may be entering an extended period of drought and when moisture comes to DWB, it may be exploited by the presence of invasive and native annuals, preventing extensive establishment of perennial grasses. The other authors feel that the seed source is present on the Butte and if several seasons of favorable summer moisture and temperatures occur in succession, perennial grasses could begin to establish again.

Implications

We collected range monitoring data on an ungrazed relict area and compared that to data collected from a similar grazed site under good management. In this study, we captured ecological changes that may only occur once in a millennium. The data we collected does not support the supposition that areas protected from livestock grazing are better equipped to handle the effects of drought. On the contrary, the grazed site was more resilient than the ungrazed site and maintained a more diverse perennial grass population that was sustained through the drought.

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Table 2. Cover data

Type of data	Year	Dutchwoman Butte	Whiskey Tank Companion Site
Distance to closest perennial plant, cm	2005	26.7 ± 1.35[a] *	17.3 ± 1.12[c] *
	2004	30.5 ± 1.52[a] *	13.7 ± 0.84[a] *
	2003	36.6 ± 1.80[b] *	28.1 ± 2.01[b] *
	2001	10.9 ± 0.71[c] *	13.0 ± 0.89[a] *
Bare ground, %	2005	14.3[a]	14.7[a]
	2004	17.6[a]	16.0[a]
	2003	25.9[a]	21.5[a]
	2001	11.6[a]	16.1[a]
Live basal vegetation, %	2005	6.7[a]	12.4[a]
	2004	13.4[a]	18.0[a]
	2003	9.4[a]	8.9[a]

Live basal vegetation cover in 2001 included annuals, so that data is not included here. Within key area, by cover classification, reported values with differing letters following them are different ($P < 0.05$). Reported values for Dutchwoman Butte vs. Whiskey Tank followed by "*" are different ($P < 0.05$) for that year within the cover classification.

Table 3. Frequency data - Perennial Grasses

Plant Species	Scientific Name	Year	Dutchwoman Butte	Whiskey Tank Companion Site
Green Sprangletop	*Leptochloa dubia* (H. B. K.) Nees	2005	3.1[a]	0.5[a]
		2004	4.4[a] *	0.0[a] *
		2003	1.3[a]	0.0[a]
		2001	23.5[b] *	0.5[a] *
Curly Mesquite	*Hilaria belangeri* [Steud.] Nash	2005	0.7[c] *	40.0[c] *
		2004	5.0[ab] *	48.3[a] *
		2003	2.0[b] *	29.8[b] *
		2001	6.5[a] *	36.7[bc] *
Sideoats Grama	*Bouteloua curtipendula* [Michx.] Torr.	2005	2.1[a]	3.5[a]
		2004	5.0[a]	5.2[a]
		2003	2.7[a]	5.7[a]
		2001	21.5[b]	20.3[b]
Hairy Grama	*Bouteloua hirsuta* Lag.	2005	1.0[a] *	9.9[c] *
		2004	0.3[a] *	18.7[b] *
		2003	1.7[a]	3.6[a]
		2001	14.3[b]	12.9[c]
Spidergrass Threeawn	*Aristida ternipes*	2005	0.7[b] *	4.9[b] *
		2004	1.0[b] *	14.0[a] *
		2003	0.0[b] *	4.6[b] *
Threeawn	*Aristida* spp.	2005	0.3[a] *	7.4[b] *
		2004	1.0[a]	3.6[ab]
		2003	0.3[a]	0.5[a]
		2001	7.5[b]	7.4[b]
Cane Beardgrass	*Bothriochloa barbinodis* [Lag.] Herter	2005	0.3[a]	1.5[a]
		2004	0.3[a]	3.1[a]
		2003	0.0[a]	2.1[a]
		2001	0.7[a] *	6.9[b] *

Within key area, by species, reported values with differing letters following them are different ($P < 0.05$). Reported values for Dutchwoman Butte vs. Whiskey Tank followed by "*" are different ($P < 0.05$) for that year within the species. Other plant species encountered at both Dutchwoman Butte and Whiskey Tank in trace amounts (less than 3%) included plains lovegrass (*Eragrostis intermedia* Hitchc.). Perennial grasses present only on Dutchwoman Butte (less than 3% frequency) were bottlebrush squirreltail (*Elymus elymoides* [Raf.] Swezey ssp. Elymoides). Perennial grasses present only on Whiskey Tank (less than 3% frequency) were Arizona cottontop (*Digitaria californica* (Benth.) Henr.) and tanglehead (*Heteropogon contortus* (L.) P. Beauv. Ex Roem. & Schult.).

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DIGITAL IMAGERY AND LANDSCAPE-SCALE RANGELAND MONITORING[†]

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ABSTRACT: Monitoring is critical when manipulating rangeland ecosystems toward a desired goal. Unfortunately, cost and(or) logistics may limit a rangeland manager's choice of monitoring tools. Ultimately, such tools must be affordable and provide rapid, accurate, and precise information that can be used to determine the status and effectiveness of management strategies. In October 2005, USDA-ARS scientists from the High Plains Grasslands Research Station (Cheyenne, WY) and the U. S. Sheep Experiment Station (Dubois, ID) hosted a rangeland monitoring workshop titled "Successfully Using Digital Imagery and Vegetation Analysis Software." The workshop goals were to demonstrate the use of and to transfer digital imagery technologies that enable rangeland managers to obtain meaningful data quickly and efficiently on a landscape-size scale. In attendance, were field technicians and regional administrators from the USDA-Forest Service, Department of Interior-(DOI) Bureau of Land Management, DOI-U. S. Fish and Wildlife; state and local coordinators of weed management cooperatives in Montana and Idaho; and range technicians from Montana State University. The ARS scientists discussed the use of high-resolution digital imagery, obtained on the ground or from a fixed-winged aircraft, combined with various vegetation-measurement software packages to determine 1) vegetation response to fire, grazing, and herbicide treatments, 2) herbivore selectivity, and 3) distribution of exotic weeds across extensive landscapes. Both in the classroom and field, these technologies were demonstrated to be quickly applied and generate data that can 1) represent large and small landscapes, 2) be analyzed immediately or during the off-season, and 3) be stored for an indefinite period of time without loss of quality. Vegetation analysis software (freeware), technology instruction bulletins, validation literature, and contact support information were given to the participants.

Key Words: Rangeland, Monitoring, Ground cover, VLSA

Introduction

Scientists at the USDA, ARS, U. S. Sheep Experiment Station (USSES) are investigating management strategies to improve the sustainability of rangeland ecosystems through ecologically sound and economically profitable means of sheep production. Understanding vegetation response to disturbances, such fire, herbivory, or exotic plant introduction, is fundamental for developing grazing strategies that are useful for rangeland managers. Because of the ecological diversity of western North America rangelands, measuring landscape-scale vegetation (or ground cover) requires both extensive and intensive monitoring. Unfortunately, cost and(or) logistics may limit a scientist's or manager's ability to conduct appropriate vegetation measurements.

A scientist at the USDA, ARS, High Plains Grasslands Research Station (HPGRS) in Cheyenne, WY, has developed several digital-imagery (Booth et al., 2004; Booth et al., 2006a) and software (Booth et al., 2006b; Booth et al., 2006c; Booth et al., 2005) technologies for landscape-scale rangeland monitoring. Beginning in 2003, USSES and HPGRS scientists have partnered to validate and test (Seefeldt and Booth, 2006) the use of close-to-earth (CTE) and very-large scale aerial (VLSA) digital imagery to monitor rangeland vegetation responses to disturbances common to the sagebrush steppe of the Snake River Plains and Eastern Idaho Plateaus CRA (Common Resource Areas; NRCS, 2003). As a result of this collaboration, monitoring methodologies, applicable to small ($<10^2$ ha) and large ($\sim10^5$ ha) areas of rangeland, have been validated and transferred to end-users.

A rangeland monitoring workshop

In October 2005, in cooperation with HPGRS, the USSES hosted a workshop titled "Successfully Using Digital Imagery and Vegetation Analysis Software." The workshop goals were to demonstrate the use of and to transfer digital imagery technologies that enable rangeland managers to obtain meaningful data quickly and efficiently on a landscape scale. In July 2005, a workshop invitation was sent to selected administrative and technical level rangeland managers, in various federal, state, and local government agencies in Idaho, Montana, and Wyoming. Fourteen participants, representing the USDA-Forest Service, Department of Interior-(DOI) Bureau of Land Management, DOI-U. S. Fish and Wildlife, Montana State University, and Idaho Continental Divide Weed Management Cooperative attended the workshop. Cumulatively, this group is responsible for managing approximately 3.1 million hectares of forests and rangelands.

The workshop speakers were Dr. D. T. Booth and Mr. S. E. Cox, HPGRS rangeland scientist and technician,

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respectively, and Dr. J. B. Taylor, USSES animal scientist. The workshop agenda was divided into four sessions: 1) Development and use of digital imagery methodologies for monitoring rangelands; 2) A participant exercise: comparison of standard field vs. digital imagery methodologies; 3) Application of digital imagery in the field; and 4) Open discussion and technology transfer. The expected outcomes were that participants would depart the workshop equipped with software technologies for measuring ground cover, trained in the use of software-based ground-cover measurement tools, and enthusiastic about implementing digital imagery-based methodologies in their rangeland monitoring programs.

Session 1: Development and use of digital imagery methodologies for monitoring rangelands

In Session 1, Dr. Booth introduced novel measurement methodologies he has developed to rapidly and accurately measure ground cover. These methodologies are based on the acquisition of high-resolution spatially-defined digital images and subsequent use of software customized for measuring ground cover. Platform technologies that allow rapid, precise, and economical acquisition of images were presented. For example, a lightweight camera stand has been developed for obtaining CTE images (Booth et al., 2004) in the field, and the unique combination of existing technologies has been described for obtaining multiple VLSA images over extensive landscapes from a fixed-wing aircraft (Booth et al., 2006a). The development and basis of specific software technologies used to accurately measure ground cover or other rangeland characteristics were described. For example, SamplePoint software was developed for computer-facilitated selection of single-pixel samples for rapid classification (Booth et al., 2006c); and ImageMeasurement, LaserLOG, and Merge software are used in combination to spatially describe an image and subsequently measure on-ground attributes of distance or area (e.g., stream width or tree canopy; Booth et al., 2006a).

Dr. Booth discussed the accuracy (correlation of known and measured) of these methodologies for potential use in rangeland environments. Specifically, SamplePoint software has a potential accuracy of 98%, whereas standard ground-cover measurement and estimating techniques, such as point sampling and ocular estimate, have potential accuracies of 97 to 99% (Booth et al., 2006b and 2006c). These accuracies were established using unique "known-population" digital images (2-m above ground) printed on 1-m^2 posters that simulated and modeled the pattern and distribution of rangeland vegetation *in situ*. The accuracy of ImageMeasurement software is >90% when used to measure the diameter of irrigation pipe in VLSA images (100-m above ground) spatially described using LaserLOG software and a laser rangefinder (Booth et al., 2006a).

Session 2: A participant exercise: comparison of standard field vs. digital imagery methodologies

In Session 2, Mr. Cox engaged the participants in a hands-on exercise to compare the accuracy of traditional in-field vs. digital imagery-based methods for measuring ground cover. Before the exercise commenced, 20 1-m^2 ungrazed plots, containing live (green) crested wheatgrass and alfalfa, were established and equally divided into four cover-assessment technique groups (Booth et al., 2006b): steel-point frame, laser-point frame, point-intercept, and ocular estimate. Briefly, the steel-point frame is a device that accommodates 10 pointed steel pins, spaced 10 cm apart across a linear frame and oriented nearly vertical (71^o) over the plot, that the user lowers until the pin-point touches an object; the laser-point frame is a device that accommodates 10 lasers placed 10 cm apart across a linear frame and oriented vertically over the plot; the point-intercept technique was accomplished using a cloth tape measure (metric) stretched across a plot for locating 10 points every 10 cm; and application of the ocular estimate technique, being subjective, was left to the participant's discretion. For each plot, Mr. Cox obtained a 2-m above-ground digital image with a Nikon 8400 8.0-megapixel camera and measured the ground cover using SamplePoint software (Booth et. al, 2006c). The workshop participants were divided into four teams. Each team was assigned to one of the four cover-assessment technique groups and allowed 30 min to assess ground cover, as a percentage of area, for each plot. Twelve of the 14 participants were familiar with measuring ground cover in a rangeland setting. The cover-assessment results from each team were tabulated and transferred, along with the SamplePoint results, to an on-screen presentation.

Consistent with previous technique-comparison studies involving a variety of range professionals (Booth et al., 2006b and 2006c), participant results from using the laser-point frame, steel-point frame, and point-intercept techniques were similar among each other and similar to the results obtained with SamplePoint from the digital images. Agreement among these methods was >95%. Interestingly, the ocular estimate technique was least consistent with the other methods. This seemed to be due to either limited participant experience or different methods used to visually estimate cover or both.

Session 3: Application of digital imagery methods in the field

Rangeland managers are typically inquisitive about the ability to identify specific plant species in the CTE and VLSA images. In response, Dr. Taylor discussed the digital imagery methods currently used in rangeland settings at the USSES. First, the use of VLSA imagery to identify exotic weeds across extensive landscapes was described. In July 2005, USSES and HPGRS scientists partnered with the Idaho Continental Divide Weed Management Cooperative to determine the usefulness of VLSA imagery for identifying the presence of spotted knapweed (*Centaurea maculosa*) across an extensive landscape. Three spotted knapweed infested locations, two scheduled for herbicide treatment (Location 1 and 2) and one untreated (Location 3), were identified for monitoring. Within each location, 12 VLSA images were obtained (fixed-wind aircraft; altitude above ground level = 100 m; ~3-m x ~4-m image; pixel width = 1.1 mm) along a pre-described flight plan (Booth et al., 2006a and Seefeldt and Booth, 2006). At each location, spotted knapweed plants were beginning to bolt. Using Adobe Photoshop LE (Adobe Systems, San Jose, CA), each image was evaluated for presence and frequency of spotted

knapweed. Afterwards, a technician visited each location and measured spotted knapweed density in 2-m x 10-m plots established near the coordinates corresponding to the digital images. Spotted knapweed was rapidly identified in one or more VLSA images from Locations 1, 2, and 3 (Table 1). Across extensive landscapes, measuring cover with VLSA imagery methods (Booth et al., 2006a and 2006c) is approximately four times quicker and one-third less expensive than traditional point-frame or ocular-estimate techniques (Seefeldt and Booth, 2006). In Locations 1 and 3, results from using digital imagery and on-ground techniques to identify and quantify spotted knapweed presence were similar (Table 1; P = 0.23 to 0.91).

Second, Dr. Taylor presented data from an experiment in which CTE imagery and SamplePoint software were used to measure grazing-sheep selectivity of leafy spurge (*Euphorbia esula*). In June 2005, while sheep were activity grazing (stocking rate = 480 sheep d/ha) three leafy spurge-infested pastures (0.1 ha), repeated leafy spurge-stem counts and CTE digital images (~1-m above ground,) were obtained (Nikon 8400 8.0-megapixel camera) for 16 permanent sampling plots (0.18 m^2) within each pasture. Percentage covers of leafy spurge canopy, ground (litter + bare ground), and other canopy (grass + forb + shrub) were measured using SamplePoint software. Counting individual leafy spurge stems is a standard method for assessing the effectiveness of herbicide or grazing treatments on removal of leafy spurge. From the stem-count data, as with previous work (Taylor et al., 2005), high-intensity sheep grazing resulted in rapid leafy spurge-stem damage and a slight reduction in standing stems (Figure 1A). Approximately 82% of the stems exhibited some signs of damage and >80% of pregrazing stems counted were present at grazing termination (d 8). The time required to count leafy spurge stems limits the time available to monitor other plant species; therefore, only inferences can be made about leafy spurge. Approximately 3 to 4 min were required to count, record, and tabulate (computer) the stem-count data for each plot. In the same amount of time, plot digital images were created, transferred to a computer, and measured with SamplePoint, which automatically generates a finalized percentage-cover output. Similar to the stem-count data, the digital imagery results (Figure 1B) indicate that high-intensity sheep grazing reduced leafy spurge canopy from approximately ~37% to 20%. Furthermore, as other canopies (grass + forb + shrub) decreased from ~25% to 19%, the rate that sheep selected leafy spurge seemed to increased, an observation not possible from the stem-count data.

Session 4: Open discussion and technology transfer

At the workshop conclusion, the participants engaged the speakers and other participants, in an open discussion format, about the use of digital imagery methodologies in rangeland environments. A general consensus among the participants was that the ability to efficaciously monitor exotic weed encroachment and vegetation recovery after wildfire was a major need among rangeland managers. Before departure, each participant was provided copies of the SamplePoint software with accompanying instructions, validation literature, and contact information.

Conclusion

USDA, ARS scientists conducted a rangeland monitoring workshop during which several novel digital imagery-based methodologies for monitoring extensive rangelands were introduced and demonstrated to rangeland managers from federal, state, and local government agencies. Cumulatively, the participants were responsible for managing 3.1 million ha of forest and rangelands. Both in the classroom and field, these methods were demonstrated to be quickly applied and generate data that can 1) represent large and small landscapes, 2) be analyzed immediately or during the off-season, and 3) be stored for an indefinite period of time without loss of quality. Participants were trained to use digital-based ground-cover measurement techniques and provided with useful software tools for incorporation in rangeland monitoring programs. Since the workshop, participants have contacted the ARS scientists for further instruction about applying digital imagery tools in rangeland settings and incorporated (two participant) VLSA imagery as a component of exotic weed mitigation programs.

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Table 1. Comparison of VLSA image vs. on-ground measurements of spotted knapweed density from three locations, two scheduled for herbicide treatment (Location 1 and 2) and one untreated (Location 3)

Location	Image density[1], plants/m^2	Plot density[2], plants/m^2	Standard error	Density method contrast[3]	Density method correlation[4]
1	1.88	2.02	0.87	0.91	0.88
2	0.12	0.68	0.18	0.05	0.60
3	0.32	0.71	0.71	0.23	-0.07

[1]Image density is the mean number of spotted knapweed plants (standard error) calculated from 12 VLSA images (1.1-mm pixel, ~3-m x 4-m image size, 100 m above ground) obtained within each Location.
[2]Plot density is the mean number of spotted knapweed plants (standard deviation) calculated from 12 on-ground plots (2-m x 10-m) established near the coordinates corresponding to the digital images at each Location.
[3]Probability of a greater *F*.
[4]Pearson correlation coefficient.

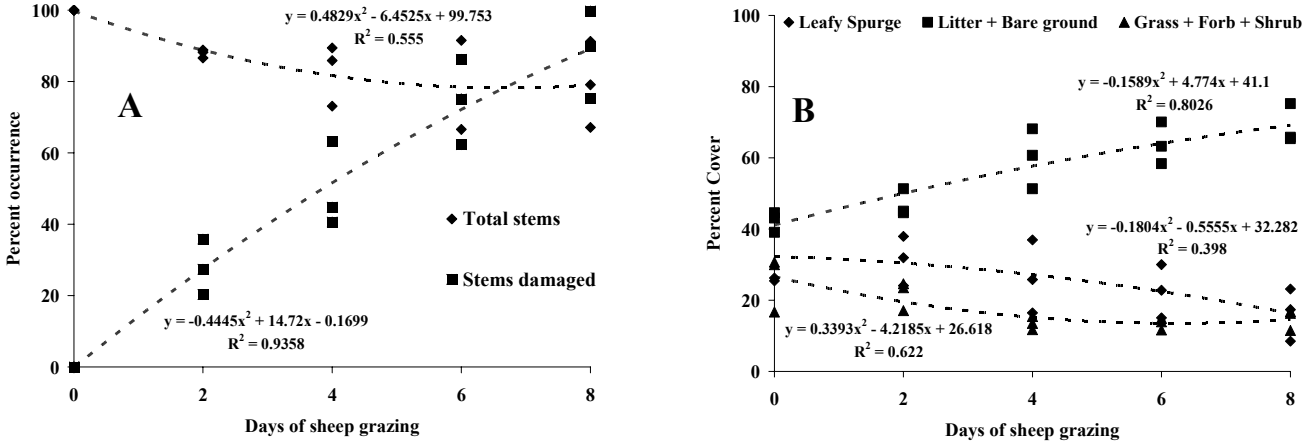

Figure 1. A. The percentage of total leafy spurge stems grazing sheep damaged and removed over 8 d. Repeated counts of leafy spurge stems were conducted (16 0.18-m plots/pasture) in three separately grazed (480 sheep d/ha) pastures (0.1 ha) during the grazing period. B. The percentage cover change of leafy spurge canopy, ground (litter + bare ground), and other canopy (grass + forb + shrub) grazing sheep induced over 8 d. Repeated digital images were obtained (16 0.18-m plots/pasture) from three separately grazed (480 sheep d/ha) pastures (0.1 ha) during the grazing period.

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VEGETATIVE MANAGEMENT USING CONTROLLED SHEEP GRAZING – THE MONTANA SHEEP INSTITUTE

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Abstract: Sheep may provide the most economical and environmentally sound alternative to chemical control of the encroachment of noxious weeds. The Montana Sheep Institute's objective is to develop, implement and evaluate controlled sheep grazing strategies for managing large infestations of leafy spurge (*Euphorbia esula*) and spotted knapweed (*Centaurea maculosa*). Suitable sites located throughout Montana were identified, after which a sheep grazing plan was developed and initiated for each specific site. Prior to the initiation of the study, planning meetings were held that included the landowners, sheep producers, county agents, weed supervisors, agency groups such as the Bureau of Land Management, and the Montana Sheep Institute and partnerships developed. Photo and vegetative production monitoring were performed prior to sheep grazing. Monitoring was also done on approximately the same date every calendar year in order to capture the vegetation in a similar stage of growth each year. A transect was placed from the photo plot and five 50 x 50 cm quadrants located and clipped. Three paired plots with individual plots within each pair visually selected to be similar in soil, topography and vegetative type, per research site were established. Prior to sheep grazing, an exclosure was placed on one plot within each pair and after grazing plots were sampled to establish utilization of target weed vs. other forage. Photo plot data from a total of eight sites indicated the composition of leafy spurge decreased and grass increased at sheep grazing sites. Following the summer grazing season meetings were held with all stakeholders to discuss results of monitoring, potential successes, and opportunities for improvements. Leafy spurge composition decreased ($P < 0.01$) by 9 % per year of grazing while the grass component increased ($P < 0.01$) by 10 %. Utilization data from 22 sites throughout Montana demonstrated 50 – 70 % utilization of noxious weed and only 30 – 40 % utilization of grasses. Over time this type of grazing should favor the re-establishment of grass and forb component of the landscape.

KEYWORDS: Sheep grazing, Leafy spurge, Noxious weeds

Introduction

One of the greatest threats to public and agricultural lands in the United States is the spread of noxious weeds. Invasive plants such as leafy spurge (*Euphorbia esula*) and spotted knapweed (*Centaurea maculosa*) overrun and destroy grazing land, trigger soil erosion, decrease availability of water, reduce biodiversity and cost agriculture millions of dollars each year. Currently, noxious weeds infest millions of acres of farm and public land in 26 northern states and six Canadian provinces (Sedivec et al., 1995; Tyser and Key, 1988). These two weeds not only make land unfit for crops and cattle grazing, they threaten native plant populations, decrease rangeland plant diversity and degrade wildlife habitat and associated wildlife recreation (Leistritz et al., 1992; Hirsch and Leitch, 1996).

Sheep may provide the most economical and environmentally sound alternative to chemical control of the encroachment of noxious weeds. Lacey et al. (1985) reported that sheep grazing substantially reduces leafy spurge density and biomass. Several reports (Cox, 1989; Olson et al., 1993) suggest that sheep readily graze spotted knapweed and that sheep grazing may potentially be used in controlling the weed. Repeated (mid-June, mid-July, early September) short duration grazing reduced flower stem production of spotted knapweed on a knapweed-infested Idaho fescue (*Festuca idahoensis*) range site in southwestern Montana (Olson et al., 1993). In some years, sheep actually grazed spotted knapweed more than they grazed Idaho fescue.

Sheep are unique in that they will consume both leafy spurge and spotted knapweed and thus prescribed sheep grazing can be utilized as a tool to economically control these invasive plants as a component of a total weed management program. The Montana Sheep Institute's objective is to develop, implement and evaluate controlled sheep grazing strategies for managing large infestations of leafy spurge and spotted knapweed.

Materials and Methods

Suitable sites located throughout Montana were identified, after which a sheep grazing plan was developed and initiated for each specific site. Prior to the initiation of the study, planning meetings were held that included the landowners, sheep producers, county agents, weed supervisors, agency groups such as the Bureau of Land Management, and the Montana Sheep Institute and partnerships developed.

Three paired plots with individual plots within each pair visually selected to be similar in soil, topography and vegetative type, per research site were established (USDA-USDI, 1996). Prior to sheep grazing, an exclosure

was placed on one plot within each pair and after grazing plots were sampled to establish utilization of target weed vs. other forage.

At some sites, photo and vegetative production monitoring were performed prior to sheep grazing in order to capture an undisturbed view of the vegetation. A 1 m x 1 m plot was staked so that the four sides ran north, south, east, and west. Photo plots were identified with GPS coordinates. Photo monitoring was also done on approximately the same date every calendar year in order to capture the vegetation in a similar stage of growth each year making the photos comparable across years. Photos were taken of the plot and of the landscape in all four directions. A transect was placed from the photo plot and five 50 x 50 cm quadrants located and clipped (USDA-USDI, 1996). Transects were run in a different direction each year. The direction was held constant for all plots. Only current year's growth was clipped. Vegetation was separated by life form (i.e., perennial grass, annual grass, forbs, shrubs, and noxious weed). Forages were dried at 60°C for 48 h and relative DM production in kg/ha of each life form were calculated.

Leafy spurge and spotted knapweed sites were divided into high, medium, and low levels of infestation based on the following calculation: % infestation = [(kg of weed/kg of total forage production for the site)*100]. Data were analyzed for level of infestation, year, year x % infestation (SAS Inst. Inc., Cary, NC). A preliminary regression of years grazed and composition was performed for 8 photo plot sites. Of these 8 sites, 3 of sites were grazed three consecutive years and 5 were grazed two consecutive years.

Following the summer grazing season, meetings were held with all stakeholders to discuss results of monitoring, potential successes, and opportunities for improvements.

Results and Discussion

Montana Sheep Institute weed projects in 2004 directly involved over 100,000 acres of weed infested Montana rangeland and about 1000 landowners. The MSI conducted 22 projects with 31 monitoring sites utilizing 30,000 sheep and goats from 31 sheep producers.

Results from 2003 and 2004 leafy spurge monitoring sites are summarized in Table 1. Year did not interact with response variables evaluated ($P > 0.10$) and thus analyses were conducted across years. Total forage productivity was similar across site infestation level classifications ($P > 0.10$) and averaged 585 kg/ha. Sites with high leafy spurge infestations had less grass productivity (106 vs. 309 and 415 kg/ha for high vs. medium and low site infestation levels, respectively). The forb component other than the target weed of the vegetation profile was basically nonexistent on all test sites. Relative utilization of leafy spurge and grass did not differ among sites with differing weed infestation levels (P>.10) and the utilization of the target weed was higher than that of the grasses (about 65% vs. 35% for weed vs. grass, respectively). This data reinforces what happens if we allow these non-native weeds to continue to invade and dominate the landscape. The first and most critical issue is that as these weeds invade the landscape our research demonstrates that the forb component is eliminated from the landscape. Forbs are a critical component of a healthy wildlife habitat. Secondly, the noxious weed component gradually replaces the grass component until landscape diversity is compromised. The landscape trend is to a monoculture of the non-native invasive plant. Many sites investigated in this project have been altered because of high weed infestation levels. Most traditional weed control methods (i.e. herbicides) would be economically prohibitive under the current infestation conditions. For instance, it has been estimated that to control the weed problem in Missoula County alone with herbicides it would cost about 12 million dollars per year for 5 years. Our data also demonstrates that under a controlled grazing régime, sheep will selectively graze leafy spurge. In our studies, we were to achieve 60 to 70% utilization of the leafy spurge and limit the utilization of the grass to 30 to 40 percent. Over time this type of grazing should favor the re-establishment of grass and forb component of the landscape.

Table 2 summarizes results for 13 sites where spotted knapweed was the target weed. Since year by response variable interaction was not significant ($P > 0.10$) comparisons were made across years. Although the total productivity of these sites were higher than the leafy spurge sites (1053 vs. 585 kg/ha for spotted knapweed vs. leafy spurge sites, respectively), forage composition trends were similar. Total forage productivity was similar between sites with differing degrees of infestation. As sites became more infested, grass production declined (775 vs. 409 vs. 108 kg/ha of grass for light, moderate and heavy infested sites, respectively; $P < 0.05$). Conversely, weed increased (33 vs. 556 vs. 935 kg/ha, respectively). It appears that with spotted knapweed, there seems to be a more prevalent or distinct trend to a monoculture as infestation becomes more severe. Spotted knapweed was utilized at a higher level at each of the three infestation levels than was grass. Relative utilization of spotted knapweed was highest when it was present at a high concentration (61% vs. 48% and 41% for high vs. medium and low infested sites, respectively; $P < 0.05$). Sheep diets were high in knapweed when infestation levels were high or medium (62% and 63% vs. 28% for high and medium vs. low infestation levels, respectively; $P < 0.05$). These data suggest that sheep can be used to selectively graze spotted knapweed and their effectiveness as a weed management tool to manage spotted knapweed may be most affective at medium to high infestation rates.

The regression of years grazed and composition for 8 photo plot sites is presented in Figure 1. Analysis indicated the composition of leafy spurge decreased and grass increased at sheep grazing sites. Leafy spurge composition decreased ($R^2 = 0.99$; $P < 0.01$) by 9 % per

year of grazing while the grass component increased (R^2 = 0.99; $P < 0.01$) by 10 %. Composition of leafy spurge decreased and grass increased at all monitoring sites except one.

One of the major components to the success of these projects is the shared project planning and evaluation. In each case the project development involved a series of meetings with all stakeholders (i.e., private landowners, government land agencies, county officials, and sheep producers to identify problems, formulate potential solutions, and discuss results of monitoring, potential successes, and opportunities for improvements. In addition, all stakeholders had individual responsibilities associated with the summer grazing project and data collection and evaluation process and these roles added to the success of MSI projects. The key to the success of MSI vegetative management projects is the shared ownership between MSI and local and state land managers.

Implications

The Montana Sheep Institute is an example of how to develop positive working relationships between stakeholders involved in weed and land management. Data collected from MSI projects suggest that over time controlled sheep grazing should favor the re-establishment of grass and forb component and lessen the negative impacts of the noxious weed component of the landscape.

Acknowledgments

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Table 1. Relative Composition, Utilization and Percent Diet Composition of Leafy Spurge (Target Weed), Grass and Forbs on Test Sites.[1,2]

Weed	High	Medium	Low
Number of Sites	13	10	2
Total forage production (kg/ha)	541	635	580
Kilograms of weed/ha	426[a]	326[a]	165[a]
Kilograms of grass/ha	106[a]	309[b]	415[b]
Kilograms of forbs/ha	9[a]	0[a]	0[a]
Relative util. of weed	61[a]	67[a]	62[a]
Relative util. of grass	32[a]	35[a]	42[a]
% of weed in the diet	87[a]	65[b]	32[c]
% of grass in the diet	12[a]	34[b]	69[c]

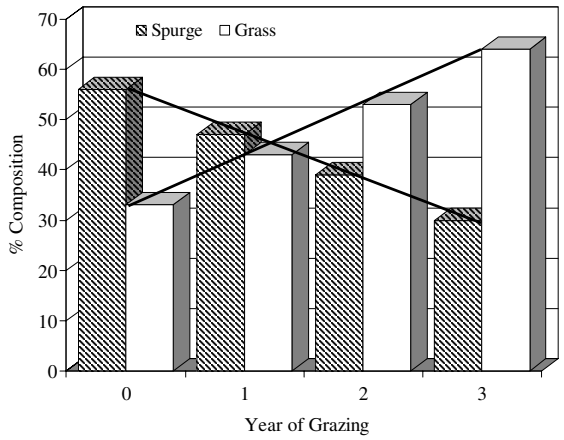
[1]Sheep Institute, 2003 & 2004 Data
[2]Sites were sorted according to the level of weed infestation (pounds of weed/total forage production for the site*100): High (100 to 68%), Medium (67 to 35%), and Low (34 to 0%).
[abc] $P < 0.05$

Table 2. Relative Composition, Utilization and Percent Diet Composition of Spotted Knapweed (Target Weed), Grass and Forbs on Test Sites.[12]

Weed	High	Medium	Low
Number of Sites	5	5	4
Total forage production (kg/ha)	1050	1057	1051
Kilograms of weed/ha	935[a]	556[b]	33[c]
Kilograms of grass/ha	108[a]	409[b]	775[c]
Kilograms of forbs/ha	7[a]	92[a]	243[b]
Relative util. of weed	61[a]	48[a]	41[a]
Relative util. of grass	33[a]	29[a]	23[a]
% of weed in the diet	62[a]	63[a]	28[a]
% of grass in the diet	38[a]	23[a]	31[a]

[1]Sheep Institute, 2003 & 2004 Data
[2]Sites were sorted according to the level of weed infestation (pounds of weed/total forage production for the site*100): High (100 to 68%), Medium (67 to 35%), and Low (34 to 0%).
[abc] $P < 0.05$

Figure 1. Regression of years grazed and composition for 8 photo plot sites



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USING PRE-WEANING AND POST-WEANING VARIABLES TO PREDICT CARCASS QUALITY

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ABSTRACT: A preliminary study was conducted to determine which pre- and post-weaning variables most contribute to predicting carcass quality (rib eye area, back fat and marbling) in a standard commercial production setting with variable treatment of animals. Data from 46 British crossbred steers and heifers reared on a Northern California ranch were grouped into three categories: pre-weaning data (birth weight, weaning weight, weaning age, sire, and sex), post-weaning through harvest data (sex, feedlot in-weight, average daily gain, days on feed, harvest age, carcass weight, and time of year when put on feed), and a group with all data combined. Calves from dams that were not artificially inseminated were DNA tested to determine their sire. The mean weaning weight of all calves was 189 kg with a SD of 20 kg. Carcass weights averaged 309 kg with a SD of 18 kg. Rib eye area, back fat, and marbling score had means of 69.5 cm^2, 5.5 mm, and 6.6 (Select≥4, Choice-≥ 5, Choice≥6, Choice+≥7) with SD of 4.6 cm^2, 1.0 mm, and 0.6, respectively. Using a linear statistical model R^2 for rib eye areas were: 0.73 for pre-weaning variables, 0.86 for post-weaning variables, and 0.97 for all variables combined. Back fat R^2 values were 0.59 for pre-weaning, 0.37 for post-weaning, and 0.85 for combined variables. Marbling score R^2 values were 0.44 for pre-weaning, 0.44 for post-weaning, and 0.74 for all variables combined. Root mean square errors for the model with all variables combined were 1.8 cm^2, 0.77 mm, and 0.57 for rib eye area, back fat and marbling, respectively. Variation in rib eye area was best accounted for in the models. Little potential was shown for prediction of marbling score or back fat from only pre-weaning or post-weaning data. Prediction values improved when all variables were combined. Results of this preliminary study indicate that common production variables from both pre- and post-weaning are of limited usefulness in explaining variation in carcass quality. Further studies will investigate how much additional variation can be accounted for by using ultrasound measures near or after weaning.
Key Words: Carcass Quality, Production Data, Beef Production

Introduction

Data collection can be a tedious and time-consuming process. Accurately obtaining records at each stage of cattle production increases management intensity and labor. Most producers expending this extra energy receive some sort of added compensation such as higher bull prices in purebred markets. For the commercial cattlemen, opportunities for added market value are limited, but they might be obtained by producing calves that return higher carcass quality through alliances or other marketing structures. If data obtained at pre- and post-weaning aids in the estimation of carcass quality, producers would be presented with an opportunity to more accurately guarantee their end product, thus gaining market power.

Veseth et al. (1993) showed a positive, but low, phenotypic correlation between weaning weight and marbling. A low negative correlation was found between birth weight and marbling. When correlating pre-weaning growth and carcass traits, Woodward et al. (1992) found that adding this pre-weaning growth data did not decrease their prediction variance for marbling score. As with Veseth et al., they also found low correlations between phenotypic expression of birth and weaning weight to marbling score. Woodward et al. results showed that birth weight and weaning weight alone are not predictive measures of carcass quality. In corroboration of this idea, Hassen et al. (1998) demonstrated significant differences in carcass traits between heifers and steers.

In terms of post-weaning data, Bruns et al. (2004) found that as hot carcass weight increased, back fat and marbling score also increased quadratically. Significant differences were found at each of five different carcass weight groups that ranged from 204 to 386 kg.

These studies demonstrate that because of multiple sources of influence, it is important to test a sufficient number of variables to adequately explain variance in carcass quality. However, research has not clearly defined which pre- and post-weaning variables could be collected to most accurately predict ending carcass quality traits.

This preliminary study was conducted to determine which pre- and post-weaning variables would be most beneficial in predicting carcass traits. The three carcass traits targeted are rib eye area, marbling score, and back fat thickness. If possible, determining which variables most affect carcass quality would enable producers to focus more on the collection of specific data rather than all production data. Commercial cattle producers could then gain the marketing benefits of added data collection, while limiting added intensity of management, labor, and time.

Material and Methods

Data from 46 British crossbred steers and heifers in a commercial, Northern California production setting were collected at both pre- and post-weaning through slaughter. Cow and calf feed consisted of annual rangeland in the winter and irrigated pasture in the summer months. Calving occurred on annual rangeland and weaning occurred at the end of their first season on irrigated pasture. Average weaning weights were 189 kg with a standard deviation of 20 kg.

In order to determine the sire effect on carcass quality it was necessary to determine the identification of both artificial insemination (AI) and non-AI bulls. Sire identification was possible on calves conceived through artificial insemination by standard production records. Parentage matching of non-AI bulls to their calves were done by DNA testing all non-AI sires and calves, as explained by Van Eenennaam et al. (2006).

A wide range in post-weaning time before feedlot entry and days on feed (152-306 d) was characteristic for this commercial ranch. The mean weight of entering feedlot calves was 289 kg with a standard deviation of 28 kg. Calves were placed on feed in six different groups throughout the season. Since all calves did not enter the feedlot at the same time, each group was assigned a season code (1-6) to account for the variation in weather conditions between feedlot groups. Cattle were individually harvested at a uniform back fat (mean of 5.4 mm with a standard deviation of 0.1 mm), thus creating the high range of days on feed.

Data analysis was broken into three groups: 1) production data collected before weaning 2) production data collected after weaning and 3) all production data collected combined. Linear regression analysis of the data was done using the GLM procedure in SAS. Group one variables included: birth weight, weaning age, weaning weight, sire, and sex. Group two variables included: weight when put on feed, average daily gain, days on feed, age at harvest, sex and carcass weight. The third group's analysis combined all the variables used in the previous groups.

Results and Discussion

Rib eye area shows the strongest correlations for each data group collected (table 1). The correlation (R^2) increased from pre-weaning data (0.73) to post-weaning data (0.86). A strong accounting of variance exists when all production data is combined to predict rib eye area (0.97). The greatest influence on the combined correlation was due to carcass weight and slaughter age ($P<0.05$), although calf sex was significant in the pre-weaning data group ($P<0.05$).

Mckenna et al. (2002) may demonstrate reasoning for sex explaining variance in the pre-weaning data groups. Using least square means, the study found significant differences between heifers and steers in determining hot carcass weight. Mckenna et al. (2002) also found a significant difference between heifers and steers for fat thickness. This is important because each animal in our analysis was harvested at a uniform back fat thickness, making sex a contributing factor in slaughter age. Thus, sex is determined to be a key contributor in influencing the two most significant variables for rib eye area correlation.

Although equal (0.44), little correlation existed for marbling score with either pre-weaning or post weaning data collection. This is in agreement with Veseth et al. (1993) and Woodward et al. (1992), who found little phenotypic correlation between pre-weaning growth traits and carcass traits. When all data was combined (group 3), the predictive capacity (0.74) did increase significantly over that of group one or two. Of greatest influence on the combined correlation was carcass weight ($P<0.05$), and again calf sex was significant in the pre-weaning data group ($P<0.05$). This was in agreement with Bruns et al. (2004) assessment of the relationship between carcass weight and marbling score.

Back fat thickness correlations show no more predictive capability than that of marbling for groups one (0.59) and two (0.37). As with marbling, R^2 did increase a great deal when all data was collected (0.85). Interestingly, sex accounted for most of the variation for the pre-weaning data ($P=0.07$), while birth weight ($P=0.12$) and weaning weight ($P=0.14$) accounted for the greatest amount of variation when all variables were combined (group 3). Unlike Bruns et al. (2004), carcass weight did not have a significant impact on back fat thickness ($P=0.28$) when all variables were combined. This was most likely due to the fact that cattle were fed to a uniform back fat thickness.

This study was not an attempt to determine which production traits should be measured to assist selection for carcass quality. It is known that carcass weight accounts for more variation in rib eye area and marbling than any other single variable. Because feeding strategies primarily control carcass weight, pre-weaning variables are of limited utility in estimating certain attributes of future carcass quality. However, for some traits pre-weaning variables are relevant e.g., back fat and weaning weight. We were primarily interested in collecting pre-weaning data under commercial conditions to determine whether this data could be used to allow producer's to obtain some estimate of downstream carcass quality.

The use of data collection does show a trend for a prediction of rib eye area at either pre- or post-weaning. This is not the case with marbling and back fat thickness. Low correlations in pre- and post-weaning collected data for marbling and back fat demonstrate that the use of these types of production data alone is of limited value for producers in predicting carcass quality. Group three data for marbling and back fat show better accounting for the variance of marbling and back fat, but not as strong a correlation for use as a predictive value. Without an opportunity for the prediction of fat thickness to compute yield grade (Drake, 2004), the prediction of rib eye area is limited in use, but can have importance to producers for optimizing product portion sizes. Dunn et al. (2000) demonstrated that optimal tenderness and cooking times could be attained when rib eye areas were between 77.4 and 96.6 cm^2. An accurate means of predicting rib eye area could aid producers in targeting this optimum range of product portion size.

The low correlation values for marbling also make prediction of a quality grade questionable (95% confidence interval of pre-weaning prediction spans 2.3 scores, or from low-select to mid-choice). Presently, in this preliminary study, there is limited benefit for commercial beef cattle producers in added data collection for carcass quality prediction.

Further studies will determine if the use of ultrasonic measurements in the model will account for more variation in rib eye area, marbling, and back fat thickness. The addition of this data could possibly lower the mean square errors of the current models. Measurements will be taken at the period of replacement heifer selection to determine if early ultrasonic measurement could be used as a possible tool for the prediction of carcass quality.

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Table 1. Correlations and mean square errors of collected data to carcass traits

	REA, cm^2		Marbling[1]		Back fat, mm	
	R^2	MSE	R^2	MSE	R^2	MSE
Group 1. Pre-wean data	0.73	3.5	0.44	0.58	0.59	0.87
Group 2. Post-wean data	0.86	1.9	0.44	0.43	0.37	0.81
Group 3. Combined data	0.97	1.8	0.74	0.57	0.85	0.77

[1]Select≥4, Choice-≥ 5, Choice≥6, Choice+≥7

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SURVEY PROVIDES INFORMATION ON COW-CALF HANDBOOK USE AND VALUE

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ABSTRACT: The Cow-Calf Management Guide and Cattle Producer's Library is an educational resource for beef cattle producers. Available in loose-leaf and CD-ROM formats, the 937-page guide has 246 fact sheets which are divided into sections: Quality Assurance, Nutrition, Reproduction, Range and Pasture, Animal Health, Management, Marketing, Finance, Genetics, and Drought. The handbook is the result of research and practical experience by members of the Western Beef Resource Committee (WBRC), which is a collaboration of state and county Extension faculty from the 12 western states. The WBRC meets annually to support fact sheet revisions, additions, and deletions. All fact sheets are peer reviewed before they are accepted in the handbook. Since the release of the Second edition in October 1992, in excess of 6,000 copies have been distributed to users in 42 states and eight countries. In 2005, a mail-in survey was conducted to gauge the use and value of the Cow-Calf Management Guide and Cattle Producer's Library. An eight-question survey was mailed to every (n=961) current handbook subscriber. Subscribers are individuals that keep their handbook current through purchased updates. Twenty-five percent (n=239) of handbook subscribers responded to the survey. Handbook users can be categorized as producers (53%), Extension faculty (30%), allied industry representatives (6%), students (3%), and agency employees (1%). The percent of handbook users owning 0 to 50, 51 to 200, 201 to 500 and more than 500 cattle was 43%, 23%, 19%, and 16%, respectively. The percent of respondents citing the frequency of handbook use as daily, weekly, monthly, and quarterly, was 2%, 19%, 42%, and 37%, respectively. The handbook format was preferred by users over the CD-ROM format (74% vs. 24%). A web version of the handbook has been considered. Thirty-one percent of respondents were in favor of, and 64% were against paying a web subscription fee. Current price of the handbook is $95.00, which was cited as appropriate by seventy-seven percent of respondents. Respondents rated the nutrition, animal health, reproduction, range and pasture, and management sections as the top five based on use.

Key Words: Handbook, Beef Cattle, Survey

Introduction

Efficient and profitable production of beef cattle is influenced by numerous and varied production, financial, environmental, and marketing factors. Through the years, beef producers have been provided with proven tools and technologies to assist them in getting the most out of their investments. In some instances, producers have not adopted/implemented these various tools and technologies which could improve production efficiency. Producers are faced with a variety of factors that directly impact the profitability of their operations. To adequately address these factors, producers must have access to resources that allow them to stay abreast of current issues and the research related to the issues. One such resource is the Cow-Calf Management Guide and Cattle Producers' Library (**CCMG**).

The CCMG is an informational and educational resource for beef cattle producers and individuals that service the beef industry. The 937-page guide has 246 fact sheets which are divided into sections: Quality Assurance, Nutrition, Reproduction, Range and Pasture, Animal Health, Management, Marketing, Finance, Genetics, and Drought. In addition to these discipline based sections, the guide contains a Miscellaneous section, an Introduction, an Index, a Management Guide, and a Troubleshooting Guide. The Management Guide section presents various production scenarios and directs users to appropriate fact sheets for further reading and reference. The Troubleshooting Guide identifies common problems faced by beef cattle producers and directs them to fact sheets that provide assistance and solutions.

The CCMG is the result of research and practical experience by members of the Western Beef Resource Committee (**WBRC**), which is a collaboration of state and county Extension faculty from Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming. The CCMG remains current because of the commitment of the WBRC, which meets annually to review handbook contents and either add, revise, or delete papers after science-based, peer review scrutiny.

The original handbook became available in November 1980. Five reprints occurred through October 1985 for a total press run of 3,750 copies. The first printing of the Second Edition occurred in October 1992. In 1997, the animal health section was put into an electronic/digital format (CD-ROM). A few years later, the entire handbook was put on CD-ROM and released as the Digital Edition. Currently, the handbook is being formatted for website presentation.

Although written from a western perspective, the CCMG contains base information about the beef cattle industry that has broad application and appeal. In total, more than 10,000 copies of the handbook have been purchased by users in at least 42 states and eight countries. The objective of this study was to gauge the use and value

of the Cow-Calf Management Guide and Cattle Producers' Library.

Materials and Methods

A survey was designed to gather information regarding the level of use and perceived value of the CCMG. A draft questionnaire was developed and reviewed by WBRC members and feedback was incorporated into the final version. The final survey consisted of eight multiple-choice questions and was mailed to every (n=961) current handbook subscriber. Subscribers are those individuals that have kept their handbooks current by purchasing updates. The survey instrument was printed on cards and included in a packet that contained a handbook update and a subscription notice. The packets were distributed to subscribers in January 2005. The survey card did not include a response deadline. Data used in this study came from responses that were received by February 2006. The survey inquired as to the subscribers' occupation, number of cattle owned, reason for handbook purchase, frequency of handbook use, preferred handbook format, willingness to pay website subscription fee, rating of handbook price, and preferred handbook sections. To determine which handbook sections are most used or preferred, subscribers were asked to cite their top four. Numerous subscribers cited all sections. The citations were compiled over all subscribers and the most cited sections were given the highest ranking. All data were entered into a spreadsheet for analysis. Results from each question are presented in Tables 1 to 8. Some subscribers chose not to respond to every question of the survey. Results are reported as the number and percentage response to each individual question, except for the final question (Table 8) where the number of citations and final numerical ranking are reported.

Results and Discussion

Of the 961 surveys mailed to current CCMG subscribers, 239 were returned for a response rate of 25%. To gain an understanding of who is using the handbook, respondents were asked to place themselves in various occupational categories. Results are shown in Table 1. The majority of individuals completing and returning the survey were producers (53%), followed by Extension faculty (30%), allied industry representatives (6%), students (3%), and government agency personnel (1%).

The beef industry is made up of operations that are quite varied in size. One method of determining operation size is to use cow numbers. The percent of handbook users owning 0 to 50, 51 to 200, 201 to 500 and more than 500 cattle was 43%, 23%, 19%, and 16%, respectively. While representation is spread fairly evenly across the cow number categories, the data from Table 2 suggest the majority of handbook subscribers are small to medium-sized producers.

At several universities, the CCMG has been adopted and used as a textbook in beef production classes. It has also been used as the primary resource for beef production laboratories. Additionally, the CCMG has been used as the curricula for various Extension programs. Considering these uses, some might expect that a large source of handbook sales would be from class/workshop participants. However, the data in Table 3 shows that 80% of respondents' handbooks were purchased on an individual basis and not for use in a class or workshop. The frequency of handbook use is presented in Table 4. The percent of respondents using their handbook on a daily, weekly, monthly, or quarterly basis was 2%, 19%, 42%, and 37%, respectively.

For educational resources to be effective, they must be presented in a useful and acceptable format. During its history, the CCMG has been presented in a handbook and digital (CD-ROM) formats. The data in Table 5 shows 74% of respondents prefer the traditional handbook format versus 24% for the digital format. While not asked on the survey, 2% of the respondents cited both formats.

Now that our information-based society is firmly entrenched in the technological age and frequently searches for resources via the internet, the WBRC has considered adding an internet version of the CCMG. For the last few years, a free, preview web site (http://wbrc.ag.uidaho.edu) has been available. Recently, the entire handbook was formatted and added to a web server for testing by WBRC members. The data in Table 6 reveals that 31% of respondents were in favor of, and 64% percent were against paying a web subscription fee.

Since approximately 2001, the price of the handbook has been $95 plus shipping and handling. The price includes the handbook and a copy of the Digital Edition. Comparing the price and amount of materials to various textbooks and other resources, the price seems reasonable. However, to gauge the perceived value of the handbook, survey participants were asked to rate the price of the handbook as appropriate, high, or low. As presented in Table 7, 77% of respondents felt the handbook was appropriately priced.

The section of the handbook used most often by subscribers depends on the issues that impact individual operations. The ranking (most used to least used) of the discipline based sections in terms of use is: Nutrition, Animal Health, Reproduction, Range and Pasture, Management, Genetics, Drought, Marketing, Finance, and Quality Assurance. Table 8 contains a complete ranking of all sections of the handbook.

Implications

The Western Beef Resource Committee, which is a collaboration of state and county Extension faculty from the twelve western states, has been successful in delivering a useful and valuable educational resource to beef industry participants over the last 25 years. This type of collaboration will become more important as positions at universities come open and are not filled. This collaborative effort has provided the mechanism for faculty to come together, discuss issues, share expertise, and participate in professional development activities. The products that come out of this effort are then taken back to home states and distributed over wider audiences.

Table 1. Handbook users

Title	#	%
Allied Industry	13	6
Agency Employee	2	1
Extension Faculty	71	30
Producer	125	53
Student	7	3
Other	16	7

Table 2. Number of cattle owned by handbook users

Number of cattle	#	%
0 – 50	87	43
51 – 200	46	23
201 – 500	39	19
500 +	32	16

Table 3. Handbooks purchased for workshop/class

Response	#	%
Yes	43	20
No	177	80

Table 4. Frequency of handbook use

Frequency	#	%
Daily	4	2
Weekly	44	19
Monthly	98	42
Quarterly	86	37

Table 5. Preferred handbook format

Format	#	%
Book	173	74
CD-ROM	56	24
Both	6	2

Table 6. Willingness of users to pay handbook web fee

Response	#	%
Yes	69	31
No	141	64
Undecided	12	5

Table 7. Value of handbook

Price Rating	#	%
Appropriate	178	77
High	45	19
Low	8	3

Table 8. Ranking of handbook sections by use

Section Title	# of Citations	Rank
Nutrition	184	1
Animal Health	153	2
Reproduction	152	3
Range and Pasture	118	4
Management	113	5
Troubleshooting Guide	77	6
Management Guide	67	7
Genetics	66	8
Drought	61	9
Marketing	58	10
Finance	51	11
Index	49	12
Quality Assurance	48	13
Introduction	42	14
Miscellaneous	41	15

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PREVALENCE OF SHIGA TOXIN-PRODUCING *ESCHERICHIA COLI* IN FEEDLOT STEERS DURING WINTER AND SPRING[1]

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ABSTRACT: Beef safety concerns have been on the rise in recent years due to tracing a large number of human illness outbreaks to Shiga toxin-producing *Escherichia coli* (STEC)-contaminated beef. The human illnesses included diarrhea, bloody diarrhea, abdominal cramps, vomiting, hemorrhagic colitis, and the life-threatening hemolytic uremic syndrome (HUS). The objective was to assess STEC prevalence in four large-scale (ranging from 13,000 to 46,000 cattle) feedlots in California during winter and spring. Fresh fecal samples were collected from 161 and 160 steers that had been on feed for the shortest (ranging from 66 to 186 d) or longest (ranging from 197 to 346 d) period of time, respectively. Over the two seasons, STEC were recovered in two of the four feedlots at a similar prevalence rate (3.8%). Prevalence rates of STEC were not altered ($P > 0.05$) by season (averaging 1.9%) or time on feed (averaging 1.9%). The STEC isolates belonged to five serotypes (*E. coli* O127:H19, O136:HUT [an untypeable H antigen], OUT [an untypeable O antigen]:H2, OUT:H$^-$ [a nonmotile isolate], and OUT:HUT). Of these STEC serotypes, two (*E. coli* OUT:H2 and OUT:H$^-$) are known to cause HUS and one (*E. coli* OUT:HUT) is known to cause other human illnesses. The *E. coli* O127:H19 serotype detected in this study has not been reported previously in cattle. Interestingly, *E. coli* O157:H7 isolates were not found in the steers tested. The results of this study emphasize the importance of testing beef cattle for STEC, in general, and suggest the need for developing pre-harvest control methods that decrease carriage and fecal shedding of these foodborne pathogens.

Key words: Food Safety, *Escherichia coli*, Beef Cattle

INTRODUCTION

The importance of food safety has increased dramatically in recent years because of the growing number of reported human illnesses associated with foodborne pathogens. According to the US Food and Drug Administration and the Centers for Disease Control and Prevention, approximately 14% of the US population (i.e., 33 million) experience foodborne illnesses annually. Recent statistics indicate the continuous rise and severity of the food safety problem as related to specific foodborne pathogens such as Shiga toxin-producing *Escherichia coli* (STEC). The association between foods of bovine origin and STEC have been established since the first two human illness outbreaks in 1982 (Riley et al., 1983). In these outbreaks, ground beef containing a rare *E. coli* serotype (i.e., O157:H7) caused symptoms such as severe abdominal cramps, grossly bloody diarrhea, and a low-grade fever in 47 people in Michigan and Oregon. In general, STEC infection causes a wide range of illnesses (Paton and Paton, 2000) that include mild or bloody diarrhea, hemorrhagic colitis, and the life-threatening hemolytic uremic syndrome (HUS). It is worth noting that other infection routes exist for STEC and include vegetables (Cieslak et al., 1993), raw milk (Martin et al., 1986; Lahti et al., 2002), dairy products (Morgan et al., 1993; Reid, 2001), and drinking water (Yatsuyanagi et al., 2002) containing cattle feces. Additional routes include person to person (Reida et al., 1994) and animal to person (Synge et al., 1993; Crump et al., 2002). Because beef remains the main source of human infection with STEC, cattle are considered reservoirs of O157 (Hancock et al., 1994; Al-Saigh et al., 2004) and non-O157 (Schurman et al., 2000; Barkocy-Gallagher et al., 2003) STEC. Thus, the safety concerns with bovine edible products, especially ground beef, have increased in recent years. Because of these concerns and the increased health risks associated with a large number of STEC serotypes (WHO, 1998; Blanco et al., 2003; Bettelheim, 2006), this study was designed to assess prevalence of O157 and non-O157 STEC in California feedlot cattle during winter and spring.

MATERIALS AND METHODS

Cattle Population

Owners of four feedlots were solicited for voluntary

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participation in this study through lists of producers compiled by Veterinary Medical Officers of the USDA and Farm Advisors employed by the University of California Cooperative Extension. The feedlots ranged in size from 13,000 to 46,000 Holstein steers. Fecal samples were collected in the winter (i.e., December and January) and spring (i.e., March and April) from 161 and 160 steers that had been on feed for the shortest (ranging from 66 to 186 d) or longest (ranging from 197 to 346 d) period of time, respectively.

Fecal Sampling

In each feedlot, fresh fecal samples were collected once in the winter and once in the spring. This was accomplished by random selection of a pen of cattle in early feeding (i.e., newly arrived; have been on feed the shortest period of time) and another in late feeding (i.e., finishing; have been on feed the longest period of time) and by collection of 20 fecal samples from each pen. During the spring sampling, the early pen for the winter sampling was used as the late pen and a new early pen was selected at random for fecal sampling. Each test pen (i.e., early or late feeding) was visually divided into quadrants and five fresh fecal samples were collected from each quadrant. Immediately following defecation, a minimum of 5 g fresh feces were taken by using a sterile tongue depressor and gloves and were placed in a sterile Whirl-pak bag (Nasco, Modesto, CA) that was labeled with the pen information. Care was taken to eliminate cross contamination or soil contamination and to extract only samples from the middle of fresh manure pats after scraping the top of the pat to the side. The Whirl-pak bags containing fecal samples were placed in a large plastic bag that was labeled with the date and feedlot code and were shipped on ice to our laboratory for analysis at ≤ 24 h after collection.

Enrichment and Initial Selection of STEC Isolates

Initial selection of *E. coli* isolates was conducted by adding 1 g of feces from each animal to 25 mL of enrichment medium (i.e., brain heart infusion [BHI]; Hardy Diagnostics, Santa Maria, CA), mixing vigorously, and bringing the total volume to 50 mL with the enrichment medium. This medium contained cefixime (Sigma, St. Louis, MO) at 50 µg/L, novobiocin (Sigma, St. Louis, MO) at 20 mg/L, potassium tellurite (Sigma, St. Louis, MO) at 2.5 mg/L, and vancomycin (Sigma, St. Louis, MO) at 40 mg/L. The diluted feces (i.e., 1:50) were immediately incubated at 37°C for 12 h with continuous shaking (i.e., 120 rpm) to allow for antibiotic selection and toxin induction. At the end of incubation time, the enriched fecal samples were serially diluted to 10^{-7} in BHI medium, plated in duplicate onto sorbitol-MacConkey (SMAC) agar (Hardy Diagnostics, Santa Maria, CA), and incubated at 37°C for 18 h. At the end of this incubation time, sorbitol-fermenting (i.e., pink colonies) and non-sorbitol fermenting (i.e., white colonies) bacteria on SMAC plates were subcultured on 4-methylumbelliferyl-β-D-glucuronide (MUG) MacConkey (MMUG; Hardy Diagnositics, Santa Maria, CA) agar grid plates. Ten (i.e., sorbitol positive or negative) or less (i.e., when unavailable) colonies from each category were randomly selected and transferred to the MMUG plates. The MMUG plates were incubated at 37°C for 18 h and observed on a UV light box (Fotodyne, New Berlin, WI). Results were recorded for MUG positive or MUG negative (i.e., blue fluorescence or no fluorescence under UV light, respectively). When available, two colonies from each of the potential four biochemical categories (i.e., sorbitol positive/MUG positive, sorbitol positive/MUG negative, sorbitol negative/MUG positive, and sorbitol negative/MUG negative) were selected at random. These potential *E. coli* isolates were transferred from the MMUG plates to 5-mL tubes containing 2 mL of tryptic soy broth (TSB; Hardy Diagnostics, Santa Maria, CA) and incubated at 37°C for 6 h with continuous shaking. At the end of incubation time, the culture was diluted with equal volume (i.e., 2 mL) of sterile glycerol, mixed well, and stored at -80°C. At that time, the same isolates from the MMUG plates were subjected to biochemical testing for *E. coli*.

Screening for Potential STEC Isolates

The enriched fecal samples were screened for STEC by using the VTEC (i.e., verotoxin-producing *E. coli*)-Screen kit (Denka Seiken Co., Ltd., Tokyo, Japan). A total of 5 mL of enriched feces and 100 µL of polymyxin solution (Denka Seiken Co., Ltd., Tokyo, Japan) were incubated at 37°C for 30 min with continuous shaking to ensure optimal extraction of Shiga toxins from the bacterial periplasmic space. The mixture was then centrifuged at 900 × *g* for 20 min and the supernatant was removed to test for Shiga toxins in 96-well V-bottom microtiter plates (Costar, Corning, NY). In the microtiter plates, the culture supernatant (i.e., 25 µL) was mixed with equal volume of the supplied diluent (i.e., phosphate buffered saline and 0.08% sodium azide). An equal volume of latex particles sensitized with rabbit polyclonal anti-Shiga toxin 1 (Stx1) and anti-Shiga toxin 2 (Stx2) immunoglobulin G antibody was mixed in the appropriate wells. The plates were mixed, covered, incubated at room temperature, and examined for latex agglutination after 18 h. The positive and negative control toxins supplied with the kit were run with each assay. A positive result was recorded when agglutination in the sample well was two levels above the control well.

Identification of STEC Isolates

The isolates that were selected based on sorbitol fermentation and β-glucuronidase activity (i.e., maximum eight for each fecal sample) were tested for *E. coli* biochemically by using the API 20E Identification System (bioMérieux Vitek, Inc., Hazelwood, MO). Only isolates that were confirmed as *E. coli* were stored at -80°C for further testing. *E. coli* isolates were then grown in 5 mL BHI at 37°C for 12 h with continuous shaking. At the end of incubation time, the cultures were subjected to the same agglutination

assay (i.e., VTEC-Screen kit) as described previously for the enriched feces to identify and preserve the *E. coli* isolates that are producing Shiga toxins (i.e., STEC).

Serotyping of STEC Isolates

The STEC isolates were serotyped for the O and H antigens by the slide agglutination method using rabbit antisera (Denka Seiken Co., Ltd., Tokyo, Japan). The STEC isolates that could not be typed for the H antigens were subjected to a motility test to assess presence or absence of bacterial flagella. The motility test medium (Remel, Lenexa, KS) contained tetrazolium dye to aid in visualization of bacterial motility. The STEC isolates were grown on TSB agar containing 5% defibrinated sheep blood at 37°C for 18 h. Using a sterile needle, a colony of each STEC isolate was picked and was used to stab a motility test medium tube once two-thirds of the way down to the bottom without touching the wall of the tube. The medium tubes were incubated at room temperature and were examined for motility according to the manufacturer's instructions after 24 and 48 h. The nonmotile STEC isolates were considered H^-.

Control Cultures

The antibiotics used during fecal enrichment and initial selection were tested on sterilized cattle feces that were inoculated with cultures containing four different *E. coli* O157:H7 isolates. These isolates were ATCC 43890 (i.e., producing only Stx1), ATCC 43889 (i.e., producing only Stx2), ATCC 43895 (i.e., producing Stx1 and Stx2), and ATCC 43888 (i.e., not producing either toxin). The *E. coli* O157:H7 isolates were grown in TSB at 37°C for 6 h with continuous shaking before mixing with the sterilized feces. The mixing occurred after the autoclaved feces reached room temperature. The sterilized/inoculated feces were treated exactly the same as the test fecal samples and, therefore, were used as controls. The results showed no detrimental effects of the antibiotic combination used on growth and recovery of the *E. coli* O157:H7 isolates. Recovery of these isolates was accomplished by using the same isolation methods described above. Determination of specific toxin production was achieved (Hussein et al., 2003) by using the VTEC-Reversed Passive Latex Agglutination (VTEC-RPLA) assay (Denka Seiken Co., Ltd., Tokyo, Japan).

Verotoxicity of the STEC Isolates

The STEC isolates were grown in 5 mL TSB at 37°C for 18 h with continuous shaking, the cultures were centrifuged (i.e., 3,000 × *g* for 10 min), and the supernatants were filtered twice through 0.22 µm sterile syringe filters (ISC BioExpress, Kaysville, UT). The sterile supernatants were used for determination of toxicity of STEC isolates to Vero (i.e., African Green-monkey kidney) cells (Konowalchuk et al., 1977; Smith and Scotland, 1993) in duplicate. Negative controls consisting of Eagle minimal essential medium (Mediatech, Inc., Herndon, VA), TSB medium, and non-STEC O157:H7 (ATCC 43888) were analyzed with each set of 96-well flat-bottom microtiter plates (Costar, Corning, NY). In addition, each set of plates contained a positive control panel of supernatants from three *E. coli* O157:H7 isolates known to produce Stx1 (ATCC 43890), Stx2 (ATCC 43889), or both toxins (ATCC 43895). The STEC-positive and STEC-negative isolates were determined by absence or presence of a confluent monolayer, respectively. Results were recorded after 24 and 48 h of incubation.

Statistical Analysis

A significant difference in the odds of STEC for factors with two levels was determined using an exact likelihood ratio test and computation of the exact 95% confidence interval for the odds ratio by using LogXact 4 Software for Windows (Mehta and Patel, 2000). The *P*-value was set at < 0.05 for statistical significance.

RESULTS AND DISCUSSION

The STEC were prevalent in two of the four feedlots at 3.8%. The prevalence rates of STEC were not altered ($P > 0.05$) by season (averaging 1.9%) or time on feed (averaging 1.9%). Interestingly, the *E. coli* isolates were of five serotypes and none of them belonged to *E. coli* O157:H7 which is commonly found in US cattle. Evaluation of published reports on feedlot cattle in the past three decades revealed prevalence rates ranging from 0.3 to 19.7% for *E. coli* O157 and from 4.6 to 55.9% for non-O157 STEC (Hussein and Bollinger, 2005). In this study, the STEC isolates belonged to the O127:H19, O136:HUT (an untypeable H antigen), OUT (an untypeable O antigen):H2, OUT:H^- (a nonmotile isolate), and OUT:HUT serotypes. Of these, two (i.e., OUT:H2 and OUT:H^-) caused HUS and one (i.e., OUT:HUT) caused other human illnesses (WHO, 1998; Blanco et al., 2003; Bettelheim, 2006). The *E. coli* O127:H19 serotype detected in this study has not been reported previously in cattle. It is worth noting that all the STEC isolates were lethal to Vero cells. This observation suggests the high virulence of these STEC to humans.

IMPLICATIONS

Fecal testing of 321 feedlot cattle in four large feedlots in California over the winter and spring revealed prevalence of five STEC serotypes in two feedlots at 3.8%. The fact that all STEC serotypes were toxic to Vero cells, two are known to cause HUS, and one is known to cause other human illnesses suggest the seriousness of the STEC problem as related to non-O157 strains. Thus, it is critically important to test beef cattle for STEC, in general, before entering the food chain. It is also important to identify pre-harvest control measures that could be implemented to decrease carriage and fecal shedding of these foodborne pathogens before shipping feedlot cattle to slaughter.

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METABOLIC HORMONE PROFILES IN RAMBOUILLET LAMBS DURING THE PREWEANING PERIOD

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ABSTRACT: Rambouillet lambs (21 singles, 54 multiples) were used to examine effects of gender and type of birth (TOB) on growth and serum concentrations of triiodothyronine (T3), thyroxine (T4), IGF-1, and prolactin (PRL). Lambs (32 males, 43 females; avg. birth date = March 24, d 0) were weighed on d 0 (5.1 ± 0.2 kg) and at weaning (60 d, 20.4 ± 0.2 kg). Serum was collected on d 1, 14, 28, 42, and at weaning. No gender x TOB interactions were detected ($P > 0.30$). Males were heavier at birth than female lambs ($P = 0.02$), but weaning weight and ADG were similar ($P > 0.20$). Single lambs were heavier ($P < 0.001$) at birth and weaning than multiple-born lambs. Likewise, ADG was greater ($P < 0.001$) in single than multiple-born lambs (0.33 and 0.23 ± 0.01 kg/d, respectively). Gender x TOB x day interactions were not observed ($P > 0.20$). Male and female lambs had similar ($P > 0.30$) serum T3, T4, and PRL (gender x day, $P > 0.15$). Male and female lambs had similar ($P > 0.17$) IGF-1 on d 1 and 14; but on d 28, 42, and at weaning, males had greater ($P < 0.01$) IGF-1 than did females. Single lambs had elevated ($P < 0.01$) T4 (TOB x day, $P = 0.98$) compared with multiple-born lambs. Serum T3, PRL, and IGF-1 were influenced ($P < 0.03$) by TOB x day interactions. Compared with multiple-born lambs, singles had elevated ($P < 0.02$) serum T3 on d 1, 14, and 28, but values were similar ($P > 0.20$) on d 42 and at weaning. Serum IGF-1 was similar ($P = 0.18$) between birth types on d 1 but was greater ($P < 0.01$) in singles on other sampling days. Serum PRL was similar ($P > 0.15$) between birth types through d 28 but was increased ($P < 0.04$) in singles on d 42 and at weaning. In general, T3 and T4 declined (linear, $P < 0.01$) from birth to weaning while PRL and IGF-1 increased (quadratic, $P < 0.01$). Serum T3 on d 1 ($r = 0.60$) and IGF-1 on d 42 ($r = 0.64$) were related ($P < 0.0001$) to weaning weight. Preweaning serum hormones are influenced by gender, TOB, and age, and early postnatal concentrations appear related to growth characteristics.

Key Words: Sheep, Growth, Thyroid Hormones, IGF-1, Prolactin

INTRODUCTION

Fast-growing, efficient animals increase profit to the livestock industry. Utilization of nutrients by ruminants is controlled in part by the endocrine system (Trenkle, 1981). Hormones such as growth hormone (**GH**), IGF-1, and prolactin (**PRL**) play important roles. Mears (1995) found plasma IGF-1 concentrations between 7 and18 wk of age to be positively correlated to BW gain prior to sampling as well as total BW gain from weaning to slaughter. In addition, reduced plasma IGF-1 (induced by 24 h fasting), had the greatest effect on heavier lambs. Growth is also affected by the thyroid hormones, triiodothyronine (**T3**) and thyroxine (**T4**), with partial thyroidectomy in beef steers increasing gain (Andrews and Bullard, 1940) and large dosages of exogenous T3 resulting in decreased growth of ewe lambs (Hinrichs and Hallford, 1987). Changes in each of these hormones during the preweaning period, their relationship to growth, and potential for early selection of fast-growing lambs, could be extremely valuable to the producer. Trowbridge et al. (1983) found that lamb sex and type of birth affect birth weight as well as weights at 60 and 120 d of age. In addition, Kahl et al. (1977) found that male calves had more circulating T4 than females between 6 and 22 wk of age. Previous work in our laboratory (Garcia et al., 2005) demonstrated that serum T3 and T4 decrease during the early growth period. Objectives of this study were to further examine changes in hormone concentrations associated with growth during the preweaning period and to evaluate the influence of lamb gender and type of birth on these metabolic hormone profiles.

MATERIALS AND METHODS

Management

Spring-born Rambouillet lambs were utilized (birth date range March 14 to April 5) for examination of serum metabolic hormone profiles. All animals were housed at the West Sheep Unit on the New Mexico State University main campus. A total of 75 lambs was studied (21 single-born lambs and 54 multiples; 32 males and 43 females). On the day of birth (d 0) lambs were individually identified via numbered ear tag and birth weight (avg. = 5.1 ± 0.2 kg), gender, type of birth, and lamb vigor were recorded. On the following day (d 1), lambs were docked and each lamb was given an injection (i.m.) of 1 mg Se and 68 USP units of Vitamin E (BO-SE, Schering-Plough Animal Health, Union, NJ). Lambs and their dams were kept in small pens with other dam and lamb groups for 1 to 2 wk before being returned to the larger flock. When lambs reached an average of approximately 10 d of age, creep feeding was initiated and lambs had free access to alfalfa hay and limited amounts of cracked corn. On d 28, lambs were

vaccinated against *Clostridium perfringens* types C and D and *Clostridium tetani* (Bar Vac CD/T; Boehringer Ingelheim Vetmedica, Inc., St. Joseph, MO). Male lambs were also castrated at this time using elastrator bands and cracked corn content of creep feed was increased to approximately 0.25 kg/lamb daily. Creep feeding continued until lambs were weaned at an average of 60 d of age at which time lambs were weighed. Weaning weights were adjusted to a single ewe lamb, mature ewe basis (Scott, 1977).

Serum Collection and Hormone Analysis

Blood samples were collected via jugular venipuncture into 10 mL serum-separator tubes (Corvac, Kendall Labs., St. Louis, MO). Samples were collected from individual lambs on d 1, 14, 28, 42, and at weaning (approximately d 60). Blood was allowed to clot at room temperature for 30 min before being centrifuged for 15 min at 4°C and 1,500 x g. Serum was then transferred to labeled plastic vials and frozen until analyzed.

Serum T3 and T4 were quantified in each sample by RIA using commercial kit components (Coat-A-Count; Diagnostic Products Corp., Inc., Los Angeles, CA) as described by Wells et al. (2003) and Richards et al. (1999), respectively. Serum IGF-1 (Berrie et al., 1995) and PRL (Spoon and Hallford, 1989) were also quantified in all samples. Within and between assay coefficients of variation were less than 15% for all hormone determinations.

Statistical Analysis

Influence of lamb gender, type of birth, and age of lamb on preweaning metabolic hormone concentrations were examined by split-plot analysis of variance using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC). Gender, type of birth, and gender by type of birth were included in the main plot and tested with animal within gender by type of birth. Sampling day (age of lamb) and its 2 and 3 way interactions with gender and type of birth were included in the subplot and tested using residual error. No gender by type of birth by day of sampling interactions were detected ($P > 0.10$). In order to examine relationships between each metabolic hormone and growth characteristics, correlation coefficients were computed.

RESULTS AND DISCUSSION

Weight Responses

Preweaning growth responses were examined in male versus female lambs and single-born lambs versus those born as twins or triplets (multiples). No gender by type of birth interactions were detected ($P > 0.30$). Male lambs were heavier than female lambs at birth ($P = 0.03$, Table 1), but differences were not present at weaning (actual or adjusted) or in ADG over the preweaning period ($P > 0.20$). Single-born lambs, however, were heavier over the entire preweaning period and grew more rapidly than multiple-born lambs ($P < 0.001$, Table 1).

Serum Hormone Profiles

Because no 2 or 3 way interactions were detected among gender, type of birth, and sampling day ($P > 0.16$) for serum T4, values were pooled across all sampling days. Single-born lambs had a greater serum T4 concentration ($P < 0.001$) than did multiple-born lambs (78 and 70 ± 2 ng/mL, respectively), yet no difference in serum T4 was observed between male and female lambs (73 and 75 ± 2 ng/mL, respectively; $P = 0.34$). Serum T4 concentration declined (quadratic, $P = 0.001$) during the preweaning period with values of 90, 83, 70, 64, and 64 (± 2) ng/mL on d 1, 14, 28, 42, and at weaning, respectively.

A birth type by sampling day interaction was present for T3 ($P = 0.01$), therefore, type of birth effects on serum T3 were examined within day. In general, serum T3 decreased over the preweaning period (linear, $P < 0.0001$) in both single- and multiple-born lambs (Figure 1). Single-born lambs had more serum T3 ($P < 0.02$) than multiple-born lambs on d 1 (3.41 and 2.75 ± 0.19 ng/mL), 14 (2.97 and 2.55 ± 0.13 ng/mL), and 28 (2.05 and 1.74 ± 0.1 ng/mL) of sampling. No differences in serum T3 concentrations were present between genders (2.14 and 2.10 ± 0.06 ng/mL for male and female lambs, respectively; $P = 0.72$; gender x day, $P = 0.16$).

Serum PRL concentration was affected by a birth type by sampling day interaction ($P < 0.0001$, Figure 1). Single-born lambs had more ($P < 0.03$) serum PRL than did multiple-born lambs on d 42 (103 and 76 ± 10 ng/mL) and at weaning (386 and 230 ± 40 ng/mL). However, male and female lambs had similar ($P = 0.70$) serum PRL concentrations during the preweaning period (107 and 103 ± 8 ng/mL, respectively; gender x day, $P = 0.56$).

Interactions occurred between both gender and birth type and sampling day for serum IGF-1, therefore, effects of gender and type of birth were examined within each sampling day. Single-born lambs had more ($P < 0.01$) IGF-1 than multiples beginning on d 14 of sampling and continuing throughout the preweaning period (Figure 1). Similarly, male lambs had more IGF-1 than did females from d 28 to weaning ($P < 0.003$). In general, IGF-1 increased from d 1 to d 14 and then decreased over the remainder of the preweaning period (quadratic, $P < 0.0001$).

Hormone and Performance Relationships

Relationships between metabolic hormones on each sampling day and actual weaning weights were also examined. All correlation coefficients between actual weaning weight and T4 and PRL on all sampling days were less than 0.45. Correlations coefficients between serum T3 and actual weaning weight were 0.60, 0.46, and 0.44 ($P < 0.0001$) on d 1, 14, and 28, respectively. Serum

IGF-1 and actual weaning weight correlation coefficients were 0.53, 0.64, and 0.62 ($P < 0.0001$) on d 28, 42, and weaning, respectively.

These data demonstrate the dramatic differences in growth responses between lambs born and raised as singles compared with those born and raised as twins. The endocrine responses observed in this study also show the effect exerted by type of birth/rearing on metabolic hormone profiles. Single-born lambs grow faster and generally have elevated T3, T4, IGF-1, and PRL concentrations during most of the preweaning period. Gender differences in hormone concentrations were less pronounced with only IGF-1 differing in male and female lambs during the last 30 d of the preweaning period. The moderate correlation coefficients between serum T3 and IGF-1 and subsequent weaning weight warrant further study.

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Table 1. Preweaning growth responses in male and female lambs born as singles or multiples[1]

Item	Gender[2]			Birth type[3]		
	Females	Males	SE	Singles	Multiples	SE
Birth weight, kg	5.1[a]	5.5[b]	0.13	5.7	4.9	0.15
Actual weaning weight, kg	22.4	21.6	0.71	25.4	18.6	0.83
Adjusted weaning weight[4], kg	23.7	22.5	0.69	25.6	20.6	0.81
Preweaning ADG, kg/d	0.281	0.270	0.01	0.319	0.231	0.01

[1]Gender by birth type interactions were not detected ($P > 0.30$). Male lambs were castrated at 28 d of age and weaning occurred at approximately 60 d of age.
[2]Row values without superscripts do not differ ($P > 0.20$).
[3]Row values differ ($P < 0.001$).
[4]Weaning weight was adjusted to a single ewe lamb mature ewe basis (Scott, 1977).
[ab]Row values within gender with different superscripts differ ($P = 0.03$).

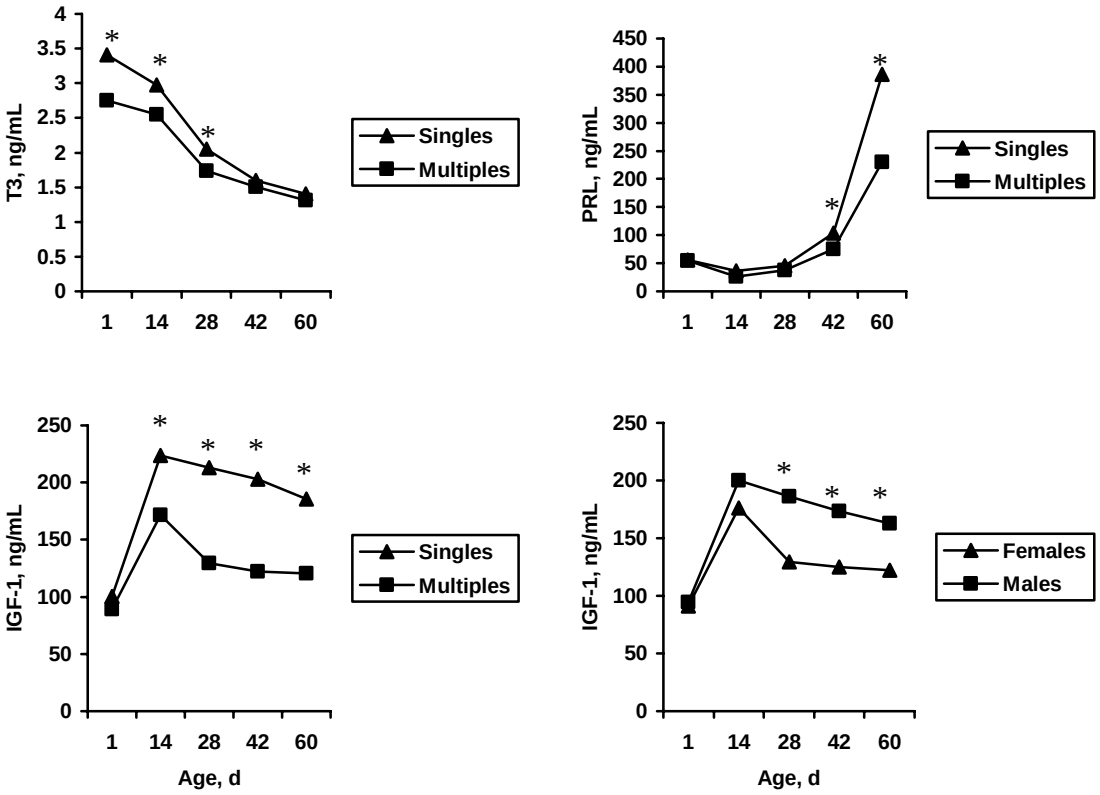

Figure 1. Serum concentrations of triiodothyronine (T3; top left panel; SE range 0.06 to 0.19 ng/mL), prolactin (PRL; top right panel; SE range 5.3 to 39.7 ng/mL), and IGF-1 (bottom left panel; SE range 6.9 to 16.0 ng/mL) in single- and multiple-birth lambs during the preweaning period (type of birth by sampling day, $P < 0.02$). The bottom right panel shows serum IGF-1 concentrations (SE range 5.8 to 13.5 ng/mL) in female and male lambs during the preweaning period (gender by sampling day, $P = 0.05$). An * indicates differences within day ($P < 0.02$).

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THE EFFECTS OF BREED TYPE AND GROWING PROGRAM ON FEEDLOT PERFORMANCE AND FAT GAINS IN BEEF STEERS

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ABSTRACT: In order to study the impact of energy restriction during the growing phase on subsequent fat development, 60 Angus x Hereford (BX) steers averaging 225 kg and 9 months of age and 60 Gelbvieh x (Angus x Hereford) (GX) steers averaging 250 kg and 10 months of age were stratified within biological type by weight and hip height and assigned to one of two dietary treatment groups. Moderate (M) and Low (L) dietary groups were fed to gain 1.50 and 0.90 kilograms per day, respectively, until reaching 327 kg (BX) or 354 kg (GX). Growing diets contained 11% crude protein and 1.32 (L) and 1.59 (M) Mcal NEm/kg DM. At that point, all animals were placed on a high-energy ration (2.22 Mcal NEm/kg DM) and fed until they reached 12 mm backfat. Backfat (UFAT) and intramuscular fat (UPFAT) were determined by real-time ultrasound at the 12-13th rib. Steers were fed in group pens (10/pen), and the pen was used as a replicate in all analyses. Average days on the high-energy rations during the finishing phase were 157, 79, 199, and 94 for BX-L, BX-M, GX-L and GX-M respectively. During the growing phase, GX steers had greater DMI and ADG than BX steers ($P < 0.001$), with no difference in gain:feed. Animals in the M dietary group had greater DMI, ADG and gain:feed in the growing phase than those in the L group ($P < 0.001$). In the finishing phase, BX steers had greater ADG and gain:feed than GX steers ($P < 0.05$), as well as more rapid gains of UFAT ($P = 0.003$) and UPFAT ($P < 0.10$) than GX steers. Also, the L dietary groups had lower UFAT and UPFAT gains than the M groups ($P = 0.005$). During the finishing phase, the L dietary groups required an increased number of DOF and also exhibited a reduced gain:feed ratio when compared to the M dietary groups. Growing program did not affect DMI or ADG during the finishing phase. However, the L dietary groups showed reduced rates of backfat and marbling fat deposition during the subsequent (finishing) phase ($P = 0.005$), supporting the hypothesis that energy restriction during the growing phase impairs adipose tissue development and fat accretion during finishing.

Keywords: beef cattle, growing program, fat accretion

Introduction

The composition of diets fed to calves during the growing phase is variable. Growing programs that are forage-based cannot guarantee a consistent nutrient supply, especially if range is the primary forage source. Variables such as weather, water supply, stock densities and plant species can all affect forage quality. Even so, stocker programs utilize forage to provide animals with enough gain to reach ½ to ⅔ of their predicted harvest weight (Sainz and Vernazza-Paganini, 2004). By implementing a stocker-based growing program, producers can make use of lower quality feed to provide gain at low cost. This practice reduces feed costs relative to concentrate rations, however animals that remain on forage-based diets for an extended period of time before the finishing phase have been found to have reduced quality grades (Schoonmaker et al., 2004a), increased intake (Owens et al., 1993) and heavier weights at time of harvest to achieve adequate finish (Sainz and Vernazza-Paganini, 2004). Steers placed directly onto high-energy concentrate diets following weaning had greater gain, lesser intake and better efficiency when compared to steers grown on pasture before finishing (Myers et al., 1999). Therefore, this study aimed to examine the effects of varying degrees of energy restriction during the growing/backgrounding period on subsequent animal performance and fat deposition.

Materials and Methods

One hundred twenty steers were placed in a growing program at the UC Davis feedlot. Sixty animals were Angus x Hereford (British; BX) steers from the UC Davis herd (average 225 kg BW, 9 months of age), and 60 were Gelbvieh x Angus x Hereford (GX) steers (average 250 kg, 10 months of age). Steers were stratified within biological type by weight and frame size (hip height) and assigned to one of two diet groups. Moderate (M) and Low (L) groups were fed growing rations (11% crude protein; 1.59 and 1.32 Mcal NEm/kg DM, respectively) on an ad libitum basis until reaching 60% of estimated slaughter weight (BX, 327 kg; GX, 354 kg). At that point, all animals were fed a high-energy ration (2.22 Mcal NEm/kg DM) on an ad libitum basis until they reached market finish (12 mm backfat as determined by ultrasound).

Steers were housed in 12 pens of 10 steers/pen. Feed offered was weighed daily and refusals were weighed weekly. Body weights and hip heights were recorded every 28 days, with no restriction of feed or water before weighing. Simultaneously, ultrasound images were collected using an Aloka 500-V instrument with a 17-cm 3.5 MHz transducer (Corometrics Medical Systems, Inc., Wallingford, CT, USA) by an Ultrasound Guidelines Council-certified field technician. Image analyses were conducted using the Biosoft Toolbox software package

(Biotronics, Inc., Ames, IA, USA). Measurements taken were: subcutaneous fat thickness at the junction of biceps femoris and gluteus medius muscle (URFAT), subcutaneous fat thickness at the ¾ position between the 12-13th ribs (UFAT), longissimus dorsi muscle area between the 12-13th ribs (ULMA) and percentage of intramuscular fat in the longissimus dorsi between 12-13th ribs (UPFAT). The University of California-Davis Campus Animal Use and Care Committee approved all procedures.

Three steers were removed from the study due to structural unsoundness. Statistical analysis of data was performed using the GLM procedure (Minitab Statistical Software, Release 13, Minitab, Inc., College Station, PA, USA). The model included genotype and diet treatment as main effects, plus the interaction term. Because all 60 steers in each dietary treatment group were fed in six pens (n = 10 steers/pen), all feedlot and carcass data were analyzed considering the pen as experimental unit. Due to the resulting small number of degrees of freedom, a 10% probability level was considered statistically significant; however actual P values are given to enable readers to draw their own conclusions.

Results and Discussion

Due to experimental design, days on feed (DOF) during the growth phase were identical for both genotypes within the two diet groups. However, DOF during the finishing phase were not constant for either genotype or diet group, as animals were not harvested at a constant DOF but rather at a constant backfat end point. The BX M group was fed the feedlot concentrate diet for the least amount of time and the GX L group remained on the feedlot diets the longest. Within each diet group, the BX steers were fed fewer days than the GX steers. This is in agreement with previous studies (Dolezal et al., 1993; Myers et al., 1999) that found that moderate frame size steers required fewer days on concentrate feed than large framed steers to reach a constant backfat end point. Also, the L diet groups remained on concentrate feed during the finishing phase for 91d longer than the M diet groups. This observation confirms the conclusions of Owens et al., (1995) that energy restriction decreases fat accretion rate, therefore increasing apparent mature size.

Dry matter intakes (DMI) during the growth phase were different ($P < 0.001$) between genotypes and diet groups; the interaction between these was significant as well ($P < 0.10$). DMI was higher for the GX steers than for BX steers within either diet group. In addition, animals fed the M diet had greater DMI than those fed the L diet, probably due to less gut fill. Neither growing program nor genotype affected DMI during the finishing phase. This is consistent with other authors (Block et al., 2001; Myers et al., 1999) who have found no differences in overall intakes when comparing British and Continental type steers. Sainz et al. (1995) found that increased DMI was a large contributing factor involved in the compensatory gain phenomenon. Since the L diet group did not demonstrate increased intake or ADG during the finishing phase relative to the M diet group, either the dietary restriction was not severe enough to cause compensatory gain, or both groups were equally affected. Therefore, compensatory growth was not considered to be relevant in this study.

Differences were seen in growth phase ADG between genotypes and diet groups and the interaction between these was significant ($P < 0.01$). As expected, the M diet groups had greater growing ADG than the L diet groups and the GX steers exceeded gains exhibited by the BX steers. During the finishing phase, this difference was reversed, with BX steers expressing greater gains than the GX steers ($P = 0$ .027). This contrasts with the results of Myers et al. (1999) who found no difference ADG between British and Continental type steers during high-concentrate finishing. There was no difference in finishing ADG between diet groups nor was there a significant interaction of genotype and diet group. However, those animals in the L diet group tended ($P = 0.109$) to gain more slowly than those in the M group. In contrast, Sainz et al. (1995) and Schoonmaker et al. (2004a) found that steers that were forage-fed or limit-fed concentrate in the growing phase gained faster during the finishing phase than steers backgrounded on a concentrate diet on an ad libitum basis. This discrepancy may be due to the fact that in this study there neither group was backgrounded on a high concentrate diet fed on an ad libitum basis.

During the growing phase, feed conversion efficiency, expressed as the gain:feed (DM basis), was higher in the M diet groups than in the L diet groups, due to their higher DMI and ADG. No differences in gain:feed were seen between genotypes ($P > 0.10$). In the finishing phase, however, the BX steers and M diet groups had increased gains and therefore were more efficient when compared to the GX steers and L diet groups, respectively. Similarly, Schoonmaker et al. (2004b) found that steers fed concentrate diets on a limit-fed or on an ad libitum basis during the growing phase were more efficient at converting feed to body weight gain during the feedlot finishing phase, than steers consuming forage-based diets ad libitum during the growing phase. Sainz et al. (1995) reported similar differences between steers backgrounded on a forage-based diet as compared to a limit-fed concentrate diet, and showed that the differences in performance were related to changes in maintenance requirement and intake.

No differences were found between growing treatment groups for carcass traits (data not shown). GX steers were heavier and had slightly greater dressing percentages (62 vs. 61%) than BX steers, there had heavier carcasses as well. Yield and grade were similar for all groups (data not shown). Table 2 presents the ultrasound scan data for the finishing phase. At the end of the finishing phase, differences were seen ($P < 0$ .10) between genotypes for ULMA, UFAT, UPFAT, UFAT gain and UPFAT gain. The GX steers continued to have larger REA in comparison to the BX steers. In contrast to their performance during the growing phase, BX steers exhibited increased UFAT, UPFAT, UFAT gain and UPFAT gain. URFAT measurements were statistically similar ($P > 0$ .10) for both genotypes and diet groups. These results are in general

agreement with previous reports (Block et al., 2001; Camfield et al., 1999; Dolezal et al., 1993). The L diet group had markedly lower UFAT gains and UPFAT gains during the finishing phase when compared to the M diet group. The only interaction found was between genotype and diet group (P = 0.074) for UFAT gain. By contrast, Hersom et al. (2004) reported that fat accretion in the finishing phase was unaffected by grazing ADG; on the other hand, marbling score and backfat were lower significantly and numerically, respectively, in the lower grazing ADG groups.

The observed differences in fat gain resulted in part from the differences in growth rates (Table 1) seen between both genotypes and dietary treatments. Once placed on the finishing diet, the BX steers (especially the M diet group) exhibited faster gains in comparison to the GX steers. The greater ADG seen in the BX M diet group coincides with the increased UFAT and UPFAT gain (Table 2) as well as the higher rate of gain and gain:feed (Table 2). Owens et al. (1995) remarked that faster gaining animals would be fatter if they had the capacity to dispose of more calories by fat accretion. In addition, those authors stated that energy restriction (as seen in the L diet) would decrease fat accretion rate, therefore altering body composition and increasing mature size. This explanation accounts for the increased final BW and lower BF and IMF gains seen with the L diet groups of either genotype. Recent results (Ross et al., 2005) that previous nutrition can affect expression of adipose-specific genes suggest a possible mechanism for the reduced fat gain in L steers. The differences in fat deposition between the L and M diet groups support the hypothesis that adipocyte development was impaired by early growth phase energy restriction.

Conclusions

During the finishing phase, steers backgrounded on a low energy diet required an increased number of DOF and also exhibited a reduced gain:feed when compared to animals grown on a moderate energy diet, regardless of genotype. Therefore, the L diet group was less efficient in comparison to the M diet group when finished to an identical backfat endpoint. Growing program did not affect intake or gain during the finishing phase, however the low energy growing diet reduced rates of fat deposition during the finishing phase compared to the moderate energy diet. These results support the hypothesis that adipocyte development is impaired by early growth phase energy restriction.

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Table 1. Least-square means for feedlot performance

	British cross		Gelbvieh cross			P values[a]	
	Low	Moderate	Low	Moderate	SEM[b]	Genotype	Group
Growing Phase							
Days on feed	83	55	83	55			
DMI, kg/d	5.30	6.25	5.95	7.77	0.222	0.001	< 0.001
ADG, kg/d	0.877	1.35	1.04	1.73	0.029	< 0.001	< 0.001
Gain:Feed	0.166	0.215	0.176	0.223	0.006	0.192	< 0.001
Finishing Phase							
Days on feed	157	79	199	94			
DMI, kg/d	8.30	8.18	8.80	8.10	0.354	0.561	0.278
ADG, kg/d	1.27	1.45	1.04	1.19	0.091	0.027	0.109
Gain:Feed	0.154	0.177	0.119	0.147	0.013	0.032	0.076

[a] Probability of a Type I error.

[b] Standard error of the mean (n = 3/group).

Table 2. Least-square means for ultrasound measurements in the finishing phase

	British cross		Gelbvieh cross			P values[a]	
Measurement[b]	Low	Moderate	Low	Moderate	SEM[c]	Genotype	Group
Final REA, cm^2	80.90	78.73	86.53	88.58	3.65	0.067	0.987
Final BF, cm	1.29	1.36	1.19	0.96	0.113	0.056	0.501
Final RU, cm	1.25	1.36	1.13	1.27	0.097	0.283	0.233
Final IMF, %	4.94	4.72	4.22	4.25	0.205	0.02	0.65
BF gain, µm/d	70.86	139.83	45.6	66.62	11.65	0.003	0.005
IMF gain,%/d (x1000)	9.58	17.74	5.64	13.08	2.03	0.067	0.005

[a] Probability of a Type I error.

[b] REA, longissimus muscle area; BF, subcutaneous backfat between the 12th and 13th ribs; RU, rump fat at the P8 site; IMF, intramuscular fat percentage.

[c] Standard error of the mean (n = 3/group).

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FEEDLOT PERFORMANCE AND CARCASS CHARACTERISTICS OF STEERS TREATED WITH TWO BETA-ADRENERGIC AGONISTS

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ABSTRACT: Fifty four crossbred steers with an average initial BW of 424 ± 26.6 kg were used in a 33 d feeding study. The steers were blocked by initial BW and assigned to 18 pens, each containing 3 steers. Pens were assigned to one of three treatments being: 1) Control (C: no feed additive in the diet), comprising a typical finishing formulation of steam-rolled wheat grain, whole Upland cottonseed, liquid molasses, Sudan hay, animal fat, and a mineral supplement; 2) a group supplemented with 60 mg of zilpaterol hydrochloride (ZH) per head per day, and 3) a group supplemented with 300 mg of ractopamine hydrochloride (RH) per head per day. Both ZH and RH feed additives were mixed into the mineral supplement that was added to the diet. Steers fed ZH and RH had 26 and 24% higher ADG vs. C steers ($P < 0.01$). RH steers consumed less ($P < 0.05$) DM (8.37 kg/d) than C steers (8.51 kg/d), but DM intake of ZH steers (8.46/d) did not differ ($P > 0.05$) from C steers. Addition of either beta-agonist to the diet considerably improved ($P < 0.01$) the gain:feed ratio (ZH: 0.253, RH: 0.248, vs. C: 0.185). Both beta-agonists increased hot carcass weights, with carcasses from ZH and RH steers being 7% and 5% heavier ($P < 0.01$) than carcasses from C steers. Carcass yield was higher in ZH steers (63%; $P < 0.01$) and RH steers (62.5%; $P < 0.05$), than in C steers (61%). The LM area was larger ($P < 0.05$) in ZH steers (75.2 cm^2) than in C steers (66.8 cm^2), but that of RH steers (72.2 cm^2) did not differ ($P > 0.05$) from C steers. There was a trend ($P = 0.055$) for ZH steers to have less 12th rib fat (1.36 cm) vs. C steers (1.65 cm), but the amount in RH steers (1.55 cm) did not differ from C steers. RH steers had a trend ($P = 0.07$) to produce more lean (79.6%) vs. C steers (77.4%), while meat yield of ZH steers (79.2%) and C steers did not differ ($P > 0.05$). Bone and fat yield were similar ($P > 0.05$) in all groups. Feedlot performance was greatly enhanced by β-adrenergic agonists, as well as some carcass characteristics.

Keywords: Feedlot Cattle, β-Adrenergic Receptor Agonists, Carcass Characteristics, Mexico.

Introduction

As the beef industry continues to adapt to changing consumer demands, beef producers develop and use research-based dietary additives to enhance feed efficiency. This is the case with the β-adrenergic agonists (β-AA), which improve feed efficiency while impacting carcass characteristics and meat quality of several animal species (Crome et al., 1996; Moloney et al., 1991). Countries such as Mexico and South Africa approved use of β-AA's over a decade ago to improve feedlot cattle performance and carcass traits and, among these agonists, are the feed additives zilpaterol hydrochloride (ZH) and ractopamine hydrochloride (RH). β-AA are organic molecules that bind to β-adrenergic receptors, molecules present on most mammalian cells, to increase skeletal muscle mass and protein content through hypertrophy, and reduce fat accretion (Yang and McElligott, 1989). Even though their individual mechanisms of action are not fully understood, researchers believe that β-AA administrated orally to mammals may increase muscle protein synthesis, decrease muscle protein degradation, or both, as well as decrease carcass fat mass (Dunshea et al., 2005), due to decreased lipogenesis and increased lipolysis (Mersmann, 1998). In Mexico, beef feedlot operators need to know the potential advantages of using these β-AA products during the feeding period, and their impact on carcass characteristics.

The objective of this study was to evaluate effects of ZH and RH as feed additives during the last 33 d of the feeding period on feedlot performance and some carcass characteristics of beef steers.

Material and Methods

The study was completed at the Feedlot Experimental Unit of the Instituto de Investigaciones en Ciencias Veterinarias of the Universidad Autónoma de Baja California, located 10 km south of Mexicali in northwestern Mexico. The zone has a latitude 32° 40' and longitude of 115° 28', is about 10 m above sea level and has Sonoran desert conditions. Forty-five crossbred steers (approximately 50% Charolais, 30% Limousine and largely Zebú in the remainder), and 9 Brangus, with an average initial BW of 424 ± 26.6 kg were used in a 33 d feeding study. Prior to initiation of the study, steers were managed identically, which included vaccination, application of vitamins, parasite control and implantation with a combination of 100 mg of progesterone and 10 mg estradiol benzoate (Synovex-C®; Fort Dodge Animal Health, Overland Park, KS). Fifty-five days later, the steers were treated again and re-implanted with a

combination of 200 mg trenbolone acetate and 28 mg estradiol benzoate (Synovex Plus®; Fort Dodge Animal Health, Overland Park, KS), and the study started 60 d later. Steers were blocked by initial BW and assigned to 18 pens, each containing 3 steers (i.e., 6 blocks). The Brangus steers were equally distributed in each of the three treatments. Pens were assigned to one of three treatments being: 1) Control (C: no feed additive in the diet), comprising a typical finishing formulation of steam-rolled wheat grain, whole Upland cottonseed, liquid molasses, Sudan hay, animal fat, and a mineral supplement; 2) a group supplemented (as fed basis) with 60 mg of zilpaterol hydrochloride (ZH: Zilmax®, Intervet, México City, México) per head per day, and 3) a group supplemented (as fed basis) with 300 mg of ractopamine hydrochloride (RH: Optaflexx™, Elanco Animal Health, Greenfield, IN) per head per day. Both ZH and RH feed additives were mixed into the mineral supplement that was added to the diet. Steers were weighed twice, at the beginning and end of the 33 d study in the early morning before diet was put in the feed bunks. The diet was fed twice daily (0700 and 1200 h) in a 60:40 proportion. Two steers were removed during the study, one from group C shortly after starting the study because of its violent temperament, while a group ZH steer died after 11 d on the study. Immediately after termination of the feeding phase, steers were transported to a commercial abattoir (Rastro TIF 301; located 5 Km south from the Feedlot Experimental Unit) for slaughter according to an approved technique (NOM-033-ZOO-1995: Humanitarian slaughter of domestic and wild animals in México). Carcass and hide weights were collected after removal of kidney, pelvic and heart fat. After carcasses were chilled for 24 h at -4°C, 12th rib fat (cm), *Longissimus dorsi* area (LM; cm^2), and weight of each carcass were recorded. Feedlot performance variables and carcass characteristics were analyzed using a randomized complete block design, weighted to the number of steers in each pen because of the two missing steers. Treatment effects were tested using orthogonal contrasts that compared C vs. the RH and ZH groups, respectively. Results are reported as least squares means and P values, using the GLM procedure of SAS (2004).

Results and Discussion

Initials BW (Table 1) were similar ($P > 0.05$) for all treated groups. However, final BW was higher ($P < 0.05$) for ZH and RH steers (497.7 and 488.8 kg, respectively) compared to C steers (478.2 kg). Steers fed ZH and RH had 26 and 24% higher ADG vs. C steers ($P < 0.01$). RH steers consumed less ($P < 0.05$) DM (8.37 kg/d) than C steers (8.51 kg/d), but DM intake of ZH steers (8.46/d) did not differ from C steers. Addition of either beta-agonist to the diet considerably improved ($P < 0.01$) the gain:feed ratio (ZH: 0.253, RH: 0.248, vs. C: 0.185). The effect of both beta-agonists is evident in hot carcass weights (Table 3), with carcasses from ZH and RH steers being 7% and 5% heavier ($P < 0.01$) than carcasses from C steers. As a result, carcass yield was higher in ZH steers (63%; $P < 0.01$) and RH steers (62.5%; $P < 0.05$), than in C steers (61%). The LM area was larger ($P < 0.05$) in ZH steers (75.2 cm^2) than in C steers (66.8 cm^2), but that of RH steers (72.2 cm^2) did not differ from C steers. There was a trend ($P = 0.055$) for ZH steers to have less 12th rib fat (1.36 cm) vs. C steers (1.65 cm), but the amount in RH steers (1.55 cm) did not differ from C steers. After carcasses were deboned, RH steers had a trend ($P = 0.07$) to produce more lean (79.6%) vs. C steers (77.4%), while meat yield of ZH steers (79.2%) and C steers did not differ ($P > 0.05$). Bone and fat yield were similar ($P > 0.05$) in all groups.

In feedlot operations, ADG, feed intake and feed conversion ratio are essential cost-effective traits which impact the time that steers spend in the feedlot and, therefore, profitability. In an experiment that fed the beta-agonist cimaterol to steers from week 4 of age to slaughter, Chikhou et al. (1993) found little beneficial effect on growth rate and feed efficiency compared to a shorter-term treatment. In contrast, using the recently USA approved beta agonist RH at the same dietary level as in the present study, Schroeder (2004) summarized results from 10 experiments completed in 5 US states during the feedlot finishing phase, and found that ADG, total weight gain and feed efficiency were improved in 26%, 11 kg and 20.5% respectively, when compared to non-supplemented controls. A slightly lower response in the same variables was observed in heifers treated with RH. However O'Neill (2001) reported an increase of 10.4% in ADG, and 15.1% in feed efficiency in steers, consuming 6 mg/d of ZH, although these differences were not statistically significant. However, Plascencia et al. (1999) reported an improvement of 36% and 39% in ADG and feed/gain ratio, respectively, of steers when the finishing diet was supplemented with 6 mg/kg of ZH. An impressive response of almost 22 kg in HCW for the ZH group, and of 14 kg for the RH group, compared to C steers has not previously been reported. Schroeder (2004) reported an improvement in HCW of 8.3 kg in steers treated with RH and Plascencia et al. (1999) reported 13 kg more in HCW in steers treated with ZH, both vs. steers with no beta agonist supplementation. Increased muscle mass in mammals is recognized as an important effect of β-AA oral administration by increasing the synthesis of muscle protein, reducing the degradation of muscle protein, or a combination of both. This induced muscle hypertrophy by beta agonist treatment is accredited to an increased rate of muscle α-actin synthesis as well as to the inhibitory activity of calpastatin (Smith et al., 1989; Helferich et al., 1990; Yang and McElligott, 1989). Apparently, these effects were more evident for the ZH group in the present study than the RH group, due to the improvement in *Longissimus* dorsi area and the tendency to reduce 12th rib fat.

Implications

Dietary supplementation of zilpaterol hydrochloride (ZH) and ractopamine hydrochloride (RH) improved feedlot performance of steers based on values of ADG and feed efficiency. Hot carcass weight and carcass yield were also increased by β-AA

supplementation. The use of β-AA during the finishing phase may be an alternative to optimize steer performance and carcass traits.

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Table 1. Least square means of feedlot performance variables in steers supplemented with two beta-agonists during the last 33-d of feeding.

	Treatment*			Contrast, P-value		
	C	ZH	RH	C vs ZH	C vs RH	SEM
Pen replicates	6	6	6			
Number of animals	17	17	18			
Live BW, kg						
Initial	426.2	427.0	420.2	0.958	0.723	26.6
Final	478.2	497.7	488.8	< 0.001	0.030	1.74
ADG, kg/d	1.58	2.14	2.08	< 0.001	< 0.001	0.033
DMI, kg/d	8.51	8.46	8.37	0.374	0.031	0.024
ADG:DMI	0.185	0.253	0.248	< 0.001	< 0.001	0.004

* C=Control; ZH=Zilpaterol Hydrochloride; RH=Ractopamine Hydrochloride.

Table 2. Least square means of carcass characteristics and yield of steers supplemented with two beta-agonists during the last 33-d of feeding.

	Treatment*			Contrast, P-value		
	C	ZH	RH	C vs ZH	C vs RH	SEM
Pen replicates	6	6	6			
Number of carcasses	17	17	18			
Hot carcass weight, kg	291.7	313.6	305.3	< 0.001	0.002	1.33
Skin weight, kg	42.7	44.4	41.2	0.365	0.418	0.75
Carcass yield, %	61.00	63.01	62.48	0.003	0.018	0.217
Longissimus area, cm^2	66.75	75.23	72.17	0.026	0.132	1.370
12^{th} rib fat, cm	1.65	1.36	1.56	0.055	0.494	0.058
Lean, %	77.42	79.15	79.63	0.138	0.071	0.454
Bone, %	5.58	5.28	5.38	0.186	0.367	0.088
Fat, %	11.74	10.74	11.36	0.376	0.736	0.458

* C=Control; ZH=Zilpaterol Hydrochloride RH=Ractopamine Hydrochloride.

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MEAT QUALITY OF STEERS TREATED WITH TWO BETA-ADRENERGIC AGONISTS

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ABSTRACT: Fifty four crossbred steers with an average initial BW of 424 ± 26.6 kg were used to determine the effect of two beta-agonists on meat quality of feedlot steers. The steers were blocked by initial BW and assigned to 18 pens, each containing 3 steers. Pens were assigned to one of three treatments being: 1) Control (C: no feed additive in the diet), comprising a typical finishing formulation of steam-rolled wheat grain, whole Upland cottonseed, liquid molasses, Sudan hay, animal fat, and a mineral supplement; 2) a group supplemented with 60 mg of zilpaterol hydrochloride (ZH) per head per day, and 3) a group supplemented with 300 mg of ractopamine hydrochloride (RH) per head per day. Both ZH and RH feed additives were mixed into the mineral supplement that was added to the diet. Meat from the ZH and RH supplemented steers had higher SF values ($P <$ 0.01) than control steers (ZH=5.11; RH=4.83; C=4.39 kg/cm^2). Variables related to meat color indicated that both beta-agonists led to a similar redness of the LM area related to C group. In general, meat tenderness from treated animals was classified as intermediate. Furthermore, meat colour was not altered by beta agonist supplementation.

Keywords: β-Adrenergic Receptor Agonists, Shear Force, Meat Quality, Mexico.

Introduction

Countries such as Mexico and South Africa approved use of β-AA's over a decade ago to improve feedlot cattle carcass traits and meat quality and, among these agonists, are the feed additives zilpaterol hydrochloride (ZH) and ractopamine hydrochloride (RH). The feed additive RH was approved in the USA in 2003 for use in cattle, but ZH has not yet been approved. Use of all β-AA's is prohibited in Europe (Council of European Communities, 1986), and there is no likelihood that this will change in the near future. β-AA are organic molecules that bind to β-adrenergic receptors, molecules present on most mammalian cells, to increase skeletal muscle mass and protein content through hypertrophy, and reduce fat accretion (Yang and McElligott, 1989). Even though their individual mechanisms of action are not fully understood, and there are variations among species, researchers believe that β-AA administrated orally to mammals may increase muscle protein synthesis, decrease muscle protein degradation, or both, as well as decrease carcass fat mass (Dunshea et al., 2005), due to decreased lipogenesis and increased lipolysis (Mersmann, 1998). In Mexico, beef feedlot operators as well as meat packers and retailers need to know the potential advantages of using these β-AA products during the feeding period, and well as their impact on carcass characteristics and meat quality, since they effect consumer decisions on meat purchase.

The objective of this study was to evaluate effects of ZH and RH as feed additives during the last 33 d of the feeding period on meat quality of beef steers.

Material and Methods

The feedlot study was completed at the Feedlot Experimental Unit of the Instituto de Investigaciones en Ciencias Veterinarias of the Universidad Autónoma de Baja California, located 10 km south of Mexicali in northwestern Mexico. The zone of study and management of steers during the feedlot phase were previously described (Avendaño-Reyes et al., 2006). Immediately after termination of the feeding phase, steers were transported to a commercial abattoir (Rastro TIF 301; located 5 Km south from the Feedlot Experimental Unit) for slaughter according to an approved technique (NOM-033-ZOO-1995: Humanitarian slaughter of domestic and wild animals in México). Two *Longissimus dorsi* steaks cut (10 cm thick) from each carcass were removed between 12th and 13rd rib interface and frozen immediately in dry ice and shipped to the Meat Quality Laboratory of the IICV-UABC in Mexicali (B.C., México) where they were frozen at -20°C and vacuum-packaged until later meat quality trait determination. Half of the steaks cut from each animal were analyzed 5 d postmortem and the remaining half at 14 d. Variables measured at these times included pH, color, shear force, water-holding capacity and drip loss. For pH analysis, a portable pH meter with a punction electrode (Delta Track Inc., ISFET pH 101, Pleasanton, CA) was used. The color values L^* (lightness), a^* (redness), and b^* (yellowness) were determined using a Minolta CM-2002 spectrophotometer (Minolta Camera, Co., Ltd, Osaka, Japan), utilizing an integrated specular component (SCI), a D_{65} illuminator, and a 10° observer. The chroma (C^*) and hue angle ($h°$) were estimated as: $C^* = (a^{*2} + b^{*2})^{½}$, and $h° = \tan^{-1}(b^*/a^*)$. The 10 cm thick steaks previously obtained from the rib were thawed and tempered for

approximately 24 h at 4°C. To obtain shear force (SF) values, previously cooked meat pieces of 1.27 cm in diameter were cut parallel to the muscle fiber orientation. The SF measurements (kg/cm^2) used a Lloyd Texturometer (Lloyd Instruments, Fareham, Hampshire, United Kingdom) equipped with Warner-Bratzler shear blades with a crosshead speed of 50 mm/min. Water-holding capacity (WHC) was determined using a modified compression technique described by Owen et al. (1982), from the method termed 'press juice' (Boakye and Mittal, 1993), in which 0.3 kg of meat sample is positioned between two layers of filter paper and two plaques of acyclic Plexiglas, and compressed at force of 5 N for 60 sec using the Lloyd Texturometer. The WHC was estimated as juice lost divided by the initial sample mass. Drip loss (DL) was measured using the technique described by Honikel and Hamm (1994). Meat quality variables measured over time (pH, *L*, a*, b*, C*, h°,* SF, WHC, and DL) were analyzed using a mixed model in a randomized complete block design, by using the REPEATED and RANDOM statements of the MIXED procedure of SAS (2004).

For each meat quality variable analyzed, several variance-covariance structures were evaluated (i.e., unstructured, simple, compound symmetry, first order autoregressive, first order heterogeneous autoregressive). Selection of the variance-covariance structure was based on Akaike's Information Criterion and the Bayesian Information Criterion, with the variance-covariance structure which resulted in these two criterions closest to zero being used (Littell et al., 1996). Simple variance-covariance structure had the best fit for WHC, *L**, *a**, *b**, *C**, and *h°* variables, while for pH and DL variables the first order heterogeneous autoregressive had the best fit. Finally, SF best fit a first order autoregressive variance-covariance structure. The linear model for meat quality variables included effects of day, block, treatments and the interaction of day by treatment. Pen within treatment was considered as a random effect. The same orthogonal contrasts were used. Least square means and standard errors are reported and significance was declared at the 5% level.

Results and Discussion

Meat quality parameters are shown in Table 1, which contains least square means and SEM for each variable in each treatment, as well as *P* values of the effects included in the model. Treatment effect was important ($P < 0.01$) for SF, indicating that both beta agonists (ZH=5.11; RH=4.83; C=4.39 kg/cm^2) led to an apparently toughening of the LM area. There was a treatment effect ($P < 0.05$) for *h°*, indicating that both beta-agonists led to increased redness of the LM area compared with C steers. There was only a trend ($P = 0.065$) for *b** in treatment RH (9.81) to be higher than in C steers (9.369), while the ZH treatment (9.26) did not differ from C steers. A day by treatment interaction occurred ($P < 0.05$) for pH, WHC, DL, *L*, a** and *C** variables. The interaction for pH indicated that, in general, LSM pH values decreased slowly from d 1 to 5, and then increased by d 14, with any value out of the normal range of pH of 5.3 to 5.7. Therefore, these changes are not large enough to suggest an alteration of meat pH. Same situation was observed with variables DL, *C** and *a** variables, suggesting that color was similar for all groups. The WHC tended to decrease from d 5 to 14 in C and RH groups, although WHC for ZH steers had an opposite effect with time (Figure 1). Meat lightness (*L**) was similar for all groups ($P > 0.05$) on days 1 and 14, however, on day 5 C steers showed lower ($P < 0.05$) *L** values than treated steers (Figure 2).

According to Price and Schweigert (1987), the pH range that categorizes a meat as 'normal' is between 5.4 and 5.8, and the pH values obtained in the present study from the three groups were close to the lower value of this range. This suggests that our beta agonists did not alter meat pH, which is consistent with results of experiments using other beta-agonists. For example, Fiems et al. (1990) fed cimaterol to Charolais and double muscled Belgian white-blue bulls and concluded that the treatment did not change meat pH, color or water holding capacity.

In the present study, both β-AA increased the shear force of meat, which has been a general result in studies using feedlot cattle supplemented with these beta agonists. Vestegaard et al. (1994) reported a dramatic increase in SF (two to three folds higher) in meat from young bulls fed cimaterol, and these results were corroborated by the taste panel evaluation. Luño et al. (1999) assessed the quality of meat from steers fed clenbuterol and found that meat texture parameters determined with a Warner-Bratzler shear blade were similar at day 1 postmortem but, at day 8 postmortem, all parameters were increased in meat from treated steers. Schroeder et al. (2004) reported that ractopamine hydrochloride increased the SF of meat from steers. In addition, the sensory panel did not detect differences in juiciness or flavor of meat from treated and control steers. However, O'Neill (2001) found no differences in shear force values for meat from steers treated, or not, with Zilpaterol hydrochloride, and concluded that this beta agonist did not cause tougher meat.

Boleman et al. (1997) suggested a categorization of meat tenderness based on Warner-Bratzler shear force where an intermediate meat is classified in a range of 4.08 to 5.40 Kg and a tough meat is classified when SF is between 5.9 and 7.1 Kg. In contrast, Miller et al. (2001) classified an intermediate meat between 3.92 and 4.5 Kg and a tough one between 5.42 to 7.2 Kg. According to these two categorizations of meat tenderness, meat from steers fed both beta agonists in the present study was within acceptable or 'intermediate' classification. Factors induced by β-AA treatment, such as reduced protein degradation, probably decreased proteolytic activity, decreased collagen solubility and changed the fibre component of the muscle, which are all considered responsible for reduced meat tenderness (Geesink et al., 1993; Vestergaard et al., 1994).

According to the meat color variables measured, a trend to redness in meat color was uniform in all groups. With time, meat also tended to become paler, even though there was more red pigment than yellow. Meat from all

three treatment groups darkened with time, but the effect was more evident in the ZH group. In general, there is no strong evidence that color was affected by either beta-agonist. A trend to paler meat has been reported in studies using beta-agonists (Vestegaard et al., 1994; Geesink et al., 1993), probably due to reduced haem pigmentation and to a larger proportion of fast twitch glycolytic fibres (Wheeler and Kolimaharee, 1992).

Implications

Dietary supplementation of zilpaterol hydrochloride (ZH) and ractopamine hydrochloride (RH) increased SF, suggesting tougher meat than in the non-supplemented steers. However, meat obtained from beta-agonist supplemented steers was classified as having intermediate toughness. In general, meat color was unaffected by beta-agonist supplementation. The use of β-AA may optimize steer performance without substantively compromising meat quality.

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Table 4. Least square means of pH, water retention capacity (WRC), drip loss (DL), shear force (SF), and meat color variables (*L*, a*, b*, C*,* and *h*°) in steers supplemented with two beta-agonists during the last 30-d of feeding.

	Treatments LSM and SEM[1]				Probability values for the effects in the model			
	C	ZH	RH	SEM	Day	Block	Treat	Day*Treat
pH	5.439	5.429	5.442	0.007	< 0.001	0.642	0.215	< 0.001
SF[2]	4.397	5.113	4.833	0.136	< 0.001	0.037	0.003	0.704
WRC	60.72	61.28	61.40	0.952	0.049	0.178	0.752	0.026
DL	4.138	6.170	5.927	0.227	< 0.001	0.724	< 0.001	< 0.001
*L**	34.88	35.56	35.99	0.302	0.004	<0.001	0.032	0.010
*a**	17.51	16.27	17.25	0.222	< 0.001	0.227	<0.001	0.001
*b**[3]	9.369	9.255	9.805	0.168	< 0.001	<0.001	0.048	0.067
*C**	19.88	18.74	19.88	0.234	< 0.001	0.092	<0.001	<0.001
h°[4]	28.15	29.67	29.52	0.446	0.227	<0.001	0.030	0.320

[1]C=Control, ZH=Zilpateroal hydrochloride, RH=Ractopamine hydrochloride, LSM=Least Square Means, SEM=Standard Error of the Mean;

[2]Contrasts: C vs ZH, P=0.0007 and C vs RH, P=0.0267;

[3]Contrasts: C vs ZH, P=0.6319 and C vs RH, P=0.0647.

[4]Contrasts: C vs ZH, P=0.0167 and C vs RH, P=0.0283.

Figure 1. LSM of WRC for the interaction storage time and treatment

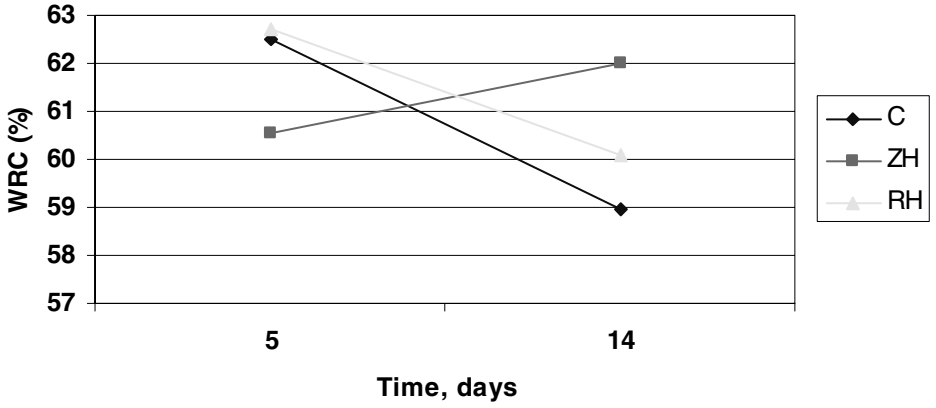
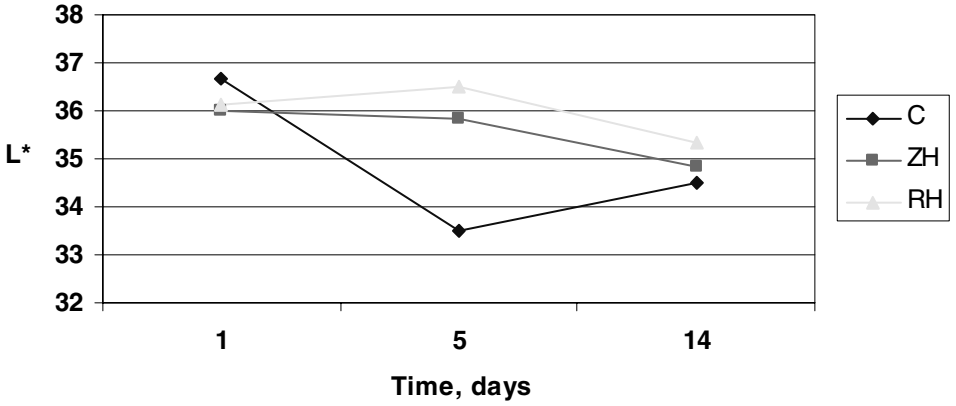


Figure 2. LSM for L* for the interaction storage time and treatment.



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EFFECTS OF FEEDING OLIVE POMACE ON THE FATTY ACID PROFILE OF PORK[1]

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ABSTRACT: The objective of this study was to determine the effects of including olive pomace in a swine finishing diet on the lipid profile of pork. Sixty crossbred gilts and barrows of Duroc, Hampshire, and Yorkshire breeding were randomly assigned to one of two treatment groups: a corn-based control versus olive pomace (10% inclusion rate) across initial weight. Swine were maintained in a concrete finishing facility at the California State University, Chico Agricultural Teaching and Research Center and given free access to feed and water throughout the trial. Upon harvest (45-d finish), *Longissimus* muscle was obtained from matching locations (post-12th rib) from each pig, aged 14 d at 34° C, and then frozen until ground for lipid analysis. Lipids were extracted from chops in triplicate using a modified version of the Stanton et al. (1997) procedure. Saturated, mono- and poly-unsaturated, omega3, omega6, and conjugated linoleic fatty acid contents of each chop were then determined by gas chromatography using procedures described by Realini et al. (2005). Data were analyzed using ANOVA (Statistix 8, 2003) as a 2 X 2 X 3 factorial where there were 2 genders, 2 diets, and 3 sire breeds. Pork finished with olive pomace was significantly lower in saturated fat, polyunsaturated fat and omega-6 fatty acids ($p<.05$) compared to the control diet. Pomace-finished pork appeared to be 5.05% lower in saturated fat, 2.22% lower in polyunsaturated fats, and 2.47% lower in omega-6 fatty acids compared to corn-finished pork. Results also suggested no significant differences among diets for monounsaturated fat, omega-3 fatty acids, omega-6:omega-3 ratio, and conjugated linoleic acid ($p>.05$). Breed and gender did not appear to significantly affect pork lipid profiles. Research suggests the inclusion of olive pomace as a component of a swine finishing diet appears to lower the percent saturated fatty acids, total polyunsaturated fatty acids, and omega-6 fatty acids in pork, providing consumers a healthier meat product from a human health point of view.

Key Words: Pork, Fatty Acid, Lipids

Introduction

United States' olive oil production represents .1% of the world's production with California accounting for 99% of the domestic production (Vossen and Devarenne, 2005). A major by-product of the olive oil production process is olive pomace, pulp with the majority of oil and water removed. While by-products such as brewer's grains and almond hulls are common in livestock diets, there appears to be an opportunity for olive oil producers to capture market share in by-product feeds, especially in California. While few studies exist characterizing the benefits of including olive pomace in sheep and cattle diets and the subsequent growth performance and meat quality (Sansoucy et al., 1984), even fewer exist on the effects of olive pomace on monogastric performance and meat attributes, such as those of swine. Thus, the objective of this study included determining the effects of including olive pomace in a swine finishing diet on the lipid profile of pork.

Materials and Methods

The olive by-product included olive waste with the oil and majority of water removed known as "partly destoned exhausted olive cake" (Sansoucy et al., 1984). Due to its water content, olive pomace spoils easily; thus, it must be fed to animals quickly or ensiled. Upon delivery of the olive pomace, a sample was sent to A&L Western Ag Laboratories (Modesto, California) for analysis to determine nutritional value. The product quickly molded; thus, the sample was also evaluated for alfatoxin due to its potential negative effects on the health of the experimental animals (Schell et al., 1993; van Heugten et al., 1994). Table 1 contains the nutritional value of the olive by-product on both a dry and as-fed basis. Olive waste appears to be a good source of fat and contributes a fair amount of crude protein to the diet. Due to the fat in the olive product, it was determined to perform feeding trials on pigs in the last 30-45 days of finishing. High energy feeds allow for fat deposition during the finishing phase of production.

On August 27, 2004, sixty crossbred gilts and barrows of Duroc, Hampshire, and Yorkshire breeding were randomly assigned to one of two treatment groups: corn-based control versus olive pomace (10% inclusion rate). Upon analysis, there were only slight differences in nutritional value of the two treatment diets (Table 2).

Pigs were maintained in a concrete finishing facility at the California State University, Chico Agricultural Teaching and Research Center. Animals were given free access to feed and water throughout the trial. Animals were fed the

[1]Funded in part by the California State University Agricultural Research Initiative and the Sierra Olive Oil Group.

grower/finishing ration over a 45-d period. During subsequent processing, one inch thick chops were removed from the *longissimus lumborum* (loin) between the 12th rib and the 5th lumbar vertebrae of each side of the carcass. The chops were then aged fourteen days and vacuum packaged on day fourteen prior to being frozen. The chops remained frozen until fatty acid profile analyses could be performed. Lipids were extracted from chops in triplicate using a modified version of the Stanton et al. (1997) procedure. Saturated, mono- and poly-unsaturated, omega3, omega6, and conjugated linoleic fatty acid contents of each chop were then determined by gas chromatography using procedures described by Realini et al. (2005). Data were analyzed using ANOVA (Statistix 8, 2003) as a 2 X 2 X 3 factorial, fitting 2 genders, 2 diets, and 3 sire breeds.

Results and Discussion

Pork finished with olive pomace was significantly lower in saturated fat, polyunsaturated fat and omega-6 fatty acids (Table 3; $p<.05$) compared to the control diet. Olive pomace fed pork appeared to be 5.05% lower in saturated fat and 2.47% lower in omega-6 fatty acids compared to corn finished pork. Similarly, Fontanillas et al. (1998) found that subcutaneous fat samples from pork fed pomace oil was 2% lower in saturated fatty acids compared to pork fed hydrogenated fat and linseed oil. Fontanillas et al. (1998) also suggested that diets including pomace oil decreased omega-6 in subcutaneous fat samples, suggesting that pork fed pomace appears to decrease both saturated and omega-6 fatty acid levels. Results also suggested no significant differences among diets for monounsaturated fat, omega-3 fatty acids, omega-3:omega-6 ratio, and conjugated linoleic acid ($p>.05$). Breed was not a significant factor in the determination of fatty acid profiles. Research by van Laack and Spencer (1999) found that the fatty acid composition of phospholipids depended upon the population studied. Researchers reported differences among swine genetic lines for saturated and polyunsaturated fats but none for monounsaturated fats.

Implications

The inclusion of olive pomace (water and oil removed) as a component of a swine finishing diet appears to lower the percent saturated fatty acids and omega-6 fatty acids in pork, providing consumers a healthier pork product from a human health/diet point of view. An opportunity to capture a share of the by-product feeds market may exist for olive oil processors currently disposing of their pomace waste. Olive pomace appears to be a viable alternative by-product feed, especially when considering its potential effects on the fatty acid profile of the resulting pork product.

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Table 1. Feed analysis for olive by-product.

Sample	Moisture %	Crude Protein %	Crude Fat %	Fiber %	NFE %[1]	Total Carbohydrate %	Ash %	Aflatoxin
Olive By-Product	0 19.91	13.75 11.01	19.53 15.64	28.09 22.5	36.35 29.11	64.44 51.61	2.28 1.83	<5 ppb

[1]Nitrogen-Free Extract

Table2. Feed analysis for olive waste diet versus corn-based (control) diet (as-fed).

Diet	Crude Protein (%)	Crude Fat (%)	Fiber (%)	Calcium (%)	Phosphorus (%)
Olive Pomace	14.0	3.9	3.1	0.6	0.53
Control	14.0	3.3	2.1	0.6	0.55

Table 3. Lipid profiles of corn-finished vs. olive-finished pork.

Treatment	SAT (%)[1]	MUFA (%)[2]	PUFA (%)[3]	Omega-3 (%)[4]	Omega-6 (%)	Omega3:Omega6	CLA (%)
Control (Corn)	35.23[a]	43.00[a]	8.72[a]	.14[a]	8.28[a]	1.63[a]	.36[a]
Olive Pomace	30.18[b]	39.06[a]	6.50[b]	.11[a]	5.81[b]	2.30[a]	.27[a]

[1]Saturated Fatty Acids
[2]Monounsaturated Fatty Acids
[3]Polyunsaturated Fatty Acids
[4]Conjugated Linoleic Acid
[a,b]Treatments within column (lipid) without common superscripts differ ($p<.05$).

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Organic Zinc in diets for weaned pigs.

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Abstract: Zinc, in the form of ZnO, has been largely used as a promoter of growth among piglets. This leads to a zinc excess over the nutritional requirement and increases the zinc output through the manure. Different studies indicated the possibility of reduction in trace mineral levels of diets using organic minerals. The objective of this study was to compare different levels of Organic Zinc to ZnO added to pig diets. Ninety 21-day-old pigs, male and female, were used in a randomized block design with five treatments (0, 300, 600, 900 ppm of Organic Zinc and 2400 ppm of ZnO) and six replicates. Data were collected in four periods (0-15; 0-21; 0-35 and 0-42 days of the experiment). There was no treatment effect on feed conversion (FC) among different periods (P>0.10). Higher levels of Organic Zinc had a linear effect on average daily feed intake (ADFI, P<0.01) and average daily weight gain (ADG, P<0.01) for the 0-15 day period, on ADFI (P<0.01) and ADG (P<0.05) for the 0-21 day period and ADFI (P<0,07) for the 0-35 day period. The treatments 900 ppm of Organic Zinc and 2400 ppm of ZnO were not different (P>0.05) for ADFI in the 0-42 day period, ADG in the 0-35 day period and ADG in the 0-42 day period. Incidence of diarrhea (ID) was evaluated in the 0-15 day period of the experiment and was lower (P<0.05) in the animals fed the 2400 ppm ZnO treatment. In conclusion, animals fed ZnO had better performance than animals fed any of the Organic Zinc diets. However, the linear response among these treatments suggests that a higher Organic Zinc level than 900 ppm may promote an equivalent result to ZnO.

Key Words: swine, growth promoter, performance

Introduction

Inorganic minerals such as Zn, Fe, Cu and Mn are frequently used in diets for pigs but organic minerals are becoming more important (Revy et al, 2003). Inorganic zinc sources like ZnO has a common use in pig nutrition in order to control diarrhea after weaning (Poulsen, 1995). The nutritional requirement for piglets is 100 ppm (NRC, 1998) but many companies use pharmacological levels between 2000 and 3000 ppm, which increases the excretion of zinc through the manure.

Organic minerals are an option to replace inorganic minerals. The higher bioavailability of organic forms leads to a lower excretion to the environment (Hahn and Baker, 1993). The objective of this experiment was to evaluate the effects of Organic Zinc as growth promoter in diets for weaned piglets.

Materials and Methods

This experiment was carried out with 90 piglets, male and female, 21 days old in a randomized block design with five treatments and six replicates. The animals received three diets, diet 1 (D1) from 0 to 15 days after weaning; diet 2 (D2) from 15 to 35 days after weaning and diet 3 (D3) from 35 to 42 days after weaning. All diets were formulated with 120 ppm of Zn, in the form of ZnSO4H2O. Treatments (T) were: T1 – D1 and D2 with 0 ppm Inorganic Zinc, as ZnO; T2 – D1 and D2 with 2400 ppm of Zinc as ZnO; T3 – D1 and D2 with 300 ppm of Organic Zinc (Zn Proteinate); T4 – D1 and D2 with 600 ppm of Organic Zinc and T5 – D1 and D2 with 900 ppm of Organic Zinc. Treatments were added to basal diets (Table 1).

Average daily feed intake (ADFI), average daily gain (ADG) and feed conversion (FC) were evaluated. Live weight was measured at 15, 21, 35 and 42 days after weaning. Occurrence of diarrhea (ID) was noted by one evaluator at the period from 0 to 15 days of experiment.

Table 1: Ingredients and feed composition of diets.

Ingredients (%)	Diet 1 (0-15days)	Diet 2 (15-35 days)	Diet 3 (35-42days)
Corn	52.23	63.19	67.55
Soy bean meal	27	27.38	28.30
Extruded soy	4.32	0.25	
Whey	8.18	4.11	
Fish meal	3.00		
Dried Red Cell	0.45	0.09	0.33
Yeast	0.75	0.63	0.45
Sugar	1.46	0.84	
Calcium Carbonate	0.70	0.81	0.67
Bicalcium Phosphate	0.91	1.41	1.35
Salt	0.28	0.43	0.57
L-lysine	0.15	0.19	0.13
DL-methionine	0.05	0.05	0.04
L-threonine	0.07	0.05	0.03
L-tryptophan	0.02		
Micromineral and flavours	0.34	0.47	0.50
Vitamins and antioxidants	0.11	0.10	0.08
TOTAL	100.00	100.00	100.00
EM (Kcal/kg)	3315	3276	3190
Protein (%)	21.82	18.78	18.93
Lysine (%)	1.39	1.15	1.11
Methionine (%)	0.39	0.32	0.31
Threonine (%)	0.92	0.76	0.74
Tryptophan (%)	0.27	0.22	0.22
Calcium (%)	0.99	0.82	0.72
Phosphoros Available (%)	0.43	0.37	0.35

Results and Discussion

Results are presented in Table 2. Animals of T2 obtained higher ADFI and ADG ($P<0.05$) than the ones from other treatments in periods from 0-15 and 0-21 days of experiment. Benefits of pharmacological levels of ZnO have been related by several authors (Hahn and Baker, 1993; Poulsen, 1995; Hill et al., 1996; Smith et al.).

ADFI from 0 to 42 days, ADG from 0 to 35 days and ADG from 0 to 42 days from T5 group animals were not different ($P>0.05$) those from T2 group. These data showed that lower levels of organic zinc achieved the same results than inorganic zinc for the 0-42 day period. Ward et al. (1996) observed the similar results for 250 ppm of Organic Zinc (Zn Methionine) and 2000 ppm of Inorganic Zinc (ZnO) in pig performance after weaning. Hollis et al. (2005) compared 125, 250 and 500 ppm of Organic Zinc; 2400 of Zn as ZnO and 125 of inorganic Zinc in different forms during 28 days. At the same level, Organic Zinc was superior for

ADFI and ADG than Inorganic Zinc. The best results for ADFI and ADG were obtained with 2400 ppm of Zn as ZnO.

ID was lower for T2 animals (P<0.05). The control mechanism of diarrhea by which Zinc works is not clear yet, but differences in Zinc solubility from organic and inorganic sources and their effects on intestinal bacteria may be involved. (Pousen, 1995; Cromwell, 2001). Carlson et al. (1999) explained the effect of pharmacological doses of ZnO by a higher level of metallothionein in the intestinal mucosa which increases protein synthesis and cell proliferation.

Linear effects were observed with the increase of level of organic zinc for ADFI (P<0.01) and ADG (P<0.01) in the period 0-15 days, for ADFI (P<0.01) and ADG (P<0.05) in the period 0-21 days and for ADFI (P<0.07) in the period 0-35 days.

In conclusion, ZnO promoted better performance than other treatments. The linear effect of different zinc doses suggests that higher levels of organic zinc may improve pig performance. Studies should be conduct in order to find the best dose and period of utilization for Organic Zinc.

Table 2. Average Daily feed intake (ADFI), average daily gain (ADG), feed conversion (FC) and incidence of diarrhea (ID) in piglets feed organic and inorganic zinc as growth promoter

Period	Item	Organic Zinc					Effect	CV
(days)	(ppm Zn)	0	300	600	900	2400		(%)
0-15	ADFI(g)	209[b]	235[b]	233[b]	278[b]	331[a]	L^1	11.90
	ADG(g)	141[b]	142[b]	159[b]	190[b]	235[a]	L^1	17.90
	FC	1.59[a]	1.69[a]	1.46[a]	1.47[a]	1.42[a]	NS	17.90
0-21	ADFI(g)	306[b]	334[b]	334[b]	382[b]	451[a]	L^1	11.00
	ADG(g)	217[b]	223[b]	236[b]	261[b]	310[a]	L^2	12.20
	FC	1.43[a]	1.50[a]	1.41[a]	1.46[a]	1.45[a]	NS	7.10
0-35	ADFI(g)	502[b]	571[b]	544[b]	596[b]	699[a]	L^3	12.10
	ADG(g)	288[b]	313[b]	313[b]	330[a]	394[a]	NS	13.30
	FC	1.76[a]	1.82[a]	1.74[a]	1.81[a]	1.78[a]	NS	5.40
0-42	ADFI(g)	628[b]	692[b]	669[b]	713[a]	800[a]	NS	10.20
	ADG(g)	359[b]	378[b]	390[a]	396[a]	457[a]	NS	11.90
	FC	1.76[a]	1.83[a]	1.72[a]	1.80[a]	1.75[a]	NS	4.70
0-15	ID(%)	24.90[b]	23.16[b]	19.03[b]	20.47[b]	0.56[a]	NS	50.80

[a,b]–Means in the same line with different letters are different - Dunnett-Hsu (P<0.05)
L^1-Linear (P<0.01), L^2- Linear (P<0.05),L^3-Linear (P<0.07)

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A STUDY OF SWEET (SURUMI, PATACAMAYA, SAYANA, CHUCAPACA) AND BITTER (REAL) BOLIVIAN QUINOA CULTIVARS COMPARED TO CORN, BARLEY AND OATS ON THE GROWTH OF IMPROVED GUINEA PIGS

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ABSTRACT: Quinoa is an Andean grain that is noted for its amino acid profile which is especially high in lysine. Traditionally the production of bitter (saponin-containing cultivars) has prevailed. However, many new sweet cultivars that are saponin-free now exist but there is little information as to their feeding value. A trial was conducted to evaluate the feeding value during growth of the sweet quinoa cultivars Surumi, Patacamaya, Sayana and Chucapaca and the bitter cultivar Real using the improved Andean guinea pig as the animal model. The quinoa-based diets were compared to those based on corn, barley and oats. The bitter variety Real was fed *as is* (saponin-containing) or washed (saponin-free). Growth and feed conversion (F:G) of the weaned guinea pigs were used as parameters. For the 42-d growth trial, 108 fourteen day old guinea pigs were divided into the nine treatment groups. Weight gains from feeding sweet quinoas (366 to 414 g) were greater ($P<0.05$) than from Real, unwashed (307 g) or washed (308 g). Growth of guinea pigs from feeding corn (337 g) was similar ($P>0.05$) to three sweet cultivars but lower than from Surumi (414 g). Surumi-fed guinea pigs exceeded ($P<0.05$) the growth of all other treatments while those fed barley (246 g) gained at a lower ($P<0.05$) rate than all others. F:G was more efficient ($P<0.05$) for the sweet quinoa treatments (4.15 to 4.37) than for feeding corn (5.71) and barley (5.71). Feed intake was lower ($P<0.05$) for Real (1278 g) and higher ($P<0.05$) for corn (1896 g) than the other feeding groups. In conclusion sweet quinoa appears especially promising as a guinea pig feedstuff. Sweet quinoa was more effective than bitter quinoa (saponin-containing or -free) in stimulating animal growth and growth from sweet quinoas exceeded that of barley and was similar to corn and oats except the cultivar Surumi which significantly exceeded all quinoas, corn and barley. Feed conversions were generally more efficient from the sweet quinoas than from traditional grains or bitter quinoa.

Key Words: Quinoa, growth, guinea pig

Introduction

Quinoa (Chenopodium quinoa) was an important pseudo cereal to the ancient Incas. It was referred to in their language, Quechua, as *chisiya mama* or "mother grain" (NRC, 1989). It is widely used in the Andean Quechuan and Aymaran cultures as an important food source. Its protein content typically ranges between 14-18 percent (Gee et al., 1993) but some report a level as high as 23 percent (NRC, 1989). It is especially noted for its amino acid profile with Fleming and Galwey (1995) reporting it was superior to that of wheat, barley and soybean and comparable to casein. Ranhotra et al. (1993) reported the lysine content (6.30g/100g protein) was comparable to soybean. Its average lipid content is 5.8% (Koziol, 1993) which exceeds corn (4.3-4.8%) but unlike corn it is not only rich in linoleic (18:2 n-6) but also linolenic acid (18:3 n-3).

Some quinoa cultivars contain the anti-nutrients saponin and triperpene glucosides that dimish their acceptability. These substances are water-soluble and are traditionally removed by a water bath before the grain is consumed. Saponins reportedly hemolyze red blood cells (Reichert et al., 1986). Gee et al. (1993) found that exposure of the small intestine mucosa of rats to saponins led to an increase in permeability to macromolecules and a reduction in the animal's ability to actively accumulate transported nutrients. Ruales and Nair (1993) reported that quinoa is further compromised by a relatively high level of phytic acid. They reported that phytates were found throughout the grain but saponins were primarily limited to the outer layers.

Feeding bitter, unprocessed quinoa has been variously reported as growth depressive (Cardozo and Bateman 1961, Mahoney et. al., 1975, Jacobsen et al., 1997, Improta and Kellems, 2001). Washing and/or dehulling quinoa (methods of removing saponins) reportedly improved its feeding value and it became noticeably less growth-depressive (Mahoney et al., 1975, Improta and Kellems, 2001) or had little impact (Jacobsen et al., 1997).

The guinea pig is used as an animal model in this study. It originates in the Andean regions of Peru, Ecuador, Colombia and Bolivia (Chauca, 1995). There it remains an important food source as evidenced in Peru where the annual consumption is 116,500 tons from more than 65 million animals (Chauca, 1995).

The objective of the current study was to evaluate the feeding value of five major Bolivian quinoa cultivars (Surumi, Patacamaya, Sayana, Chucapaca and Real) with genetically improved guinea pigs. The cultivars were

compared with each other and to corn, oats and barley. Real is referred to as bitter because it contains the bitter antinutrient saponin while the other cultivars were deemed sweet because they contain little or no saponin. Real was tested both raw (bitter) and washed (saponin free) in the traditional manner. The research methodology tried to mimic the feeding conditions of the rural Andean farm limiting dietary inputs to those available to the farmer – grain, alfalfa and salt.

Materials and Methods

A growth feeding trial was conducted at the Facultad de Agronomia de la Universidad Mayor de San Simon, Cochabamba, Bolivia to determine the feeding value of sweet versus bitter quinoa cultivars and quinoa versus corn, barley or oats The experimental design is listed in Table 1.

Table 1. Experimental design

	Number
Treatments	9
Replications	12
Animals/replication	1
Duration (weeks)	6

One hundred eight guinea pigs (male and female) were divided into 9 treatments according to the grain base (quinoa cultivars: Surumi, Patacamaya, Sayana, Chucapaca, Real, Real-washed, and corn, oats and barley) without respect to sex. Treatments were randomly assigned to each animal, but the locations for the treatments were consecutively ordered. The guinea pigs were individually housed. The trial began on day 14 of the animal's life and continued for 42 d to d 56. This period corresponds with the growth phase from weaning until slaughter. The guinea pigs had free-access to quinoa or a cereal assigned to them and salt plus approximately 20% body weight of fresh cut alfalfa (50, 50, 65, 80, 90, 100 grams/day in each of the six weeks of the trial). Parameters monitored were F:G, mortality, weekly body weights and daily feed consumption. The treatments were replicated 12 times. Results of these trials were analyzed by analysis of variance (ANOVA) and means compared by least significant difference (LSD) using Statistix (Analytical Software, 1998).

The research was designed to mimic as closely as possible the conditions that one might encounter at a small rural Andean farm having only the grain and alfalfa hay harvested at his rural farmstead coupled with salt for feed. Hence, no attempt was made to nutritionally balance the feeds of the individual feeding treatments (Table 2).

The bitter quinoa cultivar Real is saponin containing and one of the objectives of the current project was to view its feeding value with of without saponin. Traditional methods were used to remove the saponin. It was first milled with a baton to remove part of the pericarp. The baton, a stone implement shaped like a half circle, was rocked back and forth on quinoa placed on a flat surface to abrasively remove the pericarp. The quinoa was then placed in a large tub with twice its volume of water. Handfuls of quinoa were repeatedly scrubbed together with both hands and returned to the water. The saponins were periodically skimmed from the surface as foam. The water was poured off as it turned a brownish color. The tub was again filled with water and the process repeated four more times. The end product was then dried in the sun. All quinoa varieties were cracked with a small hand turned maize mill with steel burrs. It should be noted that all feed preparation processes followed were as applicable to a small farmer as possible. These methods are currently used by small farmers to prepare quinoa for their own meals.

The nutritive values of the six quinoa cultivars were determined and are published elsewhere (Pate, 2002) A few key nutritive values are listed in Table 3. The cultivars are quite similar in value except for the noticeably higher methionine content of Real and the much lower levels of threonine in Sajama and Real

Results and Discussion

Bitter quinoa vs. bitter-washed quinoa: Over the centuries Andean cultures have grown and consumed quinoa that contained saponin. To make the quinoa suitable for human use the quinoa was first washed to remove the saponin which is water soluble. In this study the saponin (bitter) cultivar Real was fed *as is* and also washed to remove its saponin (Table 4). Neither the 56-d body weights not the net gains for the six wk trial were improved by removing saponin from bitter Real. However, washing quinoa resulted in 22.4% increase in feed consumption ($P<0.05$) but since there was no improvement in gain those fed washed quinoa were less efficient ($P<0.05$) in F:G. These findings concur with Jacobsen et al. (1997) who found little improvement in the feeding value of quinoa for broiler chicks when saponin was removed and contrary to Improta and Kellems (2001) and Mahoney et al. (1975) who found the growth repressive properties quinoa were greatly improved for chicks and rats respectively following washing.

Sweet quinoa vs. bitter quinoa: In recent years geneticists have developed sweet quinoa cultivars with no or greatly reduced levels of saponin. With such varieties the cumbersome processes of washing or dehulling prior to eating can be avoided. Unfortunately, these cultivars are now vulnerable to birds who naturally avoid the bitter cultivars. In this trial four of the these cultivars were fed and all appeared very promising based in guinea pig growth (Table 4). Of the four, feeding Surumi had the most pronounced affect on growth, significantly ($P<0.05$) greater than the others. Though not significant much of the improved growth could be attributed to increased feed consumption which was 10.8% more than any other sweet cultivar. Feeding all of the sweet cultivars resulted in greater 56-d body weights and six wk gains than feeding bitter or bitter-washed quinoa. With the exception of Patacamaya, the F:G for sweet cultivars was superior ($P<0.05$) to bitter-washed quinoa.

Quinoa vs. traditional cereal grains: Corn, barley and oats are common ingredients in animal feeding and

were used for comparative purpose in evaluating the effect of quinoa on guinea pig growth (Table 4). Gains from feeding corn were similar to bitter quinoa and to three of the four sweet quinoas but inferior ($P<0.05$) to Surumi. As with corn feeding, oats resulted in gains similar to bitter quinoa but less ($P<0.05$) than that of both Surumi and Chucapaca. Gains from feeding barley were less ($P<0.05$) than those of all quinoa cultivars, corn and oats. No attempt was made to balance the diets nutritionally and grains were left to provide the nutritional needs of the guinea pigs based on their own nutritional merits (Table 2). Since quinoa contains more protein than any of the common cereal grains and its amino acid profile is distinctively better than that of the cereals, quinoa without additional supplementation more closely approximates the nutritional requirements of the guinea pig and much of the improved performance from quinoa might be attributed to these nutritional advantages.

Implications

From the standpoint post-weaning gains, removing the saponin from bitter quinoa was not advantageous. Sweet quinoa cultivars are superior to bitter quinoa for promoting guinea pig growth. When fed as stand-alone feeds, sweet quinoa cultivars are either equal to and in some cases superior to corn or oats.

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Table 2. Average nutritional composition of growth trial diets (dry matter basis)

	CP	Arg	Lys	ME	Ca	P
	%	%	%	kcal/kg	%	%
Surumi	18.3	1.27	1.02	2406	0.84	0.35
Patacamaya	19.0	1.32	1.02	2331	0.94	0.34
Sayana	18.8	1.07	0.97	2086	1.11	0.34
Chucapaca	18.6	1.17	1.01	2338	0.92	0.37
Real	18.5	1.29	0.97	2305	0.94	0.32
Real-washed	17.5	1.04	0.93	2316	0.93	0.34
Corn	14.0	0.59	0.53	2685	0.75	0.29
Oats	16.5	0.83	0.71	2017	0.95	0.27
Barley	16.7	0.71	0.68	1976	1.03	0.31
NRC[a]	20.0	1.33	0.93	3333	0.89	0.44

[a]Guinea pig requirements (NRC, 1995)

Table 3. Nutritive analyses of experimental cultivars (adapted from Pate, 2002)

Cultivar	DM[1]	Lipid[1]	CP[1]	Met[1,2]	Lys[1,2]	Thr[1,2]
	%	%	%	%	%	%
Sururmi	91.9	5.2	15.8	2.24	7.07	4.31
Patacamaya	89.0	5.4	16.6	2.13	6.73	4.09
Sayana	89.0	5.1	15.8	2.24	6.56	4.08
Chucapaca	89.4	6.0	13.9	2.13	6.84	4.64
Sajama	90.1	5.1	16.5	2.66	6.94	2.79
Real	91.0	5.3	15.8	3.17	6.99	2.82

[1]Calculated on an as-fed basis
[2]Calculated on as as-fed basis as a percent of protein

Table 4. Comparative effect of quinoa, corn, barley and oats on 42 d guinea pig growth

		Body Wt. by Days of Age[1]			42-d Performance		
Treatment	N	14 d	35 d	56 d	Wt Gain	Feed Con	F:G
		g	g	g	g	g	g/g
Surumi	12	231	417 [a]	646 [a]	414.4 [a]	1698 [b]	4.2 [a]
Patacamaya	12	227	387 [b,c]	580 [b,c]	353.5 [b,c]	1522 [b,c]	4.4 [a,b]
Sayana	12	219	383 [b,c]	586 [b]	366.2 [b,c]	1515 [b,c]	4.2 [a]
Chucapaca	12	225	380 [b,c]	596 [b]	370.6 [b]	1532 [b,c]	4.2 [a]
Real	12	231	360 [c,d]	539 [c]	307.4 [d]	1278 [d]	4.3 [a]
Real-washed	12	231	380 [c]	539 [c]	308.0 [d]	1549 [b,c]	5.1 [b,c]
Corn	12	231	392 [a,b]	569 [b,c]	337.7 [b,c,d]	1896 [a]	5.7 [c]
Oats	12	231	391 [a,b]	559 [b,c]	328.0 [c,d]	1508 [b,c]	4.7 [a,b]
Barley	12	231	341 [d]	477 [d]	245.8 [e]	1379 [c,d]	5.7 [c]
SEM		2.1	3.5	5.4	5.1	23	0.1

[1]Means followed by unlike letters are significantly different ($P<0.05$)

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THE PALATABILITY OF SWEET (SURUMI, PATACAMAYA, SAYANA, CHUCAPACA) AND BITTER (REAL) BOLIVIAN QUINOA CULTIVARS, CORN, BARLEY AND OATS AS GUINEA PIG FOODSTUFFS

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ABSTRACT: Quinoa is an Andean grain that is noted for both its protein quantity and quality. Lysine content as % of protein mirrors that of soybean. Traditionally the production of bitter (saponin-containing cultivars) has prevailed. However, many new sweet cultivars that are saponin-free now exist but there is little information as to their feeding value. It was hypothesized that these sweet varieties would be more palatable than bitter quinoa and equally as palatable as washed (saponin-free) quinoa Furthermore, they would be equally as palatable as corn, oats and barley. To test these hypotheses two trials were conducted to evaluate the palatability of the sweet quinoa cultivars Surumi, Patacamaya, Sayana and Chucapaca and the bitter cultivar Real (saponin-containing and washed, saponin-free) using the improved Andean guinea pig as the animal model. In one trial bitter quinoa was compared to sweet quinoa and in the second both sweet and bitter quinoas were compared with the common cereals corn, oats and barley. In the quinoa comparison trial, 32 four-wk old guinea pigs were separated into four replicate groups and fed only the sweet and bitter quinoa cultivars for three weeks. There was a uniform preference ($P<0.05$) for the sweet cultivars (11.5 to 24.2% of intake) and Real (washed, saponin-free) (24.1%) over the bitter cultivar Real (1.1%). In the trial comparing with cereal grains 32 weaned guinea pigs were divided into four replicate groups and concurrently offered all of the quinoa cultivars plus corn, oats and barley for three weeks. The preference for oats (46%) was overwhelming ($P<0.05$) and corn a distant second (17%). Sweet quinoa consumption was less ($P<0.05$) than corn and ranged from 10.6% for Surumi down to 1.6% for Sayana. Almost no bitter (Real) quinoa was consumed (0.3%) while washing it improved ($P<0.05$) its consumption to (7.4%). Barley consumption was similar to sweet quinoa. In conclusion, as hypothesized, removing the saponin from bitter quinoa, either as sweet cultivars or as bitter washed quinoa, improved its palatability significantly; however, when offering a concurrent choice of oats, corn, barley both oats and corn were preferred to quinoa (sweet or bitter) contrary to the hypothesis.

Key words: Quinoa, palatability, guinea pig

Introduction

Quinoa is pseudo grain that is produced and consumed extensively in the Andean countries of Peru and Bolivia. It is highly regarded for its protein content (14 to 18%) 1993) and its amino acid profile (Gee et al., 1993). Its protein quality has been favorably compared to casein (Fleming and Galwey, 1995, Mahoney et al., 1975) and soybean (Fleming and Galwey, 1995). Its greater use is impaired by the presence of the bitter antinutritional factor saponin that resides in its outer seed coat (Ruales and Nair, 1993). Saponin reportedly hemolyzes red blood cells (Reichert et al., 1986) and impairs nutrient absorption (Gee et al., 1993). Saponin is water soluble and is traditionally removed by bathing quinoa in water or may be extensively reduced by abrasively dehulling and removing the outer portion of the grain (Reichert et al., 1986).

Bitter (saponing-containing) quinoa has been observed to depress growth in broiler chickens (Improta and Kellems, 2001, Weber 1978, Jacobsen et al., 1997) and pigs (Cardozo and Bateman, 1961). For some, washing and/or dehulling quinoa improved growth (Improta and Kellems, 2001) while for others dehulling resulted in little improvement (Jacobsen et al., 1997).

To counteract the labor intensive need to either wash and/or dehull quinoa to make quinoa suitable for consumption Andean geneticists have bred sweet quinoa cultivars that have no are markedly reduced levels of saponin.

Little information exists as to the feeding value of these new cultivars; hence, two palatability trials were undertaken to compare the acceptability of the sweet cultivars Surumi, Patacamaya, Sayana and Chucapaca and the bitter cultivar Real with each other and with the common cereal grains corn, oats and barley. The cultivar Real was offered both bitter (saponin-containing) and washed (saponin free). It was hypothesized that sweet cultivars, that are largely saponin-free, and washed bitter Real cultivar with the saponin removed would be more palatable than Real in the bitter, saponin-containing state. It was further hypothesized that the sweet quinoa cultivars and saponin-free Real would be equally as palatable as the common cereals corn, oats and barley.

To simulate the conditions that exist in the rural Andean farm where the only feeding inputs available are the grain and forage no attempt was made to nutritionally balance the dietary treatments which consisted solely of the grain, fresh alfalfa and salt.

Materials and Methods

Two feeding trials were conducted at the Facultad de Agronomia de la Universidad Mayor de San Simon, Cochabamba, Bolivia to determine palatablility of bitter and sweet quinoa cultivars compared to each other and compared to corn, oats and barley The experimental design is listed in Table 1. Results of these trials were determined by analysis of variance (ANOVA) and means compared by least significant difference (LSD) using Statistix (Analytical Software, 1998).

Table 1. Experimental design

	Trial 1	Trial 2
Treatments	9	6
Replications	4	4
Animals/replication	8	8
Duration (weeks)	3	3

Corn, oats and barley were processed in a hammer-mill equipped with a 5mm screen. "Real-washed" was first milled with a baton to remove part of the pericarp. The baton, a stone implement shaped like a half circle, was rocked back and forth on quinoa placed on a flat surface to abrasively remove the pericarp. The quinoa was then placed in a large tub with twice its volume of water. Handfuls of quinoa were repeatedly scrubbed together with both hands and returned to the water. The saponins were periodically skimmed from the surface as foam. The water was poured off as it turned a brownish color. The tub was again filled with water and the process repeated four more times. The end product was then dried in the sun. All quinoa varieties were cracked with a small hand turned maize mill with steel burrs. It should be noted that all feed preparation processes followed were as applicable to a small farmer as possible. These methods are currently used by small farmers to prepare quinoa for their own meals. The diets fed to the guinea pigs during these trials were designed to mimic rural Bolivian feeding methods without regard to nutritional balance. Alfalfa and salt were included, as under traditional practice, to provide vitamin C and sodium/chlorine, respectively. Only feed ingredients commonly available to the small farmer were used as this would best illustrate the effects of including quinoa in the diets of growing and lactating guinea pigs under actual field conditions. The nutritional levels of the diets are listed in Table 2**.** A few of the nutrients properties of each cultivar are listed in Table 3 (Pate, 2002)

In the first three-wk palatability trial, eight weaned (14-18 days old) guinea pigs of the same sex were randomly placed in a large maternity pen where they had free-access to all nine treatment rations (Surumi, Patacamaya, Sayana, Chucapaca, Real, Real-washed, corn, oats and barley), salt and approximately 20% body weight of fresh cut alfalfa (50, 55, 65 grams/day for each of the three weeks, respectively). In the second three-wk trial these same guinea pigs had access to only the six varieties of quinoa (Surumi, Patacamaya, Sayana, Chucapaca, Real and Real-washed), salt and approximately 20% body weight of fresh cut alfalfa (80, 95, 115 grams/day for each of the three weeks, respectively). Location of the feeders was randomly assigned around the perimeter in the first trial and randomized again for the second trial. Locations were the same across the different replications. Feed consumption was measured weekly and values reported as a percent of total treatment feeds consumed. The trial was replicated four times.

Results and Discussion

Bitter vs. washed quinoa: When the six cultivars were offered simultaneously only 1.1% of the total consumption was bitter Real (saponin containing) (Table 4). However, when Real was offered washed (saponin free) the consumption increased significantly ($P<0.05$) to 21.9% of the total consumption. As hypothesized the presence of saponin severely impaired quinoa palatability.

Bitter cultivar washed vs. sweet cultivars: The level of consumption of the bitter-washed Real was not different from any of the sweet cultivars (Table 4) again affirming the positive impact on quinoa acceptance (palatability) from removing saponin either by processing or genetically. Again, according to the hypothesis the palatability of Real was similar to the sweet quinoas upon the removal of saponin.

Quinoa vs. common cereal grains: When the six cultivars were available concurrently with corn, oats and barley two observations were very apparent first little bitter quinoa (0.3%) was consumed and their was a decided preference for oats (45.6%) greater ($P<0.05$) than any other choice and secondly for corn (17.1%) greater ($P<0.05$) than the remaining choices. Among the quinoa cultivars washed-Real and Surumi were not different and were preferred over Sayana and Chucapaca. Contrary to the hypothesis both the common grains oats and corn were preferred to sweet or washed quinoas.

Implications

Traditionally quinoa can only be made suitable for consumption by removing its bitter saponin by washing or some other equally laborious mode which limits its use for humans or animals as compared to common cereal grains. However, the current research showed that sweet quinoa cultivars are equally as palatable as washed quinoa and their propagation in lieu of the bitter cultivars would eliminate the need for these needlessly time consuming processing procedures.

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Table 2. Average nutritional composition of palatability trial diets (dry matter basis)

	CP	Arg	Lys	ME	Ca	P
	%	%	%	kcal/kg	%	%
Surumi	18.3	1.27	1.02	2406	0.84	0.35
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NRC[a]	20.0	1.33	0.93	3333	0.89	0.44

[a]Guinea pig requirements (NRC, 1995)

Table 3. Nutritive analyses of experimental cultivars (adapted from Pate, 2002)

Cultivar	DM[1]	Lipid[1]	CP[1]	Met[1,2]	Lys[1,2]	Thr[1,2]
	%	%	%	%	%	%
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Chucapaca	89.4	6.0	13.9	2.13	6.84	4.64
Sajama	90.1	5.1	16.5	2.66	6.94	2.79
Real	91.0	5.3	15.8	3.17	6.99	2.82

[1]Calculated on an as-fed basis
[2]Calculated on as as-fed basis as a percent of protein

Table 4. Consumption of quinoa cultivars and common grains in palatability trials

Treatment	N	Trial 1	N	Trial 2
	4	% consumed	4	% consumed
Surumi		10.6 [c]		24.2 [a]
Patacamaya		6.1 [c,d,e]		19.7 [a]
Sayana		1.6 [e,f]		11.5 [a,b]
Chucapaca		4.3 [d,e,f]		21.8 [a]
Real		0.3 [f]		1.1 [b]
Real-washed		7.4 [c,d]		21.9 [a]
Corn		17.1 [b]		
Oats		45.6 [a]		
Barley		7.1 [c,d]		
SEM		1.8		0.5

Means with different superscripts are different (P<0.05)

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RUSSIAN KNAPWEED AS A PROTEIN SUPPLEMENT FOR BEEF COWS CONSUMING LOW-QUALITY FORAGE

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ABSTRACT: Russian knapweed (*Centaurea repens*) is a perennial noxious weed. Controlling Russian knapweed has proven very difficult and expensive. Sustainable invasive weed strategies may require that weeds are used in livestock production systems. Russian knapweed has protein values similar to alfalfa and may have potential as a protein supplement for beef cattle consuming low-quality forages. Therefore, we compared Russian knapweed and alfalfa (13 and 21% CP, respectively; DM basis) as protein supplements using 48 Hereford × Angus, mid-gestation, beef cows (530 ± 5 kg) offered ad libitum hard fescue straw (4% CP; DM basis) in an 84-d study. Treatments included an unsupplemented control (CON) and alfalfa (ALF) or knapweed (KNAP) provided on an iso-nitrogenous basis (approximately 0.50 kg CP/d). Cows were stratified by weight and BCS and allotted to treatments in a randomized complete block design using 12 pens (4 cows/pen; 16 cows/treatment). Means were compared using orthogonal contrasts (CON vs ALF and KNAP; ALF vs KNAP). Protein supplementation increased ($P < 0.01$) cow weight gain and BCS compared to CON with no difference between ALF and KNAP ($P = 0.47$). There was no difference ($P = 0.60$) in the quantity of straw offered between CON and supplemented groups but ALF cows were offered approximately 11% more ($P = 0.03$) than KNAP cows. Total DM offered to cows was greater ($P < 0.01$) for supplemented compared with CON cows with no difference noted between ALF and KNAP ($P = 0.79$). Russian knapweed can be used as a protein supplement for beef cows consuming low-quality forage. Thus, haying Russian knapweed in the spring and feeding in the winter may provide an alternative to controlling of large scale infestations.

Key words: Management; Ruminant, Supplementation, Weed

Introduction

Russian knapweed (*Centaurea repens*) is a perennial noxious weed native to Eurasia that is highly competitive and invades productive habitats (Duncan, 2005). It is widely established throughout the western U. S., with infestations estimated at 557,000 ha in 1998 (Whitson, 1999). Also, this weed is rapidly expanding its range, with annual spread in the western U.S. estimated between 8 and 14% (Simmons, 1985; Duncan, 2005).

Russian knapweed can be controlled with herbicides for about 3 yr, but will reinvade the site, especially if cool-season grasses cannot be established (R. L. Sheley, ARS-USDA, personal communication). A single type of treatment, such as herbicide application, will not provide a sustainable means of control for Russian knapweed. As a result, an integrated management system is the most effective for controlling this weed. However, integrated management of Russian knapweed is very difficult and expensive (Whitson, 1999).

Russian knapweed has been reported to have protein values similar to alfalfa and may have potential as a protein supplement for beef cattle consuming low-quality forages (< 6% CP; DM basis). Therefore, we compared Russian knapweed and alfalfa as protein supplements to beef cows consuming low-quality forage.

Materials and Methods

Experimental Design

Forty-eight pregnant (approximately 120 d), 3 yr old, primiparous, Angus × Hereford cows (530 ± 5 kg) were used in an 84-d performance study. Cows were stratified by body condition score (**BCS**; 1 = emaciated, 9 = obese; Herd and Sprott, 1996) and weight and assigned randomly, within stratification, to one of three treatments. Treatments were an unsupplemented control (**CON**), alfalfa supplementation (**ALF**), or Russian knapweed supplementation (**KNAP**; Russian knapweed was harvested, pre-flower, from an infested site in Harney County, OR, in May of 2005). Cows were then sorted by treatment and allotted randomly to 1 of 12 pens (4 cows/pen; 4 pens/treatment). A trace mineralized salt mix was available free choice (7.3% Ca, 7.2% P, 27.8% Na, 23.1% Cl, 1.5% K, 1.7 % Mg, .5% S, 2307 ppm Mn, 3034 ppm Fe, 1340 ppm Cu, 3202 ppm Zn, 32 ppm Co, 78 ppm I, 85 ppm Se, 79 IU/kg vitamin E, and 397 kIU/kg vitamin A). Cows were provided ad libitum access to hard fescue grass seed straw (3.8% CP; DM basis). The quantity of straw provided was noted daily. Alfalfa (20.6% CP; DM basis) and Russian knapweed (13.4% CP; DM basis) were provided Monday, Wednesday, and Friday on an iso-nitrogenous basis (approximately 0.50 $kg \bullet hd^{-1} \bullet d^{-1}$ averaged over a 7-d period). The amounts (DM basis) provided on Mondays and Wednesdays was 4.54 kg/hd and 6.80 kg/hd for ALF and KNAP, respectively. On Fridays, ALF cows received 6.80 kg/hd and KNAP cows received 10.21 kg/hd.

Data Collection

Cow body weight and BCS was independently measured every 42 d following an overnight shrink (16 h) by three trained observers. The same technicians were used throughout the experiment. Grass seed straw, ALF, and KNAP (approximately 200 g) were collected weekly, dried at 55° C for 48 h, ground through a Wiley mill (1-mm

screen), and composited by 42-d period for analysis of ADF and NDF (Ankom 200 Fiber Analyzer, Ankom Co., Fairport, NY), N (Leco CN-2000; Leco Corporation, St. Joseph, MI), and OM (AOAC, 1990).

Statistical Analysis

Cow performance data were analyzed as a randomized complete block design (Cochran and Cox, 1957) using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC). The model included block and treatment. Orthogonal contrasts (CON vs ALF and KNAP; ALF vs KNAP) were used to partition specific treatment effects. Response variables included: 1) cow weight change, 2) cow BCS change, and 3) grass seed straw offered.

Results and Discussion

Supplementation with protein has been shown to increase cow weight gain and body condition score (Clanton and Zimmerman, 1970; Bohnert et al., 2002), forage intake and digestibility (Kartchner, 1980; Köster et al., 1996), and can improve reproductive performance (Sasser et al., 1988; Wiley et al., 1991). The results of the current study agree with the studies of Clanton and Zimmerman (1970) and Bohnert et al. (2002) that protein supplementation of low-quality forage (< 6% CP; DM basis) increases cow BCS and weight gain compared with unsupplemented controls. The ALF and KNAP supplemented cows each gained 42 kg during the feeding period compared with a loss of 19 kg by the CON cows ($P < 0.01$; Table 1). No difference was noted between ALF and KNAP ($P = 0.70$). Likewise, final BCS of ALF and KNAP cows increased 0.3 and 0.2, respectively, while CON cows lost 0.9 BCS. Consequently, supplemented cows had the same BCS (5.6) at the end of the 84-d feeding period ($P = 0.47$) but greater scores than CON (4.2; $P < 0.01$).

The quantity of hard fescue straw offered was not affected by supplementation ($P = 0.60$; Table 1); however, the quantity offered to the ALF cows was 1.2 kg/d greater than that offered to the KNAP ($P = 0.03$). This was probably the result of the greater quantity of supplement DM (1.2 kg/d) provided by the KNAP which substituted for the hard fescue straw. This was verified when the total DM offered was compared. There was no difference between ALF and KNAP ($P = 0.79$; 13.2 kg/d for each), while supplemented cows had more total DM offered than the CON ($P < 0.01$).

Implications

Russian knapweed can be safely used as a protein supplement for beef cattle consuming low-quality forages. However, it should not be fed to horses because of the potential for a fatal neurological disorder, equine nigeropallidal encephalomalacia or “chewing disease”. Thus, haying Russian knapweed in the spring and feeding in the winter may provide an alternative to controlling of large scale infestations.

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Table 1. Effects of Alfalfa and Russian knapweed supplementation of low-quality, hard fescue straw offered to mid-gestation beef cows

	Treatment[a]				*P*-Value	
Item	Control	Alfalfa	Knapweed	SEM[b]	Control vs Supplemented	Alfalfa vs Knapweed
Initial Wt., kg	500	512	506	8.8	0.41	0.70
Final Wt., kg	481	554	548	5.9	< 0.01	0.47
Initial BCS	5.3	5.3	5.4	0.06	0.72	0.74
Final BCS	4.2	5.6	5.6	0.81	< 0.01	0.47
Hard fescue straw offered, kg/d	10.2	11.0	9.8	0.32	0.60	0.03
Alfalfa or Knapweed offered, kg/d	0.00	2.27	3.42			
Total DM offered, kg/d	10.2	13.3	13.2	0.32	< 0.01	0.79

[a] Control = hard fescue straw provided ad libitum; Alfalfa = Control + 2.27 kg/d alfalfa; Knapweed = Control + 3.42 kg/d Russian knapweed. All hard fescue straw, alfalfa, and Russian knapweed values are expressed as average daily DM/cow.
[b] n = 4.

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Evaluating beef cow performance: comparing crested wheatgrass/legume, big bluestem, and foxtail millet in swath grazing.

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ABSTRACT: The objective of this study was to evaluate cow performance in a swath grazing system on three different forages; crested wheatgrass *Agropyron cristatum* (CWG), big bluestem *Andropogon gerardii* (BBS), and foxtail millet *Setaria italic* (FM) in a completely random design. Grazed native range (NR) was the control treatment. For each of the swath grazing treatments, non-irrigated pasture (12.0 ha) was divided into three paddocks (4.0 ha). Three native range pastures (16.6 ha) were used as the non-swathed grazing treatment. A cooked molasses block supplement was included with the BBS due to the low CP content of the forage. One-hundred forty-four cross-bred gestating beef cows (average initial BW 557 kg ± 67 kg) were weighed and body condition scored (BCS) on two consecutive days and assigned randomly to one of four treatments. Weights and BCS were collected on two consecutive days at the conclusion of the experiment. Ten 0.25m^2 plots were clipped at ground level beginning 28 June and continuing mid-month throughout the growing season to provide samples for nutrient analysis and estimate forage production. Samples of swathed forage and clipped plots of standing native range were collected throughout the trial for nutrient analysis. Forage production for CWG, BBS, and FM was 3373, 2686, and 7414 kg DM/ha respectively. Stocking rates were 2.2, 1.7, 5.7, and 0.5 hd/ha for CWG, BBS, FM, and NR, respectively. Cows had similar final BW (P = 0.97) and BCS change was similar (P = 0.12) between treatments. While there were no differences in final BW, it is notable that the FM treatment had stocking rates 2.6 to 3.3 times that of the other treatments. Therefore, we conclude that swath grazing is an acceptable alternative to grazing native range for wintering beef cows in central North Dakota.

Key Words: Cattle, Swath Grazing, Windrowed Forage

Introduction

Many comparisons of swath grazing versus baled-forage feeding have been completed with varying results (Turner and Angell, 1987; Munson et al., 1999; Volesky et al., 2002). However, to our knowledge no direct comparison of a cool-season perennial, a warm-season perennial, or a warm-season annual exists in published literature. Volesky et al. (2002) reported calves swath grazing windrows on sub-irrigated meadows had greater weight gains than bale-fed calves in the first year of a two year study. However, in the second year, the two groups had similar gains. Schleicher et al. (2001) reported windrow-fed cows on flood irrigated meadows were 14.4 kg heavier and had a greater BCS than bale-fed cows. Turner and Angell (1987) reported similar results in a study which compared hay-fed, standing forage-fed, and rake bunch-fed cows, on flood irrigated meadow. In their study, rake-bunch fed cows were 10 kg heavier than the hay-fed group at the conclusion of the study. Munson et al. (1999) detected no differences in weight gain or BCS when heifers grazed windrowed foxtail millet compared to bale-fed foxtail millet. In contrast, Nayigihugu et al., (2002) reported cows grazing standing corn forage had greater ADG than cows grazing windrowed corn forage. Turner and Angell, (1987) reported cows grazing standing flood irrigated meadow maintained weight but had lower BCS then bale- or windrow-fed cows.

All of the previous studies have used only one class of forage. To our knowledge, no research has compared three different classes of forages in a swath grazing system. Therefore, our objectives were to evaluate cow performance in a swath grazing system on three different forages; crested wheatgrass (*Agropyron cristatum*, CWG), big bluestem (*Andropogon gerardii*, BBS), and foxtail millet (*Setaria italic*, FM).

Materials and Methods

Animals

All animal care and handling procedures were approved by the NDSU Institutional Animal Care and Use Committee prior to the initiation of the study. One-hundred-forty-four crossbred gestating beef cows were used in a completely random design. Cows grazed one of four treatments: 1) positive control grazed native range (NR), 2) swath grazed crested wheatgrass (*Agropyron cristatum,* CWG), 3) swath grazed big bluestem (*Andropogon gerardii*, BBS), or 4) swath grazed foxtail millet (*Setaria italic*, FM). All swath grazing treatment pastures were contiguous and the NR treatment pastures were 1.6 km south on similar soil types. Grazing occurred from 19 October through 15 December, 2005. Two day individual body weights and body condition scores were taken at the beginning and end of the trial. Cows were assigned BCS by visual appraisal using methods of (Richards et al., 1986).

Forage sampling

During the growing season, forage samples were collected on CWG, BBS, and FM with ten 0.25m^2 plots clipped per treatment at each sampling date. Samples were collected on 28 June, and then mid-month each month throughout the growing season, with the last clipping collected immediately prior to swathing. Native range pastures were not selected until late August, so data for production was not collected until the beginning of the grazing trial.

The CWG pasture contained a high proportion of legumes including yellow sweet clover, (*Melilotus officianalis*) and alfalfa (*Medicago sativa*). Crested wheatgrass pastures were 63% crested wheatgrass, 37% legume at first clipping, with legume decreasing to 31% of total weight DM at swathing. The big bluestem pasture also contained a large amount of other species, the majority of which was quackgrass (*Agropyron repens*). Proportions of species in BBS were (big bluestem:quackgrass) 37:63 and 31:69 at first clipping and swathing, respectively. The most prevalent species on NR were previously outlined by Schauer (2000) as being blue grama (*Bouteloua gracilis*), needle and thread (*Stipa comata*), sunsedge (*Cares heliophila*), western snowberry (*Symphoricarpos occidentalis*), and Kentucky bluegrass (*Poa pratensis*).

Swath Grazing

Swath grazing treatment pastures were swathed on 15 September. The CWG and BBS were first cut with a sickle mower then raked into windrows. The FM pasture was swathed using a hay conditioner. Each treatment pasture, except NR, was divided into three, 4 ha paddocks using electric fence, providing three (4 ha) replications for each swath grazing treatment. Electric cross fencing was used to limit access in an attempt to increase forage utilization and decrease waste. Nine to 10 days of forage was provided at each fence move. The first area grazed was immediately adjacent to water source, and cross fences were moved to allow access to water and previously grazed areas. Native range treatment groups were allowed to graze entire pasture to simulate a typical fall-winter management scenario.

Water was provided in stock tanks, which were filled every two days. Stock tanks were heated with propane tank heaters to allow cattle constant access to water. Water heaters were used from late November through the end of the trial.

The supplement for BBS treatment consisted of a 40% CP cooked molasses block (Ridley, Inc., Mankato, MN). Cattle in each of the BBS replicates were allowed access to one tub (58.6 kg) per week. All treatments were provided with trace mineral salt blocks (Cutler-Magner Co., Duluth, MN) on an ad libitum basis.

Stocking rates were determined at swathing and were based on forage quantity and 75% harvesting efficiency of swaths. Stocking rates were 2.2, 1.7, 5.7, and 0.5 hd/ha for CWG, BBS, FM, and NR, respectively. Stocking rates were calculated using final production numbers multiplied by an 80% efficiency. The 80% efficiency was used to account for forage loss during harvesting and unharvested plant material not clipped by the swathing machine.

Sub-samples of CWG, BBS, and FM swaths were collected for analysis. Swath samples were taken as random grab samples on each day cross fence were moved. Forage samples from NR were collected by clipping 0.25m^2 plots on each day of cross fence move.

Laboratory Analysis

Forage samples were dried using a forced-air oven (55° C; The Grieve Corporation, Round Lake, IL) for 48 h. Dried samples were ground using a Wiley Mill (Aurther H. Thomas Co., Philadelphia, PA) to pass a 2 mm screen. Forage samples were analyzed for DM, Ash, and CP (AOAC, 1990). Concentrations of NDF (Robertson and Van Soest, 1991, as modified by Ankom Technology, Fairport, NY) and ADF (Goering and Van Soest, 1970, as modified by Ankom Technology, Fairport, NY) were determined using an Ankom 200 Fiber Analyzer (Ankom Technology, Fairport, NY).

Statistical Analysis

Cow performance data was analyzed as a completely random design using GLM procedures of SAS (SAS Inst. Inc., Cary, NC). The experimental unit was paddock, and treatment was forage type. Statistical analysis was conducted for differences in initial BW, initial BCS, final BW, final BCS, ADG, BCS change, and total weight gain per 1 ha.

Results and Discussion

Forage Production

Forage data was compiled from clipped plots that were collected throughout the growing season and analyzed for CP, ADF, and NDF. Nutrient analysis indicated swath grazing treatments had similar changes in nutrient composition. Crude protein values decreased from initiation of sampling until swathing for all forages. At swathing, FM had the greatest CP (9.34%, DM basis) and BBS the lowest CP content (4.2%, DM basis). Values for CWG were intermediate (7.38% CP, DM basis; Figure 1). Acid and neutral detergent fibers increased throughout the growing season (Figures 2 and 3, respectively).

Forage production for CWG, BBS, and FM was 3,373, 2,686, and 7,414 kg DM/ha; respectively at time of swathing. Production for CWG peaked in mid-July, but was increasing slightly in September at the time of swathing. A major factor in the CWG production was the percent of legume present in the pasture. In late July to early August, the legume portion of CWG decreased as the forage matured. Big bluestem pastures reached peak production in mid-August, and rapidly declined in CP, and increased in ADF and NDF concentrations. Foxtail millet production doubled in the last month prior to swathing. This data indicates date of swathing is a major factor in the overall quality and quantity of the forage provided to swath grazing cattle.

The CP content of swath sub-samples was similar throughout the grazing trial (Figure 1). Acid detergent fiber and neutral detergent fiber increased throughout the grazing trial (Figure 2 and 3, respectively). A study by Lux et al. (1999) had similar findings with ADF content increasing from September through November. Both Lux et al.

(1999); and Munson et al. (1999) had similar results with NDF increasing as feeding period progressed.

Cow Performance

There was no difference in final body weight between treatments (P = 0.97; Table 1). A negative ADG was observed in CWG and BBS treatment cows (-0.05 and -0.01 $kg^{-1}hd^{-1}d^{-1}$, respectively). Cows grazing FM and NR gained weight over the trial (0.07 and 0.08 $kg^{-1}hd^{-1}d^{-1}$, respectively). However, these changes in BW were not significant (P = 0.44). When gains were compared on a per ha basis, where the total weight gain for all cows in the paddock was combined and that weight divided by the number of hectares, no differences were found between treatments (P = 0.17). The P-value, while not significant, indicates there is a trend for differences between the FM and other treatments. The numerical difference is quite large with FM gaining 24.6 kg/ha while NR, BBS, and CWG had smaller gains or loses of 2.5, -1.7, -4.6; respectively. No differences were noted in BCS change (P = 0.12).

Implications

Swath grazing is an acceptable method for wintering beef cows in central North Dakota. While no differences were noted in swath grazing treatments, additional research is needed to determine optimum forage type and swathing date to optimize grazing returns. In addition, an economic analysis should be conducted to better understand these grazing systems.

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Table 1. Body weight, body condition score, and average daily gain of windrowed forage and standing native range grazing cows at Central Grasslands Research Center, Streeter, ND in 2005

	Treatments[a]				
Item	CWG	BBS	FM	NR	P-value[b]
Initial					
BW,kg[c]	560	560	556	556	0.10
BCS[c]	5.1	5.2	5.2	5.3	0.47
Final					
BW,kg[c]	558	559	560	560	0.97
BCS[c]	5.2	5.4	5.2	5.1	0.30
ADG,kg/d[d]	-0.05	0.01	0.07	0.08	0.44
Change in BCS[e]	0.1	0.2	0.0	-0.2	0.12
Weight change/ha[f]	-4.6	-1.7	24.6	2.5	0.17

[a] Treatment abbreviations CWG = crested wheatgrass/legume, BBS = big bluestem, FM = foxtail millet, NR = native range.
[b] Overall P-value for treatment.
[c] Values are averaged across replicate within treatment.
[d] ADG = (Average Final BW – Average Initial BW)/58d.
[e] Change in BCS = Average Final BCS – Average Initial BCS.
[f] Weight change/ha = total weight gain/lost by paddock/ha in paddock.

Figure 1. Effect of sampling date on CP of crested wheatgrass (CWG), big bluestem (BBS), foxtail millet (FM), and native range (NR) at Central Grasslands Research Center, Streeter, ND in 2005

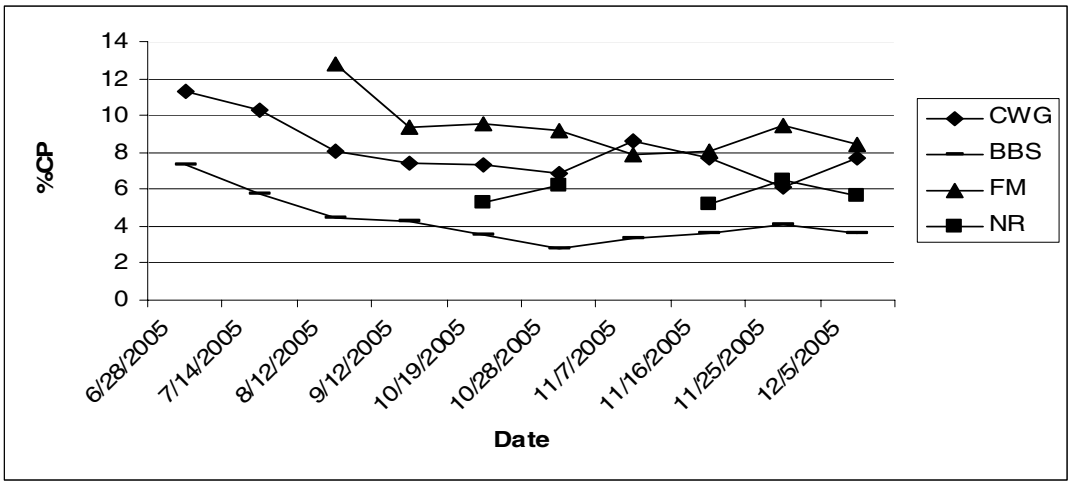


Figure 2. Effect of sampling date on ADF of crested wheatgrass (CWG), big bluestem (BBS), foxtail millet (FM), and native range (NR) at Central Grasslands Research Center, Streeter, ND in 2005

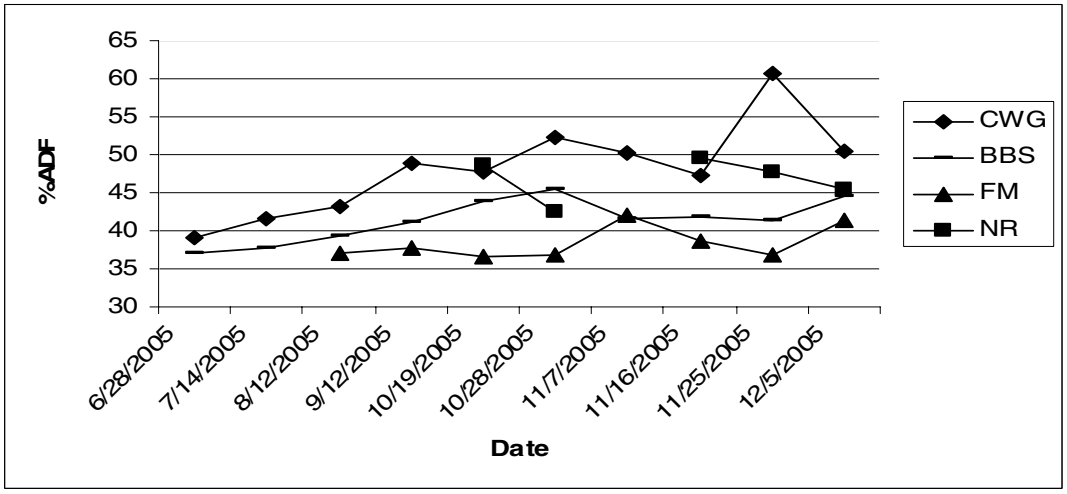
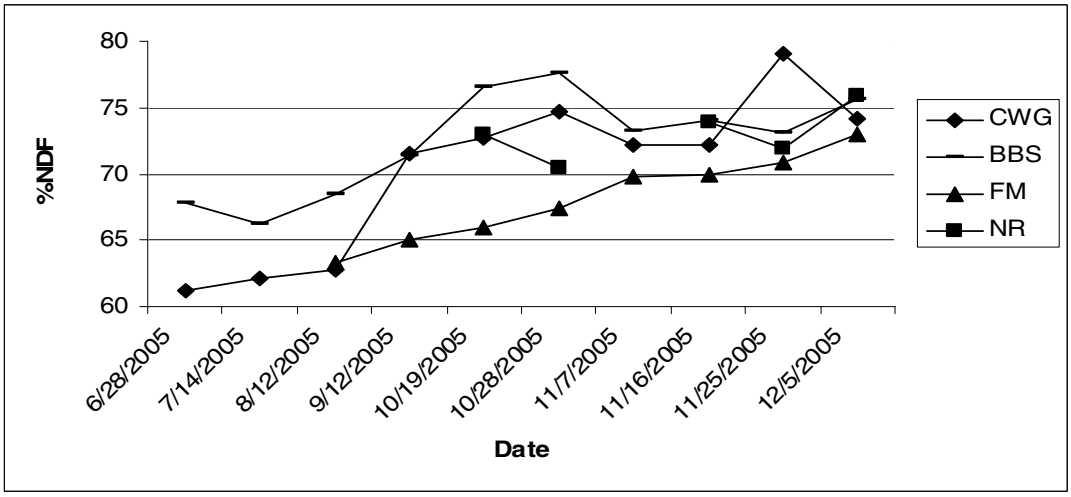


Figure 3. Effect of sampling date on NDF of crested wheatgrass (CWG), big bluestem (BBS), foxtail millet (FM), and native range (NR) at Central Grasslands Research Center, Streeter, ND in 2005



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COMPARISON OF TECHNIQUES FOR QUANTITATIVE ANALYSIS OF ACID DETERGENT LIGNIN IN ROUGHAGES

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ABSTRACT: The objective of this experiment was to compare the conventional crucible method to a semi-automated method for determination of ADL in roughages. Samples analyzed were selected to provide a broad range of cellulose and lignin content based on ADF. Samples included Kentucky bluegrass (*Poa pratensis*), liters of Wyoming big sagebrush (*Artemisia tridentata*), medic (*Medicago rigidula*), crested wheatgrass (*Agropyron desertorum*) hay, millet (*Setaria italica*) hay, wheat (*Triticum* spp) straw, and wood shavings. The efficacy of recycling filtered acid back through the crucible versus adding fresh acid was evaluated to allow for a direct comparison with the semi-automated method. Acid detergent lignin did not differ ($P = 0.38$) between recycled and fresh 72% H_2SO_4. Samples analyzed using the semi-automated method tended to have less ($P = 0.07$) ADL (% of DM) than those analyzed using the conventional crucible method. This was due to less ($P < 0.001$) ADF (% of DM) for the ANKOM^{200} filter bag technique compared with the reflux fiber digestion apparatus because content of ADL expressed as % of ADF did not differ ($P = 0.27$) between the conventional crucible and semi-automated methods. Additionally, ADL expressed as % of ADF was highly correlated ($r = 0.99$, $P < 0.001$) between the two methods. Complete ADL analysis by the semi-automated method required only 3.5 h compared with 5.5 h for completion using the conventional crucible procedure. We conclude that the semi-automated method is an acceptable and more time efficient procedure than the conventional crucible method for determination of ADL in roughages.

Key Words: Acid Detergent Lignin, Roughage Analysis

Introduction

Conventional methods (Goering and Van Soest, 1970; AOAC, 1980; Robertson and Van Soest, 1981) used to quantify ADL require a great deal of preparatory and analytical technician time. Semi-automated equipment for fiber analysis (ANKOM Technology Corp., Fairport, NY) has been used to increase sample handling capacity (Jung, 1997). Currently, the most common method for ADL determination includes hydrolyzing ADF residues in crucibles with 72% H_2SO_4 followed by crucible filtration using vacuum suction. A semi-automated method to determine ADL content using the ANKOM Daisy^{II} Incubator (ANKOM Technology Corp., Fairport, NY) equipment has been proposed (Anonymous, 1995). This method requires less technician time and increases sample handling capacity. Furthermore, the semi-automated method helps reduce technician interaction with harmful chemicals and alleviates error that can occur due to variation in crucible filtration. We are not aware of published reports comparing the conventional crucible method to the semi-automated method for ADL determination. Therefore, our objective was to compare the semi-automated ADL method to the conventional crucible method for ADL determination.

Materials and Methods

Sample Preparation

Forage samples were selected to encompass a wide range of ADF content. Monocultures of vegetative Kentucky bluegrass (*Poa pratensis*) and medic (*Medicago rigidula*) were hand-clipped from three 0.25 m^2 quadrats to leave a stubble height of 2.5 cm. Only recent year's liter growth of Wyoming big sagebrush (*Artemisia tridentata*) was collected from three transects (80 m) randomly located within a 100 m^2 plot. Each transect consisted of 10, 0.25 m^2 quadrats located every 8 m for a total of 30 sampling quadrats within the plot. Three bales of crested wheatgrass (*Agropyron desertorum*) hay, millet (*Setaria italica*) hay, and wheat (*Triticum* spp) straw, were core sampled using a homemade forage sampler modeled after the Penn State Forage Sampler (Nasco, Wisconsin, 53538). Three grab samples (~ 30.0 g) of wood shavings were collected from three different locations in a plastic wrapped, bedding bale. Samples were composited within sample type, dried at 55°C for 48 h in a model 630, Napco forced-air oven (Precision and Napco, Winchester, VA), and ground in a Wiley Mill (Arthur H. Thomas Co., Philadelphia, PA) to pass a 1-mm screen.

Conventional Crucible Method for ADL Determination

The efficacy of recycling filtered acid back through the crucible vs. adding fresh acid was evaluated to allow for a direct comparison with the semi-automated method. To evaluate the use of recycled 72% H_2SO_4, roughages were selected with low (Kentucky bluegrass), medium (crested wheatgrass hay), and high (wood shavings) ADF content. Before conducting the ADL procedure, 0.5 g of Kentucky bluegrass, crested wheatgrass hay, and wood shavings were analyzed for ADF in duplicate using the reflux fiber digestion apparatus (Goering and Van Soest, 1970). Acid detergent fiber residues were transferred to standard coarse fritted Gooch crucibles (pre-dried and pre-weighed) and rinsed 3 times (50 mL/rinse) with hot (90 to 100° C) distilled water, followed by 1 rinse with acetone (50 mL). Crucibles were allowed to air dry under ventilated hood for approximately 20 min or until acetone had evaporated. Once air-dried, crucibles were placed in a Isotemp oven (Fisher

Scientific Co. L.L.C., Pittsburgh, PA) and dried at 55° C for 48 h. Crucibles were removed from the oven and placed immediately in a Dry Keeper desiccator (BEL-ART Scienceware, Pequannock, NJ). Crucibles were allowed to cool inside the desiccator for 45 min and the weight of the crucible plus residue was determined using a Mettler AE 160 balance (Mettler Instruments Corp., Highstown, NJ). Crucibles were returned to the Isotemp oven to ensure complete removal of moisture before applying acid. Crucibles containing ADF residues were then removed from the Isotemp oven and placed in a Dry Keeper desiccator and allowed to cool for 45 min. After cooling, crucibles were placed in a 229 × 330 mm Pyrex glass pan (World Kitchen, Greencastle, PA) to collect filtered acid from fresh acid samples. For samples hydrolyzed with recycled acid, crucibles were placed in a Pyrex glass pan and a 50 mL Griffen beaker was placed under the crucible to collect filtered acid. For both fresh and recycled acid crucibles, 40 mL of fresh 72% H_2SO_4 was added initially to each crucible. For recycled acid samples, acid collected in the beaker was poured back into the same crucible and the beaker was again placed under the crucible. Acid levels were maintained at or above half volume by either recycling acid or adding fresh acid to the crucible and crucible contents were stirred with a 3.2 × 76.2 mm glass rod every 30 min for the 3 h analysis. After completion of acid treatment for both recycled acid and fresh acid, remaining acid was removed by vacuum suction. Acid detergent lignin residues were rinsed 3 times (50 mL/rinse) with hot (90 to 100° C) distilled water, followed by 1 rinse with acetone (50 mL). Crucibles were allowed to air dry under ventilated hood for approximately 20 min or until acetone evaporated. After complete evaporation of acetone, crucibles were placed in an Isotemp oven and dried at 105° C for 24 h. Crucibles were then removed from the Isotemp oven and placed directly in a Dry Keeper desiccator. Samples were allowed to cool inside the desiccator for 45 min and then weight was determined using a Mettler AE 160 balance.

Samples (0.5 g) of wheat straw, crested wheatgrass hay, medic, millet hay, Wyoming big sagebrush, or wood shavings were analyzed in duplicate for ADF content using the reflux fiber digestion apparatus (Goering and Van Soest, 1970), and ADL was determined using recycled acid as described previously.

Semi-automated Method for ADL Determination

Duplicate pre-weighed and pre-labeled filter bags (FP-57, 25 µ pore size; ANKOM Technology Corp., Fairport, NY) containing 0.5 g of wheat straw, crested wheatgrass hay, medic, millet hay, Wyoming big sagebrush or wood shavings were subjected to ADF analysis using the ANKOM filter bag technique (ANKOM Technology Corp., Fairport, NY). Filter bags were then placed in a 162 × 112 mm plastic container (Airlite, Omaha, NE), and submerged in 500 mL of acetone to assist in removal of moisture. Filter bags were removed from acetone and allowed to air dry in a ventilated hood for approximately 20 min or until acetone evaporated. Once air-dried, filter bags were placed in a Isotemp oven and dried at 55° C for 48 h. Filter bags were removed from the Isotemp oven and placed immediately in a Dry Keeper desiccator and allowed to cool for 20 min and then weight was determined using a Mettler AE 160 balance. Based on observations from our laboratory, the ADF residue generated from the ANKOM Fiber Analyzer should not be transferred into the coarse fritted Gooch crucibles for ADL determination because the transfer weight of ADF residue material could be more than the actual ADF residue weight due to inclusion of filter bag constituents. Incomplete transfer of residue from the filter bag could also occur, resulting in a transfer weight lower than the actual ADF residue weight.

After completion of ADF analysis, filter bags were returned to the Isotemp oven to ensure complete removal of moisture before applying acid. Filter bags containing ADF residues were then removed from the Isotemp oven and placed in a Dry Keeper desiccator and allowed to cool for 20 min. After cooling, filter bags were placed into the ANKOM Daisy^{II} Incubator vessel (3.7 L) with 72% H_2SO_4. The volume of acid added to the vessel was 40 mL/sample or 480 mL for 12 samples; which was the same volume (per sample) of acid added to each crucible in the conventional crucible method using recycled acid. After 3 h of submersion and rotation, samples were removed from the vessel and placed in a 385 × 200 mm acid resistant, plastic tub (Rubbermaid, Lima, OH) filled with 3.0 L of cold distilled water. Once inside the plastic tub, filter bags were submerged and circulated by hand (acid resistant gloves) throughout the container for 5 min. The pH of the distilled water within the tub was measured using an Accumet Portable AP5 pH meter (Fisher Scientific Co. L.L.C., Pittsburgh, PA). The protocol provided by ANKOM (Anonymous, 1995) suggested that the pH of the rinse water should be ≥ 6 and acid-contaminated water be discarded in an acid waste container between rinses. For this experiment, two rinses were required to raise the pH of the distilled water to ≥ 6. Samples were then removed from the tub and placed in a 162 × 112 mm plastic container (Airlite, Omaha, NE) and submerged in 500 mL of acetone to assist in removal of moisture. Samples were allowed to air dry in a ventilated hood and then dried in a Isotemp oven at 105° C for 24 h. Samples were then removed from the Isotemp oven and placed directly in a Dry Keeper desiccator. Samples were allowed to cool for 45 min within the desiccator and then weights were determined using a Mettler AE 160 balance.

Statistics

Data were analyzed as a one-way ANOVA using GLM procedures of SAS (SAS Institute, Cary, NY). The model included treatment (semi-automated method and conventional method) as the independent variable. A correlation between ADL content for the two analytical methods was determined using PROC CORR of SAS.

Results and Discussion

Acid detergent lignin (% of DM) did not differ (P = 0.38) between fresh (Kentucky bluegrass; 6.2%, crested wheatgrass; 10.6%, and wood shavings; 31.5%) and recycled (Kentucky bluegrass; 4.9%, crested wheatgrass; 10.5%, and wood shavings; 31.5%) 72% H_2SO_4. Thus, recycled acid may be used for the conventional ADL

analysis. Use of recycled acid during the conventional analysis permits a more direct comparison to be made with the semi-automated method for determination of ADL.

Content of ADF (% of DM) averaged 3.0 units greater ($P < 0.001$) for samples analyzed using the reflux fiber digestion apparatus (48.5%) compared with the ANKOM filter bag technique (45.5%). This finding is consistent with results of Komerack (1993), who reported greater ADF values for corn silage using the conventional method compared with ANKOM method. Likewise, Vogel et al. (1999) reported 2.5 unit greater ADF content for gramineae species analyzed using the conventional method compared with the filter bag technique. The slightly greater magnitude of difference noted between methods herein than that of Vogel et al. (1999) may be related to the wider range in cellulose and lignin content of samples used in our experiment. Average ADF values reported by Vogel et al. (1999) ranged from 30.0 to 49.0%, whereas samples used in our experiment had ADF values from 27.4 to 78.7%.

Initial results indicated that samples analyzed using the conventional crucible method tended to have greater ($P = 0.07$) ADL (% of DM) than the semi-automated method. This result was due to differences in ADF because content of ADL expressed as a percentage of ADF did not differ ($P = 0.27$) between analytical methods. Additionally, ADL values expressed as a percentage of ADF were highly correlated ($r = 0.99$; $P < 0.001$) between the two methods.

Table 1 depicts the CV of laboratory duplicate samples when ADL is expressed as a percentage of ADF. Except for wood shavings, CV values were less for the semi-automated method than the conventional method. We suspect that the higher CV for the conventional method was due to variations in crucible filtration. Galyean (1997) suggested that an acceptable CV for ADL duplicate samples was 4.0%. Because the residual weight obtained from the ADL analysis is very light (39.8 to 129.6 mg; 8 to 26% of the original sample size), slight differences in residue mass between duplicate samples in addition to balance drift (± 0.1 mg, Mettler AE 160) could result in a CV above 4.0%. Coefficient of variance > 4% may also reflect unequal distribution of the composite or inherent heterogeneity of lignin in the respective samples.

Complete ADL analysis by the semi-automated method required only 3.5 h compared with 5.5 h for completion using the conventional crucible procedure. We conclude that the semi-automated method is an acceptable and more time efficient procedure than the conventional crucible method for determination of ADL in roughages.

Implications

The semi-automated method for acid detergent lignin determination provides researchers with a more time-efficient analysis with larger sample handling capacity. This method also decreases technician exposure to acid and the chance of introducing analytical error.

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Table 1. Comparison of methods for determination of acid detergent lignin

	Method			
Species	Conventional	CV[1]	Semi-automated	CV[1]
	% of ADF			
Wheat straw	17.36	4.14	18.32	2.31
Crested wheatgrass hay	20.87	5.96	19.20	5.36
Medic	21.89	2.04	23.46	0.16
Millet hay	22.40	0.86	23.12	0.68
Wyoming big sagebrush	32.26	0.26	33.57	0.54
Wood shavings	33.41	1.81	34.09	5.70
Overall mean[2]	24.69		25.29	

[1]CV = determined for duplicate samples.
[2]n = 6; SE = 0.34; $P = 0.27$.

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COMPARISON OF CATALYSTS FOR DIRECT TRANSESTERIFICATION OF FATTY ACIDS IN FREEZE-DRIED FORAGE SAMPLES

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ABSTRACT: Our objective was to compare 1.09 *M* methanolic HCl to 14% BF_3 in methanol as catalysts for direct transesterification of fatty acids in freeze-dried forage samples. Samples included blue grama (*Bouteloua gracilis*), fringed sage (*Artemisia frigida*), western wheatgrass (*Pascopyrum smithii*), needle-and-thread (*Stipa comata*), dalmation toadflax (*Linaria dalmatica*), needleleaf sedge (*Carex eleocharis*), and scarlet globemallow (*Sphaelercea coccinea*). Thin layer chromatographic evaluation revealed complete conversion of total lipid extracts to fatty acid methyl esters using both catalysts. Additionally, GLC analysis confirmed similar (P = 0.96) total fatty acid concentrations for both catalysts. Concentrations of most identified fatty acids (13:0, 14:0, 16:0, 16:1, 17:0, 17:1, 18:0, 18:1, 18:2, 18:3, 19:0, 20:0, 20:1, 22:0, 22:1, 22:3, 24:0, 24:1, and 28:0) were similar (P = 0.17 to 0.99) for both catalysts. Concentrations of 14:0 tended to be greater (P = 0.07) for HCl but weight percentages of 14:0 did not differ (P = 0.23) between catalysts. Concentrations and weight percentages of 17:1 were less (P < 0.0001) for HCl compared with BF_3. Boron-trifluoride may cause partial isomerization of predominant fatty acids because the concentrations of unidentified fatty acids with GLC retention times of 8.0, 13.9, and 31.9 min were greater (P = 0.005 to 0.05) for BF_3; whereas, only the concentration of unidentified fatty acid eluding at 14.8 min was greater (P = 0.02) for HCl. Nevertheless, total concentration of unidentified fatty acids did not differ (P = 0.71) between catalysts. Additionally, total weight percentages of identified fatty acids and unidentified fatty acids were not affected (P = 0.37) by catalyst (91.2 and 8.8% vs. 90.6 and 9.4% for HCl and BF_3, respectively). It is also possible that BF_3 is more efficient at catalyzing methylation of less common or unusual fatty acids, but BF_3 costs \$0.19 per sample more than HCl. We conclude that 1.09 *M* methanolic HCl is both a cost effective and appropriate substitute for 14% BF_3 in methanol for preparation of fatty acid methyl esters from freeze-dried forage samples.

Key Words: Fatty acids, Forages, Methyl esters

Introduction

Procedures for preparation of fatty acid methyl esters from forages using single-step transesterification have been well documented. Outen et al. (1976) demonstrated a one-step extraction and esterification method using benzene and 5% methanolic HCl. Sukhija and Palmquist (1988) later recommended that benzene or toluene be used for extraction and formation of methyl esters. The use of benzene and toluene are now discouraged due to high toxicity and carcinogenic properties (EPA, 2002). Recognizing the hazards of benzene and toluene, Whitney et al. (1999) substituted these solvents with 14% BF_3 in CH_3OH for direct transesterification of feedstuffs.

Although BF_3 has proven to be an effective catalyst for direct transesterification of fatty acids in forages (Whitney et al., 1999) and animal tissues (Rule, 1997), BF_3 is very volatile and can be toxic if inhaled (NIOSH, 2004). Boron-trifluoride also must be sealed with N_2 and stored in a cool, dark environment to maintain reactivity. In contrast, methanolic HCl is less volatile than BF_3, maintains shelf-life longevity without special preparation, and costs \$101.50/L less than BF_3.

Garcés and Mancha (1993) demonstrated that methanolic HCl is an efficient catalyst for preparing methyl esters, with solubility of transmethylated end products being a factor limiting its utility. Complete esterification of less soluble and less reactive lipids, however, can be accomplished if frequent vortex-mixing while heating is performed in a disciplined manner (Rule, 1997). Kucuk et al. (2001) modified the procedure of Whitney et al. (1999) by substituting BF_3 in CH_3OH with methanolic HCl for direct transesterification of lipids in feedstuffs; however, results comparing BF_3 in CH_3OH to methanolic HCl as catalysts in single-step direct transesterification have not yet been reported. Our objective was to compare BF_3 in CH_3OH to methanolic HCl as catalysts for direct transesterification of fatty acids in freeze-dried forage samples.

Materials and Methods

Sample Collection

Beginning in May and every 3 wk until October, whole plants were harvested in 2004 from a single enclosure (0.5 ha) located approximately 15 km northwest of Cheyenne, WY. Two transects (each 25 m) were randomly located within the enclosure and permanently established for the entire collection period. To harvest samples, 0.1 m^2 (0.2 × 0.5 m) quadrats were randomly located on each transect and individual plant species located within each quadrat having the same phenological stage of development were clipped 2.5 cm above the ground surface until 5.0 g/species (as-fed basis) was attained. Samples included blue grama (*Bouteloua gracilis*; BOGR, warm-season perennial grass), western wheatgrass (*Pascopyrum smithii*; PASM, cool-season perennial grass), needle-and-thread (*Stipa comata*; STCO, cool-season perennial grass), needleleaf sedge (*Carex eleocharis*; CAEL, cool-season perennial grasslike), scarlet globemallow (*Sphaelercea coccinea*; SPCO, perennial forb), dalmation toadflax (*Linaria dalmatica*;

LIDA, perennial forb), and fringed sage (*Artemisia frigida*; ARFR, sub-shrub). Clipped samples were immediately placed on dry ice, transported to the laboratory, and freeze-dried (Genesis Freeze Dryer, Virtis Co., Gardiner, NY). After freeze drying, samples were ground in a Wiley Mill (Arthur H. Thomas Co., Philadelphia, PA) to pass a 1-mm screen, pooled by species within each month, and stored in plastic containers with teflon-lined caps at -20° C.

Total lipid Extract for TLC

Freeze dried samples (0.5 g) for each species were subjected to extraction with (15 mL for BOGR, PASM, CAREX, and LIDA or 30 mL for ARFR and SPCO) a mixture containing $CHCl_3$, CH_3OH, and H_2O (1:2:0.8 vol/vol/vol; Bligh and Dyer, 1959) in 29 × 123 mm screw-cap, borosilicate tubes with teflon-lined caps. Volumes were individually adjusted (15 mL vs. 30 mL) due to the absorptive nature of ARFR and SPCO. Tubes were then placed on a Wrist Action Shaker (Burrell Corporation, Pittsburgh, PA) for 24 h. After extraction, 3.0 mL of $CHCl_3$, 1.5 mL of H_2O, and 1.5 mL of a solution containing aqueous 0.1 *N* HCl/2 *M* KCl were added to each tube and vortex-mixed for 15 s at a low speed, using a Fisher Vortex Genie 2 (Scientific Industries Inc., Bohemia, NY) electronic mixer with adjustable speed. Tubes were centrifuged (Beckman Model TJ-6 Centrifuge, Beckman Instruments Inc., Fullerton, CA) at 1300 × *g* for 3 min to separate phases and the upper, aqueous phase was siphoned and discarded. The lower, $CHCl_3$ phase was transferred into a clean, hexane rinsed 16 × 125 mm screw-cap, borosilicate tube with a teflon-lined cap. Residue in the original tube was extracted twice with 2.0 mL of $CHCl_3$. Tubes were then placed in a Meyer N-Evap Analytical Evaporator (Associates Inc., South Berlin, MA) where $CHCl_3$ was evaporated under N_2 gas at 22° C. Extract residues within tubes were re-suspended in 2.0 mL of $CHCl_3$ and split by transferring 1.0 mL into a clean, hexane rinsed 16 × 125 mm tube. The $CHCl_3$ in each tube containing 1.0 mL of the split extract residue was then evaporated under N_2 gas at 22°C. Direct transesterification was performed by adding 2.0 mL of either 14% BF_3 in CH_3OH or 1.09 *M* methanolic HCl and 2.0 mL of CH_3OH to each tube. Tubes were placed on a hot block at 80° C for 1 h. Following 5 min of initial heating, tubes were individually vortex-mixed every 3 min for 1 h. Tubes were then allowed to cool for approximately 20 min. When tubes reached ambient temperature, 2.0 mL of H_2O and 2.0 mL of hexane (HPLC grade, Sigma-Aldrich, St. Louis, MO) were added to each tube followed by vortex-mixing for 15 s. After centrifugation at 1300 × *g* for 3 min, the upper hexane phase was transferred to GLC auto-sampler vials containing a 1 mm bed of anhydrous sodium sulfate and sealed before loading. Thin layer chromatography was accomplished by loading 15 µL of each upper hexane phase sample onto a lane of a TLC plate (20 × 20 cm) coated with 250 µm Silica-gel G (Analtech, Newark, DE). The TLC plate was placed in a mobile phase mixture of petroleum ether, diethyl ether, and glacial acetic acid (85:15:1 vol/vol/vol) for 1 h. The plate was developed under I_2 vapors and visually assessed for band formation. Purified standards (Sigma-Aldrich, St. Louis, MO) of methyl-oleate, monoacylglycerols, diacylglycerols, and triacylglycerols were used for visual comparison of bands.

Direct Transesterification

For the direct transesterification procedure, 1.0 mL of $CHCl_3$ containing 1.0 mg/mL of heneicosanoic acid (21:0; internal standard) was added to pre-weighed 29 × 123 mm screw-cap, borosilicate tubes with teflon-lined caps and evaporated under N_2 gas at 22° C. Freeze-dried forage samples were individually weighed (0.5 g) into tubes containing the internal standard. Fatty acid methyl esters were prepared by adding either 4.0 mL of either 14% BF_3 in CH_3OH or 1.09 *M* methanolic HCl and 4.0 mL CH_3OH directly to tubes containing samples. Due to their absorptive nature ARFR and SPCO required more reagent for saturation. For these samples, 8.0 mL of either 14% BF_3 in CH_3OH or 1.09 *M* methanolic HCl and 8.0 mL CH_3OH was used. Tubes were capped and placed in water bath incubator (Isotemp 220, Fisher Scientific, Pittsburgh, PA) at 80° C. After 5 min of initial heating, tubes were individually vortex-mixed every 3 min for 1 h and then allowed to cool. Sukhija and Palmquist (1988) suggested that transesterification may remain incomplete if forage samples are not frequently vortex-mixed at slow speeds. Emphasis was placed on vortex-mixing individual tubes every 3 min to ensure complete transesterification (Rule, 1997). After tubes cooled to ambient temperature, 4.0 mL of H_2O and 4.0 mL of hexane were added followed by vortex-mixing for 15 s. Tubes were centrifuged at 1300 × *g* for 3 min; the upper hexane phase was transferred to GLC auto-sampler vials containing a 1 mm bed of anhydrous sodium sulfate and sealed.

Fatty acid methyl esters were separated by GLC using an Agilent 6890 Gas Chromatograph (Agilent Technologies, Wilmington, DE) equipped with a flame ionization detector and a 30 m × 0.32 mm (i.d.) fused siloxane capillary column (BPX-70, 0.25 µm film thickness, SGE, Inc. Austin, TX). Oven temperature was maintained at 110° C for 5 min, and then increased to 200° C at 5° C/min. Injector and detector temperatures were 200° C and 225° C, respectively. Hydrogen was the carrier gas at a split ratio of 25:1 and a constant flow rate of 1.0 mL/min. Fatty acid peaks were recorded and integrated using GC ChemStation software (Agilent Technologies, version A.09.03). Individual fatty acids were identified by comparing retention times with known fatty acid methyl ester standards (Nu-Chek Prep. Inc., Elysian, MN and Matreya Inc., Pleasant Gap, PA).

Statistics Analyses

Quantitative data were analyzed as a one-way ANOVA using GLM procedure of SAS (SAS Institute, Cary, NY). The model included treatment (BF_3 in CH_3OH and methanolic HCl in CH_3OH) as the independent variable.

Results and Discussion

For the TLC analyses, total lipid extracts from intact forage lipids had complete conversion to methyl esters using 1.09 *M* methanolic HCl or 14% BF_3 in CH_3OH as catalysts for transesterification (Figure 1). These results

indicated that either BF_3 or methanolic HCl can be used as a catalyst for direct transesterification of lipid extracts.

For the GLC analyses, concentrations of total fatty acids ($P = 0.96$) and most identified fatty acids ($P = 0.17$ to 0.99) were similar for both catalysts (Table 1). Concentrations of 14:0 tended to be greater ($P = 0.07$) for HCl but weight percentages of 14:0 did not differ ($P = 0.23$) between catalysts (Table 2). Concentrations and weight percentages of 17:1 were less ($P < 0.0001$) for HCl compared with BF_3. It is possible that BF_3 is more efficient at catalyzing methylation of less common fatty acids, but BF_3 costs $0.19 per sample more than HCl. Additionally, BF_3 in the form of its coordination complex with CH_3OH is a powerful acidic catalyst and has serious drawbacks due to the formation of methoxy artifacts from unsaturated fatty acids when used in high concentrations with CH_3OH (Christie, 1993). Therefore, BF_3 may cause partial isomerization of predominant fatty acids because the concentrations of unidentified fatty acids with GLC retention times of 8.0, 13.9, and 31.9 min were greater ($P = 0.005$ to 0.05) for BF_3, whereas only the concentration of unidentified fatty acid eluding at 14.8 min was greater ($P = 0.02$) for HCl. Christie (1993) also noted that all fatty acids are esterified at approximately the same rate by methanolic HCl and differential losses of specific fatty acids are unlikely during the esterification step. Certain classes of simple lipids are not soluble in methanolic HCl (Christie, 1993); however, extensive vortex-mixing while heating results in complete methylation of these simple lipids when methanolic HCl is used (Rule, 1997). Nevertheless, total concentration of unidentified fatty acids did not differ ($P = 0.71$) between catalysts. Additionally, total weight percentages of identified fatty acids and unidentified fatty acids were not affected ($P = 0.37$) by catalyst.

In addition to partial isomerization, the unidentified fatty acids listed in Table 3 could be "unusual" fatty acids (Moire et al., 2004) synthesized with hydroxyl, epoxy, acetylenic, or carboxylic functional groups, as well as those with conjugated unsaturated bonds (Jaworski and Cahoon, 2003). The unusual fatty acids can also be incorporated into triacylglycerols for storage (Moire et al., 2004). For freshly harvested forages, detection of unusual fatty acids with shorter chain lengths would most likely be low due to β-oxidation of unusual fatty acids to maintain integrity of the lipid membrane (Millar et al., 1998). Derivatives of peroxisomal β-oxidation can also have unusual conformity. For example, Moire et al. (2004) reported that peroxisomal β-oxidation of 18:3 resulted in intermediates 14:3, 12:2, 10:2, 8:1 and 6:0. Those authors also noted that peroxisomal β-oxidation of 18:1 resulted in 14:1, 12:0, 10:0, 8:0, and 6:0. Further investigation would be required to identify these unusual fatty acids. As a reference, the retention times of unidentified fatty acids have been reported in relation to predominant fatty acids (Table 3).

Implications

Fatty acid methyl esters can be prepared by using hydrochloric acid in a direct transesterification procedure. This catalyst is both cost effective and an appropriate alternative to boron-trifluoride for methylation of most common fatty acids.

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Table 1. Fatty acid concentrations of freeze-dried forage samples using boron-trifluoride in methanol or methanolic hydrochloric acid as catalysts for direct transesterification

Fatty acid[a] retention time	Fatty acid	Catalyst BF_3	Catalyst HCl	SE^1	*P*-value
--- min ---		------- mg/g of DM -------			
6.6	13:0	0.137	0.133	0.008	0.76
10.0	14:0	0.289	0.330	0.016	0.07
15.8	16:0	3.174	3.259	0.111	0.59
16.6	16:1	0.230	0.247	0.017	0.46
17.9	17:0	0.085	0.073	0.006	0.17
18.6	17:1	0.120	0.076	0.007	< 0.0001
19.7	18:0	0.505	0.504	0.024	0.97
20.3	18:1	0.251	0.244	0.129	0.97
21.1	18:2	4.760	4.781	0.835	0.99
21.8	19:0	0.066	0.073	0.005	0.39
22.3	18:3	8.368	8.537	0.478	0.80
22.8	20:0	0.245	0.234	0.012	0.53
23.2	20:1	0.059	0.063	0.007	0.63
25.5	22:0	0.311	0.282	0.014	0.17
25.8	22:1	0.739	0.762	0.074	0.83
28.0	22:3	0.297	0.276	0.014	0.29
28.2	24:0	0.273	0.263	0.019	0.69
28.7	24:1	0.087	0.083	0.027	0.92
36.3	28:0	0.261	0.233	0.025	0.43
Unidentified		2.054	1.950	0.200	0.71
Total		22.311	22.403	1.228	0.96

[1]n = 82.

Table 2. Fatty acid weight percentages of freeze-dried forage samples using boron-trifluoride in methanol or methanolic hydrochloric acid as catalysts for direct transesterification

Fatty Acid	Catalyst BF_3	Catalyst HCl	SE^1	*P*-value
	------ g/100g of total fatty Acids ------			
13:0	0.64	0.63	0.03	0.67
14:0	1.53	1.76	0.13	0.23
16:0	14.97	15.31	0.25	0.33
16:1	1.04	1.13	0.05	0.28
17:0	0.40	0.35	0.02	0.16
17:1	0.58	0.36	0.02	< 0.0001
18:0	2.25	2.23	0.08	0.82
18:1	0.81	0.80	0.28	0.97
18:2	18.52	18.48	1.25	0.98
19:0	0.32	0.36	0.03	0.37
18:3	39.18	39.88	1.25	0.69
20:0	1.14	1.08	0.05	0.49
20:1	0.27	0.30	0.04	0.64
22:0	1.50	1.36	0.08	0.23
22:1	2.93	2.92	0.26	0.98
22:3	1.46	1.35	0.09	0.40
24:0	1.31	1.24	0.11	0.68
24:1	0.47	0.46	0.15	0.95
28:0	1.32	1.19	0.14	0.51
Total identified	90.64	91.19	0.42	0.37
Unidentified	9.36	8.81	0.42	0.37

[1]n = 82.

Table 3. Concentrations and relative retention times of unidentified fatty acids in freeze-dried forage samples using boron-trifluoride in methanol or methanolic hydrochloric acid as catalysts for direct transesterification

Fatty acid retention time	Catalyst BF_3	Catalyst HCl	SE^1	*P*-value	Relative retention time 16:0	18:2	18:3
-- min --	---- mg/g of DM ----				---------- min ----------		
8.0	0.049	0.030	0.007	0.05	-7.8	-13.1	-14.3
8.9	0.042	0.043	0.008	0.98	-6.9	-12.2	-13.4
10.6	0.105	0.126	0.008	0.07	-5.2	-10.5	-11.7
13.9	0.043	0.022	0.006	0.005	-1.9	-7.2	-8.4
14.8	0.117	0.152	0.011	0.02	-1.0	-6.3	-7.5
20.1	0.818	0.819	0.182	1.00	+4.3	-1.0	-2.2
26.8	0.055	0.056	0.003	0.91	+11.0	+5.7	+4.5
29.5	0.051	0.042	0.005	0.24	+13.7	+8.4	+7.2
31.3	0.205	0.158	0.019	0.08	+15.5	+10.2	+9.0
31.9	0.035	0.014	0.007	0.03	+16.1	+10.8	+9.6
33.9	0.044	0.034	0.009	0.39	+18.1	+12.8	+11.6
Other[2]	0.490	0.458	0.040	0.57	NA	NA	NA
Total	2.054	1.950	0.200	0.71	NA	NA	NA

[1]n = 82.
[2]Other = sum of non-major peaks.

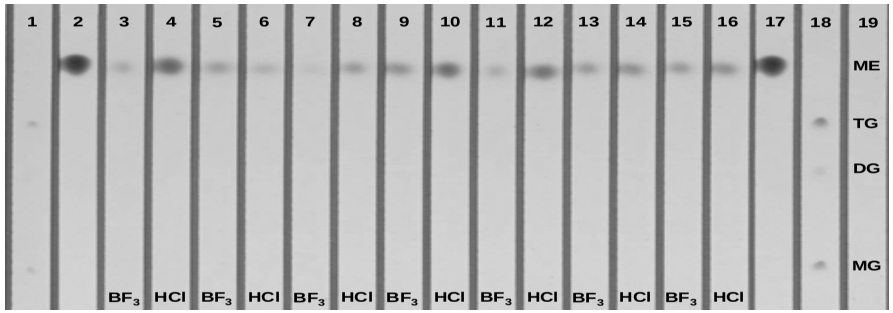

Figure 1. Thin layer chromatogram of methyl esters (ME) prepared from total lipid extract using direct transesterification with 14% boron-trifluoride or 1.09 M methanolic HCl. Lanes 1 and 18 represent monoacylglycerol (MG), diacylglycerol (DG), and triacylglycerol (TG) from purified standards. Lanes 2 and 17 represent a purified ME standard (methyl oleate). Lanes 3, 5, 7, 9, 11, 13, and 15 represent 15 µL of fatty acid ME prepared from 0.5 g of each sample (BOGR, ARFR, PASM, STCO, LIDA, CAEL, and SPCO, respectively) using total lipid extract followed by direct transesterification with 14% BF_3 in CH_3OH. Lanes 4, 6, 8, 10, 12, 14, and 16 represent 15 µL of fatty acid ME prepared from 0.5 g of each sample (BOGR, ARFR, PASM, STCO, LIDA, CAEL, and SPCO, respectively) using total lipid extract followed by direct transesterification with 1.09 *M* methanolic HCl. Lane 19 depicts the location of ME, TG, DG, and MG on each lane.

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BEEF CATTLE GRAZING AND FORAGE PRODUCTION COMPARISONS OF ALFALFA-GRASS VERSUS SAINFOIN PASTURES

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ABSTRACT: Mixing alfalfa (*Medicago sativa* L.) with grasses has been the most practical bloat prevention method. However, beef cattle producers still are concerned about potential bloat hazards when alfalfa dominates mixtures in the semiarid region of the Canadian prairie. Sainfoin (*Onobrychis viciifolia* Scop.), a non-bloat legume, can provide good forage and beef production in semiarid regions, but sainfoin exhibits poor persistence when grown in combination with other forages. The objective of this study was to compare the grazing and forage production between a new alfalfa-grass mixture (Spredor 4 and hybrid brome) (**A+G**) versus sainfoin (**S**) grown as a monoculture. Sainfoin and A+G were established in 2003 and the pastures were grazed at the S bloom stage and when the alfalfa was about 10% bloom, respectively. The experimental design was a 2 X 2 factorial (forages: S & A+G and pasture utilization: 50 & 70%) with three replications. Grazing and forage production data were collected in 2004 and 2005 for average daily gains (**ADG**), available forage yield (**AYD**) and grazing days (**GD**). No significant interactions were observed for ADG and AYD. However, a significant two way interaction (forage treatments x year) was observed for GD. As expected, available forage yield was higher ($P < 0.05$) for the A+G vs. S, and the values were 5,912 and 4,838 ∀ 251 kg of DM ha^{-1}, respectively. Average daily gains were similar between the A+G and S pastures and the values were 0.71 and 0.67 ∀ 0.10 kg d^{-1}, respectively. However, a higher ($P < 0.01$) number of GD were observed for A+G vs. S, and the values were 146 and 77 ∀ 17 d ha^{-1}, respectively. A distinctive grazing behavior was observed for yearling steers grazing S, which may explain the similar ADG observed between the two forage treatments and provide a possible grazing strategy to improve the longevity of the S stand. Sainfoin has good grazing and forage potential for the semiarid region of the Canadian prairies, however stand persistence concerns still are being evaluated.

Key Words: Sainfoin, Alfalfa-grass, Pasture grazing

Introduction

Alfalfa (*Medicago sativa* L.) is the oldest known domesticated forage and historically has been used for more than 3,300 years (Bolton et al. 1972). The potential benefits of grazing alfalfa are well-documented (high yields, animal performance and excellent forage quality) and many livestock producers are interested in its use. However, proper grazing management and preventing bloat are two of the challenges when grazing alfalfa. The use of alfalfa-grass (**A+G**) mixtures has been the most practical bloat prevention method for beef cattle production in western Canada but may not always be effective. As the stand ages, winter-kill and over-harvest take its toll, resulting often in a reduction in the alfalfa portion of the stand to mostly grass. The recent introduction of a new grazing tolerant alfalfa Spredor IV (*M. sativa* spp. *falcata*) combined with the hybrid AC-Knowles bromegrass (*B. riparius x B. inermis*), that has characteristics intermediate to the two parental species but reduced creeping characteristics, may provide an excellent A+G mixture (Coulman and Jefferson 2000).

Sainfoin (*Onobrychis viciaefolia* Scop.) (**S**) is a non-bloat forage legume that has been grown in mixtures with grasses and alfalfa but it is generally short lived (Kilcher 1982; Jefferson et al. 1994). However, Hanna et al. (1977) concluded that maximum productivity and quality can be obtained from S grown as a monoculture and with proper grazing management the persistence of the S stands can be maintained and even increased due to natural reseeding (Mowrey and Matches 1991) Sainfoin is highly palatable and preferred by cattle over alfalfa due to its high sugar and carbohydrates concentrations (Parker and Moss 1981), as a result, grazing cattle gains on S can be similar or greater than alfalfa but carrying capacity is much lower (Marten et al. 1987). Improved S stand persistence with acceptable cattle gains may be possible if the right grazing management strategies are utilized.

The objective of this study was to compare the grazing and forage production between a new alfalfa-grass mixture (Spredor 4 and hybrid bromegrass) versus sainfoin grown as a monoculture under different pasture utilizations (50 vs. 70%).

Materials and Methods

The experimental pastures, Al+G and S, were seeded into a previously fallowed Swinton loam soil at the beginning of May in 2003 at the Agriculture and Agri-Food Canada – Semiarid Prairie Agricultural Research Centre (**AAFC-SPARC**), Swift Current, Saskatchewan (50^0 16' N, 107^0 44' W, 825 m elev.). Seeding rate and row spacing for the A+G and S pastures were 2+8 and 35 kg ha^{-1} and 30.5 cm, respectively. Weed and grasshopper control for all seeded pastures were accomplished by using a Cobutox 400 herbicide (applied in the spring of 2003 and 2004) and Ecobran, respectively. No data was

collected in the establishment year and the average annual precipitation for AAFC-SPARC is 35.8 cm.

The experimental design was a 2 x 2 factorial (forages: S & A+G and pasture utilization: 50 and 70%) with three replications. A total of twelve pastures, each 0.8 ha in size, were utilized for this research study. Grazing and forage production data were collected in 2004 and 2005 for average daily gains (**ADG**), available forage yield (**AYD**) and grazing days (**GD**). Pastures were grazed at the S bloom stage and when the alfalfa was about 10% bloom. Estimations of available and residual pasture yields were determined using a procedure from Cook and Stubbendick (1986) in which four representative m^2 quadrat samples were taken from each pasture. Hand-plucked forage samples were taken randomly throughout the different pastures to determine what the grazing animals were ingesting. In 2004 and 2005, 48 and 60 Red Angus yearling steers were used to graze the pastures. Lower stocking rates were used on the S pastures in 2004 due to poor pasture production as a result of the Cobutox 400 herbicide stunting and delaying S productivity. For all years, yearling steers were initially weighed after a 12 hr shrink prior to being placed on the pastures. Once the pasture utilization level for each pasture was achieved based on visual estimation, the steers were removed from the pasture and weighed after a 12 h shrink. The grazing period for the steers lasted from the end of June to the end of July. Forage quality analyses were performed on all pasture samples. All forage material was dried in a forced air oven for 48 h and ground through a 1 mm screen Wiley mill grinder. Percent organic matter (**OM**), organic matter digestibility (**OMD**), crude protein (**CP**), neutral detergent fibre (**NDF** and acid detergent fibre (**ADF**) were determined (Troelsen and Hanel 1966; Goering and Van Soest 1970).

Statistical Analysis. The MIXED procedures of SAS (SAS Inst. Inc., Cary, NC. 2000) were used to determine the effect of treatment on the forage (AYD etc.) and animal performances (ADG, GD etc.). Mean separation was performed using least significant differences (means ± SEM; Snedecor and Cochran, 1989) when the F statistic was significant ($P < 0.05$). The statistical model consisted of treatments (pasture type or utilization level), year, and treatments by year interactions. Since year was a repeated measure, various variance-covariance structures were fitted and the best model was selected for final analysis.

Results and Discussion

No significant interactions were observed for ADG and AYD. However, a significant two way interaction (forage treatments x year) was observed for GD. As expected, AYD was higher ($P < 0.05$) for the A+G vs. S, and the values were 5,912 and 4,838 ∀ 251 kg of DM ha^{-1}, respectively. Goplen et al. 1991, reported a much higher S productivity (6,300 kg ha^{-1}) while Jefferson et al. 1994, reported a lower value (1,200 kg ha^{-1}) for S grown on similar dry land and soil conditions. In 2004, S AYD was affected (stunting and delaying forage growth) by a herbicide treatment, therefore, the AYD of the S pasture in this study is under estimated. The higher ($P < 0.001$) AYD for 2005 vs. 2004 was a result of higher pasture production and the effect of the herbicide treatment on the S. In 2004, the mean AYD for the S was 50% less than the A+G, while in 2005 the difference was only 15%. A lower ($P < 0.05$) AYD was observed for the 70% pasture utilization vs. the 50% and this could be an indication that grazing intensity was affecting stand persistence. Average daily gains were similar between the A+G and S pastures and the values were 0.71 and 0.67 ∀ 0.10 kg d^{-1}, respectively. Krall et al. (1971) reported a similar ADG for yearling steers grazing irrigated S at a similar stocking rate and grazing days over three grazing seasons. Higher ADG on S vs. A have been reported (Marten et al. 1987). As expected, higher ($P < 0.01$) ADG associated with 2005 vs. 2004 was a result of the higher pasture production due to the good and consistent moisture received that year. Although S is a very palatable forage its carrying capacity is much lower than the A+G pastures. Higher ($P < 0.01$) number of GD were observed for A+G vs. S, and the values were 146 and 77 ∀ 17 d ha^{-1}, respectively. The significant ($P < 0.05$) forage treatments x year interaction for GD can be explained due to the effect that herbicide treatment had on the AYD for S in 2004. Other researchers (Gutek et al. 1974; Parker and Moss 1981) have observed that animal prefer S over less palatable legumes and grasses. In this study the S was grazed at the full bloom stage and the steers preferred to graze the top 10 to 15 cm of the plant (flowering portions). Although the grazing animals were very selective, some S plants were still able to set seed, especially if the pasture is only utilized at 50%. Thus, moderate grazing pressure may allow the S stand to improve and maintain its longevity through natural re-seeding.

The hand-plucking forage qualities between A and S were similar within the 2004 years (Table 1). The

Table 1. Forage composition between alfalfa, hybrid bromegrass and sainfoin harvested in July of 2004 and 2005

	Chemical composition				
Pasture	OM	OMD	CP	NDF	ADF
2004					
A	92.1	58.9	10.6	44.1	34.8
HB	94.7	50.6	8.3	61.7	34.3
S	94.0	59.4	11.2	42.2	34.3
2005					
A	90.8	64.4	17.6	37.5	29.1
HB	92.5	53.8	9.1	57.6	31.7
S	93.9	59.5	15.0	32.8	34.3

A = alfalfa; HB = hybrid brome; and S = sainfoin.

the consistent precipitation provided in 2005 resulted in good growing conditions for the A and gave higher percent OMD and CP compared to the S. As expected the percent NDF for the HB was higher than the legumes. The average A+G sward consisted of about 15% A and 85% HB on a DM basis.

Implications

A distinctive grazing behavior was observed for yearling steers grazing S, which may explain the similar ADG observed between the two forage treatments and provide a possible grazing strategy to improve the longevity of the S stand. Moderate grazing pressure may allow the S stand to improve and maintain its longevity through natural re-seeding. Sainfoin has good grazing and forage potential for the semiarid region of the Canadian prairies, however stand persistence concerns still are being evaluated. Research in this area is still continuing and future research is evaluating the potential effect of the tannin content in S versus A+G pastures on mitigating methane emissions from grazing yearling steers

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RELATIONSHIPS AMONG HARVEST INDEX, FORAGE QUALITY, MATURITY AND OTHER FACTORS IN BARLEY CULTIVARS

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Abstract: Producers growing annual forages such as barley *Hordeum vulgare* L. species for production desire both yield and quality. The objectives of this study were to (1) evaluate yield and quality of forage, grain, and straw of different forage lines and (2) analyze the relationships among these components. Twenty-four barley lines were grown in three replicates under dryland conditions, near Bozeman, MT in 2005. Plots were harvested in the soft dough stage and the samples were dried for 48 h at 60°C. Straw, forage, and grain samples were ground through a 5 mm screen and a sub sample was then ground through a 1 mm screen. Samples were analyzed on a dry matter basis for acid detergent fiber (ADF), protein and 48 h *in situ* dry matter disappearance (ISDMD). Data were analyzed using the GLM and CORR procedure of SAS. Differences among lines were found (0.01 level) in forage yield, grain yield, straw yield, harvest index, forage and straw ADF, 48 h straw ISDMD and heading date. Correlation analyses indicated that forage yield was positively correlated with grain yield ($P = 0.002$), straw yield ($P < 0.001$), biomass yield ($P < 0.001$). Grain yield was positively correlated with straw yield ($P = 0.002$), biomass yield ($P < 0.001$) and harvest index ($P < 0.001$). Forage ADF was positively correlated with heading date ($P = 0.002$), while straw ADF was negatively correlated with heading date ($P = 0.002$) and forage yield ($P < 0.001$). Plant maturity had a significant effect on forage and straw quality. A negative correlation was found between forage ADF and straw ADF ($P = 0.041$), suggesting that quality changed with maturity. There was no significant correlation ($P > 0.05$ level) between forage ADF and forage, grain, and straw yield. This study indicates that varieties can be developed with both high grain and forage yield. By simultaneously selecting for high quality and high grain and forage yield, multipurpose varieties could be developed which would give producers more options when deciding to harvest for forage or grain.

KEYWORDS: Barley, Forage quality, Forage yield, Grain yield, Selection

Introduction

Barley is the fourth most important cereal crop in the United States, uses range from human consumption to animal feed and forage. Barley is highly regarded as an important supply of forage in Montana and provides a flexible source of livestock feed. Annual forage cultivars have become a reliable source of feed for Montana livestock producers (Stowe et al., 2001). In 2005, 'Haybet' was the most popular cultivar of hay barley grown in Montana, planted on 163.4 thousand acres and accounting for 17% of total barley acres planted in Montana (Montana Agricultural Statistics Service, 2005). In addition to forage, barley also supplies a valuable source of feed grain. In 2005, barley for forage was planted on approximately 20% of total barley acreage in Montana and barley for feed was planted on approximately 21% of total barley acreage in Montana. (Montana Agricultural Statistics Service, 2005).

Research has shown significant variation in feed quality characteristics exists in barley. (Bowman et al., 2001). Hooded hay barley cultivars generally have lower grain yields and test weight compared to feed barley lines. Since forage and grain quality evaluation is readily available, these traits could be selected simultaneously with yield and agronomic characteristics in barley breeding programs. Barley forage and grain quality and yield are important traits when developing new forage barley cultivars.

The objectives of this study were to evaluate yield and quality of forage, grain, and straw of different lines and analyze the relationships among these components.

Materials and Methods

Twenty-four barley cultivars and experimental lines, including two-rowed feed and forage varieties six rowed malt, feed, and forage varieties, were grown in dryland conditions in a randomized complete block design with three blocks near Bozeman MT in 2005. Agronomic data including plant height and heading date were recorded throughout the growing season. Forage clippings of 30.48 cm were cut at stubble height during soft dough growth stage. Samples were dried in a forced air oven for 48 h at 60°C and dry matter forage yield was then calculated. Straw and grain samples were taken at grain harvest and grain weight and straw yield were calculated.

Forage and straw samples were ground through a 5mm screen in a Wiley mill; sub samples were taken and ground through a 1mm screen. Grain samples were cracked in a Buehler mill and sub samples were ground through a 1mm screen in a Udy mill. All samples were then analyzed for DM, ADF, CP, and *in situ* dry matter disappearance (ISDMD).

For the ISDMD procedure, duplicate nylon bags were filled with approximately 5 g of 5mm ground sample of each barley variety or experimental line and incubated in the rumen of 2 cannulated cows for 48 h. Duplicate samples

of straw, forage, and grain were incubated in the rumen at different times throughout the study. Cannulated cows were adapted to a medium quality grass hay diet for approximately 21 days before starting the procedure to allow the rumen microbial population to adapt to the feed being consumed. Before incubating the grain samples, the cannulated cows were adapted to 3.6 kg cracked barley and the same medium quality hay for approximately 14 days. An empty bag was also included in the incubation of each run to measure microbial contamination and influx of rumen material. Additionally, a standard bag was incubated containing Harrington barley straw to measure any significant changes in digestion. After the incubation process, nylon bags were removed, hand washed in cold water to destroy further microbial digestion, and dried in a forced air oven and 60 ºC for 48 h. The following equation was used to calculate *in situ* dry matter disappearance: ISDMD% = 100-{[(dry sample and bag wt. out – bag weight) – (blank bag wt. out – blank bag weight in)]/(sample wt. in × DM)×100}.

Data were analyzed using the GLM procedure of SAS to evaluate yield and quality of the different lines as well as analyze the relationships among these components. Significant correlations were then separated and analyzed ($P < 0.05$) using the SAS CORR procedure.

Results and Discussion

Maximums and minimums of grain, forage, and straw values are presented in Table I. Crop growing conditions were good for barley forage and grain production in 2005. Forage (5.9 to 9.4 t/ha) and grain (2.3 to 5.0 t/ha) yields were typical of past research trials (P.F. Hensleigh, unpublished data).

Quality and yield components of forage, grain, and straw were analyzed and significant correlations were found, and are presented in Tables II, and III, IV. Correlation analyses indicated that forage yield was positively correlated with grain yield ($P = 0.002$), straw yield ($P < 0.001$), biomass yield ($P < 0.001$). Grain yield was positively correlated with straw yield (P=0.002), biomass yield ($P < 0.001$) and harvest index ($P < 0.001$). Significant differences ($P < 0.001$) were found between varieties in forage yield, grain yield and straw yield. These relationships suggest that simultaneous selection for barley varieties with high grain and forage yield could be utilized. Haybet is an excellent source of forage for livestock producers demonstrating superior average daily gain and feed efficiency in feed lot steers (Surber, et al., 2003), however this cultivar produces very little grain yield. 'Hays', a cultivar of barley developed at Montana State University in 2003, has shown significantly greater grain and forage yields. With this information, varieties that produce greater grain and forage yields could be developed.

A negative correlation was found between grain yield and grain ADF ($P = 0.005$) and a positive correlation was found between grain yield and grain DMD ($P = 0.018$). In this study, as grain yield increased quality and digestibility of grain also increased. Since ADF has been determined to be the most significant variable affecting energy value of a grain (Bowman et al., 2001) and % ISDMD represents digestibility, these characteristics can be used to select for varieties with higher grain quality. Significant differences ($P < 0.05$) were found between varieties in grain ADF ($P < 0.001$) and grain DMD ($P = 0.003$). Positive correlations between test weight, grain yield ($P < 0.001$), grain DMD ($P < 0.001$) and grain protein ($P = 0.004$) suggest that forage varieties with high yield and quality can be selected that also have high grain yield and quality. Forage and grain varieties with lower ADF values and greater digestibility are a better quality, and a more efficient source of livestock feed. Forage and grain yield are also important to producers as total production can be as important as the quality.

A negative correlation was found between forage ADF and straw ADF ($P = 0.041$), suggesting that quality can change with plant maturity. It is well accepted that plant maturity affects every facet of forage quality (Surber et al., 2003). There was no significant correlation ($P = 0.05$ level) between forage ADF and forage, grain, and straw yield. A positive correlation between forage yield and forage protein ($P = 0.004$) was also found to exist. These results suggest that while plant maturity will always affect forage quality, it would be possible to develop high yielding grain and forage varieties that retains high quality grain and forage. These varieties would be valuable to livestock producers because they would provide a larger quantity of more valuable feed.

Implications

Hay barley cultivars are a vital source for feed for livestock producers in Montana. Developing cultivars with high forage and grain yield and quality would give producers more flexibility when producing forage or grain in their operation. This study demonstrates that simultaneous selection for forage and grain yield and quality is possible in barley breeding programs. Multi-purpose barley cultivars could be utilized for forage or for grain depending on growing conditions or other variables such as price of hay or grain.

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Table I. Simple Statistics for yield, quality and agronomic characteristics in (DM basis) forage barley varieties and experimental lines grown in 2005

Characteristic	n	Min	Max	Mean	SD
Forage Yield, t/ha	72	5.91	9.38	7.86	0.86
Grain Yield, t/ha	72	1.82	6.79	4.78	1.09
Straw Yield, t/ha	72	2.30	4.99	3.58	0.58
Harvest Index, ratio	72	0.35	0.66	0.57	0.06
Forage ADF	72	22.61	41.19	33.20	3.73
Grain ADF, %	72	3.97	10.22	5.86	1.01
Straw ADF, %	72	32.50	53.30	48.11	4.39
Grain DMD, %	46	14.38	47.42	31.75	6.71
Forage Crude Protein, %	72	11.19	17.50	13.38	1.00
Grain Crude Protein, %	72	12.60	17.80	15.04	1.00
Straw Crude Protein, %	72	5.06	9.68	6.75	1.00
Plant Height, cm	72	73.00	102.00	86.01	5.78
Head Date, Julian date	72	189.00	180.00	185.26	2.64

Table II. Correlation coefficients (r) of yield, quality, and agronomic characteristics of grain

	Grain				
Characteristic	Yield	ADF	ISDMD	CP	Test Weight
Grain					
Yield	--	-0.33**	0.35*	0.04	0.47**
ADF	-0.33**	--	-0.35*	-0.04	-0.65**
ISDMD	0.35*	-0.35*	--	-0.17	0.60**
CP	0.04	-0.04	-0.17	--	0.33**
Test Weight	0.47**	-0.65**	0.60**	0.33**	--
Agronomic					
Harvest Index	0.79**	-0.23*	0.38**	-0.01	0.45**
Plant Height	-0.41**	0.27*	-0.10	-0.02	-0.17
Head Date	0.13	0.17	-0.48**	-0.18	-0.45**

** = P<0.01, * = P<0.05

Table III. Correlation coefficients (r) of yield, quality, and agronomic characteristics of forage

	Forage			
Characteristic	Yield	ADF	ISDMD	CP
Forage				
Yield	--	0.22	0.11	-0.33**
ADF	0.22	--	-0.08	-0.04
DMD	0.11	-0.08	--	-0.07
CP	-0.33**	-0.04	-0.07	--
Grain				
Yield	0.36**	-0.08	0.23*	0.03
ADF	-0.28*	0.31**	-0.36**	-0.02
ISDMD	0.05	-0.38**	0.18	-0.21
CP	0.26*	0.13	0.02	-0.23
Test Weight	0.33**	-0.34**	0.25*	-0.18
Straw				
Yield	0.41**	-0.18	0.17	-0.04
ADF	-0.46**	-0.24*	-0.20	-0.01
ISDMD	0.03	-0.06	0.27*	0.44**
CP	0.04	0.08	-0.15	0.03
Agronomic				
Harvest Index	0.10	-0.18	0.19	0.06
Plant Height	0.23	0.25*	-0.05	-0.27*
Head Date	0.25*	0.36**	-0.15	0.33**

** = $P < 0.01$, * = $P < 0.05$

Table IV. Correlation coefficients (r) of yield, quality, and agronomic characteristics of straw

	Straw			
Characteristics	Yield	ADF	ISDMD	CP
Grain				
Y	0.36**	-0.08	0.44**	-0.05
ADF	-0.16	0.24*	-0.03	-0.01
ISDMD	-0.03	0.17	-0.16	-0.15
CP	0.11	0.04	-0.27*	-0.11
Test Weight	0.05	0.06	-0.11	-0.00
Straw				
Yield	--	-0.16	0.22	-0.14
ADF	-0.16	--	-0.22	-0.17
ISDMD	0.22	-0.22	--	-0.04
CP	-0.14	-0.17	-0.04	--
Agronomic				
Harvest Index	-0.24*	0.02	0.30*	-0.01
Plant Height	-0.06	-0.08	-0.39**	0.17
Head Date	0.35**	-0.39**	0.42**	0.10

** = $P < 0.01$, * = $P < 0.05$

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ASSESSING THE NUTRITIVE VALUE OF ONE-SEED JUNIPER IN SHEEP

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ABSTRACT: One-seed juniper (*Juniperus monosperma*; **JM**) encroachment on rangelands is a problem in the Southwest. A proposed method of JM control is defoliation by small ruminants. Juniper produces secondary metabolites that may be antimicrobial in nature. Ruminants depend on ruminal microbes for digestion of feed. Five ruminally fistulated wethers (BW 55 ± 15 kg) were used in two cross-over experiments composed of two 20-d periods to estimate nutritive value of JM as a forage. In Exp.1, sheep were fed either 100% buffalo grass straw (*Buchloe dactyloides*; **BS**; 93% DM, 76.5% NDF, 4.5% CP (DM basis)) or a mixed diet of 75% buffalo grass straw and 25% JM (**BS+JM**; JM contained 73% DM, 71.7% NDF, 6.0% CP (DM basis)) at 2% of BW. In Exp. 2, either soybean meal (**SBM**) or fish meal (**FM**) was added to BS+JM to achieve 12% CP. Protein sources of differing rumen degradabilities were fed to determine the potential for associative effects. Sheep were gradually adapted to a diet over a 10-d period fed at 2% of BW. Orts were weighed and then placed directly into the rumen via rumen cannulae. Total feces and urine were collected and subsampled on d 6-10 of each period. Rumen evacuations were conducted on d 10 of each period. Dry matter and NDF were determined for composited fecal and rumen samples for each sheep fed each treatment combination. Dry matter and NDF digestibility results were analyzed using the GLM procedure of SAS. Rumen NDF and DM fill were similar ($P > 0.05$) among sheep and diets; sheep had similar diet digestibilities ($P > 0.05$). The BS+JM diet showed higher ($P < 0.05$) DM and NDF digestibility compared to the 100% BS diet (BS+JM: 56.18, 65.90% ± 1.83; BS: 47.71, 54.39 ± 1.48, for DM and NDF digestibility, respectively). The addition of SBM or FM to the mixed diet had no influence ($P \geq 0.15$) on DM or NDF digestibility (SBM: 49.07, 50.85 ± 1.79; FM: 57.37, 61.26% ± 1.41 for DM and NDF digestibility, respectively). Based on these data, adaptation to diets containing JM may reduce the antimicrobial effects of secondary metabolites found in JM.

Keywords: *Juniperus monosperma*, Juniper, Digestibility

Introduction

There is an abundance of Juniper (*Juniperus monosperma*) in much of the southwestern United States, including New Mexico. Juniper encroachment reduces the availability of desirable forage. One method of control is thought to be defoliation by small ruminants. However, low nutritional quality and high levels of essential oils result in low consumption of juniper by goats (Pritz, 1997). Still, juniper is often grazed when other forage is scarce, such as a period of drought. Laboratory analysis shows that one-seed juniper contains at least 51 terpenoids, some of which have been found to be antimicrobial in nature, and inhibit the growth of rumen and lower gut microbes (Nagy et al., 1964; Oh et al., 1967; Utsumi et al., 2006). In addition, these compounds may contribute to its lack of palatability to the ruminant animal. A reduction in the viability of the rumen microbial population could result in decreased feed digestibility, passage, and yield of fermentation products, leading to compromised animal health (King et al., 1995; Nagy and Tengerdy, 1967). These secondary metabolites, which include terpenes, may also result in toxicosis to the animal, (Estell et al., 2005; Launchbaugh et al., 1964; Pritz et al., 1997; Painter, 1971). However, despite juniper's possible toxicity, it is apparent that it does possess value as a livestock and wild ungulate browse specie. Yet, limited data exist regarding the value, if any, of juniper as a feedstuff, and its effect on the digestibility of other forages. Therefore, information is needed regarding the nutritional value of juniper as a feedstuff.

The objective of this study was to evaluate the digestibility of one-seed juniper when fed with a basal diet of mature buffalo straw hay, as well as evaluate the possibility of any associative effects when juniper is consumed with protein supplements.

Materials and Methods

Five ruminally fistulated crossbred wethers (BW 55 ± 15 kg) were used in two cross-over experiments composed of two 20-d periods to estimate nutritive value of one-seed juniper (*Juniperus monosperma*; JM) as a forage. Juniper was harvested at the Corona Range and Livestock Center, Corona, NM in early September 2005. The Corona Range and Livestock Research Center is located 300 km northeast of Las Cruces, NM (average elevation = 1900 m; average precipitation = 400 mm). Harvested juniper consisted of individual leaves stripped from the ends of branches of immature shrubs. The leaves were stored in a cooler at 4°C for the duration of the study, as Utsumi et al. (2006), showed that cold storage prevents changes in terpenoid profiles. Any particularly large leaf segments were individually cut into smaller pieces (± 5 cm in length) to allow for easier consumption and(or) digestion.

Each 20-d experimental period was made up of two phases. The first phase consisted of 5 d of adaptation to the diet, while the second 5 d made up the collection phase. The diets were then repeated with the remaining animals to conduct the remainder of the crossover

experimental design. In Exp. 1, sheep were fed either 100% buffalo grass straw (*Buchloe dactyloides*; BS) or a mixed diet of 75% buffalo grass straw and 25% juniper (BS+JM) at 2% of BW. In Exp. 2, either soybean meal (SBM) or fish meal (FM) was added to BS+JM to achieve 12% CP. Protein sources of differing rumen degradabilities were fed to determine the potential for associative effects. Orts were weighed and then placed directly into the rumen via rumen cannulae. Nutrient compositions of buffalo grass straw, juniper, soybean meal, and fish meal were determined by methods described above, and are shown in Table 1.

Total fecal and urine collections were taken the last 5 d of each period. A 10% aliquot was reserved each d and compiled by period for later analysis. Urine was frozen until laboratory testing. Feces were divided into two parts, one to remain fresh for nitrogen analysis (Leco FP-528, Leco Corp., St. Joseph, MI) and one to be dried and ground through a 2-mm screen for NDF and mineral (aluminum, cobalt, copper, iron, manganese, molybdenum, and zinc) analysis. Rumen evacuations were conducted on d 10 of each period to account for any residual amounts of feed. Dry matter and NDF were determined for composited fecal and rumen samples for each sheep fed each treatment combination. Nitrogen and mineral retentions were also analyzed using fecal and urine samples. Results of the analysis were used to calculate daily nitrogen retention, NDF digestibility and mineral retention.

Blood samples were collected at 0, 4, and 8 h after juniper consumption via the jugular vein on d 10 of each trial. Samples were centrifuged (1500 × *g* 15 min., 4°C). Serum was separated and stored frozen until analyzed for evidence of toxicosis through testing of liver-specific enzymes, including ALT transfertase and alkaline phosphatase, (Texas Veterinary Medical Diagnostic Laboratory System, Amarillo, TX).

Dry matter and NDF digestibility, nitrogen and mineral retention, and serum clinical profiles were analyzed using the GLM procedure of SAS (SAS Inst., Inc., Cary, NC).

Results and Discussion

Dry matter and NDF digestibility of treatment diets is shown in Table 2. Dry matter digestibility (DM basis) for the basal buffalo grass straw diet was 47.7% ± 1.49 and 56.2% ± 1.49 for the diet containing 25% one seed juniper. Neutral detergent fiber digestibility was 54.4% ± 1.83 for the straw diet and 65.9% ± 1.83 for the juniper containing diet. These results indicate that the consumption of juniper in a diet similar to dormant native range increased total diet digestibility. These digestibility results contrast with the views of Launchbaugh et al., (1997) who stated that the reduced activity of microbes in the digestive tract would lead to decreased diet digestibility. A possible explanation for this contrast may be the length of time sheep were allowed to adapt to juniper in the present study. In addition, White et al., (1980) found that 77% of terpenes are lost through mastication, and may actually never reach the rumen.

Dry matter digestibility (DM basis) for the mixed diet with soybean meal was 49.1% ± 1.79 and 50.8% ± 1.79 for the diet containing fish meal. Neutral detergent fiber digestibility was 57.4% ± 1.41 for the diet containing soybean meal and 61.3% ± 1.41 for the fish meal containing diet. These results indicate that there are a lack of associative effects associated with total diet digestibility when one-seed juniper is fed with protein supplements.

Serum clinical profiles showed no evidence of toxicosis ($P > 0.05$) in levels of the two liver enzymes tested, ALT transfertase and alkaline phosphatase. Normal levels of ALT transfertase are 30 ± 4 U/I, and normal levels of alkaline phosphatase are 178 ± 102 U/I (Kaneko, 1989). Laboratory testing yielded averages of 11.5 ± 0.60 and 11.1 ± 0.60 U/I of serum ALT transfertase for the basal diet and the mixed diet, respectively, and 12.9 ± .34 and 12.2 ± .32 U/I with the additions of soybean and fish meal. Levels were 53.5 ± 1.06 and 54.3 ± 1.06 U/I for serum alkaline phosphatase, respectively, and 58.8 ± 1.50 and 55.8 ± 1.43 U/I with the additions of the protein supplements. These results are consistently below average for toxicosis. These findings are converse to those by Pritz et al., (1997) who found some levels of tissue damage as evidenced by liver-specific enzymes in Angora goats and King et al., (1995) for sheep fed Tarbush, a shrub rich in terpenes. However, it should be noted that Pritz el al., (1995), offered freshly harvested branches which may have accounted for higher terpene concentrations than the cold-stored branches used in this study. We did not measure terpene concentration in juniper leaves and do not know if the harvesting procedure affected the rate of terpene volatilization.

Implications

Results from the current work imply that juniper may indeed be a feasible feedstuff when browsed by small ruminants. Although laboratory measurements indicate that juniper is highly digestible, palatability may reduce its consumption in a practical setting. Thus, adaptation to diets containing juniper may be necessary, and may also reduce the antimicrobial effects of secondary metabolites found in juniper. Digestibility of the diet containing juniper was higher than that of the basal buffalo grass straw diet, implying that the addition of juniper to a range diet will not negatively impact overall diet digestibility over a short period of time. Testing of liver-specific enzymes also yielded no evidence of toxicosis due to the secondary metabolites found in juniper, and although juniper was not analyzed, we believe that juniper consumption did not compromise hepatic function in sheep used in this study.

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Table 1. Nutrient composition of buffalo grass straw, one-seed juniper, soybean meal, and fish meal.

Item	DM %	NDF, %DM	CP, %DM
Buffalo Grass Straw	93.2	76.5	4.7
One-Seed Juniper	72.8	71.7	6.0
Soybean Meal	90.1	8.5	63.1
Fish Meal	90.5	15.9	45.1

Table 2. Dry Matter and Neutral Detergent Fiber digestibility of treatment diets, where BS=buffalo straw, JM=juniper, SBM=soybean meal, FM=fish meal, and SE=pooled standard error.

	Experiment 1			Experiment 2		
Item	BS	BS+JM	SE	BS+JM+SBM	BS+JM+FM	SE
DM digestibility, %	47.7^{a}	54.4^{b}	1.49	49.1^{x}	50.8^{x}	1.79
NDF digestibility, %	56.2^{c}	65.9^{d}	1.83	57.4^{y}	61.3^{y}	1.41

Means lacking a common superscript differ (P<0.05)

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BREEDING PERFORMANCE OF PRIMIPAROUS BEEF COWS EXPOSED TO THE BIOSTIMULATORY EFFECT OF BULLS USING A PROGESTIN-BASED ESTROUS SYNCHRONIZATION PROTOCOL[1]

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ABSTRACT: The objective of these experiments was to determine if factors associated with the biostimulatory effect of bulls alter breeding performance of primiparous suckled beef cows using progestin based estrus synchronization (ES) protocol. We tested the hypotheses that the ES response and AI pregnancy rates do not differ among cows exposed to bulls, continuously exposed to bull urine, and exposed to fence-line contact of bulls, or cows not exposed to bulls or bull urine. Data were collected from three experiments (Exp) performed over consecutive years. Cows were assigned to: physical bull exposure (BE; n=26) or no bull exposure (NE; n=27); bull urine exposure (BUE; n=19) or steer urine exposure (SUE; n=19); bull fence-line contact (BFL; n=26) or no fence-line contact (NE; n=26) in Exp 1, 2, and 3, respectively. The ES protocol in each Exp included the use of CIDR (d -10), $PGF_{2\alpha}$ (PG; d -3), GnRH and fixed-time AI (d 0), and cows that were observed in estrus by 60 h after PG were bred AI 12 h later. In Exp 1, 2, and 3 cows were exposed directly to bulls, bull urine, or bull fence-line contact for 35, 64 and 42 d, respectively. Data were analyzed between treatments within each Exp. Proportion of cows cycling did not differ between treatments at the start of each Exp; however, more (P <0.05) BE and BFL cows were cycling at the start of ES than NE cows in Exp 1 and 3. Proportion of cows that showed estrus and interval to estrus after PG did not differ in Exp 1 and 3; however, in Exp 2, BUE cows tended (P=0.09) to have shorter intervals to estrus and exhibit estrus after PG than SUE cows. Overall AI pregnancy rates were greater (P<0.05) for BE and BUE cows than NE and SUE cows in Exp 1 and 2, respectively. There was no difference between treatments in Exp 3. The presence of bulls and exposure to bull urine appeared to improve breeding performance of primiparous beef cows using a progestin-based ES protocol, whereas, fence-line bull exposure apparently is insufficient to cause this biostimulatory effect.

Key words: biostimulation, breeding performance, CIDR

Introduction

Prolonged postpartum anestrus is the major cause of cows failing to rebreed or breeding late in the breeding season. This is a particular problem in first-calf suckled cows that require 15 to 25 d longer to return to estrus than multiparous cows (Short et al., 1994). For this reason it can be a challenge to successfully synchronize estrus or ovulation in first-calf suckled beef cows.

Cows exposed to bulls or bull excretory products after calving resume luteal function soon than cows not exposed to bulls or bull excretory products (Custer et al., 1990; Berardinelli and Joshi, 2005b). Berardinelli et al. (2006) reported that AI pregnancy rates are not significantly improved by bull exposure using a GnRH-based estrous synchronization (ES) protocol. However recently we found a tendency that timed AI (TAI) pregnancy rates can be improved if cows are previously exposed to bulls (Anderson et al., 2002). The question we asked in this study is "Can the biostimulatory effect of bulls be used to improve ES response and AI pregnancy rates of first-calf suckled beef cows using a progestin-based ES protocol?"

Our objectives were to determine if short-term bull exposure, continuous bull urine exposure, or fence-line bull exposure of first-calf suckled beef cows alters estrous synchronization (ES) response and improves AI pregnancy rates using a progestin-based ES protocol that included a controlled internal drug release device (CIDR; d -10), $PGF_{2\alpha}$ (PG; d -3), GnRH and fixed-time AI (d 0; 72 h after PG). We tested the hypotheses that, 1) the proportion of cows that resume luteal function before the breeding season, 2) ES response, and 3) AI pregnancy rates did not differ among first-calf postpartum: cows exposed to the physical presence of bulls (BE) or not exposed to bulls (NE) in Experiment 1 (Exp 1); cows continuously exposed to either bull urine (BUE) or steer urine (SUE) in Experiment 2 (Exp 2); and cows exposed to fence-line contact with bulls (BFL) or not exposed to bulls (NE) in Experiment 3 (Exp 3).

Materials and Methods

Animals and Treatments

Experiments were conducted in three consecutive years at the Montana State University Livestock Teaching

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and Research Center, Bozeman. Animal care, handling, and protocols used in these experiments were approved by the Montana State University Institutional Large Animal Care and Use Committee.

In each experiment (Exp) cows were maintained in a single pasture after calving and had not been exposed to bulls or bull excretory products since the previous breeding season. Before the start of treatment cows were stratified by calving date, calf BW, cow BW, cow BCS and dystocia score, and assigned randomly to one of two treatments within each experiment; physical presence of bulls (BE) or no bull exposure in Exp 1; continuous bull urine exposure (BUE) or continuous steer urine exposure (SUE) in Exp 2; and bull fence-line exposure (BFL) or no bull exposure (NE) in Exp 3. The calving season for cows in each of the experiments started January 27 and ended March 10. Average calving dates were February 16, 9, and 10 for cows in Exp 1, 2, and 3 respectfully. Treatment started 28 and 35 d before the start of the estrous synchronization (ES) protocol in Exp 1 and 3 respectfully. In Exp 2 cows were exposed to urine starting 39 to 42 d after calving. In Exp 1, 2, and 3 cows were exposed directly to bulls, bull urine, or bull fence-line contact for 35, 64 and 42 d, respectively. Cows and calves remained in there respective treatments throughout each experiment until 3 d after the end of exposure.

Animal Housing Areas and Bull Exposure

The same two lots areas were used each experiment, designated north and south by their geographic location. Each lot contained four pens (41 m x 18 m) that were similar in east-west configuration, bunk space, aspect, slope, and connection to open-shed shelters. Cows were allowed to move between two pens in each lot. Lots were approximately 0.35 km apart. These lots and arrangements have proven to be effective in previous experiments involving bull-cow interactions (Berardinelli and Joshi, 2005a,b).

In Exp 1 bulls were housed in the north lot area and were allowed to move freely within pens the pens that housed BE cows, while NE cows were housed in the south lot area. In Exp 2 BUE cows were housed in the north lot area and SUE cows were housed in the south lot area; bulls and steers were housed in two separate pens approximately 80 m apart and in a separate lot area north of lots that housed cows by approximately 0.4 km. In Exp 2 urine was collected from bulls and steers and exposed to cows as described by Tauck (2005). In Exp 3 bulls were housed in small enclosures within the two pens that housed BFL cows in the north lot area; a vacant enclosure (housed no animals) that equaled the size of the enclosure that housed bulls in the north lot area was built within pens that housed NE cows in the south lot area. Bull exposure, bull and steer urine exposure, and bull fence-line exposure ended 3 d before the end of treatment in Exp 1, 2, and 3 respectfully.

Nutrition

In each experiment cows had free access to good quality, chopped mixed-grass alfalfa hay, and any pasture grasses that were available before the start of each experiment. Once cows and calves were moved into pens, they were given free access to the same hay, 0.5 kg●hd $^{-1}$●d $^{-1}$ cracked barley, water, and a trace mineral-salt supplement. The TDN of the diet exceeded the NRC requirement for lactating beef cows with a mature weight of 545 kg by approximately 18% (NRC, 1996).

In Exp 1 bulls were housed with cows at the start of treatment and were fed the same diet as cows. In Exp 2 bulls had ad libitum access to fair quality, chopped barley hay. During urine collection periods in Exp 2, bulls were fed 0.5 kg of cracked barely and good quality, chopped mixed-grass alfalfa hay. Steers in Exp 2 were fed a finishing ration that consisted of 70% concentrate (50% corn and 50% barley) and 30% roughage (ground grass/alfalfa hay) throughout the experiment and during urine collection periods. In Exp 3 bulls within the small enclosure were fed ad libitum mixed grass-alfalfa hay.

Estrus Synchronization, AI, and Pregnancy Diagnosis

In each experiment cows were given exogenous progesterone via a controlled internal drug release device (CIDR) ten d before TAI. Seven d later CIDRs were removed cows were given $PGF_{2\alpha}$ (PG), at the same time bull exposure, bull and steer urine exposure, and bull fence-line exposure ended in Exp 1, 2, and 3 respectfully. Cows that showed estrus within 60 h after CIDR removal were bred by AI 12 h later. Cows that did not show estrus within 60 h were given GnRH (100 ug/hd) and bred by fixed-time AI 72 h after CIDR removal, at which time treatments ended and cows were combined and managed as one group in each experiment. Cows were exposed to natural service bulls 18 d later for 21 d. Pregnancy rates to AI were determined by transrectal ultrasonography of the uterine contents of each cow 35 d after TAI.

Criteria for Resumption of Luteal Activity

Exp 1 and 2

Blood samples were obtained from each cow in each treatment by jugular venepuncture every third d over the course of the exposure periods used in these experiments. Serum was harvested and stored at –20^{o}C until assayed for progesterone. Progesterone was assayed using solid-phase RIA kits (Diagnostic Products Corp., Los Angeles, CA) validated in our laboratory for bovine serum (Custer et al., 1990). Changes in progesterone concentrations were used to assess the resumption of ovarian cycling activity. An increase in baseline progesterone concentrations in three consecutive samples that exceeded 1.0 ng/mL was used as evidence of resumption of luteal function in these experiments.

Exp 3

Ovaries of each cow were examined by transrectal ultrasonography using an Aloka 200 with a 5 MHz rectal transducer at the start of the experiment and at 7-d intervals over the 42-d exposure period used in this trial. The presence of a corpus luteum in the same anatomical position of an ovary in two successive scans was used as evidence of resumption of luteal activity.

Statistical Analyses. Data were analyzed between treatments within each experiment. Intervals from PG to estrus were analyzed by ANOVA for a completely randomized design using PROC GLM of SAS (SAS Inst. Inc., Cary, NC). The model included treatment and means were separated by the PDIFF procedure of SAS. Proportions of cows that resumed luteal function, showed estrus after PG injection, and AI pregnancy rates were analyzed by chi-square analyses using the PROC FREQ procedure of SAS.

Results

Proportion of cows cycling did not differ between treatments at the start of each Exp; however, in Exp 1 and 3 more ($P < 0.05$) BE (100%) and BFL (85.7%) cows were cycling at the start of ES than NE cows (70.4% and 72.8%, respectfully). In Exp 2 there was no difference in the proportion of cows that resumed luteal function between BUE (15%) and SUE (33%) cows.

Proportion of cows that showed estrus and interval to estrus after PG did not differ in Exp 1 and 3; however, in Exp 2, BUE cows tended ($P = 0.09$) to have shorter intervals to estrus and exhibit estrus after PG than SUE cows (Table 1). Overall AI pregnancy rates were greater ($P < 0.05$) for BE and BUE cows than NE and SUE cows in Exp 1 and 2, respectively (Table 1). There was no difference between treatments in Exp 3 (Table 1).

Discussion

The physical presence of bulls decreases the postpartum anestrous interval in first-calf suckled beef cows (Custer et al., 1990; Fernandez et al., 1993; 1996). We found that resumption of normal luteal activity was stimulated in cows exposed to close physical contact of bulls (Exp 1) and fence-line contact of bulls (Exp 3). These results are similar to and support those reported by Fike et al. (1996) who showed that exposing primiparous cows to fenceline contact with bulls, in a manner similar to that used in Exp 3, accelerated resumption of ovarian cycling activity.

Cows exposed to the excretory products of bulls resumed ovarian cycling activity earlier after calving than cows not exposed to bulls (Berardinelli and Joshi, 2005b). From these data it appears that bulls excrete a pheromone into the urine, feces, or from cutaneous glands that may initiate a neuroendocrine-endocrine cascade which results in the resumption of ovarian cycling activity. Most male to female interactions that alter the reproductive activity of the female are mediated by pheromones excreted in the urine of males (for review, see, Vandenberg, 1983). Thus, the most likely excretory product to evaluate for pheromonal activity in the biostimulatory effect of bulls is urine. In Exp 2 the percentage of SUE cows cycling by the end of the exposure period was comparable to the percentage of cows cycling that were not exposed to bulls in previous years (Berardinelli and Joshi, 2005 a,b). However, only 15% of BUE cows were cycling by the end of the exposure period. These data are contrary to those of Berardinelli and Joshi (2005b) who reported that more cows exposed to the excretory products of bulls resumed cycling activity than cows exposed to their own excretory products or cows not exposed to bulls or their own excretory products. These results indicate that the manner of bull urine exposure in Exp 2 was not appropriate and postpartum anestrous cows to mature bull urine in a continuous manner does not alter the occurrence of resumption of luteal activity, however both the physical presence of bulls and fence-line contact stimulated resumption of luteal activity.

One objective of this study was to evaluate the effect of bull exposure on estrous synchronization (ES) response. We found a tendency that more BUE exhibited estrus within 60 h after PG than SUE cows in Exp 2, however there was no difference in ES response between treatments for cows in Exp 1 and 3. These results are similar to previous experiments conducted in laboratory which found bull exposure had no effect on the proportion of cows that exhibited estrus in response to GnRH-based ES protocols (Berardinelli et al., 2006).

The primary objective of this study was to evaluate the effect of bull exposure on AI pregnancy rates. In Exp 3 there was no difference in AI pregnancy rates between cows exposed to fence-line contact with bulls and cows not exposed to bulls. This result is consistent with Fike et al. (1996) who reported that bull fence-line contact had no effect on AI pregnancy rates. However, overall AI pregnancy rates were higher for BE and BUE cows than SUE and NE cows in Exp 1 and 2 respectfully. This result is not consistent with that of Anderson et al. (2002) who reported that AI pregnancy rates did not differ among; cows exposed to the excretory products of bulls, cows exposed to their own excretory products, cows exposed to the physical presence of bulls, and cows not exposed to bulls or their own excretory products. One difference between Anderson et al. (2002) and the present experiment is the use of CIDR. Progestin was not used by Anderson et al. (2002) and recently, Stevenson et al. (2003) reported that progestin treatment concurrent with a GnRH fixed-time AI ES protocol improved pregnancy rates in suckled beef cows after AI. Thus, fence-line bull exposure was insufficient to improve AI pregnancy rates however; it appears that the physical presence of bulls and continuous bull urine exposure was sufficient to improve AI pregnancy rates.

We conclude that continuous bull urine exposure was inappropriate to stimulate resumption of luteal activity, however the physical presence of bulls whether in close contact or fence-line contact stimulated resumption of luteal activity. Additionally, AI pregnancy rates are not altered by fence-line contact however; AI pregnancy rates can be improved by the use physical presence of bulls and continuous bull urine exposure in conjunction with a progestin-based ES protocol.

Implications

Taken together these results indicate that the manner, frequency, duration, and magnitude of pheromone stimuli involved with the biostimulatory effect of bulls influences resumption of luteal activity and fertility through divergent physiological methods. However, further study to elucidate this subject is needed.

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Table 1. Estrus synchronization (ES) response and AI pregnancy rates for first-calf postpartum cows; not exposed (NE) or exposed to bulls (BE) in Experiment 1 (Exp 1), continuously exposed to either bull (BUE) or steer (SUE) urine in Experiment 2 (Exp 2), and not exposed (NE) or exposed to fence-line contact with bull (BFL) in Experiment 3 (Exp 3) using an ES protocol that included CIDR (7 d), $PGF_{2\alpha}$ (PG), and timed AI (TAI) and GnRH 72 h after PG

	Treatment (Exp 1)				Treatment (Exp 2)				Treatment (Exp 3)			
Variable	BE	NE	X^2	*P* value	BUE	SUE	X^2	*P* value	BFL	NE	X^2	*P* value
n	26	25			19	19			26	26		
Interval to estrus after PG, h[a]	65.8	67.8		0.67	54.4	63.1		0.09	65.8	67.6		0.67
Proportion showing estrus after PG, %	42.3	36.0	0.2	0.64	80.0	52.6	2.9	0.09	61.5	50	0.7	0.40
Estrus AI pregnancy rate, %	100	66.7	4.3	< 0.05	86.7	50.0	4.0	< 0.05	56.3	77.0	1.4	0.24
TAI pregnancy rate, %	73.3	56.3	1.0	0.32	100	60.0	2.2	0.13	60.0	77.0	0.8	0.38
Overall AI pregnancy rate, %	84.6	60.0	3.9	< 0.05	89.5	55.0	5.7	< 0.05	57.7	77.0	2.1	0.14

[a]Standard error for means, for interval to estrus after PG: Exp 1 = 17.0; Exp 2 = 16.2; Exp 3 = 15.0.

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COMPARISON OF CIDR AND MGA AS PROGESTIN SOURCES IN AN ESTRUS SYNCHRONIZATION PROTOCOL THAT INCLUDED PROGESTIN, PGF_{2A}, AND TIMED AI AND GNRH IN BEEF HEIFERS[1]

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ABSTRACT: The objective of this experiment was to compare the estrus synchronization (ES) response and AI pregnancy rates of beef heifers using protocols that included controlled internal drug release devices (CIDR) or melengesterol acetate (MGA), $PGF_{2\alpha}$ (PG), and, timed AI (TAI) and GnRH. We tested the hypotheses that: 1) ES response after progestin (P) removal and after PG injection; and, 2) AI pregnancy rates do not differ between heifers synchronized using the CIDR or MGA protocol. On d 0 of the experiment 80 yearling crossbred Angus X Hereford heifers were stratified by age, BW, BCS, uterine tract score, and ovarian structures and assigned to be fed a supplement that contained MGA (0.5 MGA mg/hd/d) for 14 d (MES; n = 40) or given a CIDR and fed the same supplement without MGA for 14 d (CES; n = 40). On d 14 MGA supplementation ceased and CIDR were removed. Heifers were observed for estrus 3 to 4 times daily for 96 h after removal of P and twice daily until PG injection on d 29 and 31 for CES and MES heifers respectively. Thereafter, heifers were observed for estrus during the next 60 h from 0600 to 2400 h. Heifers that exhibited estrus within 60 h after PG were bred by AI 12 h later, heifers that did not exhibit estrus by 60 h were TAI at 72 h after PG and given GnRH (100 ug/hd). The proportion of heifers that exhibited estrus after P removal tended ($P = 0.087$) to be greater for CES heifers than for MES heifers. Interval for heifers that exhibited estrus after P removal was shorter ($P < 0.05$) for CES heifers than MES heifers. More ($P < 0.05$) CES heifers exhibited estrus and were bred by AI within 60 h after PG than MES heifers. Overall AI pregnancy rates did not differ between CES and MES heifers. We conclude that using CIDR as a progestin source in a 14 d progestin, PG, and timed AI and GnRH estrus synchronization protocol is as effective as MGA to synchronize estrus and generate AI pregnancies in beef heifers.

Key Words: CIDR, estrus synchronization, heifers

Introduction

The onset of puberty is a primary factor that determines if and when pregnancy occurs in beef heifers. If heifers are bred and conceive early in their first breeding season then the probability that that lifetime productivity increases (Lesmeister et al., 1973). Progestin treatment for 9 or 14 d of melengesterol acetate (MGA) can induce puberty in young beef heifers (Short et al., 1976; Jaeger et al., 1992). Estrus synchronization (ES) protocols that include progestin treatment for at least 9 d can be an effective method to increase the proportion of heifers that become pregnant early in their first breeding season. There are many methods for ES available to producers. The most widely used and accepted ES method for yearling heifers is feeding MGA fed for 14 d followed by $PGF_{2\alpha}$ (PG) 17 to19 d later and using artificial insemination (AI) 12 h after estrous or fixed-timed AI 72 h after PG injection (Brown et al., 1997; Patterson et al., 1992). Unfortunately, many cow-calf producers lack the facilities, time, and labor necessary to successfully implement this ES method. The development of an ES technology that includes a controlled internal drug release device (CIDR) for 14 d may be an alternative ES management strategy for producers that cannot use the standard MGA ES protocol in beef heifers.

The objective of this experiment was to compare the ES response and AI pregnancy rates of beef heifers using protocols that included CIDR or MGA, PG, and, timed AI (TAI) and GnRH. We tested the null hypotheses that interval to estrus after progestin removal, proportion showing estrus after progestin removal, interval to estrus after PG, proportion showing estrus after PG, and AI pregnancy rates do not differ between heifers synchronized using 14 d of either CIDR or MGA.

Materials and Methods

Animals and Treatments

Eighty Angus-Hereford beef heifers (12 to 14 mo of age) were used in this experiment conducted at the Montana State University Livestock Teaching and Research Center, Bozeman. Animal care, handling, and protocols used in this experiment were approved by the

[1]Supported by the Montana Agricultural Experiment Station. Contributing project to Multisate Research Project, W-112, Reproductive Performance in Domestic Ruminants.

Montana State University Institutional Large Animal Care and Use Committee.

At the start of the treatment the average age, weight and BCS of heifers were 12.8 ± 0.6 (mean ± SE), mo., 379.5 ± 22.0 kg, and 4.8 ± 0.2, respectfully. One d before the start of treatment heifers were stratified by age, BW, BCS, uterine score, and ovarian structure. Uterine score was assessed by palpation of the size of the uterine horns and ranged from 1 to 3 (1 = diam. ≤ 1 cm, 2 = diam. 2-3 cm, 3 = diam. ≥ 3 cm). Ovarian structures was measured by transrectal ultrasonography and ranged from 0 to2 (0 = No follicles present on ovaries or follicles on ovaries were < 10 mm, 1 = follicles present on ovaries ≥ 10mm, 2 = presence of a corpus luteum). Once stratified, heifers were assigned randomly within strata to one of two treatments to ES protocols that included CIDR (CES; n = 40) or MGA (MES; n = 40) as the progestin source.

Animal Housing Areas

Two lots were used for this experiment, designated north and south by their geographic location. Lots were adjacent to each other and separated by a barb-wire fence and were identical in east-west configuration, bunk space, aspect, and slope. Heifers were allowed to move between two pens in each lot.

Nutrition

Heifers were given 12.7 kg●hd $^{-1}$●d $^{-1}$ of good quality, chopped mixed-grass alfalfa hay, 1.1 kg●hd $^{-1}$●d $^{-1}$ cracked barley, 0.45 kg●hd $^{-1}$●d $^{-1}$ supplement that contained 38% protein and 200 mg of Rumensin, water, and a trace mineral-salt supplement throughout the experiment. Heifers were fed one half of the ration in the morning (0800-1000 h) and one half late in the afternoon (1600-1700 h). At the start of treatment CES heifers were fed the same supplement and MES heifers were fed the same supplement plus MGA, each MES heifer received 0.5 mg●hd $^{-1}$●d $^{-1}$ MGA.

Estrus Synchronization, AI, and Pregnancy Diagnosis

Each CES heifer was administered a CIDR (EAZI-BREED™, Pharmacia and Upjohn Co, Kalamazoo, MI 49001) and MES heifers were fed MGA starting March 30 (d 1). Fourteen days later (d 14) CIDR were removed and MGA feeding ceased. Heifers in each treatment were then observed for estrus twice daily for the next 10 d. CES and MES heifers were given PG (25mg/hd) 17 and 19 d, respectively, after CIDR removal or last MGA feeding. Heifers were visually observed for estrus thrice daily after PG injection (0730, 1200, 1800 h). Heifers that exhibited estrus within 60 h after PG injection were bred by AI 12 h later. Heifers that did not exhibit estrus by 60 h after PG were bred by AI 72 h after PG (TAI), and were given GnRH (100 μg/hd) intramuscularly. Artificial insemination was accomplished using a single AI technician and semen from a single bull. Heifers were exposed to bulls for natural service 18 d after TAI for 21 d. Pregnancy was diagnosed by transrectal ultrasonography of the uterine contents of CES and MES heifers 35 d after TAI.

Statistical Analyses. Intervals from progestin removal to estrus and from PG injection to estrus were analyzed by separate ANOVA for a completely randomized design using PROC GLM of SAS (SAS Inst. Inc., Cary, NC). The model included treatment and means were separated by the PDIFF procedure of SAS. Proportions of heifers that showed estrus by 120 h after progestin removal, proportions of heifers that exhibited estrus by 60 h after PG injection and AI pregnancy rates were analyzed by separate chi-square analyses using the PROC FREQ procedure of SAS. Cumulative frequency distributions at 12-h intervals for the ES response after progestin removal were analyzed by chi-square analyses using the PROC FREQ procedure of SAS.

Results

Heifers that exhibited estrus after 120 h after progestin removal were considered to be non-responsive to the ES protocol and were not used in analyses of the ES response after progestin removal. Interval to estrus after progestin removal occurred 43.6 h earlier ($P < 0.05$) in CES heifers than in MES heifers and there was a tendency ($P = 0.087$) for more CES heifers (62.5%) to show estrus within 120 h after progestin removal than MES heifers (42.4%; Table 1). Examination of the cumulative percentage distributions of the ES response between CES and MES heifers after removal of progestin indicated that more CES heifers exhibited estrus sooner ($P < 0.05$) after progestin removal than MES heifers (Figure 1).

Table 1. Interval to estrus and percentages of CIDR (CES)- or MGA (MES)-treated heifers that showed estrus after CIDR and MGA removal

	Treatment				
Variable	CES	MES	SEM	X^2	*P* value
n	40	40			
Interval to estrus, h[1]	40.4	84.0	9.3		< 0.001
% showing estrus[1]	62.5	42.4		2.9	0.087

[1]Includes only heifers that showed estrus within 120 h after progestin removal.

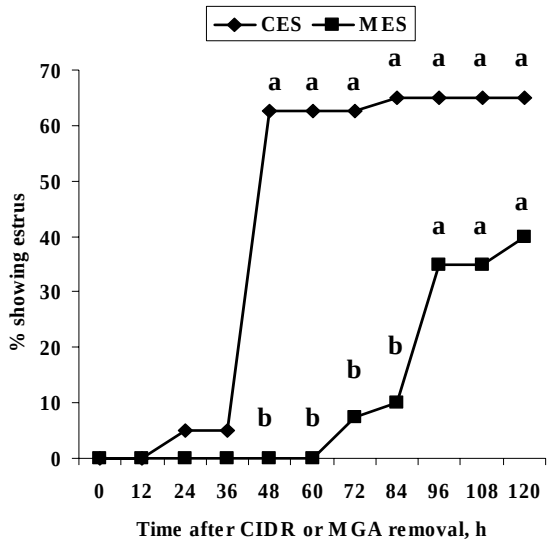

Figure 1. Cumulative frequency distribution for percentages of CIDR-treated (CES) and MGA-treated (MES) heifers that showed estrus after removal of progestins. Points within h that lack the same letter differ ($P < 0.05$).

Interval to estrus after PG did not differ ($P = 0.26$) between CES and MES heifers (Table 1) and averaged 54.2 h. A greater ($P < 0.05$) proportion of CES heifers exhibited estrus than MES (85.0% and 65.0%, respectively; Tables 2).

Table 2. Interval to estrus and percentages of heifers showing estrus after $PGF_{2\alpha}$ (PG) in beef heifers using a 33-d estrus synchronization protocol that included 14 d of either CIDR (CES) or MGA (MES) treatment

	Treatment				
Variable	CES	MES	SEM	X^2	*P* value
n	40	40			
Interval to estrus, h[1]	52.8	55.6	10.2		0.26
% showing estrus[2]	85.0	65.0		4.3	0.04

[1]Includes only heifers that showed estrus within 72 h after PG.

[2]Proportions of heifers that showed estrus by 60 h after PG.

There was no difference in the proportion of heifers that showed estrus and inseminated artificially by 72 h after PG (Table 3), and in pregnancy rates for heifers inseminated 12 h after estrus, inseminated at TAI (72 h after PG), or overall AI pregnancy rates between CES and MES heifers (Table 3).

Table 3. Pregnancy rates for beef heifers bred 12 h after estrus, timed AI at 72 h (TAI) after $PGF_{2\alpha}$ (PG), and overall AI pregnancy rates using a 33-d estrus synchronization protocol that included 14 d of either CIDR (CES) or MGA (MES) treatment [1]

	Treatment			
Variable	CES	MES	X^2	*P* value
n	40	40		
% bred AI 12 h after estrus	85.0	65.0	4.3	0.039
Pregnancy rate for heifers bred by AI 12 h after estrus'	64.7	73.0	0.5	0.50
TAI pregnancy rate	16.7	42.9	1.3	0.26
Overall AI pregnancy rate	57.5	62.5	0.2	0.65

[1]Pregnancy rates determined by ultrasonography 35 d after TAI.

Discussion

Estrus synchronization protocols that include progestin hasten the onset of puberty in beef heifers (Short et al., 1976; Jaeger et al., 1992; Anderson et al., 1996) and may increase the proportion of heifers that become pregnant early in the breeding season. Productivity over the lifespan of heifers increases if they are bred early in their first breeding season (Lesmeister et al., 1973). A reliable method to synchronize estrus in heifers is feeding MGA for 14 d followed by PG 17 to19 d later is a (Johnson and Day, 2004). However, successful implementation of this protocol relies upon heifers consistently consuming 0.5 mg•hd $^{-1}$•d $^{-1}$ of MGA, and usually works best in feedlot environments where heifers receive a mixed ration fed in bunks. The use of MGA-based ES becomes problematic when heifers are supplemented in pastures, where there is the potential for some heifers to consume less than the required dosage of MGA. In these types of situations MGA-based ES protocols often yields inconsistent ES responses and unacceptable AI pregnancy rates (personal observation).

One of the objectives of this experiment was to compare interval to estrus after withdrawal of the progestin source (CIDR or MGA) and proportions of heifers that showed estrus within 120 h after progestin removal. We found more CIDR-treated heifers showed estrus in a shorter period of time after removal of the CIDR than MGA-treated heifers. These indicate that heifers treated for 14 d with CIDR exhibit a more highly synchronized estrous response after progestin removal than heifer treated for 14 d with MGA. This may have been related to a difference between treatments in the number of heifers that were cycling

before treatment. Heifers that are cycling before progestin-based estrus synchronization protocol have improved ES responses than heifer that are not cycling before treatment (Lucy et al. 2002). However, this could not explain the results of the present study because heifers were assigned randomly to each treatment based upon the presence or absence of a corpus luteum in the ovaries. A more likely explanation for this result may be related to the difference in clearance rate of progesterone (CIDR) and melengesterol acetate (MGA) in heifers in each of these treatments. Removal of a CIDR results in a rapid decline in systemic progesterone concentrations over a 12- to 24-h period in intact cows (Perry et al., 2004) which allows for the occurrence of estrus quite rapidly after CIDR removal. Whereas, fecal concentrations of MGA are 1.4 times higher at 24 than at 12 h after feeding (Schiffer et al., 20010), indicating that biologically active of MGA is present for a longer period after withdrawal than progesterone after removal of CIDR due to the passage of MGA through the digestive tract.

Another objective of this experiment was to examine the ES response after PG injection for heifers on the CIDR or MGA protocols. Interval to estrus after PG did not differ between CES and MES heifers. Johnson and Day (2004) reported that interval to estrus after PG administration was 65 to 67 h for heifers synchronized with MGA. We found that this interval for MES-treated heifers was 55.6 h which is slightly lower than that reported by Johnson and Day (2004). The discrepancy may be related to the period of estrous detection. They observation were taken up to 120 h after PG, while in the present experiment estrus was monitored only for 72h after PG. However, we found that more CES heifers exhibited estrus within 60 h after PG and were inseminated 12 h after estrus than MES-treated heifers. This is an interesting observation and might indicate that precise synchronization observed after removal of the CIDR is carried through to ovarian follicular development in the next cycle. This may be related to the day after CIDR removal that PG was injected. Heifers given CIDR were injected 2 d 17 d after CIDR removal while MGS-treated heifers received PG 19 d after MGA removal. Given the fact that after CIDR removal we observed a more precise ES response it is likely that follicular development in these heifers was more precisely timed resulting in this difference between CES and MES heifers for the proportion of heifers that showed estrus by 60 h after PG.

The last objective of this experiment was to evaluate AI pregnancy rates for heifers treated with the CIDR and MGA protocols. We found that overall AI pregnancy rates, TAI pregnancy rates, and pregnancy rates for heifers bred 12 h after estrus did not differ between CES and MES heifers. Johnson and Day (2004) synchronized estrus in heifers using MGA, PG and TAI (76-80 h after PG) similar to the ES breeding protocol used present experiment, they reported that overall AI pregnancy rate was 63.5%, which is similar to the overall AI pregnancy rate of 60.0% observed in the present experiment. Taken together, these data indicate that acceptable AI pregnancy rates can be achieved by using 14 d of either CIDR or MGA as the progestin source.

In conclusion, the ES responses after progestin removal and after PG are more precise if heifers are given a CIDR than if they are given MGA as a progestin source in an ES protocol that includes 14 d of progestin. However, use of both protocols yield acceptable similar and acceptable AI pregnancy rates.

Implications

Using CIDR as a progestin source in a 14 d progestin, PG, and timed AI and GnRH estrus synchronization protocol is as effective as MGA to synchronize estrus and generate AI pregnancies in beef heifers. The use of this CIDR protocol may be beneficial to and should be considered by producers that have limited feeding facilities and labor resources. Furthermore, there is the possibility that use of CIDR containing progesterone for 14 d may result in a more precise synchrony of follicular development in the synchronized estrous cycle.

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SUPERIMPOSING 14 d MGA PRE-FEEDING AND(OR) 7 d CIDR ON THE SELECT SYNCH (GnRH-PG) ESTROUS SYNCHRONIZATION PROTOCOL IN BEEF COWS[1]

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ABSTRACT: Angus-based cows (n = 260, yr 1; n = 247, yr 2) were used to evaluate the combined effect of 14 d MGA pre-feeding and CIDR for 7 d, compared to three proven Select Synch-based estrous synchronization protocols, on estrous response and pregnancy rate to AI. In each year, cows were randomized by BCS, age, and calving date into four treatment groups. The Select Synch protocol (GnRH followed by PG after 7 d) was administered to all cows. Progestin treatments included: 1) MGA pre-feeding for 14 d followed by Select Synch 12 d later (MGA), 2) insertion of CIDR for 7 d concurrent with Select Synch (CIDR), 3) MGA pre-feeding for 14 d followed 12 d later by insertion of CIDR for 7 d concurrent with Select Synch (MGA+CIDR), and 4) Select Synch without a progestin (control). Following PG, cows were observed for estrus for 72 h, and inseminated approximately 12 h after estrus was first observed. Cows not observed in estrus within 72 h of PG were mass inseminated at approximately 78 h post PG and given 100 ug GnRH. Cows were not exposed to bulls for 9 d following mass insemination, and pregnancy rates to AI were determined by transrectal ultrasonography 40 d after mass insemination. Overall estrous response was 31.5%, and pregnancy rate to AI was 61.2%. Rate of estrus was not different (P>0.10) between MGA+CIDR and MGA, but both MGA+CIDR and MGA were lower (P<0.01) than CIDR and Control, which did not differ (P>0.10) from each other. Pregnancy rate to AI did not differ (P>0.10) among the four treatments. When data were evaluated for main effects (MGA and CIDR), pregnancy rate to AI was not affected (P>0.10) by either MGA or CIDR. In contrast, rate of estrus was greater (P<0.01) for cows that did not receive MGA compared to cows that received MGA, although rate of estrus was not affected (P>0.10) by CIDR. Results indicate that combining both MGA pre-feeding and CIDR into the Select Synch protocol does not result in a higher pregnancy rate to AI. Furthermore, incorporation of MGA into the Select Synch protocol appears to delay estrous response to PG, which could be beneficial in a mass insemination protocol.

Key words: Beef cattle, CIDR, MGA

Introduction

The Select Synch estrous synchronization protocol (GnRH followed by PG 7 d later) is an effective method to synchronize estrus in the majority of cows in a herd (Geary et al., 2000). However, detection of estrus several days in advance of the PG injection is necessary to maximize its effectiveness (Patterson et al., 2003). Geary et al. (2000) reported that cows in d 15 to 17 of their estrous cycle at the time of GnRH injection consistently expressed estrus prior to the PG injection in the Select Synch protocol. In order to avoid early estrus by these cows, recent research has incorporated progestins into Select Synch to "pre-synchronize" cows and reduce the length of time necessary to observe estrus, and ultimately improve the protocol's synchronization efficiency.

Common progestins include MGA (pre-fed for 14 d starting 26 d before GnRH) and CIDR (inserted vaginally concurrent with the 7-d GnRH-PG period). The inclusion of MGA into the Select Synch protocol consistently yields higher rates of estrous and pregnancy response than Select Synch alone (Patterson et al., 2002). Similarly, inclusion of CIDR into a GnRH-PG-based protocol resulted in a greater pregnancy rate than without a CIDR (Lamb et al., 2001).

Although recent experiments have compared MGA- and CIDR-based protocols, the main effects of MGA and CIDR have not been evaluated in the same trial, and the combined effects of MGA and CIDR on reproductive performance have not been reported. Therefore, the objectives of this experiment were to: 1) determine the main effects of MGA and CIDR in a Select Synch-based protocol, 2) evaluate the effectiveness of a "Double Progestin Select Synch" (14 d MGA and 7 d CIDR in the same protocol) compared to 3 commonly-used Select Synch-based protocols, and 3) compare three commonly-used protocols – Long Term MGA Select Synch (MGA-GnRH-PG), CIDR Select Synch (GnRH-CIDR-PG), and Select Synch (GnRH-PG) – on estrous and pregnancy response in suckled beef cows.

Materials and Methods

General procedures. In two consecutive years, pregnancy response of crossbred (Angus-based) beef cows (n = 260, yr 1; n = 247, yr 2) was evaluated on a northern Colorado ranch. Cows had an average BCS of 5.1 ± 0.52 (10% were BCS 4 or lower) and included 10% first-calf heifers. In each year, cows were randomized by

[1]The authors wish to acknowledge support for this research to Intervet, Inc. for donation of Fertagyl®, Pfizer Animal Health for donation of Lutalyse® and the EAZI-BREED™ CIDR® Cattle Inserts, Select Sires, Inc. for donation of semen, and the Rabbit Creek Ranch (Livermore, CO) for use of their cowherd.

BCS, age, and calving date into four treatment groups. The Select Synch protocol [GnRH (Fertagyl®, Intervet Inc., Millsboro, DE) followed by PG (Lutalyse®, Pfizer Animal Health, New York, NY) after 7 d] was administered to all cows. However, some cows were also given a progestin [MGA (Pfizer Animal Health) and(or) the EAZI-BREED™ CIDR® Cattle Insert (Pfizer Animal Health)] in addition to the basic Select Synch protocol.

Treatments. As seen in Figure 1, treatments included: 1) MGA pre-feeding for 14 d followed by Select Synch 12 d later (**MGA**; Long-Term MGA Select-Synch; n = 126), 2) insertion of CIDR for 7 d concurrent with Select Synch (**CIDR**; CIDR Select Synch; n = 121), 3) MGA pre-feeding for 14 d followed 12 d later by insertion of CIDR for 7 d concurrent with Select Synch (**MGA+CIDR**; Double Progestin Select Synch; n = 123), and 4) Select Synch without a progestin (**Control**; Select Synch; n = 137).

Cows were fed mature mixed hay (90% grass, 10% alfalfa; approximately 10 $kg \cdot hd^{-1} \cdot d^{-1}$) and range cubes (high energy, 12% crude protein; RanchWay Feeds, Fort Collins, CO; approximately 1.8 $kg \cdot hd^{-1} \cdot d^{-1}$) with or without MGA in two separate pastures beginning 26 d prior to the start of the Select Synch protocol. The MGA-containing cubes provided MGA at a rate of 0.5 $mg \cdot hd^{-1} \cdot d^{-1}$ for 14 d to cows in the MGA and MGA+CIDR treatments. In both years, AI occurred during the first week of May before significant pasture was available.

At the start of the Select Synch protocol, all cows received 100 ug GnRH i.m. followed 7 d later with 25 mg of PG i.m. Cows were observed for behavioral estrus for at least 60 min. twice daily (morning and evening) for approximately 72 h following PG. Cows observed in estrus (**EAI**) during this period were inseminated approximately 12 h after estrus was first observed. Cows not observed in estrus during the 72-h period were mass inseminated approximately 78 h after PG, and given 100 ug GnRH (**TAI**). Experienced AI technicians inseminated all cows, and were randomized across treatments. Calves were not intentionally removed to stimulate estrus, but were removed for short intervals during sorting and insemination. Cows were not exposed to bulls for 9 d following mass insemination, and pregnancy rates to AI were determined by transrectal ultrasonography 40 d after mass insemination.

Data analyses. Reproductive performance (including estrous and pregnancy response) were analyzed using logistic regression (PROC GENMOD, SAS Inst., Inc. Cary, NC) with animal as the experimental unit. Initial models for reproductive response contained fixed effects of treatment, BCS, year, sire, and technician, in addition to relevant two- and three-way interactions. When an interaction was not significant, it was removed from the model. If the year × treatment interaction was not significant, data were pooled across years. Main effects were determined using contrast statements; comparisons made were: 1) with MGA vs. without MGA and 2) with CIDR vs. without CIDR.

Results and Discussion

There was no year × treatment interaction for either estrous or pregnancy response; therefore data were combined across years. Overall estrous response was 31.5%, and pregnancy rate to AI was 61.2%. Estrous and pregnancy response have been compared among treatments and reported in Table 1.

Estrous response was not different ($P>0.10$) between MGA+CIDR and MGA; however, both MGA+CIDR and MGA were lower ($P<0.01$) than CIDR and Control. There was no difference ($P>0.10$) in estrous response between CIDR and Control. Estrous response to all treatments was low (31.5%). However, only 7.2% of cows were observed in estrus within the first 48 h after PG administration. The distributions of time to estrus (period of time from PG administration to observed estrus) by treatments (mean ± SD) were: 48.5 ± 5.94 h (MGA), 48.3 ± 6.88 h (CIDR), 49.2 ± 3.48 h (MGA+CIDR), and 47.3 ± 9.87 h (Control). Based on an acceptable overall pregnancy rate to AI of over 60%, it appears that many cows responded well to the synchronization protocols but had longer PG-to-estrus intervals and therefore did not exhibit estrus within the 72-h estrus detection period.

Pregnancy rate to AI did not differ ($P>0.10$) among the four treatments. Pregnancy rate to AI within the Control cows was numerically lower, yet due in part to the binomial nature of pregnancy data statistical differences were absent. Patterson et al. (2005) reported a greater pregnancy rate in cows receiving MGA Select Synch compared to cows receiving Select Synch. Comparing the effectiveness of MGA vs. CIDR as a progestin, Kojima et al. (2004) replaced 14-d MGA pre-feeding with 14-d CIDR insertion and improved the synchrony of estrus and pregnancy rate in beef heifers.

Due to the absence of a progestin effect, the main effects of MGA and CIDR have also been reported (Table 2). Pregnancy rate to AI was not affected ($P>0.10$) by either MGA or CIDR. In contrast, rate of estrus was greater ($P<0.01$) for cows that did not receive MGA compared to cows that received MGA, although rate of estrus was not affected ($P>0.10$) by CIDR. Based on these data, it appears that "pre-synchronization" with MGA can alter the time from PG injection to estrus.

Implications

Several proven Select Synch-based estrous synchronization protocols that incorporate progestins are available for beef cattle producers, and can result in acceptable estrous and pregnancy rates. However, combining both progestin sources (MGA pre-feeding and CIDR) into the Select Synch protocol does not result in a higher pregnancy rate to AI of cows in good body condition. Furthermore, incorporation of MGA into the Select Synch protocol appears to delay estrous response to PG while inclusion of CIDR does not, which could be beneficial in a mass insemination protocol.

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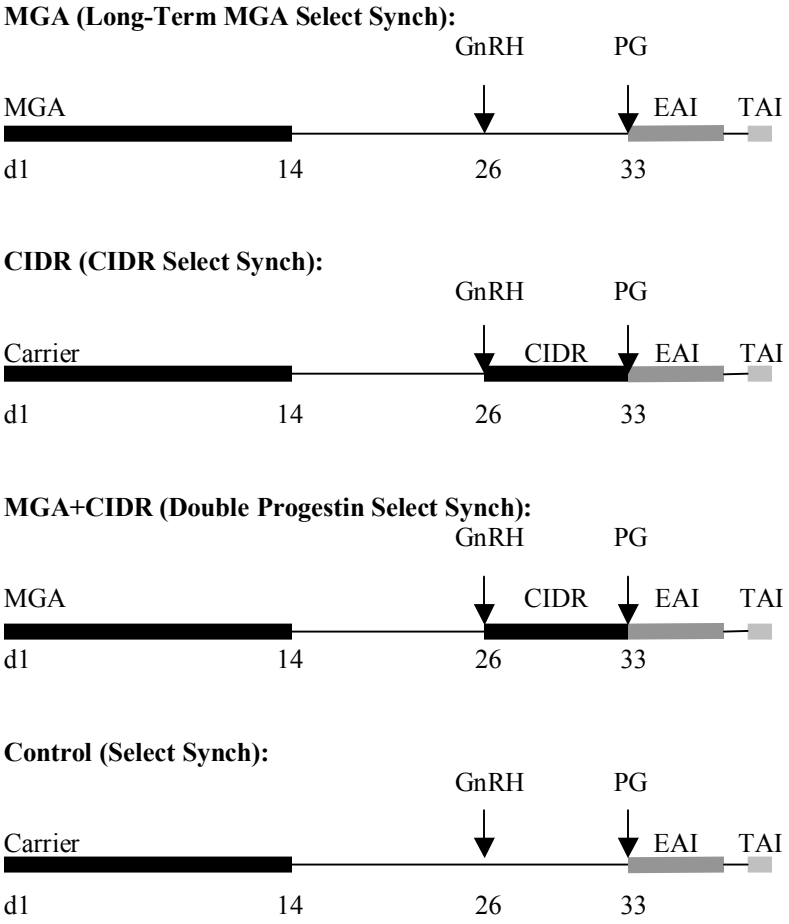

Figure 1. Timelines of the four treatments utilized to synchronize estrous in beef cows[a,b]
[a]MGA = melengestrol acetate (0.5 $mg \cdot hd^{-1} \cdot d^{-1}$ for 14 d); CIDR = controlled internal drug release device inserted vaginally; GnRH = gonadotropin releasing hormone (100 ug i.m.); PG = prostaglandin $F_{2\alpha}$ (25 mg i.m.).
[b]All cows were observed for signs of behavioral estrus for a period of 72-h post PG. During that period, cows observed in estrus were inseminated approximately 12 h later (EAI) while cows not observed in estrus were mass inseminated approximately 78 h post PG and given 100 ug GnRH i.m. (TAI).

Table 1. Comparison of beef cow reproductive performance among four estrous synchronization treatment protocols[a]

	Synchronization Treatment[b]			
Item	MGA	CIDR	MGA+CIDR	Control
Estrous response within 72 h of PG	17.8%[c]	46.4%[d]	20.2%[c]	41.3%[d]
Pregnancy rate to AI	61.8%	63.6%	60.2%	56.8%

[a]All cows were administered the Select Synch protocol (100 ug GnRH followed by 25 mg PG 7 d later). Some treatments also included the administration of a progestin.

[b]MGA = MGA pre-feeding for 14 d followed by Select Synch 12 d later; CIDR = insertion of CIDR for 7 d concurrent with Select Synch; MGA+CIDR = MGA pre-feeding for 14 d followed 12 d later by insertion of CIDR for 7 d concurrent with Select Synch; Control = Select Synch without a progestin.

[c,d]Within row, means without a common superscript are different ($P<0.01$).

Table 2. Main effects of MGA and(or) CIDR on beef cow reproductive performance within the Select Synch estrous synchronization protocol[a]

	MGA effect		CIDR effect	
Item	with MGA[b]	without MGA[c]	with CIDR[d]	without CIDR[e]
Estrous response within 72 h of PG	19.0%[f]	43.7%[g]	33.2%	29.9%
Pregnancy rate to AI	62.4%	60.0%	63.3%	59.2%

[a]All cows were administered the Select Synch protocol (100 ug GnRH followed by 25 mg PG 7 d later).

[b]With MGA = includes cows receiving the MGA treatment (MGA pre-feeding for 14 d followed by Select Synch 12 d later) and the MGA+CIDR treatment (MGA pre-feeding for 14 d followed 12 d later by insertion of CIDR for 7 d concurrent with Select Synch).

[c]Without MGA = includes cows receiving the CIDR treatment (insertion of CIDR for 7 d concurrent with Select Synch) and the Control treatment (Select Synch without a progestin).

[d]With CIDR = includes cows receiving the CIDR treatment (insertion of CIDR for 7 d concurrent with Select Synch) and the MGA+CIDR treatment (MGA pre-feeding for 14 d followed 12 d later by insertion of CIDR for 7 d concurrent with Select Synch).

[e]Without CIDR = includes cows receiving the MGA treatment (MGA pre-feeding for 14 d followed by Select Synch 12 d later) and the Control treatment (Select Synch without a progestin).

[f,g]For the MGA effect, within row means without a common superscript are different ($P<0.01$).

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MICROARRAY ANALYSIS OF GENE EXPRESSION IN ANTERIOR PITUITARY GLANDS FROM ANESTROUS AND CYCLING POSTPARTUM BEEF COWS [1]

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ABSTRACT: Oligionucleotide microarrays (GeneChip Bovine Genome Arrays, Affymetrix Inc., Santa Clara, CA) were used to evaluate gene expression profiles in anterior pituitary glands collected from four anestrous and four cycling postpartum beef cows. Anestrous cows were harvested 40 to 61d after calving at ~2 yr of age. Cycling cows were harvested 7 to 13 d after estrus, at 54 to 77 d after calving. Anterior pituitary tissue was collected and snap-frozen in liquid nitrogen within 22 to 37 min after exsanguination. Total RNA was isolated from each sample and was reverse transcribed into double stranded cDNA and subsequently transcribed in the presence of biotinylated UTP to generate target for hybridization on the Bovine Genome GeneChip . Each sample was hybridized to an individual Genechip containing 24,027 total probe sets including 23,080 bovine transcripts representing 19,000 unigene clusters as of March 2004. Hybridization signal were normalized across arrays using GeneChip Operating Software (GCOS; Affymetrix), and average intensities of each probe set were compared between groups by t-test. Expression of 25 transcripts were greater ($P < 0.01$) in pituitaries from cycling cows than anestrous cows; including: gastrin-releasing peptide, Ig heavy chain variable region, claudin 1, IGFBP-3, peroxisome proliferative activated receptor gamma, coactivator 1; 11 transcripts that share some homology (41 to 99%) to human proteins, and 9 uncharacterized transcripts. Transcripts expressed at decreased levels in cycling than anestrous cows included: signal transducer and activator of transcription 3, versican), alpha 1 acid glycoprotein, type 1 inositol 1, 4, 5-triphosphate receptor, calmodulin-dependent phospodiesterase 1B, protein S alpha; 9 transcripts that share some homology (56 to 99%) to human proteins and 1 uncharacterized transcript.. Although further study is required to confirm the role of these genes in the transition from anestrous to cycling status, results demonstrate potential of this methodology for identifying novel mechanisms regulating reproductive function..

Key Words: Pituitary, Anestrus, Gene expression

Introduction

A major limitation to successful reproduction is failure of cows to resume estrus following parturition. The mechanisms that control resumption of estrus following parturitions has been the subject of study for decades (Short et al., 1990), and it is now well documented that prolonged periods of postpartum anestrus are associated with insufficient endocrine signal (GnRH) from the hypothalamus to the anterior pituitary (Schillo 1992; Dunn and Moss 1992; Wettemann et al., 2003). However, research to date indicates that many factors influence the temporal changes in the hypothalamic-pituitary axis that are required for resumption of estrus, and the complex nature of numerous interactions among physiological and environmental factors that affect this axis has vulnerable progress in this area of research. The recent development of microarrays specific for the bovine provides an opportunity to perform near genome wide evaluations of gene expression. Thus the objective of the present research was to compare gene expression profiles in anterior pituitary glands collected from anestrous and cycling postpartum beef cows, to provide additional insight into the molecular changes that occur coincident with the acquisition of cycling status.

Materials and Methods

A group of 14 crossbred primiparous cows was monitored during the postpartum period by weekly ultrasonographic evaluation of their ovaries, using an Aloka SSD-500 ultrasound 7.5 MHz linear probe (Aloka Co., Ltd, Wallingford, CT) to identify cows to be harvested before (n=4) and after (n=4) resumption of estrus. Blood samples were collected from the tail vein at 7-d intervals beginning at approximately 3 wk after calving and ending at slaughter. Serum concentrations of progesterone in these blood samples were determined directly without extraction by RIA, as reported previously (Roberts et. al., 2005). Week in which estrus resumed was confirmed by detection of progesterone concentration that exceeded 1 ng/mL in the sample collected in the subsequent week.

Cows were scheduled in advance to be harvested at a small commercial abattoir on one of two dates that were 14 d apart. Calves were maintained on cow up until time of slaughter. The slaughter schedule resulted in 4 anestrous cows that were harvested 40 to 61d after calving and 4 cyclic cows that were harvested 7 to 13 d after estrus, at 54 to 77 d after calving. Anterior pituitary tissue was collected and snap-frozen in liquid nitrogen within 22 to 37 min after exsanguination. Total RNA was extracted from each sample using Trizol Reagent (Invitrogen, Chicago, IL)

[1]USDA-ARS is an equal opportunity/affirmative action employer and all agency services are available without discrimination. Mention of a proprietary product does not constitute a guarantee or warranty of the product by USDA or the authors and does not imply its approval to the exclusion of other products that may be also suitable.

An aliquot of 5 ug total RNA from each cow was reverse transcribed into double stranded cDNA and subsequently transcribed in the presence of biotinylated UTP to generate target for hybridization on oligionucleotide microarrays (McLean et al., 2002). Each sample was hybridized to an individual GeneChip containing 24,027 total probe sets including 23,080 bovine transcripts representing 19,000 unigene clusters as of March 2004 (GeneChip Bovine Genome Arrays, Affymetrix Inc., Santa Clara, CA). Each probe set representing a bovine transcript included 11 different 25-bp oligonucleotide probes complementary to the bovine transcript (perfect match). Each perfect match oligo was paired with an identical 25-bp oligonucleotides in which the 13th bp was changed to result in a mismatched probe, which allowed for correction for nonspecific binding.

Detection of hybridization was performed on a Probe Array-GeneChip Scanner 3000 (Affymetrix Inc.). Signal intensities of individual oligio probe within each probe set were determined using the GeneChip Operating Software (GCOS; Affymetrix). This software was also used to normalize average signal intensity for each probe across GeneChips, and qualitatively assess expression of each probe set (absent or present). If expression was not detected in a minimum of 3 of 4 pituitary samples from at least one of the treatment groups, the probe set and likewise the transcript was deemed to be not expressed and was omitted from further analysis. Average normalized intensities of each probe set remaining in the data were then compared between treatments by Student's t-Test. Level of expression was considered to differ if probability of the t-test was $P < 0.01$, the log 2 transformation of the ratio of signal for anestrous to cycling was equal or greater than 0.6 (expression in cycling animals is increased by at least 1.5 fold) or equal to or less than –0.6 (expression decreased by at least 35% in cycling cows), and change in signal intensity was greater than 10 units.

Results and Discussion

Expression was not detected (absent) for 7303 of the 24,027 total probe sets on the GeneChips (30.4%). For the remaining probe sets representing bovine transcripts, intensity of hybridization signal in pituitary samples from cycling cows was decreased ($P < 0.01$) in 16 (Table 1) and increased ($P < 0.01$) in 25 (Table 2) probe sets compared to samples from anestrous cows using the criteria defined in the methods. Of the 16 transcripts that exhibited decreased levels of expression in pituitaries form cycling cows, 7 represent genes currently characterized in cattle, 8 have some degree of homology with sequence for human proteins, and one is uncharacterized when these results were submitted. Transcripts that were present at greater levels in pituitaries from cycling cows included 5 genes that have been characterized for cattle, 11 have some homology with sequence for human proteins, and 9 are uncharacterized.

The gene that exhibited the greatest change between the physiological states was gastrin-releasing peptide (GRP), which was expressed in cycling cows almost 43 times above that observed in anestrous cows. Information concerning the role of this gene in regulating pituitary function is limited. In rodents, GRP has been shown to stimulate gonadotropin secretion by gonadotrophs (Morel et al., 1994) and decrease anterior pituitary secretion of TSH (Santos et al., 1995). Yet there appears to be a paucity of information concerning any association GRP may have with resumption of estrus. Likewise, several of the other genes that exhibited differential levels of expression have limited information regarding roles in regulating reproduction. These results indicate that the methodology used in this study may provide opportunities to identify novel mechanisms regulating reproduction and other traits important for livestock production.

The observation that IGFBP-3 was expressed at greater levels in anterior pituitaries from cycling cows than anestrous cows is consistent with our previous observations that levels of this protein in the pituitary fluctuate with stage of the cycle (Funston et. al., 1995; Roberts et. al., 2001). In general, IGF binding activity of IGFBP-3 in the bovine pituitary was shown to be inversely associated with circulating levels of progesterone throughout the estrous cycle. However, IGFBP-3 activity in the anterior pituitaries from pubertal heifers is much greater than that observed in pituitaries from prepubertal heifers (unpublished observation). These results indicate that additional research focused at elucidating the role of IGFBPs in the pituitary during the transition from an anestrous to cycling status is warranted.

Detection of greater levels of peroxisome proliferator activated receptor-γ coactivator-1α (PGC-1) expression in cycling animals is of significance due to the potential of this gene to regulate expression of estrogen–related receptor –α in response to metabolic changes (Puigserver and Spiegelman, 2003; Liu et. al., 2005). Thus, it can be hypothesized that PGC-1 may have a role in changing sensitivity of the anterior pituitary to estrogen feedback as a cow enters a metabolic state that is sufficient to allow resumption of estrus.

Of the 41 transcripts exhibiting differences in levels of expression due to cycling status, 10 (24%) represent transcripts that are not yet characterized and do not exhibit homology with sequences from other species. The number of uncharacterized transcripts exhibiting differential patterns of expression is representative of the total number of uncharacterized transcripts without homology to other species that are contained on the GeneChip (31%). This large number of uncharacterized probes on the bovine GeneChip is indicative of the current status of the field of bovine genomics, and provides a challenge in the fact that a great deal of change in annotation is expected overtime, requiring that data generated in studies like the present be continually reappraised. An example of this challenge is provided by the fact that the original unigene cluster containing the sequence encoding for GRP has been retired, and sequences originally assigned to this unigene are now distributed in 5 other clusters, or no longer reside in a cluster. Thus the original unigene cluster is no longer informative, and the original reference sequence used in generating to probe is required to determine proper annotation.

At present, minimal linkage exist between bovine sequence data and gene ontology databases. Therefore, as with other aspects of bovine genomics research, incorporation of gene ontology information into results from microarray

studies is very dependant on working through nucleotide sequence and protein data from human and rodents. This limitation combined with the large number of uncharacterized transcripts, greatly impedes the rate of progress that will be achieved from microarray studies in cattle when compared to similar research in humans or rodents. Regardless of these current limitations, results from the present study indicate that microarray technology provides tremendous potential for advancing basic knowledge concerning molecular mechanisms of rate limiting steps of livestock production.

Implications

Although further verification of the results of this research is required, the majority of genes identified in this study have not been previously considered to have major roles in regulating reproductive function, or the transcripts represent as of yet uncharacterized genes. Thus, results from the present study indicate that microarray analysis of gene expression profiles in bovine reproductive tissues collected at different physiological stages will undoubtedly result in the identification of novel mechanisms involved in regulating reproduction.

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Table 1. Signal intensities of genes exhibiting decreased expression in anterior pituitaries from cycling cow (CYC) when compared to anestrous cows (ANES)

Gene	ANES	CYC	P =	Unigene	Description[1]
STAT3	308	53	0.005	Bt.15334	Signal transducer and activator of transcription 3
ADH6	148	47	0.007	Bt.9697	77% similar to alcohol dehydrogenase 6
CSPG2	113	38	0.047	Bt.5395	Versican
IGcam	24	9	0.002	Bt.6038	82% similar to sialic acid-binding immunoglobulin-like lectin 1
VLCAD	29	14	0.003	Bt.8845	56% similar to very long chain acyl-CoA dehydrogenase
MCAT	62	30	0.009	Bt.11770	92% similar to mitochondrial carnitineacylcarnitine carrier protein
Unknown	48	24	0.001	Bt.23732	Transcribed sequence
TRIM7	24	13	0.008	Bt.28150	47% similar to tripartite motif-containing 7 isoform 1
TPCC	30	17	0.001	Bt.49083	100% similar to slow skeletal and cardiac muscle Troponin C
AGP	142	81	0.007	Bt.49064	Alpha-1 acid glycoprotein (AGP)
ITPR1	176	102	0.003	Bt.1758	Inositol 1,4,5-triphosphate receptor, type 1
SAP30BP	97	57	0.002	Bt.4851	94 % similar to transcriptional regulator protein
PDE1B	20	12	0.001	Bt.3910	Phosphodiesterase 1B, calmodulin-dependent
PROS1	104	62	0.002	Bt.5366	Protein S (alpha)
HHAT	28	17	0.005	Bt.18717	83% similar to hedgehog acyltransferase
ZNF8	126	81	0.008	Bt.17868	68% similar to zinc finger protein ZNF8 - human

[1]Tentative classification of probes derived from transcribed sequences are denoted by % similarity to human protein sequence when compared to anestrous cows

Table 2. Signal intensities of genes exhibiting increased expression in anterior pituitaries from cycling cow (CYC) when compared to anestrous cows (ANES)

Gene	ANES	CYC	P =	Unigene	Description[1]
GRP	4	170	0.001	Bt.22843	Gastrin-releasing peptide (Ref seq for probe=NCBI BP107621)
Unknown	97	474	0.003	Bt.2501	Transcribed sequences
VH	6	18	0.004	Bt.32564	Clone 17 immunoglobulin heavy chain variable region
Unknown	9	25	0.006	Bt.17564	Transcribed sequences
CLDN1	274	624	0.002	Bt.49689	Claudin 1
KRP1	99	206	0.004	Bt.6972	95% similar to Kelch-related protein 1
IGFBP-3	100	168	0.007	Bt.422	Insulin-like growth factor binding protein 3
PGC1α	49	98	0.009	Bt.20920	Peroxisome proliferator activated receptor-γ, coactivator-1α
Unknown	11	21	0.008	Bt.17051	Transcribed sequences
RL12	13	25	0.010	Bt.23981	41% similarity to 60S ribosomal protein L12
Unknown	19	36	0.002	Bt.27158	Transcribed sequences
Unknown	16	29	0.002	Bt.12673	Transcribed sequences
Unknown	84	154	0.003	Bt.27256	Transcribed sequences
	21	36	0.006	Bt.9996	Similar to mKIAA0018 protein [Rattus norvegicus]
Unknown	31	51	0.009	Bt.14682	Transcribed sequences
MY5B	17	29	0.009	Bt.13650	93% similar to protein Myosin V b
FBL4	122	193	0.001	Bt.21681	88% similar to F-box and leucine-rich repeat protein 4;
Unknown	173	274	0.005	Bt.12034	Transcribed sequence
Unknown	22	35	0.005	Bt.19109	Transcribed sequences
	52	80	0.001	Bt.27736	86% similar to hypothetical protein FLJ11218
ALS2	47	72	0.007	Bt.24359	Similar to ALS2 C-terminal like isoform 1 [Canis familiaris]
	246	375	0.000	Bt.14570	52% similar to NPD009 protein
	21	32	0.007	Bt.7860	99% similar to dystrobrevin, beta isoform 1
TSPAN-4	36	55	0.005	Bt.21730	93% similarity to tetraspan TSPAN-4
	42	62	0.004	Bt.14059	98% similar to AU-specific RNA-binding protein

[1]Tentative classification of probes derived from transcribed sequences are denoted by % similarity to human protein sequence when compared to anestrous cows

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EFFECTS OF DAM NUTRITION ON GROWTH AND REPRODUCTIVE PERFORMANCE OF HEIFER CALVES

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ABSTRACT: A 3-yr study was conducted with heifers (n = 170) whose dams were used in a 2x2 factorial to determine effects of late gestation (**LG**) or early lactation (**EL**) dam nutrition on subsequent heifer growth and reproductive performance. In LG, cows received either 0.45 kg/d of 42% CP supplement (**PS**) or no supplement while grazing dormant winter range. During EL, cows were either fed cool-season grass hay or grazed sub-irrigated meadow. Cows were managed in a common group the remainder of the year. Heifer birth date and birth weight were not affected ($P > 0.10$) by LG or EL dam nutrition. Spring meadow grazing and PS increased ($P = 0.02$; $P = 0.07$) heifer 205-d weight. Pre-breeding weight and weight at pregnancy determination were greater ($P = 0.04$; $P = 0.03$) for heifers from PS dams, but EL nutrition did not affect ($P > 0.10$) either weight. There was no effect ($P > 0.10$) of LG or EL dam nutrition on age at puberty or percentage of heifers cyclic before breeding, and no difference ($P > 0.10$) in pregnancy rates or calving data due to EL nutrition of the dam. However, first service and overall pregnancy rates were greater ($P = 0.003$; $P = 0.05$) for heifers from PS dams. Heifers born to PS cows calved earlier ($P = 0.07$) in their initial calving season, had a greater proportion unassisted births ($P = 0.03$), but similar ($P = 0.61$) calf birth weights. Body weight and BCS at the beginning of the second breeding season were not affected by maternal nutrition ($P > 0.10$). Dam nutrition did not affect ($P > 0.10$) individually-fed heifer ADG or G:F ratio. There was an LG x EL interaction for DMI ($P = 0.09$) and residual feed intake (**RFI**; $P = 0.07$). Heifers from PS dams had greater DMI ($P = 0.09$) and RFI ($P = 0.07$) if their dams were fed hay during EL, but not if their dams grazed meadows. Protein supplementation during LG improved growth and pregnancy rate in heifer offspring.

Keywords: Protein Supplement, Fetal Programming, Heifer Development, Fertility

Introduction

The nutritional requirements of spring-calving beef cows grazing dormant Sandhills range during late gestation exceed the nutritional value of the forage (NRC, 1996). In order to maintain cow body condition, protein supplements are often fed during the last trimester of gestation. These supplements are expensive and do not always improve subsequent reproductive performance (Stalker et al., 2005). However, the additional cost of protein supplementation is recovered in improved calf performance at weaning and feedlot endpoints (Stalker et al., 2005).

Additionally, nutrient requirements of the cow are greatest during early lactation (NRC, 1996), which coincides with the beginning of the breeding season. Allowing cows to graze cool-season meadows during this time has improved reproductive performance and calf weaning weight compared to cows fed cool-season grass hay (Stalker et al., 2005).

Fetal programming is the concept that maternal stimuli during fetal development has lasting impacts on progeny postnatal growth and physiology (Barker et al., 1993). Primiparous heifers energy restricted during the final 100 d of pregnancy had reduced progeny birth weight and pubertal age of the resulting heifer calves was increased by 19 d (Corah et al., 1975). In ewes, brief late-gestation nutrient restriction of resulted in altered endocrine function in adult female progeny independent of differences in birth weight (Bloomfield et al., 2003. Furthermore, male lambs born to ewes energy-restricted from week 10 of pregnancy until term had reduced testicular cord volume and Sertoli cell numbers at birth (Alejandro et al., 2002) but postnatal reproductive development was not assessed. Extensive data exists concerning the effects of intra-uterine growth retardation in sheep on postnatal development (Anthony et al., 2003; Vonnahme et al., 2003). However, limited data concerning the influence of moderate differences in late-gestation nutrition of female ruminants on reproductive performance of their progeny exists. Therefore, the objectives of the current study were to determine if supplemental protein during late gestation or early lactation plane of nutrition of cows influences future growth or reproductive performance of their heifer calves.

Procedure

The University of Nebraska-Lincoln Institutional Animal Care and Use Committee approved the procedures and facilities used in this experiment. A 3-yr study was conducted with heifers produced at Gudmundsen Sandhills Laboratory (**GSL**), Whitman, NE. The heifers were born to cows used in a 2x2 factorial treatment design to determine effects of late gestation and postpartum nutrition on reproductive performance and calf growth (Stalker et al., 2005). During the last trimester of gestation (December 1 through February 28) cows received either the equivalent of 0.45 kg/d of 42% CP supplement fed three times per wk or

no protein supplement. The cows were managed as a single group during the calving season, March 1 to April 30. From May 1 until May 31, half the cows were fed cool-season grass hay while the other half grazed sub-irrigated meadow. On June 1, cows were again combined and were managed in a common group throughout the breeding season and remainder of the production cycle.

During yr 1 and yr 3, heifers were managed as a single group from June 1 until the end of data collection. Data available from yr 1 is limited to birth and weaning records. In yr 2, additional reproduction and calving data was collected. The proportion of heifers cycling before the beginning of the breeding season in yr 2 was determined by progesterone concentration in two blood samples collected 10 d apart. Heifers from yr 2 were exposed to bulls for breeding, and first service and overall pregnancy rates were determined using transrectal ultrasonography approximately 30 d after the end of the breeding season and confirmed by calving date.

Heifers born in yr 3 remained at GSL for 109 d after weaning and were then transported to the North Dakota State University Animal Nutrition and Physiology Center, Fargo, ND. After an adaptation and training period, heifers were individually fed for 84 d using Calan gates. Heifers were housed in a climate-controlled facility with the light cycle being 14 h light, 10 h dark. All heifers were allowed ad libitum consumption of hay (7.5% CP, 71% NDF, 52 % ADF, DM basis) fed in the morning and supplemented daily with 0.90 kg of 16% CP pellets in the afternoon. Orts were collected twice weekly and analyzed for DM to determine DMI. Two d consecutive weights were taken at the beginning and end of the feeding period, with interim weights and blood samples collected every 14 d. Following completion of the individual feeding period on May 17, 2005, heifers were transported to the West Central Research and Extension Center, North Platte, NE and pre-breeding weights were recorded. Heifers were exposed to bulls for a 45 d breeding season and pregnancy status was determined via transrectal ultrasonography approximately 50 d following completion of the breeding season

Blood samples were cooled immediately and serum harvested and frozen at -20° C until analysis. Serum progesterone concentrations in yr 2 were determined by direct solid-phase RIA (Coat-A-Count, Diagnostics Products Corp., Los Angeles, CA) with modifications described by Schneider and Hallford (1996). Serum progesterone concentrations in samples from yr 3 were analyzed by solid-phase, competitive chemiluminescent enzyme immunoassay (Immulite 2000, Diagnostics Products Corp., Los Angeles, CA). Progesterone concentration greater than 1 ng/mL were interpreted to indicate ovarian luteal activity.

Performance data were analyzed as a 2x2 factorial using PROC MIXED of SAS. Reproductive and calving difficulty data were analyzed using Chi-square procedures in PROC GENMOD of SAS. The model included dam treatment during late gestation and dam treatment during the spring. The interaction between gestation and spring treatments were included for data sets when significant. In multi-year analyses, year was included as a random variable. Pen was included in the random statement for heifers in the individual feeding trial.

For yr 3, RFI was calculated by regressing DMI on mid-test weight and ADG using PROC REG of SAS. The slope coefficients (b_m and b_g, respectively) from these analyses were then used to predict DMI using the following equation: Predicted DMI = Average DMI of the group + b_m(mid-test weight) + b_g(ADG). Residual feed intake was calculated as the difference between observed and predicted DMI; therefore, lower values indicate increased efficiency.

Results and Discussion

Birth and weaning data are summarized in Table 1. Dam nutrition did not affect ($P > 0.10$) heifer birth date or birth weight. Supplementing cows with protein during LG tended ($P = 0.14$) to increase subsequent heifer weaning weight, and increased ($P = 0.02$) adjusted 205 d weight. Cows that grazed sub-irrigated meadows during the spring produced heifer calves with increased actual ($P = 0.09$) and adjusted ($P = 0.07$) weaning weight compared to heifers from cows fed hay. Pre-breeding weight was greater ($P = 0.04$) for heifers from PS dams than heifers from unsupplemented dams, but EL treatment did not affect ($P > 0.10$) heifer pre-breeding weight. Overall ADG between weaning and the first breeding season was not affected by dam treatment ($P > 0.10$; data not shown).

There was no effect ($P > 0.10$) of dam nutrition on the proportion of heifers from yr 2 exhibiting ovarian luteal activity prior to the breeding season, nor was there a difference in age at puberty of heifers born in yr 3 (Table 2). The difference of 5 d in age at puberty for heifers from PS or unsupplemented dams in this study is less than the 19 d difference in age at puberty that Corah et al. (1975) documented in female progeny of primiparous heifers restricted to approximately 70% of NRC recommended energy intake. However, there was not a difference in age at puberty for heifers born to cows in either our study or the study reported by Corah et al. (1975). Furthermore, there was no difference ($P > 0.10$) in pregnancy rates or calving data due to EL dam treatment. First service pregnancy rate was 88% for heifers from PS dams and 45% for heifers born to unsupplemented cows ($P = 0.003$). Overall pregnancy rate was 93% versus 80% ($P = 0.05$) for heifers from PS or unsupplemented dams, respectively. The mechanism responsible for the differences in first service and overall pregnancy rates between heifers from PS and unsupplemented dams is not clear from this study but is independent of age at puberty or estrous cyclicity immediately prior to the breeding season. Heifers born to PS cows calved earlier in their first calving season ($P = 0.07$; Table 2) and had a greater proportion of unassisted births (69% vs 38%; $P = 0.08$) than heifers whose dams were not supplemented with protein during LG. However, no differences ($P = 0.61$) in calf birth weight were detected. Weight and BCS prior to the second breeding season were

not affected by maternal nutrition ($P > 0.10$; data not shown).

Data from the individual feeding trial (yr 3) are presented as simple effects (Table 3). Heifers from PS cows were heavier ($P = 0.08$) at the end of the 84 d trial but had similar initial weights ($P > 0.10$) and similar BCS at both time points ($P > 0.10$) compared to heifers from cows that were not supplemented. Dam nutrition during EL did not affect weight or BCS ($P > 0.10$). Neither ADG nor the G:F ratio was affected ($P > 0.10$) by maternal nutrition.

In young cattle, RFI is a measure of feed efficiency correlated to reduced mature cow feed intake but not mature cow size, suggesting that selection for RFI is more likely to improve cow feed efficiency than selection for G:F ratio alone (Arthur et al, 2004 J. Anim. Sci. Suppl. 1:449). Dry matter intake and RFI were affected ($P = 0.09$, $P = 0.07$, respectively) by the interaction of maternal nutrition during LG and EL. Heifers born to PS dams had greater DMI ($P = 0.09$) if their dams were fed hay during EL, but not if their dams grazed meadows in EL ($P > 0.10$). Similarly, heifers from PS dams had greater RFI ($P = 0.07$) if their dams were fed hay during EL, but not if their dams grazed meadows during EL ($P > 0.10$). Greater RFI values indicate that heifers from PS cows fed hay during EL were less efficient than heifers from unsupplemented cows fed hay during EL. In this data set, it appears that selecting for feed efficiency based on RFI would result in reduced DMI, but not improved ADG. In fact, the heifers with more favorable RFI also had numerically lower ADG, but the differences were not statistically significant. Gain to feed ratio was not affected by treatment.

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Table 1. Effects of dam protein supplementation during the last trimester of gestation and grazing sub-irrigated meadow or fed grass hay during early lactation on growth performance of heifer calves[a]

	Treatment[b]					P-values	
Item	Prot	NoProt	Meadow	Hay	SEM	Gest	Spring
Birth date, Julian d	86	84	85	86	1	0.29	0.67
Birth wt, kg	36	35	35	36	1	0.25	0.15
Act wn wt, kg	212	207	212	206	7	0.14	0.09
Adj 205 d wt, kg	226	218	225	219	7	0.02	0.07
Pre-breeding wt, kg	276	266	272	270	9	0.04	0.70
Weight at first pregnancy diagnosis, kg	400	386	391	395	31	0.03	0.56

[a]Includes birth and weaning (wn) data from 170 heifer calves born from yr 1 to yr 3 , and pre-breeding and pregnancy check weights from 91 heifers born in yr 2 and yr 3.

[b]No gestation by lactation treament interactions were detected, therefore main effects are reported. Prot = dams supplemented three times per week with the equivalent of 0.45 kg/d 42%CP cake during the last trimester of gestation; NoProt = no protein supplement fed to dams during gestation; Meadow = dams grazed sub-irrigated meadows between the end of calving and the breeding season; Hay = dams fed cool-season grass hay from the end of the calving season until initiation of the breeding season

Table 2. Effects of dam protein supplementation during the last trimester of gestation and grazing sub-irrigated meadow or fed grass hay during early lactation on reproductive and calving performance of heifers[a]

	Treatment[b]					P-values	
Item	Prot	NoProt	Meadow	Hay	SEM	Gest	Spring
Age at Puberty, d	339	334	341	332	10	0.70	0.48
Cycling at beginning of breeding season, %	61	67	56	73		0.45	0.15
First service pregnancy rate, %	88	45	64	65		0.003	0.59
Overall pregnancy rate, %	93	80	83	91		0.05	0.18
Calving date, Julian d	63	71	68	66	3.3	0.07	0.71
Calf birth wt, kg	34	34	33	34	1	0.61	0.29
Unassisted births, %	75	38	61	50		0.03	0.69

[a]Includes puberty data from 50 heifers born in yr 3, reproductive data from 89 heifers born in year 2 and 3, and calving data from 32 heifers born in yr 2.

[b]No gestation by spring treatment interactions were detected, therefore only main effects are reported. Prot = dams supplemented three times pre week with the equivalent of 0.45 kg/d 42%CP cake during the last trimester of gestation; NoProt = no protein supplement fed to dams during gestation; Meadow = dams grazed sub-irrigated meadows between the end of calving and the breeding season; Hay = dams fed cool-season grass hay from the end of the calving season until initiation of the breeding season

Table 3. Effects of dam protein supplementation during the last trimester of gestation and grazing sub-irrigated meadow or fed grass hay during early lactation on growth, BCS, and residual feed intake of heifers individually-fed for 84 d[a]

	Treatment Effects[b]					P-values		
Item	P/M	P/H	NP/M	NP/H	SEM	G	Sp	G*Sp
Initial wt, kg	275	260	256	259	9	0.19	0.45	0.26
Initial BCS	5.53	5.54	5.43	5.54	0.10	0.62	0.53	0.65
Final wt, kg	310	298	293	286	8	0.08	0.22	0.71
Final BCS	5.13	4.96	4.96	4.92	0.09	0.20	0.23	0.42
ADG, kg/d	0.37	0.42	0.42	0.39	0.06	0.86	0.75	0.15
DMI, kg/d	6.57[de]	6.92[d]	6.79[de]	6.20[e]	0.29	0.37	0.65	0.09
G:F	0.057	0.062	0.060	0.067	0.007	0.40	0.27	0.88
RFI, kg/d[c]	-0.14[de]	0.28[d]	0.18[de]	-0.41[e]	0.28	0.50	0.74	0.07

[a]Includes data from 50 heifers born in yr 3.

[b]P/M = dams supplemented with the equivalent of 0.45 kg/d 42% CP cake during gestation and grazed meadows from the end of the calving season until the breeding season; P/H = dams supplemented with the equivalent of 0.45 kg/d 42% CP cake during gestation and were fed cool-season grass hay from the end of the calving season until the breeding season; NP/M = dams not supplemented with protein during gestation, grazed meadows between in the interval between the end of calving and initiation of the breeding season; NP/H = dams not supplemented with protein during gestation, fed cool-season grass hay between in the interval between the end of calving and initiation of the breeding season;

[c]Residual feed intake, the difference between observed DMI and predicted DMI.

[de]Within a row, means without a common superscript differ.

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EFFECTS OF PRESERVATION AND TIME OF PROCESSING ON BLOOD GLUCOSE CONCENTRATIONS IN BEEF HEIFERS

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ABSTRACT: Eighty-four Angus × Gelbvieh rotationally crossed beef heifers (369 kg average BW) were used to evaluate preservation method and time of processing on blood glucose concentrations. Whole blood was collected from each heifer via venipuncture of the jugular vein into tubes (3 tubes/heifer) containing sodium fluoride and potassium oxalate (plasma) and tubes (3 tubes/heifer) containing no preservative (serum). All tubes were placed immediately on ice, transported to the laboratory, and stored at 4 ° C until processed. Serum or plasma was separated by centrifugation at 2, 12, or 24 h after sampling, collected into 5 mL polypropylene tubes, and immediately stored at -20 ° C for subsequent glucose analysis. Glucose concentration data were analyzed by ANOVA with a 2 × 3 factorial arrangement of treatments. A preservation method × time of processing interaction ($P = 0.04$) was noted for glucose concentration. Concentrations of glucose from serum samples decreased from 2 to 12 h and from 12 h to 24 h. Glucose concentrations in plasma samples were greatest at 2 h but did not differ between 12 and 24 h. Glucose oxidation occurred during the first 12 h of storage despite the presence of sodium fluoride and potassium oxalate; however, oxidation was arrested in plasma samples after 12 h. Glucose continued to be oxidized through the first 24 h in serum samples collected without a preservative. For samples pooled across time, glucose concentrations were greater ($P < 0.001$) in serum compared with plasma. These data suggest that serum and plasma should be harvested before 12 h after collection of whole blood to obtain accurate values of glucose concentration. Caution also should be exercised when comparing mean glucose concentrations from non-preserved serum to plasma collected in a preservative.

Key Words: Beef Heifers, Blood, Glucose

Introduction

Blood glucose concentrations are routinely used as an indicator of organ function or nutrient utilization in both ruminant and non-ruminant animals. Glucose concentrations in human blood are often evaluated in serum, where samples are usually analyzed almost immediately (Khan et al., 1998). The quantity and frequency of blood sampling required during many large animal experiments limits the possibility of immediate analysis. Whole blood samples are, therefore, refrigerated and processed for hematocrit separation at a later time. The biological profile of plasma or serum may be altered during the lag between sampling and hematocrit separation because cellular metabolism permits continued uptake and release of ions, substrates, and metabolites (Hrubec et al., 2002). Preservatives that inhibit glycolysis have been used in blood samples collected for glucose analysis. Sodium fluoride has achieved the greatest degree of popularity as a preservative (Overfield et al., 1972). Although NaF may effectively inhibit glycolysis, immediate preservation is not attained. Chan et al. (1989) reported that oxidation rates in whole blood samples collected with NaF as a preservative were similar to oxidation rates in unpreserved whole blood samples up to 4 h after collection of blood. Additionally, NaF produces osmotic shifts, complexes calcium, and inhibits enzymes such as urease, thereby making it difficult to use the plasma for other metabolite and hormone assays (Sazama et al., 1979).

Our objective was to evaluate the use of NaF as a preservative and time of whole blood processing on glucose concentrations in blood samples collected from beef heifers.

Materials and Methods

General

The University of Wyoming Institutional Animal Care and Use Committee approved all procedures for the following study. Eighty-four Angus × Gelbvieh rotationally crossed beef heifers (369 kg average BW) were fed forage-based diet and housed in a dry lot. Whole blood was collected preprandially from each heifer via venipuncture of the jugular vein into Vacutainer (Becton, Dickson and Co., Franklin Lakes, NJ) collection tubes (three 6 mL tubes/heifer) containing 15 mg of NaF and 12 mg of K oxalate per tube (**plasma**) and tubes (three 12 mL tubes/heifer) containing no preservative (**serum**). All tubes were placed immediately on ice, transported to the laboratory, and stored at 4° C until processed. Serum or plasma was separated by centrifugation (1300 × *g* for 30 min) at 2, 12, or 24 h after sampling, decanted into 5 mL polypropylene tubes, and immediately stored at -20° C for subsequent glucose analysis.

Laboratory Analysis

Plasma and serum samples were analyzed for glucose concentrations (mg/dL) using the Infinity Glucose kit (Thermo Electron Corporation, Melbourne, Australia; intra- and inter-assay CV of 4.3 and 5%, respectively).

Statistical Analyses

Data were analyzed by ANOVA with the MIXED procedure of SAS (SAS Institute, Cary, NC) as a

completely randomized design with a 2 × 3 factorial arrangement of treatments. Fixed effects in the model included type of preservation method, time of processing, and the preservation method × time of processing interaction. Individual heifer within preservation method was used as the random effect.

Results and Discussion

A preservation method × time of processing interaction (P = 0.04; Figure 1) was noted for blood glucose concentrations. Concentrations of glucose from serum samples decreased (P < 0.001) from 2 to 12 h and from 12 h to 24 h. Glucose concentrations in plasma samples were greatest (P < 0.001) at 2 h but did not differ (P = 0.36) between 12 and 24 h. Glucose oxidation occurred during the first 12 h of storage despite the presence of NaF and K oxalate; however, oxidation was arrested in plasma samples after 12 h. Glucose continued to be oxidized through the first 24 h in serum samples collected without a preservative. Assuming the disappearance of glucose was attributed solely to oxidation, extent of glucose oxidation was 9% from 2 to 12 h. However, between 12 and 24 h after sampling the preservative effectively limited the oxidation of glucose to 1.9%. Glucose oxidation rate was 6.6% from 2 to 12 h in serum samples, however, unlike the plasma samples, oxidation of glucose continued at a rate of 0.79 %/h from 12 to 24 h after sampling.

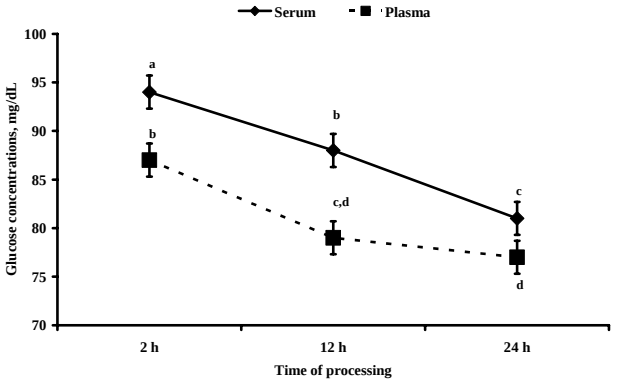

Figure 1. Preservation method × time of processing interaction (P = 0.04) for glucose concentrations in blood collected from beef heifers. Whole blood was collected from each heifer via venipuncture of the jugular vein into tubes containing NaF and K oxalate (plasma) and tubes containing no preservative (serum). Serum or plasma was processed at 2, 12, or 24 h after sampling. Data points lacking a common superscript differ (P < 0.05; pooled SE = 1.69).

These results are in agreement with Chan et al. (1990) who reported that 7% of glucose was oxidized during the first 4 to 6 h after sampling in human blood samples preserved with NaF. Likewise, Sidebottom et al. (1982) reported stable glucose concentrations in preserved plasma after a decline during the first few hours. Chan et al. (1989) also reported that glucose concentrations remain constant in blood samples collected with NaF for up to 3 d; however, those authors noted a 7% decrease in glucose concentrations during the first 4 h after blood collection. Although we measured at least a 9% reduction in plasma concentration of glucose during the first 12 h after of sampling in plasma, oxidation of glucose was likely inhibited after 4 h. The primary mechanism by which fluoride arrests glycolysis is through inhibition of the glycolytic enzyme enolase and membrane bound ATPase (Feig et al., 1971). Hexokinase and phosphofructokinase reactions continue to proceed until cellular levels of ATP are diminished. However, inhibition of enolase prevents the reduction of NAD and effectively halts glucose oxidation. The suggested 4 h lag time until oxidation completely ceases is likely due to utilization of existing cellular concentrations of ATP (Feig et al., 1971).

Published reports comparing glucose concentrations in serum vs. plasma are inconsistent. Lum and Gambino (1974) and Hrubec et al. (2002) reported no differences between serum or heparinized plasma glucose concentrations taken from humans and chickens, respectively. The greater (P < 0.001) overall glucose concentration in serum samples compared with plasma samples from the current study are in agreement with Landenson et al. (1974). It is important to note that blood was immediately centrifuged after sampling in the studies of Lum and Gambino (1974) and Hrubec et al. (2002). Similar glucose concentrations for serum and plasma noted in previous studies may be because glucose is metabolized by leukocytes and erythrocytes more rapidly in heparinized plasma than in serum (Landenson et al., 1974).

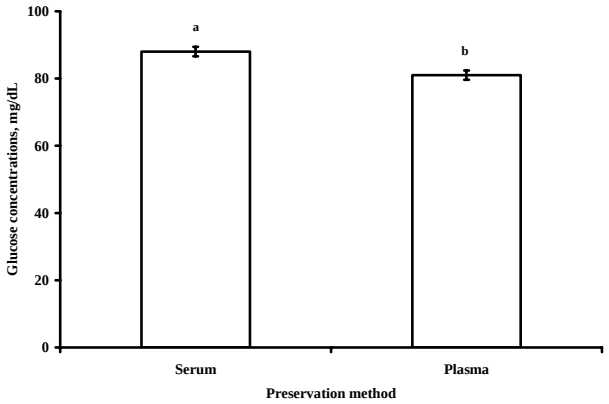

Figure 2. Main effects of preservation (P < 0.001) method on blood glucose concentrations. Whole blood was collected from each heifer via venipuncture of the jugular vein into tubes containing NaF and K oxalate (plasma) and tubes containing no preservative (serum). Serum or plasma was processed at 2, 12, or 24 h after sampling. Data points lacking a common superscript are different (P < 0.05; pooled SE = 1.2).

We conclude that serum should be harvested from whole blood within 2 h of collection to obtain accurate glucose values. Results of Chan et al. (1989; 1990) suggest that when NaF is used as an inhibitor of glycolysis, samples should be stored for at least 4 h to ensure that initial glycolysis is complete. Apparent extent of glycolysis at 2 h post-collection in our experiment was comparable to that reported by Chan et al. (1989; 1990) for samples processed 4 h after blood collection. Thus, whole blood of heifers collected into NaF and K oxalate should be stored for at least 2 h before centrifugation if samples cannot be centrifuged immediately. Inconsistencies in processing time before 2 to 4 h may result in variation of glucose concentration due to cellular metabolism and not

experimental design. Due to the cost of research sampling and analysis, utilization of blood samples for more than one metabolite may be desired. Serum may be used in these instances; however, extreme care in processing samples at a consistent time after blood collection is critical if samples are to be analyzed for glucose concentration. Caution also should be exercised when comparing mean glucose concentrations from non-preserved serum to plasma collected in a preservative.

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EFFECT OF DILUTION, REFRIGERATION AND CRYOPRESERVATION ON CAPACITATION-LIKE CHANGES IN RAM SPERMATOZOA [1]

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ABSTRACT: The objective was to quantify capacitation-like changes on spermatozoa of diluted, refrigerated and frozen ram semen at different time periods. Three young (1 yr old) and three adult rams of each Pelibuey and Blackbelly hair sheep breeds were used. Five ejaculations in sessions at least 3 d apart were obtained per ram. Each ejaculation sample was diluted with a citrate-yolk base extender and divided into three aliquots. One was conserved as fresh semen in a digital water bath at 36ºC and evaluated at 3 (F3) and 6 h (F6). A second aliquot was cooled to a refrigeration temperature (5ºC) and evaluated at 3 (R3), 6 (R6) and 24 h (R24). The third aliquot was added with a second part of the extender (citrate-yolk + glycerol) and frozen (FN) in liquid nitrogen. The sample was then thawed for evaluation. Evaluation was for patterns B (acrosome intact capacitated spermatozoa) and AR (acrosome reacted spermatozoa) of the chlortetracycline epifluorescence assay (CTC), and for sperm progressive motility (PM). A linear model with fixed effects of type-time subclass of preservation (PRE), breed of ram, age of ram (young and adult), double and triple interactions among those effects, and random effects of ram within breed by age, and interaction of ram by PRE within breed by age subclasses, was adjusted. Least squares means for the B pattern percentages were 23.9, 30.8, 32.8, 42.5, 44.5 and 36.6 (SE = 2.3; $P < 0.01$) for F3, F6, R3, R6, R24, and FN, respectively. There was an interaction effect of PRE by age of ram for pattern AR. The mean percentage of the AR pattern was greater ($P < 0.01$) for the young than for the adult rams in refrigerated semen at 24 h (27.8 ± 1.6 *vs* 19.8 ± 1.6) and in frozen semen (33.9 ± 1.6 *vs* 26.3±1.6), but not for the rest of PRE levels. Progressive motility of spermatozoa was reduced ($P < 0.01$) with dilution at 36ºC for 6 h and with freezing, in comparison to the remaining PRE levels. In conclusion, fresh diluted semen is well preserved for 3 h but progressive motility is reduced at 6 h if semen is not refrigerated. Freezing increases acrosome reacted spermatozoa and decreases progressive motility.

Key Words: Ram Semen, Cryopreservation, CTC Assay

Introduction

Sperm capacitation is a required step for the normal process of fertilization to be acomplished. Nowadays, it is known that cryopreservation of semen causes capacitation-like changes in spermatozoa (Bailey *et al.*, 2002; Cormier and Bailey, 2003) due to the effects on the sperm membrane integrity (de Leeuw *et al.*, 1993), which can save the *in vitro* induced sperm capacitation when *in vitro* fertilization techniques are used (Cormier *et al*., 1997); however, those cryopreservation induced changes in spermatozoa might result in reduced conception rates when artificial insemination is used (Bailey and Buhr, 1994).

In addition, results reported by Cormier *et al*. (1997) and Pérez *et al*. (1997) suggest that for ram semen a similar process (compared to the one observed with cryopreservation) and related effects on conception rates to AI can occur with refrigeration or regular dilution of fresh semen when the factor time is involved.

The objective of this study was to quantify the capacitation-like changes in spermatozoa induced at different times by dilution, refrigeration, and cryopreservation of ram semen, to aim on recommendations for the use of preserved ram semen on artificial insemination programs.

Materials and Methods

A total of twelve rams, three one year old and three adult of Pelibuey and Blackbelly hair sheep breeds were used. A breeding soundness test was conducted prior including the rams in the study. Just before ejaculation, rams were moved from their pen to an area close to the semen processing laboratory. Five ejaculations in sessions at least 3 d apart were obtained from each ram using an artificial vagina (Evans and Maxwell, 1990). For some rams, two ejaculates were obtained in one session.

Semen was visually assessed for volume, appearance and color, and at the microscope for progressive motility, and percentages of abnormal and live cells, using eosine-nigrosine staining. Samples showing either less than 70 % motile, 85 % normal or 70 % live sperm cells were discarded. Also, only samples with a volume greater than 0.5 ml were processed. Sperm concetration was measured using a haemocytometer, as described by Sorensen (1982).

Fraction A of extender included 2.9 g of sodium citrate, 20 % (v/v) egg yolk, 0.1 g of fructose, 1000 IU/ml sodic penicillin, and 1 mg/ml streptomycin per each 100 ml of distillated water. For fraction B, glicerol was added (14 % v/v).

Just after each semen sample was collected and accepted for processing, a .25 ml aliquot of semen was

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obtained from each sample and diluted with 2.25 ml of extender fraction A. From this, 1 ml was conserved in a water bath at 36°C and .25 ml aliquots were taken for evaluation at 0, 3, and 6 h. Another 1.5 ml of diluted semen was cooled to 5°C in 1 to 1.5 h, and .25 ml aliquots were taken for evaluation at 3, 6, and 24 h. The remainder of the evaluated ejaculate was prepared for freezing. First, 1 ml of extender fraction A was added and as soon as number of straws was decided, the rest of fraction A was added as to get 240 x 10^6 sperm cells per straw before adding extender fraction B. Once the temperature was reduced to 5°C in 1 to 1.5 h, extender fraction B was added in four 15 min intervals (10, 20, 30, and 40 % of extender fraction B, respectively) as to get a final concentration of 120 x 10^6 sperm cells per straw (.5 ml). Equilibration time before freezing was 2 to 3 h. Thereafter, semen was packed in straws and frozen in two steps (-120°C for 12 min and then -196°C) in liquid nitrogen. For evaluation, straws were thawed at 36°C in a water bath for 40 s.

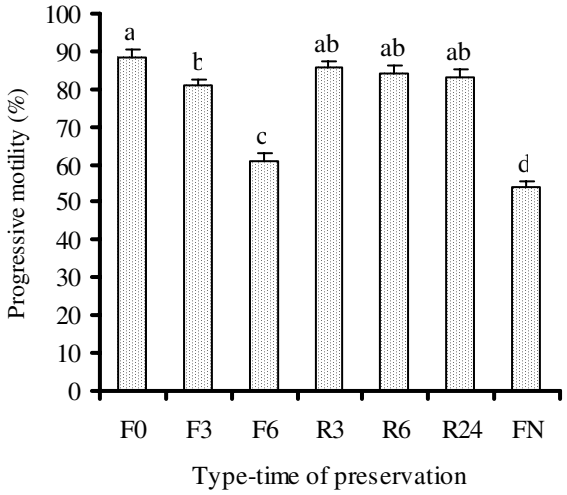
Semen samples were purified through Percoll gradients (45/70; Sigma-Aldrich, St. Louis, MO). Percoll was diluted with Sperm TL stock medium added with penicillin-streptomycin + sodium piruvate stock (ICN Biomedicals, Inc.) and warmed to 36°C before adding semen. Once semen was added, samples were centrifuged (Precision®, Durafuge 200) at 2000 rpm for 30 min and excess volume of washing medium was decanted. Ten microliters of the semen sample were taken and added with 90 µl of water to assess sperm cells concentration. The remaining pellet was re-suspended with IVF-TALP medium (Specialty Media) to obtain a concentration of 10 x 10^6 sperm cells/ml.

Rates of sperm capacitation were evaluated by the chlortetracycline (CTC) method modified by Chamberland *et al*. (2001), using an Olympus BX41 microscope with blue-violet illumination, V-2A filter (400-500 nm excitation, 470 nm emission) and 40x epifluorescence lens. For each sample, two slides were prepared and 48 h later 100 spermatozoa were counted and classified according to the following patterns: F, showing uniform fluorescence on the head, indicating uncapacitated, acrosome intact spermatozoa; B, represented by a fluorescence-free band on the post acrosomal region, indicating capacitated, acrosome intact spermatozoa; and AR, represented by a uniformly fluorescence-free head and with a fluorescence band in the equatorial region, indicating acrosome reaction.

Percentages of progressive motility just before Percoll purification, and percentages of the B and AR patterns were statistically analyzed using PROC MIXED of SAS (1999). The model included fixed effects of type-time preservation (PRE) subclasses [fresh at 3 (F3) and 6 h (F6); refrigerated at 3 (R3), 6 (R6) and 24 h (R24); and frozen (FN)], breed of ram (Pelibuey and Blackbelly), age of ram (young and adult), second and third order interactions among those effects, and random effects of ram within breed by age and interaction of ram by PRE within breed by age subclasses. When factor PRE was statistically significant, comparisons among means for PRE levels were evaluated using Fisher's LSD test.

Results and Discussion

For progressive motility (PM), there were significant effects ($P < 0.01$) of type-time subclass of preservation and breed of ram, but not for age of ram or any interaction ($P > 0.05$). For fresh semen, there was an 8 % decrease ($P < 0.01$) on PM (Figure 1) from time 0 to 3 h of preservation at 36°C (80.7 ± 1.9 *vs* 88.5 ± 1.9 %), and from 3 to 6 h the decrease was of 19 % (61 ± 1.9 *vs* 80.5 ± 1.9 %), but this was not the case ($P > 0.05$) when semen was cooled down to 5°C for 3, 6 or 24 h (85.5, 84.2 and 83.3 %, respectively; SE = 1.9).



[a,b,c,d]Different letters indicate differences ($P < 0.05$) among means

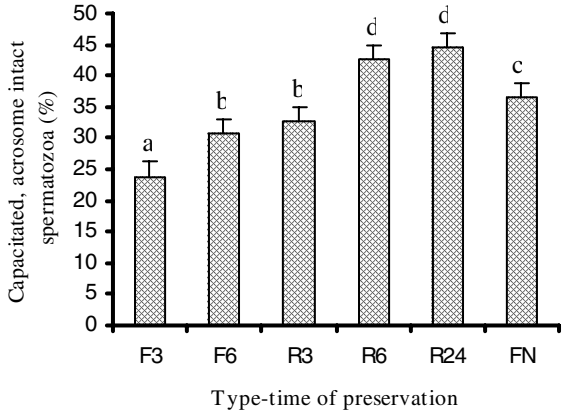
Figure 1. Least squares means for percentages of progressive motility in semen with different levels of type-time subclass of preservation [Diluted fresh at 36ºC for 0 (F0), 3 (F3) and 6 h (F6); Refrigerated at 5ºC for 3 (R3), 6 (R6) and 24 h (R24); Frozen (FN)].

Progressive motility was least lowest ($P < .01$) for frozen semen with an average of 53.7 ± 1.9 %. Ram spermatozoa have high metabolic rates and it has been recommended (Vivianco, 1998) for ram dilute semen not to be preserved for more than 4 h at 30 to 39°C. It has already been shown that approximately 50 % of ram spermatozoa retain their viability when semen is frozen (Bailey and Buhr, 1994), which agrees with the PM values observed in our study.

When comparing breeds of ram, Pelibuey had a greater ($P < 0.01$) average (79.4 ± 1 %) than Blackbelly (74 ± 1 %).

For percentage of capacitated spermatozoa with intact acrosome (Pattern B of the CTC assay), only type-time subclass of preservation showed a significant effect (Figure 2; $P < 0.05$). Cooled semen at 5°C for 6 and 24 h showed the greatest values ($P < 0.01$; 42.5 ± 2.2 and 44.5 ± 2.2 %), with intermediate values for freshly diluted semen at 6 h, cooled semen at 3 h, and frozen semen (30.8, 32.8 and 36.6 %, respectively; SE = 2.2). The

lowest value ($P < 0.01$) was for fresh diluted semen preserved at 36°C for 3 h (23.9 ± 2.2 %). Similar results were reported by Morrier *et al*. (2002) with 34 ± 2 and 40 ± 4 % for the B patern in ram semen cooled at 5°C for 3 h and frozen semen, respectively. As indicated by Bailey *et al*. (2002), this is due to the sperm membrane changes caused by the cool and freezing temperatures used for cryopreservation, which results in increased inctracellular Ca^{+2} levels (Bailey and Buhr, 1994), similar to sperm capacitation (Cormier and Bailey, 2003).



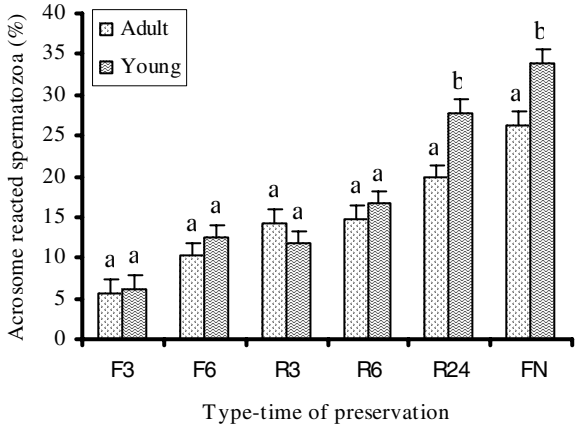
[a,b,c,d]Different letters indicate differences ($P < 0.05$) among means

Figure 2. Least squares means for percentages of capacitated, acrosome intact spermatozoa (Pattern B of CTC assay) in semen with different levels of type-time subclass of preservation [Diluted fresh at 36ºC for 3 (F3) and 6 h (F6); Refrigerated at 5ºC for 3 (R3), 6 (R6) and 24 h (R24); Frozen (FN)].

In the case of capacitated, acrosome reacted spermatozoa (pattern AR of the CTC assay), an interaction ($P < 0.01$) of the type-time subclass of preservation by age of ram was observed. As time of preservation passed and type of preservation passed from dilution to refrigeration and then to freezing, the percentage of spermatozoa with pattern AR increased from around 6 to above 26 % (Figure 3), and this increase was larger ($P < 0.01$) for young than for adult rams in refrigerated semen at 24 h and in frozen semen (27.7 ± 1.5 *vs* 19.8 ± 1.5 % and 33.8 ± 1.6 *vs* 26.3 ± 1.5 %, respectively). This effect of age on the AR pattern in bulls was reported by Lunstra and Echternkamp (1982) and Januskauskas *et al*. (1999). Some authors (Corteel, 1980; Dott *et al*., 1979) suggest that the effect of age on viability and motility of spermatozoa is due to maturity of the accesory sexual glands in the male. Lunstra and Echternkamp (1982) showed that the protein concentration of seminal plasm increased significatively from 7 to 13 months of age, improving spermatozoa viability and motility.

Implications

The low temperatures used for cryopreservation of ram sheep semen, as well as storage at 36ºC for 6 h and cooling of dilute ram semen results in an important proportion of capacitated spermatozoa. As a consequence, low pregancy rates in artificial insemination programs may result. Proportion of capacitated ram spermatozoa was not as great when diluted semen was stored at 36ºC as when low temperatures were used for refrigeration or freezing; however, progressive motility of spermatozoa was greatly affected after 6 h or more if dilute semen was not cooled to a refrigeration temperature.



[a,b]Different letters indicate differences ($P < 0.001$) between means within each type-time subclass of preservation

Figure 3. Least squares means for percentages of acrosome reacted spermatozoa (Pattern AR of CTC assay) in semen of adult and young rams with different levels of type-time subclass of preservation [Diluted fresh at 36ºC for 3 (F3) and 6 h (F6); Refrigerated at 5ºC for 3 (R3), 6 (R6) and 24 h (R24); Frozen (FN)].

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ESTRUS SYNCHRONIZATION AND FERTILITY IN CREOLE COWS TREATED WITH CIDR®, PROGESTERONE, β-ESTRADIOL AND $PGF_{2\alpha}$.

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ABSTRACT: Creole cows do not respond favorably to estrus synchronization protocols; therefore, the objective was to study estrus response and fertility using fixed-time artificial insemination (AI) after a hormonal protocol. To increase progesterone levels (P_4) during the CIDR® treatment (1.9 mg of P_4), 11 cycling cows (T1) received 50 mg of P_4+1 mg of β-estradiol i. m. and 11 cows (T2) received 1 mg of β-estradiol. At CIDR® removal, all cows received 30 mg of Lutalyse® + 1 mg of β-estradiol 24 h later. Cows were IA'ed 54 h after CIDR® removal. Blood samples were collected every day from day 0 (CIDR insertion) to day 6 and daily from day 7 to day 10 (AI). Serum progesterone concentrations decreased progressively from day 0 (P_4 > 4 ng/ml) to day 9 (P_4 < 1 ng/ml), which coincided with the day all cows were detected in estrus. On day 9 estrogen (E2) levels were higher (P<0.01) in T1 (34 ng/ml) than in T2 (26.7 ng/ml). Pregnancy rate was similar (P> 0.05) in both groups (18.18%). It was concluded that treating cycling Creole cows with 50 mg of progesterone in addition to 1 mg of β-estradiol at time of CIDR® insertion did not improved conception rate.

Keywords: Creole cows, estrus synchronization fertility, CIDR, β- estradiol.

Introduction

An efficient hormone treatment that synchronizes and produces a fertile estrus should prevent persistent ovarian follicles (POF). When a luteal phase is prolonged artificially with a P_4 controlled intravaginal drug-releasing device (CIDR), subluteal levels can be produced and prolong the development of a dominant ovarian follicle (Stock and Fortune, 1993). Subluteal levels are below the normal levels of the luteal phase, but higher than the base levels of the follicle phase. Normal levels of P_4 promote a regression of the dominant follicle and the development of the subsequent follicular wave. This is because P_4 levels between 1-2 ng/mL (subluteal levels) are associated with prolonged dominant follicle growth of the follicular wave present at the moment of treatment. The dominant ovarian follicle is accompanied by high levels of 17β-estradiol and by total absence of ovarian follicles ≥ 5 mm in diameter. Therefore, the administration of P_4 at dosages used typically to synchronize estrus in cattle results in a greater frequency of LH pulses than when CL is present (Kojima *et al*., 1992; Sánchez *et al*., 1995). Greater secretion of LH is associated with elevated concentrations of 17β-estradiol, which prolongs the half-life of the dominant ovarian follicle. Consequently, POF are generated (Savio *et al*., 1993; Stock y Fortune, 1993), and fertility is low (Sánchez *et al*., 1993; Mihm *et al*., 1994). In previous work, application of E_2 at initiation of progestagen and/or P_4 treatments eliminated preovulatory follicles, allowing the development of a new follicular wave when these were removed (Loy *et al*., 1982; Abad Zavaleta *et al*., 2006). The problem with Creole rodeo cows is that they do not respond favorably to the hormonal protocols of estrus synchronization. One study compared the physiological response of Creole cows with that of Hereford cows to Syncromate-B (implant with 6 mg of norgestomet + i.m. injection with 5 mg of estradiol valerate and 3 mg of norgestomet). When it was applied early in the luteal phase a variation in the P_4 levels occurred when the implant was removed, affecting the development of the ovulatory wave. Furthermore, in Creole cows POF occurred in all of the phases of the estrous cycle, unlike the Hereford cows in which POFs occurred only at the beginning of the treatment of the luteal phase (Torres *et al*., 1997). The objective was to compare two treatments in Creole rodeo cows; the first treatment (T1) consisted of an additional 50 mg of P_4, attempting to simulate the typical concentrations of P_4 of a mean luteal phase, while the second treatment (T2), without the 50 mg of P_4, would allow observation of the difference in fertility with artificial insemination.

Materials and Methods

Twenty-two Creole multi-calf cows were subjected to limited nursing twice a day (6:00 and 18:00 h). Estrus detection was conducted daily during nursing plus 30 minutes of observation. Two random groups of 11 animals each were formed for the treatments. In T1 the cows received CIDR® with 1.9 g of P_4 and one i.m. injection of 1 mg β-estradiol plus 50 mg of P_4. CIDR® was removed at 7 d, and an i.m. injection of Lutalyse® with 30 mg of $PGF_{2\alpha}$ was applied. Finally, after 24 h, the cows received 1 mg of β-estradiol and were inseminated 54 h after the

CIDR® was removed. T2 was similar, but when CIDR® was received, the injection contained 1 mg of β-estradiol without P_4. To compare the P_4 and E_2 seric levels of the treatments, blood samples were taken by puncturing the coccigean vein. Sampling was conducted every other day as of day 0 of the treatment, and daily as of day 7 up to day 10 post-treatment. The samples were placed on ice and transported to the laboratory where they were kept for 24 h at 4º C until centrifugation. The serum was decanted and kept at a temperature of -20º C until E_2 and P_4 concentrations were determined (not extracted), using a commercial solid state kit (DPC, Los Angeles California, USA). The coefficient of variations within and between tests was 3.9 and 15% for P_4 and for E_2 5.9 and 5.2%, respectively. Measurement of the hormone profiles was conducted in the radioimmunoanalysis laboratory, New Mexico State University, USA. Body condition (BC) was evaluated every two weeks on a scale of 1 (emaciated cow) to 9 (obese cow). The distribution of estrus hours (EH), after application of $PGF_{2\alpha}$ was analyzed with a χ^2 test. To determine the differences in levels of P_4 and E_2 an ANOVA was performed, considering treatment and its interaction as a fixed effect. The GLM procedure of the SAS 9 (Statistical Analysis System) software was used. The statistical design was completely random using one covariable.

Results and Discusión

Estrus occurred in 100% of the animals between day 9 and 10. A T*DS interaction was observed for the concentrations of P_4 and a statistical difference (p=0.0674) between treatments was found on day 0 (29.13 ng/mL vs 13.17 ng/mL). Figure 1 shows minor concentrations during estrus for T1 (0.66 ng/mL) and for T2 (0.68 ng/mL). An interaction (p=0.0001) was detected in the mean concentrations of E_2 (Figure 1) on day 0 (118.90 pg/mL and 182.36 pg/mL), as well as on day 9 (34.00 pg/mL vs 26.72 pg/mL). As in Sahiwal cows (Mondal and Prakash, 2003) and water buffalo cows (Kaur and Arora, 1984), lower concentrations of P_4 were found in the Creole cows during estrus, while concentrations previous to estrus were similar to those of a CL of normal lifespan. These results indicate that they were followed by ovulation on day 10 of the synchronization protocol, and like commercial breed and buffalo cows, the E_2 concentrations were higher around the day of estrus (Hafez and Hafez, 1993). No differences in percentage of animals in which estrus occurred were found between T (p>0.05). The distribution of estrus tended to cluster between 36 and 43 h after application of $PGF_{2\alpha}$ (Figure 2). These results coincide with those reported by Martínez *et al*.

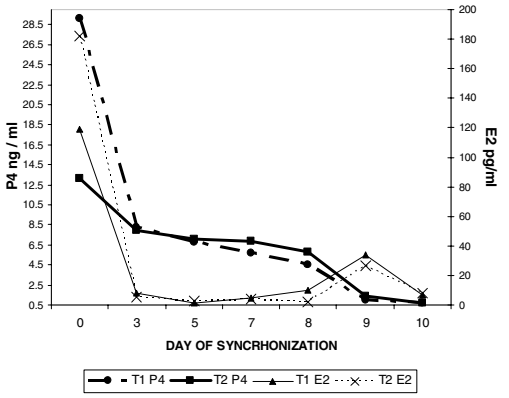

Figure 1. Levels of P_4 and E_2 in T1 y T2.

(2002), who compared CIDR-B and MGA treatments and found the same distribution of estrus with CIDR-B. The expression of estrous behavior was marked and can be attributed to the high levels of P_4 obtained in the two treatments, since at the moment of its application, all of the animals had a functional CL. This has been observed in the protocols with the application of $PGF_{2\alpha}$, in which high concentrations of P_4 before luteolysis are associated with pronounced estrous behavior (Stevenson *et al*., 1998). No statistical differences were found between treatments (p>0.05) in conception rate obtained by artificial insemination at fixed time (18.18%). All of the cows that became pregnant were grouped in the last 43 h of estrus detection. This could suggest that more time was allowed to pass than was recommendable for the cows that were observed to be in heat during the first 36 to 37 h. It is possibly necessary to use the AM, PM technique to inseminate 12 hours after estrus occurs; this could increase conception rate. All of the cows showed synchronized estrus between 36 and 43 h after $PGF_{2\alpha}$ application.

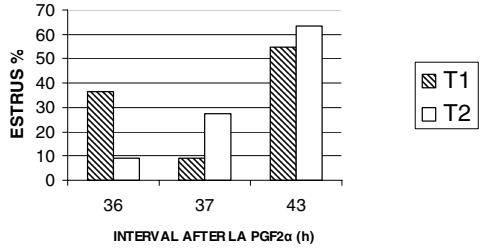

Figure 2. Distribution of estrus by treatment after application of PGF2α.

Implications

T1 produced higher P_4 concentrations during the first three days, and a higher concentration of E_2 on day 9, as compared with the results of T2. However, there was no effect on conception rate.

It is feasible to implement a program of reproductive management in Creole rodeo cattle whith estrus synchronization; however, more work is needed to improve conception rates to AI service for synchronized Creole cows.

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Determination of diet protein and digestibility of native Sandhills upland range

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ABSTRACT: Feed accounts for the majority of the variable costs with beef production. Formulating supplements for grazing cattle to accurately meet their nutrient requirements with economical feedstuffs is challenging due to the limited data on diet quality of pastures. The objective of this study was to determine diet CP and *in vitro* organic matter digestibility (IVOMD) of Sandhills upland range pastures following varying levels of forage removed by grazing (e.g. high, moderate, and un-grazed). Monthly diet samples were collected from esophageally fistulated cows from May 2003 through November 2005. Samples were freeze dried, ground and composited for CP and IVOMD analysis. There was a year by grazing level interaction ($P<0.05$) in CP values and no interactions on IVOMD. There was a year effect for IVOMD ($P<0.01$) where 2003 was lower than both 2004 and 2005, which may be explained by drought conditions (54.8, 60.0, and 61.4% for 2003, 2004, and 2005, respectively). High intensity of grazing decreased ($P=0.01$) IVOMD of diet samples compared to moderate and un-grazed (57.1, 59.2, and 60.0% for high, moderate, and un-grazed levels, respectively). The IVOMD increased ($P<0.001$) in May and decreased to dormant levels in September and remained relatively constant throughout the dormant season. *In vitro* OMD were 57.3, 57.8, 58.6, 59.9, 62.6, 61.2, 60.2, 59.6, 56.0, 57.9, 57.0, and 56.8% for January through December, respectively. Monthly CP values followed a similar pattern as IVOMD (6.5, 5.9, 6.9, 9.8, 13.5, 11.2, 11.5, 8.8, 8.3, 7.2, 6.9, and 6.7%, for January through December, respectively). Increasing grazing pressure most likely decreased OM digestibility of diet samples by lowering availability of highly digestible plants and plant components. Crude protein and IVOMD data from this trial may be used with the NRC model to precisely determine nutrient status of cattle and more accurately formulate supplements during the year.

Key Words: crude protein, esophageal, grazing cattle, *in vitro*

Introduction

Feed inputs account for the majority of the variable costs which are associated with beef production. It has been shown that the use of year round grazing systems can reduce the need to feed harvested or purchased forages (Adams et al., 1994). This can increase profit potential for beef producers. Forages can be harvested during periods when the quality is higher and that quality may be preserved until time of feeding. However, when grazing native range year round diet quality varies throughout the year and with different levels of grazing pressure (Lardy et al., 1997; Patterson et al., 2000). Lower diet quality during the dormant months may increase the need for protein and energy supplements during these periods to meet the animals requirement (Lardy et al., 1997). Reports of

diet digestibilities collected by grazing cattle are limited. Lardy et al. (1997) demonstrated that diet dry matter digestibility of Sandhills upland range is the highest in June and July and decreased through the dormant season. However, these digestibility estimates are relative differences and *in vivo* digestibility was not estimated.

Accurate *in vivo* estimates are necessary in order to formulate supplements and also needed to predict animal performance. Geisert et al. (2006) reported a 5 percentage unit difference in OMD between *in vitro* and *in vivo* digestibility of forages. *In vivo* digestibility can be estimated by including a calibration set of samples (with known *in vivo* digestibility) within *in vitro* procedures (Goldman et al., 1987). Regression equations can be established to adjust *in vitro* values to *in vivo* values within each run.

Materials and Methods

Diet samples were collected at the Gudmundsen Sandhills Laboratory, Whitman, Nebraska using six esophageally fistulated cows. Collections began May 2003 and continued through November 2005. Pastures were chosen for sampling based on the grazing level prior to sampling in order to establish a range from un-grazed to high grazing level. One pasture was not grazed and was sampled at every collection while the remaining three pastures varied based on the ranch's grazing rotation. Diet samples were collected every 3 weeks during the growing season and monthly during the dormant season. Diet samples were frozen immediately following collection. They were subsequently freeze dried, ground through a Wiley Mill using a 1 mm screen. Samples were then composited by pasture and analyzed for CP (AOAC, 1996) and IVOMD. *In vitro* OMD followed the procedure outlined by Tilly and Terry (1963) with the inclusion of five forages with known *in vivo* digestibility as standards. Due to the large number of diet samples collected, four separate *in vitro* runs were completed. Regression equations were generated from each *in vitro* run and the data were adjusted within the respective run. Statistics were analyzed using the mixed procedures in SAS version 9.1.

Results and Discussion

A year by grazing effect (P=0.02) was found for CP of diet samples. As expected high levels of grazing decreased CP in 2005 compared to medium and no grazing. However, in 2003 and 2004 CP values were higher at the high grazing level than the other two grazing levels. This could be explained by drought conditions in 2003 and recovering drought conditions in 2004. Cows may have selected plants such as forbs which were generally higher in CP but lower in digestibility.

There was a year effect (P<0.001) on IVOMD where 2003 was lower than 2004 and 2005. The average IVOMD for each year was 54.8, 60.0 and 61.4% for 2003, 2004, and 2005, respectively. This could be explained by drought conditions. Annual precipitation was 13, 15, and 18 inches for 2003, 2004, and 2005, respectively. The average precipitation for this area is between 18 and 20 inches annually. There was no difference (P=0.10) in IVOMD between 2004 and 2005.

Grazing level significantly effected (P=0.01) IVOMD of diet samples where high grazing levels decreased digestibility compared to moderate and non-grazing (57.1, 59.2, and 60.0% for high, moderate, and un-grazed, respectively). There were no differences (P=0.43) in IVOMD between moderate and un-grazed pastures. Grazing cattle naturally consume plants and plant components which are higher in

digestibility. As more grazing pressure is applied to a pasture the availability of highly digestible plants and plant parts decreases forcing cattle to consume diets with lower digestible .

Diet IVOMD was significantly ($P<0.01$) effected by month (Table 1) where diets collected May through July were more digestible than diets collected during the dormant season. Diets collected during the dormant season remained relatively constant in IVOMD and values gradually increased to peak growing season. Lardy et al. (1997) showed similar results where digestibility was the greatest in the growing season and lowest throughout the dormant season.

Regression equations formulated from each *in vitro* run were used to adjust the IVOMD values to *in vivo* values. These adjustments allow for comparison of samples analyzed in different runs. The average adjustment for all IVOMD runs for this current trial was 3 percentage units. There is a 2 percentage unit difference in digestibility comparing the data set from Lardy et al. (1997) (not adjusted to *in vivo* values) to the data generated from this trial. When comparing IVOMD data from Patterson et al., (2000) to IVOMD data from this trial, the average difference is 5.4 percentage unit. This is similar to the difference seen by Geisert et al., (2006). However, due to variability between *in vitro* runs one cannot simply assume a constant adjustment percentage. The regression equation from samples with known digestibility must be generated for each in vitro run to accurately adjust the data.

Diet CP values (Table 1) followed a similar pattern to IVOMD values. These patterns agree with previous data from Lardy et al. (1997) where CP is highest in the growing season and lowest during the dormant months.

Conclusions and Implications

Diet IVOMD was significantly higher during the growing season than the dormant season. It was also lower in pastures had higher levels of grazing pressure and during 2003. There was a year by grazing level effect on CP values of diet samples.

In vitro OMD and CP values obtained from this trial may be used with the NRC model to predict animal performance and more precisely formulate supplements. The adjustment of *in vitro* values to *in vivo* values increases the precision and accuracy of results from the NRC model.

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Table 1: Monthly average IVOMD (% DM) and CP (% DM) values of diet samples from native Sandhills upland range pastures.

Sample Date	Ave IVOMD[1]	NG IVOMD[2]	MG IVOMD[3]	HG IVOMD[4]	CP[5]
January	57.3	59.0	58.3	54.6	6.5
February	57.8	58.5	58.7	56.3	5.9
March	58.6	59.0	59.1	57.7	6.9
April	59.9	57.7	60.7	61.2	9.8
May	62.6	64.8	64.0	69.0	13.5
June	61.3	62.1	61.9	59.9	11.2
July	60.2	61.7	62.3	56.5	11.5
August	59.6	62.5	61.0	55.4	8.8
September	56.0	58.4	51.8	57.9	8.3
October	57.9	60.2	56.4	57.0	7.2
November	57.0	58.0	57.7	54.6	6.9
December	56.8	57.2	58.4	54.6	6.7

[1] IVOMD (% DM) for all pastures
[2] IVOMD (% DM) values for un-grazed pastures
[3] IVOMD (% DM) values for moderate grazing levels
[4] IVOMD (% DM) values for high grazing level
[5] IVOMD (% DM) values for non-grazed pastures

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DIET QUALITY IMPACTS ON EWE NUTRIENT PARTITIONING

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ABSTRACT: Diet quality has been implicated as a regulator of nutrient partitioning by altering tissue sensitivity to insulin. Our objective was to investigate diet-induced changes in insulin sensitivity of non-pregnant, non-lactating ewes (n = 18). During baseline phase (**BPHASE**), ewes were fed 50% wheat straw/sorghum sudangrass hay (5.1% CP, 84% NDF, OM basis) and 50% alfalfa hay (21.1% CP, 40% NDF, OM basis) for 4 wk. After BPHASE measurements (glucose tolerance test, 0.5 mg/kg BW), ewes were assigned in an experimental phase (**EPHASE**) to one of three diets fed 4 wk: 1) 100% alfalfa hay ad libitum (**ALF**), 2) 100% wheat straw/sorghum sudangrass hay ad libitum (**STRAW**), or 3) 100% alfalfa pair-fed with a straw/sorghum sudangrass ewe (**PAIR**). Measurements were repeated after EPHASE. Experimental diet did not impact glucose half-life (phase × trt $P = 0.85$; 73 and 87 ± 9 min; BPHASE and EPHASE). Ewes fed STRAW had larger glucose area under the curve (**AUC**) compared to BPHASE values ($P = 0.06$; 13498 vs 10359 ± 1134 units, respectively). Insulin AUC were similar within phase (phase × trt $P = 0.49$; 155 and 273 ± 22 units; BPHASE and EPHASE). Because glucose and insulin AUC were similar in BPHASE, insulin resistance was considered equal. In EPHASE, insulin AUC were again similar; therefore, glucose AUC measured insulin's ability to mediate disposal of infused glucose. Because STRAW ewes had larger glucose AUC in EPHASE, insulin resistance was induced. Insulin and glucose concentration indices (insulin AUC:glucose AUC) can indicate insulin resistance. A lower index would be diagnostic of insulin resistance since glucose AUC remained larger even though insulin AUC were similar. Indices for ALF and PAIR ewes increased compared to BPHASE values ($P \leq 0.03$; ALF 0.019 vs 0.025, PAIR 0.016 vs 0.024 ± 0.003; BPHASE vs EPHASE), while STRAW ewes had a similar index in both phases (0.017 vs 0.018 ± 0.003; BPHASE vs EPHASE). Low quality forage diets can induce insulin resistance in a non-pregnant, non-lactating ruminant model.

Key Words: Insulin Sensitivity, Low Quality Forage, Glucose

Introduction

Nutrients may be partitioned via altered insulin sensitivity in target tissues. Lactation and diet quality have both been implicated to regulate nutrient partitioning in this manner (Bines and Hart, 1982; Tovar-Luna et al., 1995). Endecott et al. (2003) found that glucose half-life decreased in young postpartum cows from spring to summer as diet quality increased. Unfortunately, the effect of diet quality was confounded with stage of lactation, so it was not possible to determine whether the increased sensitivity to insulin was due to improved diet quality, progression of lactation, or an additive effect of both. Cows were at different stages of lactation in spring and summer, and insulin sensitivity increases as lactation progresses (Bines and Hart, 1982). In a subsequent experiment, Endecott et al. (2004) investigated tissue response to insulin and glucose clearance of lactating and non-lactating cows grazing dormant forage 57 and 135 d postpartum. Regardless of physiological state, glucose half-life increased as time after calving increased, which appears to contradict results from Endecott et al. (2003). However, in the first year, glucose half-life decreased as diet quality improved with summer precipitation. In the second year, lack of summer precipitation resulted in a decrease in diet quality and an increase in glucose half-life. Thus, results from both experiments support the hypothesis that diet quality has an impact on glucose clearance and nutrient partitioning. In the current study, the objective was to create and document diet-induced changes in insulin sensitivity of non-pregnant, non-lactating ewes.

Materials and Methods

All animal handling and experimental procedures were conducted in accordance with guidelines of the Institutional Animal Care and Use Committee of New Mexico State University. The study consisted of two phases, a baseline phase (**BPHASE**) and an experimental phase (**EPHASE**). During BPHASE, non-pregnant, non-lactating ewes (n = 18, avg BW = 75 ± 2 kg) were individually fed a diet consisting of 50% wheat straw/sorghum sudangrass hay (5.1% CP, 84% NDF, OM basis) and 50% alfalfa hay (21.1% CP, 40% NDF, OM basis) for 4 wk. Dietary intakes of ewes were managed so that no straw refusals remained. During EPHASE, ewes were assigned to one of three diets also fed individually for 4 wk: 1) 100% alfalfa hay ad libitum (**ALF**), 2) 100% wheat straw/sorghum sudangrass hay ad libitum (**STRAW**), or 3) 100% alfalfa pair-fed with a straw/sorghum sudangrass ewe (**PAIR**). Because poor intakes were anticipated for ewes consuming the STRAW diet during EPHASE, ewes were evaluated based on their preference for the BPHASE diet. Ewes exhibiting strong preference for BPHASE diet were assigned to the STRAW diet in EPHASE. Intake differences between ALF and STRAW ewes were expected due to diet quality and acceptability differences, so the PAIR treatment was included to control for ad libitum intake differences. Ewes were housed in individual 1.5 m × 3.6 m partially shaded pens and had

access to clean, fresh water at all times. Ewes were subjected to the same measurements at the conclusion of each phase, including a glucose tolerance test, collection of rumen fluid for volatile fatty acid analysis, and whole-blood β-hydroxybutyrate concentration. For each glucose tolerance test, 50% dextrose solution was infused at 0.5 mL/kg BW via indwelling jugular catheter. Blood samples were collected at –1, 0, 3, 6, 9, 12, 15, 20, 40, 60, 80, 100, 120, 140, 160, and 180 min relative to infusion. Serum was harvested via centrifugation (2000 × *g* at 4°C for 25 min) and was stored at -20°C until further analysis. Serum glucose was analyzed with a commercial kit (enzymatic endpoint method, Thermo DMA, Louisville, CO). Serum insulin was analyzed by solid-phase radioimmunoassay (DPC kit, Diagnostic Products Corp., Los Angeles, CA), as validated by Reimers et al. (1982). Intra- and inter-assay coefficients of variation were less than 10%. Serum glucose and insulin areas under the curve (**AUC**) were calculated using trapezoidal summation. Glucose half-life was estimated by determining time required for 50% decrease in peak serum glucose concentration. Rumen fluid samples (~10 mL) were collected via stomach tube for VFA analysis by gas chromatography (Star 3400, Varian, Walnut Creek, CA). Whole-blood β-hydroxybutyrate concentrations were measured with a handheld ketone sensor (Medisense/Abbott Laboratories, Abingdon, UK, validated by Byrne et al. (2000)) using ~1 drop of whole blood collected before glucose infusion during the glucose tolerance test.

Data were analyzed using the MIXED procedure of SAS (SAS Inst., Inc., Cary, NC) with ewe as the experimental unit. The model included phase, treatment, and their interaction, with the effect of individual ewe in the RANDOM statement. The treatment component of the model refers to EPHASE dietary treatment. Baseline glucose concentration was used as a covariate in the analysis of glucose AUC. Intake as a percent of BW was used as a covariate in the analysis of whole blood β-hydroxybutyrate.

Results and Discussion

Dietary intake varied according to experimental design (Table 1). To ensure successful completion of the experiment, adequate consumption of EPHASE diets was imperative. Assigning ewes to EPHASE treatments based on their BPHASE intakes allowed us to achieve our objective of adequate consumption of the STRAW diet.

Experimental diet did not impact glucose half-life (phase × treatment $P = 0.85$; Table 2). Glucose half-lives were 73 and 87 ± 9 min for BPHASE and EPHASE, respectively. Ewes fed STRAW during EPHASE had larger glucose AUC in response to glucose tolerance test compared to BPHASE values ($P = 0.06$), while ewes fed ALF and PAIR during EPHASE had similar glucose AUC in BPHASE and EPHASE ($P \geq 0.14$). Insulin AUC were similar within phase (phase × treatment $P = 0.49$) and were 155 and 273 ± 22 units for BPHASE and EPHASE, respectively. Because glucose and insulin AUC were similar for all ewes in BPHASE, insulin resistance was considered equal. In EPHASE, insulin AUC were again similar for all ewes; therefore, glucose AUC measured insulin's ability to mediate disposal of infused glucose. Because STRAW-fed ewes had larger glucose AUC in EPHASE, insulin resistance was induced. Insulin and glucose concentration indices (insulin AUC:glucose AUC) can indicate insulin resistance. A lower index would be diagnostic of insulin resistance since glucose AUC remained larger even though insulin AUC were similar. Indices for ALF and PAIR ewes increased compared to BPHASE values ($P \leq 0.03$; Table 2), while STRAW ewes had a similar index in both phases (P = 0.60). These differences in insulin sensitivity among diets of differing forage quality provide support for results reported in grazing range cows during dormant and active forage growth periods, which suggested insulin sensitivity improved with green vegetation (Endecott et al., 2004; Endecott et al., 2003).

A phase effect was noted for glucose AUC ($P = 0.02$), insulin AUC ($P < 0.01$), and insulin:glucose ratio ($P < 0.01$), which suggests that as the experiment progressed, ewes became more insulin resistant, regardless of dietary treatment. A potential explanation for this phenomenon could be lack of exercise. Prior to the initiation of the experiment, ewes were housed as a group in a 9 m × 12 m pen; during the experiment, ewes were housed individually in 1.5 m × 3.6 m pens. Visual observations suggested that when ewes were housed in the larger pen, they were more active (standing, walking to eat and drink, interacting with other ewes) compared to when ewes were individually penned, where they were less active (more time lying, less walking to eat and drink). Both acute physical activity and long-term exercise training have been shown to enhance insulin-mediated glucose metabolism in humans and rodents (Henriksen, 2002). James et al. (1985) found increased whole body glucose disposal in exercise-trained rats compared to sedentary controls. Both moderate- and high-intensity exercise over 24 wk resulted in a reduction in insulin resistance compared to sedentary human subjects (O'Donovan et al., 2005).

Acetate:propionate ratio was lower during EPHASE for ALF and PAIR ewes compared to BPHASE ($P \leq 0.05$; Table 3), while the ratio was similar during both phases for STRAW ewes ($P = 0.13$). Non-glucogenic ratio (Orskov et al., 1974) were similar within phase (phase × treatment $P = 0.13$) and were 5.9 and 5.4 ± 0.07 for BPHASE and EPHASE, respectively.

Exposure to β-hydroxybutyrate impaired insulin action in rat cardiomyocytes (Tardif et al., 2001), and blood β-hydroxybutyrate and other ketones can be synthesized from volatile fatty acids (excluding propionate) and long-chain fatty acids (Bruss, 1997). Increased ruminal acetate concentrations and slow acetate clearance have been observed when animals are consuming low-quality forage diets (Appeddu-Richards, 1998; Cronje et al., 1991); acetate buildup may result in increased β-hydroxybutyrate concentration. Ewes fed ALF had lower whole-blood β-hydroxybutyrate concentrations compared to BPHASE ($P = 0.02$; Table 3). Ewes fed STRAW and PAIR had similar whole-blood β-hydroxybutyrate concentrations during both phases ($P \geq 0.48$).

Responses of STRAW and ALF ewes were different from one another for glucose AUC, insulin:glucose ratio, acetate:propionate ratio, and whole-blood β-hydroxybutyrate concentration. For these same criteria, PAIR ewes responded similarly to ALF ewes in three of four variables, but had similar β-hydroxybutyrate concentrations compared to STRAW ewes. The PAIR treatment was designed to combine the high quality diet of the ALF treatment with the anticipated lower intake of the STRAW treatment; ewe responses from this treatment group suggest that the treatment design accomplished our objective. The opposite responses observed for STRAW and ALF ewes for VFA and blood ketone concentrations in combination with differences observed in glucose clearance suggest that these variables may interact with one another in the mechanism of action of diet-induced insulin resistance.

Implications

Low quality forage diets can induce insulin resistance in a non-pregnant, non-lactating ruminant model. To our knowledge, this is the first instance where differences in ruminant insulin sensitivity have been demonstrated among diets containing forage only. Year-to-year variation in animal productivity and nutrient status may be partially explained by differences in insulin sensitivity and nutrient partitioning due to variation in forage quality.

Acknowledgements

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Table 1. Intakes of non-pregnant, non-lactating ewes after consuming two different forage diets for 4 wk each.

Item	Phase[a]	Treatment[a]			Phase × Treatment *P*-value	BPHASE vs EPHASE *P*-value		
		ALF	STRAW	PAIR		ALF	STRAW	PAIR
Intake, % BW	BPHASE	1.9 ± 0.14	2.1 ± 0.14	1.7 ± 0.14	< 0.01	< 0.01	< 0.01	0.19
	EPHASE	2.7 ± 0.14	1.4 ± 0.14	1.4 ± 0.14				

[a]During baseline phase (BPHASE) all ewes were fed 50% wheat straw/sorghum sudangrass hay + 50% alfalfa hay. During experimental phase (EPHASE) ewes were assigned to 100% alfalfa hay ad libitum (ALF), 100% wheat straw/sorghum sudangrass hay ad libitum (STRAW), or 100% alfalfa hay pair-fed with a wheat straw/sorghum sudangrass hay ewe (PAIR).

Table 2. Glucose tolerance test responses of non-pregnant, non-lactating ewes after consuming two different forage diets for 4 wk each.

Item	Phase[a]	Treatment[a]			Phase × Treatment *P*-value	BPHASE vs EPHASE *P*-value		
		ALF	STRAW	PAIR		ALF	STRAW	PAIR
Glucose half-life, min	BPHASE	54 ± 15	72 ± 15	93 ± 15	0.85	0.32	0.50	0.82
	EPHASE	76 ± 15	86 ± 15	98 ± 15				
Glucose AUC, units	BPHASE	8697 ± 1160	10359 ± 1134	11471 ± 1128	0.63	0.14	0.06	0.49
	EPHASE	11092 ± 1160	13498 ± 1134	12538 ± 1128				
Insulin AUC, units	BPHASE	137 ± 38	165 ± 38	164 ± 38	0.49	0.03	0.07	< 0.01
	EPHASE	243 ± 38	251 ± 38	325 ± 38				
Insulin: glucose ratio[b]	BPHASE	0.019 ± 0.003	0.017 ± 0.003	0.016 ± 0.003	0.17	0.03	0.60	< 0.01
	EPHASE	0.025 ± 0.003	0.018 ± 0.003	0.024 ± 0.003				

[a]During baseline phase (BPHASE) all ewes were fed 50% wheat straw/sorghum sudangrass hay + 50% alfalfa hay. During experimental phase (EPHASE) ewes were assigned to 100% alfalfa hay ad libitum (ALF), 100% wheat straw/sorghum sudangrass hay ad libitum (STRAW), or 100% alfalfa hay pair-fed with a wheat straw/sorghum sudangrass hay ewe (PAIR).
[b]Insulin AUC/Glucose AUC.

Table 3. Acetate:propionate ratio, non-glucogenic VFA ratio, and whole blood β-hydroxybutyrate concentrations of non-pregnant, non-lactating ewes after consuming two different forage diets for 4 wk each.

Item	Phase[a]	Treatment[a]			Phase × Treatment *P*-value	BPHASE vs EPHASE *P*-value		
		ALF	STRAW	PAIR		ALF	STRAW	PAIR
Ac:Pr Ratio[b]	BPHASE	5.2 ± 0.14	5.1 ± 0.14	4.9 ± 0.14	0.15	< 0.01	0.13	0.06
	EPHASE	4.5 ± 0.14	4.8 ± 0.14	4.6 ± 0.14				
Non-glucogenic ratio[c]	BPHASE	6.2 ± 0.13	6.0 ± 0.13	5.7 ± 0.13	0.13	< 0.01	< 0.01	0.05
	EPHASE	5.5 ± 0.13	5.3 ± 0.13	5.4 ± 0.13				
Whole-blood β-hydroxy-butyrate, mmol/L	BPHASE	0.22 ± 0.04	0.13 ± 0.04	0.08 ± 0.04	0.10	0.02	0.54	0.48
	EPHASE	0.05 ± 0.06	0.09 ± 0.05	0.12 ± 0.05				

[a]During baseline phase (BPHASE) all ewes were fed 50% wheat straw/sorghum sudangrass hay + 50% alfalfa hay. During experimental phase (EPHASE) ewes were assigned to 100% alfalfa hay ad libitum (ALF), 100% wheat straw/sorghum sudangrass hay ad libitum (STRAW), or 100% alfalfa hay pair-fed with a wheat straw/sorghum sudangrass hay ewe (PAIR).
[b]Acetate/Propionate.
[c](Acetate + 2 Butyrate)/Propionate.

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EFFECT OF FAT SUPPLEMENTATION OF STEERS GRAZING WHEAT PASTURE ON FORAGE INTAKE AND DIGESTION CHARACTERISTICS

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ABSTRACT: Nine ruminally cannulated mixed-breed steers were used in a complete randomized block design to evaluate effects of fat supplementation and forage maturity on intake, digestibility and rumen fermentation characteristics. Treatments were supplements containing: mineral pack (M) offered at 114g/d; mineral pack plus fiber as soybean hulls-wheat middlings (MF) offered at 0.50% BW; and mineral pack plus fiber as soybean hulls-wheat middlings and tallow (MFT) offered at 0.625% BW. Stage of wheat maturity was used as block (prior to jointing, mid-March, MAR; and post-jointing, early April, APR). Steers grazed in a single wheat pasture with supplements offered individually once daily at 0700. There were supplement type x forage maturity interactions ($P < 0.05$) for forage OM, CP, and NDF intakes. During MAR, forage OM, CP, and NDF intakes differed (MF > M, $P < 0.05$, and MF = MFT, $P > 0.05$). During APR, forage OM, CP and NDF intakes differed (MF > M = MFT, $P < 0.05$). Steers receiving M and MFT supplements were not different ($P > 0.05$) during APR or MAR. There were also supplement type x forage maturity interactions ($P < 0.05$) for forage OM and NDF digestibility. During MAR, OM and NDF digestibility differed (MF > MFT > M, $P < 0.05$). During APR, OM and NDF digestibility differed (MF > M = MFT, $P < 0.05$). Crude protein digestibility was affected by supplement type (MF > MFT > M, $P < 0.05$) and stage of maturity (MAR > APR, $P < 0.05$). Rates of DM and NDF ruminal disappearance where not affected ($P > 0.05$) by supplement or maturity. Supplementation increased ($P < 0.05$) ruminal propionate concentration (19.7, 21.4, and 25.1 ± 0.49 mol/100mols for M, MF, and MFT, respectively). Tallow can be used in wheat pasture supplements to increase energy intake without negatively affecting forage intake, ruminal fermentation, and digestion particularly if used before the jointing stage of wheat maturity. Additional research is required to determine the optimum level of tallow supplementation.

Key Words: Stocker, Wheat Pasture, Fat Supplementation

Introduction

Growing cattle on winter wheat pasture is a beef cattle production program common in the southern Great Plains. Wheat pasture is a high-quality forage that contains over 20% CP and over 70% DM digestibility (Mader, and Horn, 1986; Branine and Galyean, 1990). Wheat pasture allows for moderately high BW gains (Werrell et al., 1990) at low cost (Torrell et al., 1999). Wheat pasture grazing allows for maturation of muscle and bone while restricting fat deposition. However, an intramuscular lipid content of 3% is needed for acceptable beef palatability in the United States (Sarell and Cross, 1988). If backgrounding systems restrict fat deposition, and intramuscular fat at finishing is difficult to deposit then cattle need more days on feed and are also slaughtered at heavier weights to achieve acceptable carcass quality (Lewis et al., 1990; Choat et al., 2003). Managements schemes to increase intramuscular fat deposition during grazing can reduce days on feed at finishing and improve carcass quality. We know that fat deposition increases with increasing energy intake (Owens et al., 1995). Fat supplementation increases diet energy density, ADG, feed efficiency, and carcass fat deposition in feedlot cattle (Zinn and Plascencia, 1996). However, palatability problems as well as decreased fiber digestibility were associated with feeding fats to ruminants (Johnson and McClure, 1973), probably because of a toxic effect of long chain fatty acids on ruminal bacteria (Henderson, 1973). Because wheat pasture fiber content is low, fat supplementation may not have a major negative effect on fiber digestibility of wheat forage. Moreover, it might decrease production of methane produced by rumen fermentation, which could result in greater ruminal production of propionate (Zinn and Plascencia, 1996), and decrease energy losses (Czerkawski, 1973). Therefore the objectives of this experiment were to evaluate effects of fat supplementation and forage maturity on intake, digestibility, and rumen fermentation characteristics.

Materials and Methods

Nine mixed-breed steers fitted with ruminal cannulas were used in a complete block design. Steers were assigned randomly to one of three experimental supplements: (1) mineral pack supplement (**M**) offered at 114 g/animal/d, (2) fiber supplement based on soybean hulls-wheat middlings (**MF**) offered at 0.50% BW, and (3) tallow supplement (**MFT**) consisting of the fiber supplement offered at 0.50% BW and tallow offered at

0.125% of BW (at feeding, MF supplement 80% and liquid tallow 20% were mixed by hand). The M supplement contained 7.9% wheat middlings and was designed to deliver 200 mg/head/day of monensin. While MF supplement contained 48.9% wheat middlings and 40.8% soybean hulls and also designed to deliver 200 mg/head/day of monensin. The experiment consisted of two 15-d sampling periods conducted during the grazing season: mid March (MAR), prior to the jointing stage of wheat, and early April (APR), immediately after the jointing stage of wheat began. Steers grazed a single wheat pasture, with supplements offered individually, once daily at 0700. All procedures and experimental protocols were approved by the New Mexico State University Institutional Animal Care and Use Committee.

Collections. Chromic oxide was used to estimate fecal output. Gelatin capsules containing chromic oxide (8 g) were dosed ruminally twice a day (0700 and 1900) on d 7 through 15 of each collection period. Also, total fecal output was collected using fecal bags on d 10 through 15 of each collection period. Fecal bags were emptied and weighed twice daily at 12-h intervals. A 10% (wet basis) sub sample of feces was collected from each steer daily during the collection period.

All steers were gathered into a holding pen for ruminal evacuations at 0700 on d 1 of each period. Digesta was placed in plastic bags lining 133-L plastic containers. After evacuation, steers returned to pasture and were allowed to graze for 60 min. Steers were then re-gathered, masticate samples were collected, and a 10% sub sample was kept to estimate in situ and in vitro digestibility. In situ digestibility was determined in both periods using masticate samples collected on day 1 of period 1. Masticate samples were dried in a forced-air oven (50°C) to a constant weight, ground in a Wiley Mill (2-mm screen), and composited on an equal dry weight basis within treatment. Five-gram samples were sealed, with an impulse sealer, into dacron bags (10 × 20 cm, 50 ± 15 µm pore size; Ankom, Fairport, NY). On d 10 to 13, composited forage in situ bags were ruminally incubated within nylon lingerie washing bags (30.5 × 25.4 cm) for 72, 48, 36, 24, 18, 12, 8, 4, 2, and 0 h in all steers. All bags were removed at 0 h and rinsed with tap water to remove large particulate matter. In situ bags were then rinsed in a top loading washing machine using the delicate cycle. The machine was filled with 45 L of cold water, bags were agitated for 1 min, and the machine was drained, and spun for 2 min. This cycle was repeated five times for all bags. Bags were dried in a forced-air oven at 50ºC, weighed, and stored at room temperature for analysis of DM, CP, NDF, and purines.

On d 14, CoEDTA (200 mL; Uden et al., 1980) was dosed intra-ruminally at 0600 for a marker of fluid passage rate. Ruminal fluid samples were collected at 0 (before dosing), 3, 6, 9, 12, 18, and 24 h after dosing. Ruminal fluid pH was determined immediately after collection and then samples were acidified with 7.2 NH_2SO_4 at a rate of 1 mL/100 mL rumen fluid and frozen (-10°C) in whirl pack bags for later analysis of Co, ammonia, and VFA's. Also on d 14, Yb-labeled wheat-grass (1 kg; Sindt et al., 1993) was intra-ruminally dosed at 0600 for a marker of particulate passage rate. Ruminal content samples were collected at 0 (before dosing), 3, 6, 9, 12, 18, 24, 36 and 48 h after dosing.

Steers were gathered at 0600 on d 15 of each experimental period. During this time, a 2-kg sub sample of rumen contents was taken and mixed with 1 L of saline solution (0.9% NaCl; wt/vol) for isolation of bacterial cells (Zinn and Owens, 1986). Ruminal content samples were frozen (-10°C) for later proximal analysis.

Laboratory Analyses. Fecal samples were thawed, mixed, and sub sampled (10% of total), then fecal, supplement, and masticate samples were dried in a forced-air oven (50°C) for 48 h. Samples were then allowed to equilibrate at room temperature and ground in a Wiley Mill (2-mm screen). Fecal, masticate, and supplement samples were analyzed for DM, OM, and CP (Methods 930.15, 942.05, and 990.02, respectively; AOAC, 1997).

The ADF analyses was conducted according to Goering and Van Soest (1970) and NDF according to Robertson and Van Soest (1991) using an Ankom 200 fiber analyzer (Ankom Co., Fairport, NY) sequentially.

In vitro OM digestibility of masticate samples and supplements (IVOMD; Tilley and Terry, 1963) were determined using composited inoculate from two ruminally cannulated steers fed a grass hay diet.

Ruminal fluid samples were centrifuged at 20,000 × g for 20 min and analyzed for NH_3-N (Broderick and Kang, 1980), VFA (Goetsch and Galyean, 1983), and cobalt was determined using an air-plus-acetylene flame using atomic absorption spectroscopy as described by Uden et al. (1980). Ytterbium was extracted as outlined by Hart and Poland (1984), and marker concentration was determined by atomic absorption spectroscopy using a nitrous oxide-plus-acetylene flame.

Ruminal bacteria was isolated from a 2-kg sample of rumen contents. Ruminal contents were blended on a high speed in a food processor for 1 min, and the mixture was strained through four layers of cheesecloth. Feed particles and protozoa in ruminal samples was removed via centrifugation at 1,000 × g for 10 min. Bacteria was separated from the supernatant by centrifugation at 20,000 × g for 20 min. Isolated bacteria was dried in a forced air oven (50°C), and analyzed for DM, ash, N (as previously described), and purines (Zinn and Owens, 1986).

Calculations. Forage intake was calculated using the total fecal output and forage in vitro OM indigestibility. Forage fecal output (DM) was converted to an OM basis using the OM content of feces. Forage fecal output on an OM basis was determined by

subtracting the indigestible fraction of the supplement from feces of supplemented steers using in vitro OM indigestibility of the supplement. To determine forage OM intake, forage fecal output of OM was divided by forage in vitro OM indigestibility. Liquid dilution rate was calculated by regressing the natural *log* of Co concentration on sampling time, and particle dilution rate by regressing the natural *log* of Yb concentration on sampling time.

In situ data were evaluated using the Ørskov and McDonald (1979) model, $d = a + b\ (1 - e^{-kd})$, where a is the soluble fraction, b is the slowly degradable fraction, d is the extent of digestion, and kd is the rate of degradation. Protein remaining in in situ bags was adjusted for microbial protein contribution. Microbial protein was calculated using the N to purine ratio of ruminally isolated bacteria and purine content of in situ remaining material.

Statistical Analysis. The Mixed procedures of SAS (SAS Inst., Inc., Cary, NC) was used for all statistical computations. Data was analyzed as a split-plot in time. The whole plot was experimental period which occurred in MAR, and APR, where as the three treatments served as the split-plot. For intake, digestibility, liquid and particle passage rates, and in situ data, fixed effects in the model included treatment, period, and the period × treatment interaction. The repeated effect was period and animal within treatment was used to test treatment effects. When significant, ($P < 0.05$), F-statistics were noted, means were separated using the method of least significant difference. Tendencies are discussed when ($0.05 > P < 0.10$).

The mixed procedures of SAS were also used to analyze the ruminal fermentation data (pH, NH_3-N, and VFA) using a split-split-plot analysis. The fixed effects in the statistical model included treatment, period, and period × treatment interaction. The repeated effect was time and animal within period × treatment was used as the error term for split-split-plot.

Results and Discussion

Effects of supplement type and stage of forage maturity on OM intake and digestibility are shown in Table 1. There were supplement type x forage maturity interactions ($P < 0.05$) for forage OM, CP, and NDF intakes. During MAR, forage OM, CP and NDF intakes were greater ($P < 0.05$) for MF supplemented steers than for those supplemented with M. However, for APR grazing, forage OM, CP and NDF intakes were greater ($P < 0.05$) for MF supplemented steers than those supplemented with M and for those supplemented MFT. Forage OM, CP and NDF intakes did not differ ($P > 0.05$) for steers receiving MFT and M supplements during both collection periods. When total OM intake was expressed as g/kg BW a supplement type × forage maturity interaction ($P < 0.05$) was also observed. During MAR, total OM intake (g/kg BW) was greater for MF and MFT supplemented steers than for those receiving the M. While during APR, total OM intake (g/kg BW) was greater ($P < 0.05$) for MF steers than those receiving M and tended ($P = 0.07$) to be greater than those receiving MFT, but steers receiving the MFT and M supplements were not different ($P = 0.16$). With respect to OM and NDF digestibility a supplement type × forage maturity was observed ($P = 0.02$). During MAR, OM and NDF digestibility was greater ($P < 0.01$) for MF than for MFT supplemented steers, and for MFT ($P < 0.01$) than for M supplemented steers. While during APR, OM and NDF digestibility was greater ($P < .01$) for MF supplemented steers than for MFT and M supplemented steers, and MFT tended to be greater ($P = 0.12$) than M supplemented steers. Digestibility of CP was greater ($P < 0.05$) for MF followed by MFT and smaller for M. Also, CP digestibility was greater ($P < 0.05$) during MAR than during APR.

Our results for OM intake and digestibility are consistent with the results of Horn et al. (1995), which suggested that supplementing wheat pasture cattle with a highly digestible fiber source improves intake and digestibility, and performance of grazing cattle. Improvement of OM intake and digestibility of cattle grazing wheat pasture when supplemented with a source of highly digestible fiber is most likely due to the fact that wheat pasture is deficient in energy because of its low structural carbohydrate content. Supplementing cattle grazing wheat pasture with an energy source improves the rumen environment by improving the OM: CP ratio and increases the efficiency of the rumen microbes (Pond et. al. 1995). Previously no work has been done with the addition of fat to the diets of stocker cattle grazing wheat pasture. However, when tallow has been supplemented to cattle consuming medium to low-quality forages, it has been reported to decrease fiber digestibility by inhibiting fibrolytic bacteria (Palmquist, 1988), and has been shown to diminish ruminal fermentation of fiber in sheep (Jenkins et al., 1989). Because wheat pasture is low in fiber, similar results to those observed when fat is included in feedlot finishing diets was expected (Zinn and Plasencia, 1996). Our data suggests that supplementing tallow prior to the jointing stage of wheat had no detrimental effect on fiber digestibility, but as forage maturity increased, the tallow supplementation decreased OM intake and OM digestibility as previously observed (Palmquist, 1988).

Ruminal kinetic parameters are shown in Table 2. DM particle flow rate (%/h), ruminal volume (L), fluid dilution rate (%/h), fluid flow rate (L/h), and turnover time (h), no supplement type x forage maturity interactions were observed ($P > 0.1$), therefore simple effects are discussed. Ruminal volume (103.9, 92.8, and 72.2 ± 8.07 L) and fluid flow rate (10.3, 9.1, and 8.3 ± 0.5

L/h) tended to decrease ($P \leq 0.08$) for MFT compared to M-supplemented steers with MF-supplemented steers being intermediate between the other 2 treatments ($P \geq 0.10$). These results can not be explained by OM or DM intake. However, lower ruminal volume may allow to increase DMI when rumen fill limits voluntary feed intake.

Fluid flow rate (7.9 and 10.6 ± 0.54 L/h) increased ($P = 0.02$) and turnover time (12.5 and 7.4 ± 0.99 h) decreased ($P = 0.02$) for steers grazing wheat during the APR compared to MAR grazing. Particle flow rate (25.7 and 21.7 ± 1.8% 5/h) tended to decrease ($P = 0.07$) and fluid dilution rate (9.1 and 14.3 ± 1.6 %/h) tended to increase ($P = 0.09$) for steers grazing wheat pasture during APR as compared with when they grazed wheat at MAR. Particle flow rate was expected to decrease with increasing NDF intake and coarseness of forage, and decreasing forage digestibility with advancing stage of maturity. Welch (1982) suggested that coarseness and/or greater particle size decreases particle passage rate.

Ruminal CP kinetics and in situ DM and NDF disappearance are shown in Table 2. Rates of DM and NDF ruminal disappearance were not affected ($P > 0.05$) supplement type or stage of forage maturity. Forge incubated was collected during the pre-jointing stage of forage maturity, but was incubated during both collection periods. Our data implie that when forage composition changed with advancing forage maturity, ruminal microbial environment was not affected by supplement type or forage quality.

Ruminal propionate molar proportion increased ($P = 0.01$) for MFT supplemented steers (19.7, 21.4, and 25.1 ± 0.49 mol/100mols for M, MF, and MFT, respectively). Fat supplementation increases propionate production and decreases methane production in feedlot diets (Zinn and Plascencia, 1996). Ruminants use propionate for gluconeogenesis (Fahey and Berger, 1988). Smith and Crouse (1984) demonstrated that glucose provides 50 to 75% of the acetyl units for in vitro lipogenesis in the intramuscular fat depot. Therefore, elevated propionate production from fat supplementation may be a key component in triggering intramuscular adipocyte development in young calves grazing wheat pasture.

Implications

Tallow can be used in wheat pasture supplements to increase energy intake without negatively affecting forage intake, ruminal fermentation and digestion particularly if used before the jointing stage of wheat maturity. Besides increasing energy intake, tallow promotes higher proportion of propionate that may lead to greater intramuscular fat deposition during the grazing backgrounding period

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Table 1. Effect of supplement type[a] and forage maturity[b] on OM, CP, and NDF intake and digestion of beef steers grazing wheat pasture

	MAR			APR				P-values		
Item	Control	Fiber	Tallow	Control	Fiber	Tallow	SEM	Trt	Pd	Trt × Pd
OM intake, Kg/d										
Forage	5.36	8.07	6.58	6.14	8.44	4.61	0.380	0.01	0.33	0.01
Supplement	0.01	2.59	3.29	0.01	2.59	3.29	–	–	–	–
Total	5.37	10.66	9.87	6.15	11.02	7.89	0.380	0.01	0.33	0.01
Total OM intake, g/Kg BW	9.51	18.62	18.77	10.26	18.36	13.82	0.001	0.01	0.04	0.01
CP intake, Kg/d										
Forage	1.39	2.09	1.70	1.55	2.13	1.16	0.097	0.01	0.15	0.01
Supplement	0.00	0.41	0.41	0.00	0.41	0.41	–	–	–	–
Total	1.39	2.50	2.11	1.55	2.54	1.57	0.096	0.01	0.15	0.01
NDF intake, Kg/d										
Forage	2.81	4.23	3.45	3.81	5.24	2.86	0.216	0.01	0.02	0.01
Supplement	0.00	1.22	1.24	0.00	1.23	1.25	–	–	–	–
Total	2.81	5.45	4.69	3.81	6.47	4.11	0.216	0.01	0.02	0.01
Fecal output, kg/d										
OM	1.74	2.33	2.80	2.30	2.76	2.79	0.117	0.01	0.01	0.08
CP	0.39	0.51	0.53	0.53	0.65	0.61	0.029	0.02	0.01	0.50
NDF	1.22	1.74	1.79	1.68	2.05	1.89	0.090	0.01	0.01	0.28
Digestibility, % of intake										
OM	67.65	78.13	71.63	62.48	74.93	64.53	0.455	0.01	0.01	0.02
CP	71.19	79.72	74.66	65.49	74.48	61.07	1.724	0.01	0.01	0.10
NDF	56.16	68.05	61.78	55.82	68.36	54.04	1.233	0.01	0.07	0.06

[a]Supplement Type: Control = 113.5 g of mineral supplement (Table 1); Fiber = mineral supplement plus soybean hulls-wheat middlings offered at .50% BW; Tallow = mineral supplement plus soybean hulls-wheat middlings offered at .50% BW and tallow offered at 0.125% BW.

[b]Forage Maturity: MAR = grazing occurred during middle March before the jointing stage of wheat began; APR = grazing occurred early April right after the beginning of the jointing stage of wheat.

Table 2. Effect of supplement type[a] and forage maturity[b] on DM intake, ruminal volume, fluid dilution rate, fluid flow rate, turnover time, CP ruminal kinetics, and DM and NDF ruminal disappearance particulate flow rate in beef steers grazing wheat pasture.

	MAR			APR				P-values		
Item	Control	Fiber	Tallow	Control	Fiber	Tallow	SEM	Trt	Pd	Trt × Pd
DM intake										
Kg/d	5.37	10.66	9.87	6.15	11.03	7.89	0.380	0.01	0.33	0.01
g/Kg/BW	9.51	18.62	18.77	10.26	18.36	13.82	0.001	0.01	0.04	0.01
DM Particle flow rate, %/h	28.02	27.00	22.20	18.66	27.21	19.17	3.112	0.30	0.07	0.19
Ruminal Volume, L	98.41	116.31	83.47	109.31	69.35	60.89	16.288	0.08	0.28	0.41
Fluid dilution rate, %/h	7.67	7.67	12.00	12.00	14.67	16.33	0.028	0.21	0.09	0.89
Fluid flow rate, L/h	7.68	8.94	7.00	12.99	9.28	9.57	0.931	0.07	0.02	0.16
Turnover time, h	12.85	13.03	11.61	8.40	7.56	6.30	1.719	0.55	0.02	0.96
CP Kinetic Parameters										
Soluble, %	23.03	19.13	17.81	8.27	19.88	6.58	0.044	0.50	0.01	0.01
Slowly degradable, %	67.87	77.42	71.47	80.42	71.19	82.36	0.034	0.76	0.01	0.01
Degradation rate, %/h	3.32	2.74	3.57	11.41	8.41	9.20	0.010	0.45	0.01	0.03
Effective degradability, %	90.89	96.55	89.28	88.70	91.07	88.94	0.025	0.38	0.01	0.02
Ruminal disappearance, %/h										
DM	5.88	6.79	7.12	7.19	6.03	4.82	0.014	0.92	0.60	0.44
NDF	5.67	7.93	6.95	6.86	5.63	4.81	0.015	0.87	0.36	0.39

[a]Supplement Type: Control = 113.5 g of mineral supplement (Table 1); Fiber = mineral supplement plus soybean hulls-wheat middlings offered at 0.50% BW; Tallow = mineral supplement plus soybean hulls-wheat middlings offered at 0.50% BW and tallow offered at 0.125% BW.

[b]Forage Maturity: MAR = grazing occurred during middle March before the jointing stage of wheat began; APR = grazing occurred early April right after the beginning of the jointing stage of wheat.

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EFFECT OF FERROUS CHLORIDE ON SUCKLING CALVES AND ON MICROBIAL GROWTH AND METABOLISM USING AN IN VITRO RUMEN CULTURE SYSTEM

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ABSTRACT: Water is an important but often overlooked nutrient in man and animals. Fe and other minerals can exist dissolved in drinking water, and may be present at detrimental concentrations even in palatable water. In ruminants, Fe may affect microbial growth or interact with other minerals such as Mo, Cu, or S in the rumen environment. A study was designed to take advantage of the esophageal groove of suckling calves in order to bypass the rumen. Fifteen individually-housed Holstein calves, 45 to 55 days old, were given water with 0, 20, or 40 mg Fe L^{-1}, as ferrous chloride, for 8 w utilizing a nipple delivery system. No significant differences were observed between treatment groups for water or feed intakes, growth rates, or liver mineral content. Further studies focused on the rumen. To determine the effects of Fe on microbial metabolism and growth, changes in pH and DNA concentrations were measured. Rumen contents were cultured for 9 h in the presence of 0, 25, 50, 100, 200, 400 or 800 mg Fe L^{-1}, as ferrous chloride. Rate of ruminal pH drop was inversely related (P = 0.059) to Fe concentration and was highly significant (P = 0.005) during the final 3 h of culture. During the final 3 h of culture, an inverse relational trend (P = 0.058) was observed between rates of DNA concentration change and Fe concentration. During the final 6 h of culture, this inverse relationship was significant (P = 0.044). Concentrations as low as 50 mg Fe L^{-1} were significantly detrimental to rumen microbes in culture. As this was a single administration of Fe at the beginning of culture, and when taking into account the amount and frequency of water consumed daily by high production dairy cows, concentrations of Fe well below this 50 mg L^{-1} are likely to result in adverse effects. Depression of microbial growth and metabolism likely translate into altered VFA production or profiles, decreased milk or milk protein yield, and/or altered milk fat%.

KEYWORDS: Iron, Rumen, Microbes, Calves, Cattle

Introduction

High-production dairy cows consume as much as 110 L water per day to meet production and maintenance demands. Minerals dissolved in the water are therefore also ingested, and many studies have shown that high concentrations of dissolved minerals can be toxic to ruminants (Beede, 2005).

The Minnesota Extenstion Service set a “no limit” recommendation for iron in the drinking water of livestock as being reasonable (Bergsrud and Linn, 1989 rev.) and only recent publications even suggest a maximum concentration for livestock (Puls, 1994). Much of the laxity in concern with iron lies in the fact that oxygenation, for a few h, of waters high in iron results in the oxidation of the iron from the ferrous to ferric form (Davison and Seed, 1983; Sharma et al., 2002). Thus, there is little soluble iron in most livestock waters due to the precipitation of the iron. However, with electronic watering, paddle systems, and nipple systems, water is not exposed to air long enough for precipitation to occur and the soluble, reduced iron is ingested at concentrations that may result in adverse effects.

Dietary iron has been shown to have an impact on animal production. Dairy cattle grazing on pastures irrigated with water containing high ferric hydroxide had scouring and weight loss, as well as reduced production of milk and milkfat (Coup and Campbell, 1964). Effects of added Fe on decreased weight caused by high iron were considered transient (Standish et al., 1969).

Toxicity of Fe in animals can be linked to its redox effects on body tissues (Abalea et al., 1998; Valerio and Petersen, 1998; Holovská et al., 2002). These effects include damage to lipid membranes and oxidative stress, as well as protein and DNA damage from cross-linking or chemical alterations. Similar effects would be expected to occur in organisms within the rumen. Damage to proteins and DNA also has been linked to Fe overload in animal tissues (Abalea et al., 1998; Valerio and Petersen, 1998). It is reasonable to assume that these types of damage would also occur in the rumen microbes.

A clinical case involving a dairy herd provided the impetus for this study (Hall, 1990). That herd experienced poor milk production, poor reproductive functions and weight loss; as well as clinical Cu and Se deficiencies while on maximal approved concentrations of both. Just prior to the clinical conditions occurring, the water supply was changed to one containing up to 78 mg soluble Fe L^{-1}.

With these experiments, we evaluate the effect of added Fe in drinking water on preruminant calves, and rumen culture metabolism and microbial growth as a possible toxic effect of Fe that depresses fermentation and microbial replication.

Materials and Methods

To evaluate the effect of Fe, as ferrous chloride, in the drinking water of preruminant calves, 15 Holstein calves, 45-d old, were randomly assigned to one of three treatment groups. These groups were control water, low-iron water, and high-iron water. As preliminary studies indicated the calves had an aversion to drinking deionized water, 40 mg Ca L^{-1} as $CaCl_2$ was added to the deionized water used as

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control water. Low iron water consisted of 20 mg Fe L^{-1} as $FeCl_2$ and 20 mg Ca L^{-1} as $CaCl_2$. High iron water consisted of 40 mg Fe L^{-1} as $FeCl_2$. Calves were given the water in collapsible plastic containers with a nipple delivery system, were watered and fed *ad libitum*, and were individually housed. Calves were acclimatized to the watering system for two w on control water, then given treatment water for 8 w, then all were back on control water for one w as a follow-up period. Calves were weighed at the beginning of each w throughout the experiment. Water intakes for each calf were determined each w, and containers replaced as needed. Calves were fed chopped alfalfa and a calf-starter grain mix twice daily and feed intake determined each d. Blood samples were pulled for each calf at d 0, d 42, and d 70 and were analyzed for serum mineral content. Liver biopsies were taken from each calf at d 7 and d 70 and analyzed for mineral content. Minerals were analyzed using an ICP-MS (Perkin Elmer, Norwalk, CT).

To determine the effect of Fe, as ferrous chloride, on rumen microbial growth and metabolism, a technique developed by Broderick was used (1978). A mature, previously cannulated Holstein cow from the milking herd at the USU Caine Research and Teaching Dairy was used to obtain a rumen content sample used for preparing each of five culture replicates. On each occasion, a rumen content were collected after the morning milking but before the animal was fed. Animals were not restricted in diet or water intake, and were on an alfalfa hay plus grain concentrate diet.

At the laboratory, carbon dioxide was used to maintain an anaerobic environment. Rumen contents were filtered through 4 layers of cheesecloth, and an equal volume of buffer (McDougall, 1948) was used to rinse. The liquid was now considered the inoculum. The rumen inoculum was added to individual spinner flasks (Corning, Corning, NY) that each had 3.0 g ground corn and were treated with either 0, 25, 50, 100, 200, 400, or 800 mg Fe L^{-1} as ferrous chloride.

For each spinner flask, CO_2 was allowed to gently flow into the spinner flask via one side-arm opening. The culture was established by adding 90 ml of inoculum to the flask and placing the flask on a stir plate to begin mixing, while CO_2 continued to flow into the flask. A pH probe was inserted in the side arm opening for a direct pH reading of the sample solution. The pH value was recorded, and two 2 ml sub-samples were removed and added to the appropriately labeled tubes containing 200 µl of 2.75 N perchloric acid (**PCA**). Each tube was capped and gently agitated. The CO_2 supply was removed, the spinner flask sealed, and the flask placed in an incubator at 39°C on one position of a multiple-position stir plate. This process was repeated for each of the subsequent flasks. Dosing and initial sampling for each flask took between 1 and 2 minutes, with time being recorded to ensure accuracy of subsequent samplings. Direct measurement of culture pH and collection of samples for DNA analysis were performed at 0, 3, 6, and 9 hours post-inoculation using this same process, except that the samples were only inoculated at time 0 hr. After samples were collected for each time point, they were stored at –20°C until they were analyzed for DNA content. Each culture flask was purged with CO_2 after each manipulation.

Relative concentrations of DNA for each flask were assayed by a colorimetric method developed by Burton (1956), and modified to chelate the iron using EDTA (Bunderson, 2000), as iron had been shown to interfere with the assay. To chelate the iron, 1 ml of 1.003 M EDTA was added to each tube. Samples were analyzed by use of an UV-Vis spectrophotometer (Shimadzu) measuring absorbance at 600 nm wavelength. Quantification of DNA was made by calculating absorption based on a prepared standard curve. Slopes of DNA change (in µg DNA hr^{-1}) over time of the rumen culture sampling events were calculated and analyzed for 0 to 3 hours (initial third), 3 to 6 hours (middle third), 6 to 9 hours (final third), 0 to 6 hours (initial two-thirds), and 3 to 9 hours (final two-thirds), and 0 to 9 hours (entire).

Each culture flask was evaluated for adequate microbial metabolism of the control cultures (0 added Fe) to verify that the pH had reduced by more than one pH unit over the culture period. This drop in pH was indicative that adequate growth of microbes occurred, and that microbes present were species producing volatile fatty acids (VFA) sufficient for the cow's energy requirements (McAllister et al., 1996; Beckman and Weiss, 2005). Adding iron to the cultures would not in itself affect pH (Bunderson, 2000; Nagalakshmi et al., 2003). For each of the culture sampling events, a change in pH for that interval was calculated. Slopes of pH change over time of the culture sampling events were calculated and analyzed for 0 to 3 hours (initial third), 3 to 6 hours (middle third), 6 to 9 hours (final third), 0 to 6 hours (initial two-thirds), and 3 to 9 hours (final two-thirds), and 0 to 9 hours (entire).

DNA and pH results were analyzed using the mixed model procedure of SAS (SAS Inst., Inc., Cary, NC). A setting of $\alpha = 0.05$ was established for determination of significance, although with microbial systems it would not be unreasonable to choose a setting of $\alpha = 0.10$ due to the complexities involved in such systems. The LS Means function was used to separate significant versus insignificant data on control versus added Fe treatments.

Results and Discussion

In the calf study, calves on both high and low Fe water showed an increased tendency, and increased frequency to bite the watering nipple, causing leakage of water which could not therefore be accounted for, resulting in potential overestimation of intake. This biting may have been a result of a desire to drink, but an aversion to the available water. While not significant, intakes of water were reduced in both high and low Fe water treatment groups, especially in the latter part of the experiment. The lack of significant differences in water intake between the treatment groups may also have been a result of the suckling action preventing the animal from fully tasting the water. No significant differences between treatment groups were detected for feed intake, although there did appear to be a reduction in the feed intake in the high Fe water group during the last few w of the treatment period. Growth rates

were measured, but no statistical differences were observed between the different treatment groups. No significant differences were observed for Fe content of either blood or liver samples. As these results indicated the lack of an effect of Fe in the drinking water of calves prior to the development of a functioning rumen, detrimental effects of Fe was theorized to be due primarily to the effect of Fe on rumen microbes.

In the rumen culture study, a slope of the change in pH over the culture period was calculated for each flask. The average treatment slopes for pH of the various intervals are reported in Table 1. There was a highly significant difference ($P = 0.005$) in slopes during the final third of the culture, which can be interpreted as an inverse relationship of added Fe on changing pH in the flasks during the final three hours of the culture. There was also a tendency over the entire culture period ($P = 0.059$) of a depressive influence of added Fe on the change in pH in the flasks over the nine-hour culture period. Diminished rate of pH drop with increasing Fe was interpreted as depression of the overall metabolism by the culture microbes.

The pair-wise mean comparisons between 0 and the other Fe treatments on the rate of pH drop for the entire culture were evaluated. The slope of the 200 and 400 mg added Fe L^{-1} treatments were significantly reduced compared to the 0 Fe treatment ($P < 0.05$). In addition, the 800 mg added Fe L^{-1} treatment has a significantly reduced slope in comparison to the control slope ($P < 0.01$). From this data, 200 mg added Fe L^{-1} significantly reduces metabolism of rumen microbes grown in cultures.

These findings are similar with researchers who estimated an added Fe of 100 mg L^{-1} ferric chloride significantly reduced dry matter digestibility of microbes in rumen cultures in comparison with no added Fe (Harrison et al., 1992). The authors estimated that this concentration of Fe was sufficient to modify the activity of rumen microorganisms, possibly causing digestive problems within the rumen. Environmental pH has an inverse effect on rumen fermentation rates (Grant and Mertens, 1992). Rumen metabolic by-products accumulate in culture, rather than being absorbed or flushed from the rumen as *in vivo*. This results in an emphasized effect on the environmental pH. It also can result in a slowing of the pH drop as metabolic by-products accumulated in the 0 added iron flasks that reached pH values of 4.8 to 5.7 (Therion, et al., 1982). Thus, slowing of the terminal drop in pH could mask differences in the slope of lower Fe treatments. The significance of Fe affecting microbial metabolism is in its ability to change to amounts and profiles of microbial metabolic products, such as VFA, microbial proteins, and microbial biomass (Harrison et al., 1992). By decreasing VFA amounts, the efficiency of nutrient utility is also decreased, and thereby reducing the energy released from fibrous feeds. Additionally, varying VFA profiles directly impacts milk components such as milk fat.

Due to the high variation in amounts of DNA within treatments and among replicates, the data were transformed into rates of DNA change (in $\mu g\ h^{-1}$) for the sampling events of each flask, and are hereafter referred to as slopes of DNA change. This transformation of data was performed to minimize differences between batches of cultures, as the cultures were performed over a period of several months. A significant change in the slopes of the different treatments ($P = 0.044$) were observed over the final two-thirds of the culture period. A similar tendency also was observed during the final third of the culture period ($p = .057$). This indicates that microbial growth, as measured in change in amount DNA per hour, was depressed with increasing concentrations of Fe in the culture media. An inverse relationship was observed between microbial growth and concentration of added Fe.

Our results are in agreement with Harrison, et al., who observed a similar relationship for beef cattle cultures (1992). In their study, both ferric chloride and ferrous chloride caused a reduction in gas (as measured as CO_2 and methane) production, with the ferric form causing the reduction at a lower concentration of Fe than the ferrous form. The protocol used was an indirect method to determine relative microbial growth, whereas the protocol in this paper is intended as a direct measurement of the relative amount of microbial growth as indicated by changes in DNA measured per h.

The slopes of DNA change for the differing Fe concentrations were significantly different for the final two-thirds of the culture period (Figure 1). Here, there is evidence that 50 mg Fe L^{-1} is significantly detrimental to increasing DNA in rumen cultures, which is also indicative of a detrimental affect on microbial growth. When one takes into account that the present study was with a single administration of Fe, and that high-production dairy animals consume water multiple times per day, the detrimental concentration of Fe is likely much lower. These findings are in agreement with Coup and Campbell (1964) who predicted that 50 mg Fe L^{-1} in drinking water would be sufficient to affect the health of dairy cows. Additionally, these findings may explain the clinical observations of weight loss, poor reproductive functions, and poor milk production in a dairy herd that provided the impetus for this study (Hall, 1990). Just prior to clinical conditions occurring, the water supply had been changed to one containing up to 78 mg soluble Fe L^{-1}. In addition, the clinical case had Cu and Se deficiencies while on maximal approved concentrations of both, indicating adverse interactive effects of Fe on bioavailability is another potential effect on the whole animal that was not addressed by the rumen culture experiments. The interactive, adverse effects of iron with other minerals have been extensively studied in ruminants (Humphries et al., 1983; Gengelback et al., 1994; Kumar et al., 2003).

The change in slope of the DNA increase during the final one-third of the culture period had an inverse relationship to the iron concentrations (Figure 2). While most treatment means were not significantly different from that of the zero added Fe treatment, there was a tendency similar to that of the final two-thirds of the culture period. Since the preparation of the inoculum was likely stressful on the microbes, an absence of significant effects during the first one-third of culture period is not unexpected. Furthermore, in those cultures with lower concentrations of added Fe, during the last time period it is possible that a

combination of lowered pH and loss of essential culture substrates limited additional growth (Therion et al., 1982).

With rapid microbial growth, significant amounts of microbial biomass are constantly being lost from the rumen to the rest of the digestive tract (Therion, et al., 1982; (Grant and Mertens, 1992)). When microbial growth is slowed, their metabolic byproducts become less abundant for use by the animal. Damage to microbial DNA would decrease DNA replication, by either delaying replication while repair enzymes correct the DNA damage or halting replication if the damage is not repairable (Abalea, et al., 1998). By either means, this would result in less microbial biomass for digestion and absortion. With changes in microbial DNA production rates, changes or shifts in microbial populations may occur (Therion, et al., 1982; (van Soest, 1982). These shifts may be a change in species dominance, or total microbial population. These changes may effect further changes on the contributions microbes make to the animal's nutritional needs, such as the bioavailable microbial proteins.

Iron, as ferrous chloride, in drinking water in excess of 50 mg Fe L^{-1} has a significant deleterious effect on growth and metabolism of rumen microbes from dairy cows. While high production dairy cattle consume in excess of 100 L water daily at multiple times, the amount of iron that could cause a significant decrease may be much lower. This data provides justification for Fe limitations in livestock drinking water.

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Table 1. Average slopes of pH change over time for spinner flasks of rumen cultures provided varying amounts of added ferrous iron

Trt[a], mg Fe L^{-1}	Fraction of culture period[b]			
	Init. 1/3	Mid. 1/3	Final 1/3	Entire
0	-0.159	-0.160	-0.213	-0.18
25	-0.149	-0.151	-0.209	-0.17
50	-0.155	-0.156	-0.208	-0.17
100	-0.142	-0.153	-0.194	-0.16
200	-0.143	-0.140	-0.179	-0.15
400	-0.132	-0.151	-0.183	-0.16
800	-0.135	-0.156	-0.158	-0.15
SE[c]	0.02	0.02	0.03	0.01
Sig.[d]	ns	ns	**	†

[a]Treatment of rumen culture flasks, single application of added Fe as ferrous chloride.

[b]Mean slope of pH for each fraction of culture period.

[c]SE is standard error. N = 70

[d]Significance are ns = not significant, † = tendency (P < 0.1), and ** = highly significant (P < 0.01).

Table 2. Average slopes of change in DNA content over time for spinner flasks of rumen cultures provided varying amounts of added ferrous iron

Trt[a], mg Fe L^{-1}	Fraction of culture period[b]			
	Init. 1/3	Mid. 1/3	Final 1/3	Entire
0	7.0	62.4	29.4	33.0
25	89.2	21.9	34.6	48.6
50	128.0	-14.7	17.8	43.7
100	88.7	37.8	-3.6	41.0
200	113.4	31.3	-27.0	39.2
400	106.5	20.8	-2.4	41.6
800	89.5	-3.1	15.1	33.8
SE[c]	0.02	0.02	0.03	0.01
Sig.[d]	ns	ns	*	†

[a]Treatment of rumen culture flasks, single application of added Fe as ferrous chloride.

[b]Mean slope of DNA, µg hr^{-1}, for each fraction of culture period.

[c]SE is standard error. N = 140

[d]Significance are ns = not significant, † = tendency (P < 0.1), and * = significant (P < 0.05).

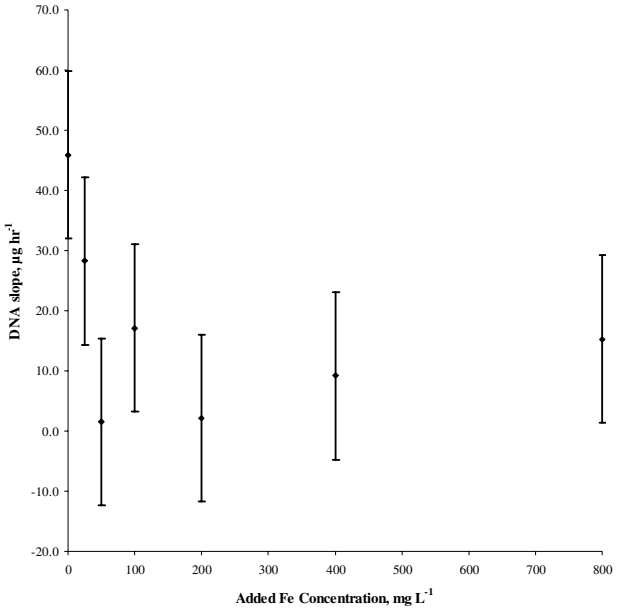

Figure 1. Slopes of DNA change from 3 to 9 hours in µg DNA hr^{-1}. Rumen contents were cultured with single applications of 0, 25, 50, 100, 200, 400 and 800 mg added Fe L^{-1}, as ferrous chloride. Slopes of change in DNA content were calculated for the final six hours of a total of nine hours of culture. Error bars indicate standard error. N = 20.

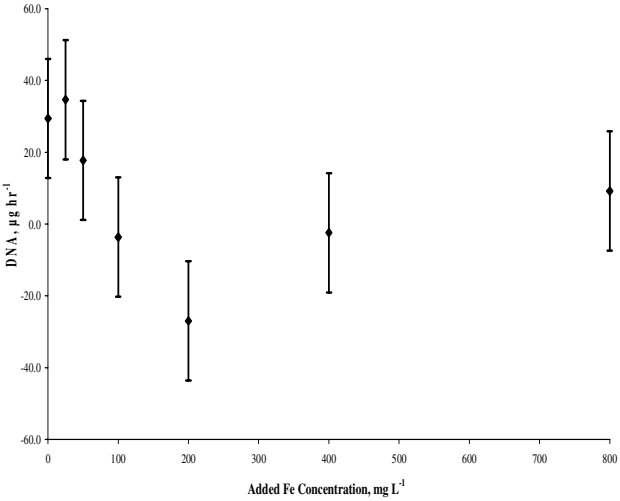

Figure 2. Slopes of DNA change from 6 to 9 hours in µg DNA hr^{-1}. Rumen contents were cultured with single applications of 0, 25, 50, 100, 200, 400 and 800 mg added Fe L^{-1}, as ferrous chloride. Mean slopes of change in DNA content were calculated for the final three hours of a total of nine hours of culture. Error bars indicate standard error. N = 20.

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CORRELATION BETWEEN WATER MINERAL CONTENT AND PRODUCTION PARAMETERS IN DAIRY CATTLE

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ABSTRACT: A survey of dairy herd drinking water was performed at 75 dairies in Utah and Idaho, and mineral content in the water was correlated with production parameters from Provo Dairy Herd Improvement Association (DHIA). Two water samples, taken 30 to 60 d apart, were obtained from a single source of the herd drinking water at each dairy, analyzed for minerals, and averaged. The water was analyzed for Ag, Al, As, B, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, Sb, Se, Si, Sn, Sr, Tl, V, and Zn. Eight dairies had water mineral content with one or more minerals (As, Fe, K, Mg, Mn, Na, and P) above the currently recommended standards. The maximal estimated percentage of the recommended daily intake (RDI) for P was less than 1%, Mn was 11%, Mg was 20%, Fe was 53%, and Na was 62%. Ca, Cu, and Zn were also present in maximal amounts of 17 to 52% of RDI even though these minerals were not above their standard. Minerals are often fed at maximal RDI based only on dietary components; thus, this study suggests not taking mineral water content into consideration in formulating diets could result in intakes exceeding upper RDI limits for these minerals.

DHIA milk test records were obtained for the three-month period surrounding the two water-sampling dates, and averaged. Nine DHIA parameters had correlations ($P < 0.05$) or trends towards correlation (trends, $P < 0.1$) with one or more minerals. The minerals that had correlations or trends were Al, Ca, Fe, Mo, Pb, and Si. The majority of these correlations or trends indicated a detrimental impact on the DHIA parameter involved. Al had a detrimental impact on three reproduction parameters, including two relating to spontaneous abortions. The highly significant ($P < 0.001$) positive correlation of Al with abortion before 151 d gestation ($r = 0.60$) was the strongest found in this study. It is of interest that of these six correlating minerals, only Fe was found to be above standards in livestock drinking water. Further studies are needed to determine whether the adverse effects of Al, Ca, Pb, and Si in drinking water have firm scientific basis in dairy cattle.

KEYWORDS: Mineral, Water, Milk Production

Introduction

Water nutrition is often overlooked by dairy owners and their nutritional consultants (Beede, 2005). Water is one of the most essential components of nutrition. Due to the high demand for drinking water by lactating dairy cattle (Aseltine, 1992), it is important for dairy owners to understand what optimal water intake is essential for maximal production.

Water consumption is based on several factors including environmental conditions, animal production status, diet, and water quality (Shirley, 1985; Puls, 1994). Water quality can include factors present in the water that adversely affect metabolic or physiological function. Minerals dissolved in drinking water may be present in sufficient quantities to cause a marked effect on herd production or reproduction efficiencies (Smith, 1980; Coup and Campbell, 1964). These effects may be due to water minerals providing a significant portion of the nutrients required, interfering with the uptake of other elements, or affecting digestibility of dietary constituents. High mineral concentrations may or may not affect palatability while directly impacting animal health or production. Furthermore, some elements may be toxic to animals at concentrations found in otherwise palatable drinking water. This may be due to a cumulative effect of the element, such as F or As, where the intake exceeds excretion rate (DOI, 1968), or when the element accumulates in milk, meat, or eggs intended for human consumption (EPA, 1972). Testing of water for mineral content is recommended regularly, and, at least annually (Aseltine, 1992).

Minerals in drinking water may be more available than that present in feedstuffs. Coates and Ternouth (1992) found that supplementing P in drinking water is absorbed more efficiently by cattle than by feeding forages higher in phosphorous. In addition, the ferrous state of Fe is more water soluble than the ferric state, and rumen microbes convert Fe to the ferrous state for utilization (Raab and Feldmann, 2003).

Mineral interactions have been shown to cause toxicoses or deficiencies in ruminants. Interactions between Mo, Cu, Fe, and S have been seen in beef and dairy cattle (Gengelback et al., 1994; Telfer et al., 2004).

A clinical case involving a dairy herd provided the impetus for this study (Hall, 1990). That herd experienced poor milk production, poor reproductive efficiency and weight loss; as well as clinical Cu and Se deficiencies while on maximal approved concentrations of both. Just prior to the clinical conditions occurring, the water supply was changed to one containing up to 78 mg soluble Fe L^{-1}. This prompted a study on the effect of added Fe in drinking water on preruminant calves and a preliminary rumen culture study (Bunderson, 2000). The preliminary study found a decrease in growth rate and metabolism of microbes in culture with increasing Fe. Based on adverse health effects in cattle and preliminary indications of a ruminal effect of soluble iron, more information was needed to determine potential problems in the

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intermountain west. With this study, we examine the diversity of water mineral content and potential effects on dairy productivity in Utah and Idaho. We anticipate that increased concentrations of one or more minerals will have a negative correlation with milk production or reproduction parameters.

Materials and Methods

A list of dairies, with contact information, that participate in the Dairy Herd Improvement Association (DHIA) was obtained from Provo DHI Computing Service. Dairies were contacted to determine willingness to participate in the study. Dairies that agreed to participate in this research project answered a management practices survey. Completed surveys were coded to protect dairy privacy, and were stored separately from the original DHIA list with identifying information.

Seven management parameters were obtained from the surveys to be used as main effects in statistical modeling. Water source for the herd was classified as private well and spring, or municipal. Breeds at the dairy were classified as 90% or more Holsteins, 90% or more Jerseys, or other breeds and mixed herds. Housing of the animals was classified into open lot, free stall, or other, including mixed. Also examined was whether the herd was fed in strings or groups, a nutritional consultant was used, bovine somatotropin was used, or if the diet was fed as a total mixed ration.

Two water samples were collected from each of 75 dairies across Utah and Idaho. Each water sample for a dairy was collected from a single location at that premises from the same drinking water supply as the cows utilized. The second water sample was taken a minimum of 30 d, but less than 60 d following the date of the first sample collection and was taken from the same location as the first water sample collection. Sample bottles were high-density polyethylene (Nalgene, Nalge Nunc International, Rochester, NY). Concentrated, trace-metal grade nitric acid (Fisher, Pittsburg, PA) was added to each bottle in order to act as a preservative and to bring final concentration in the bottle to 5% (vol/vol) nitric acid.

Prior to collection, a faucet or valve attached to the herd drinking water supply was activated to allow maximal water flow for at least 2 min. Water samples were then collected by holding a sample bottle in the stream of water until the water reached the brim. Upon filling, bottles were capped and agitated to mix with the nitric acid. Bottles were kept in an insulated carrier to protect from extreme changes in weather

Preserved water samples were analyzed analyzed using an Inductively-Coupled Plasma Mass Spectrophotometer (ICP-MS) (Perkin Elmer, Wellesley, MA). Each water sample was analyzed for 29 elements. Those elements were aluminum, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, cobalt, fluorine, iron, lead, lithium, magnesium, manganese, molybdenum, nickel, phosphorus, potassium, selenium, silicon, silver, sodium, strontium, sulfur, tin, thallium, vanadium, and zinc. The two water sample results for each dairy were then averaged for each element.

DHIA test records for the three-month period surrounding the two water-sampling events included milk production and reproductive efficiency data for the herd.

Water sample averages for each element were used as main effects in modeling against herd averages for production and reproduction data from DHIA test records. Management practices data from the survey responses also were used as main effects and 2-way interactions in modeling. Co-linearity of mineral data was determined using the PROC REG procedure of SAS (SAS Inst., Inc., Cary, NC) with options to compute variance inflation factors and produce co-linearity analyses. The PROC GLM procedure was used to develop models for each of the production parameters of interest. Terms were removed in descending order of Pr > F. When main effects were removed, all remaining interactions of that main effect were also removed. Terms were removed individually, in descending order, until all terms remaining, if any, were significant at $P < 0.05$. The PROC CORR procedure was used to determine any correlations of any minerals remaining in the model for the appropriate dependent variable. Trends were stated to occur with correlation coefficients of $P < 0.10$, and deemed statistically significant when $P < 0.05$. Mean, standard error, minimum values, and maximum values for minerals were determined using the PROC MEANS procedure.

Results and Discussion

No further examinations of the data for Ag, B, Be, Cd, Co, Cr, Ni, Sb, Se, Sn, Tl, or V were made because these minerals were not found above detection limits of 0.001 mg L^{-1}. K and Li were determined to be behaving collinearly in modeling. Li does not have any standards in drinking water above which it is deemed dangerous to humans or animals (Puls, 1994). Li was therefore chosen to be used in modeling rather than K to determine any possible adverse correlations with any of the tested DHIA parameters. The means, standard errors, minimum and maximum values for the minerals used for statistical analyses are presented in Table 1. Eight dairies had one or both water samples in which mineral concentration(s) were above the appropriate livestock standards (Puls, 1994). The mineral(s) with elevated concentrations were As, Fe, K, Mg, Mn, Na, and P.

Milk production parameters for each dairy were modeled using ANOVA with the minerals listed in Table 1 and management variables as main effects. There were three models where a mineral was not significantly correlated with the production variable, but did have a trend towards correlation. These were mature-equivalent milk production for cows in the first lactation, current-month average milk production, and current-year milk production. The mineral was Si. It is considered relatively non-toxic, other than inhalation toxicity of dust forms of Si, known as silicosis (Bagchi, 1992), and has a dietary function to bind Al in the alimentary tracts to reduce Al absorption (Birchall, 1994). Therefore, any effect Si may have on milk production, either in first lactation, or on a monthly or yearly basis, may be due to an overall decrease in palatability, or possibly interactive effects of binding with

other mineral(s) prior to absorption, rendering them less bioavailable.

Table 1. Mineral concentrations in dairy herd drinking-water samples

Mineral[a]	Mean.	SE[b]	Minimum	Maximum
			g L^{-1}	
Ca	0.058	0.003	0.005	0.126
Mg	0.021	0.002	0.002	0.096
Na	0.037	0.007	0.001	0.320
Si	0.010	0.001	0.002	0.029
			mg L^{-1}	
Al	0.036	0.014	0.000	0.766
As	0.004	0.001	0.000	0.045
Ba	0.084	0.008	0.005	0.384
Cu	0.038	0.006	0.001	0.230
Fe	0.351	0.034	0.048	2.040
Li	0.028	0.005	0.001	0.253
Mn	0.015	0.007	0.000	0.337
Mo	0.002	0.001	0.000	0.051
P	0.065	0.016	0.000	0.801
Pb	0.001	0.000	0.000	0.013
Sr	0.303	0.036	0.037	2.050
Zn	0.061	0.028	0.000	2.040

[a]Two samples were taken, for dairies in Utah and Idaho, 30 to 60 d apart, analyzed on an ICP-MS, and averaged.
[b]SE is standard error, N = 75.

For those cows in the second lactation, mature-equivalent milk production produced a model that was highly significant ($P < 0.01$) with an $r^2 = 0.38$. The two mineral terms Ca and Mo as well as the management main effect of breeds remained in the model. Ca had a slight negative correlation, with $r = -0.229$ and $P = 0.050$. Even though calcium would account for only a small percentage of daily intake, many dairy rations are at or above the upper range of calcium in the diet. Thus, added calcium in the water could result in excessive calcium intake and interfere with dietary utilization of other minerals.

Reproduction parameters were modeled using ANOVA using the minerals listed in Table 1 as main effects, and the management variables. After iterative removal of all terms with $P > 0.05$, eight resulted in models that were determined to be statistically relevant at $P < 0.05$. Those mineral terms that were remaining in the rest of the models were then correlated with the appropriate reproduction variable.

Services per cow not resulting in pregnancy produced a model that was significant ($P < 0.05$, $r^2 = 0.1051$). Fe was the only term remaining in the model and had a significant ($P = 0.014$) slight negative correlation, with a correlation coefficient of $r = -0.318$. This finding that increasing Fe results in fewer services per cow not resulting in pregnancy, or better reproduction, is in divergence with a study showing no effect of Fe on reproductive performance (Campbell and Miller, 1998).

The model for age at first calving was significant ($P < .05$, $r^2 = 0.068$), and had only Al as a significant remaining term. Al ($P = 0.0001$) showed a slight to moderate positive correlation ($r = 0.4287$). This indication of Al having a negative impact on reproductive efficiency of replacement heifers is unexpected, as the history of replacement heifers was not specifically addressed in the management survey. This finding prompts the query, were the replacement heifers given the same water as the lactating cows in the study? There are several possible reasons for heifers not receiving water of comparable quality, including heifers having a different water source from the milking herd, or water-quality changes over time. Thus, one cannot make significant interpretations of this finding.

Abortions in the current month had a model that was significant ($P < 0.05$, $r^2 = 0.118$), with Al as the only term remaining in the model. Al ($P = 0.0056$) had a slight to moderate positive correlation ($r = 0.4105$). This negative impact on current-month abortions by Al will be discussed jointly with abortions at less than 151 d gestation. Abortions at less than 151 d gestation had a model that was highly significant ($P < 0.0001$, $r^2 = 0.407$), with Al and Pb being the only terms remaining in the model. Al ($P < .0001$) had a moderate positive correlation ($r = 0.6006$), and Pb ($P < 0.05$) had a slight positive correlation ($r = 0.2599$). The negative impact of Al on abortions in the early part of pregnancy as wll as abortions in the current month fits with studies in mice (Bellés et al., 1999) and rabbits (Yokel, 1987). The effects of Al on skeletal development in mice were not found to be mitigated by Al chelators or by competition with other minerals during absorption. Slight to moderate correlations of these two abortion parameters with Al, combined with scientific studies showing negative effects of Al on fetal development in rodents, indicates that this relationship warrants further study in cattle. It is worth further study into possible effects of Al on cattle abortions, especially as Al was not found to be in excess of standards in any of the water samples in this study. Pb has been shown to be a reproductive toxin in humans (Hertz-Picciotto, 2000; Landrigan et al., 2000). The effects of Pb have been demonstrated as abnormal fetal growth due to both paternal exposure prior to conception, and maternal exposure during pregnancy.

With the range of values found for several of the minerals (Ca, Cu, Fe, Mg, Mn, Na, P, and Zn) in water samples of this study, minimum and maximum percentages of these minerals' recommended daily intake (RDI) (NRC, 2001) were calculated and presented in Table 2. The following assumptions were made. Water intake used in these calculations was 95 L d^{-1}, based on the water intake estimation table of Beede (2005). Average milk yield in this study was 33.6 kg d^{-1}, based on mature-equivalent milk production (fat-corrected and averaged over 305 d), and was used to determine average daily requirements for Holsteins and Jerseys for each of these minerals. Drinking water provides less than 1% of the RDI for P, which is a trivial contribution to dietary intake. Up to 11% of the RDI for Mn may be found in drinking water, which, while not trivial, is not likely to affect animal nutritional needs. Up to 20% of the RDI for Ca, Mg, and Zn may be provided by drinking water, which may begin to influence the supplemental amounts of these minerals in diets. The amounts of Cu, Fe, and Na in drinking water may be as

high as 60% of the RDI, which might seriously affect the contributions these minerals make to the diet. Mineral balance in the diet is critical to prevent adverse interactions, such as high Fe, Mo, and S causing Cu deficiencies (Bremner et al., 1987). This study shows that water mineral content should be included in any dietary nutritional management system.

Table 2 Minimum and maximum percentage of the recommended daily intake of minerals provided by dairy herd drinking-water samples[a]

Mineral	NRC RDI[b]	Mean[c,d]	Min.	Max.
	(g d^{-1})	%	%	%
Ca	67	8.22	0.76	17.8
Mg	45	4.44	0.52	20.0
Na	49	7.15	0.29	62.1
P	57	0.01	0.00	0.1
	(mg d^{-1})	%	%	%
Cu	42	8.53	0.11	52.0
Fe	368	9.07	1.23	52.7
Mn	293	0.48	0.00	10.9
Zn	1,140	0.51	0.00	17.0

[a]Water consumption was estimated to be 95 L d^{-1}. Two water samples were taken, for each of 75 dairies from Utah and Idaho, 30 to 60 d apart, analyzed on an ICP-MS, and averaged.

[b]NRC (2001) recommended daily intake (RDI) was averaged across 50-120 d milk production, 25-54.4 kg milk produced d^{-1}, and 20-30 kg DMI d^{-1} for Holstein and Jersey breeds.

[c]Mean, minimum, and maximum values reflect percentage of RDI for these minerals.

[d]N = 75.

By using only dairies that participate in the Provo DHIA testing program, it is probable that biases exist, especially in management parameters. However, to have access to the production and reproduction parameters of interest, utilizing DHIA records was necessary. It also is likely that dairies with much poorer water quality were not included in the study.

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EFFECTS OF GRADED LEVELS OF ZEOLITE ON THE DIGESTIBILITY AND NUTRIENT INTAKE OF SHEEP

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ABSTRACT: The effect of four levels of zeolite on the digestibility and nutrient intake of sheep fed with alfalfa hay and concentrate was determined. Four fistulated Pelibuey males with an average liveweight 32.55±1.43 kg of liveweight were allocated to four treatments in a Latin square design: 0% zeolite (T1), 1.5% zeolite (T2), 3% zeolite (T3) and 4.5% zeolite (T4). Results for apparent dry matter digestibility (DMD), dry matter intake (DMI), organic matter intake (OMI), acid detergent fiber intake (ADFI), neutral detergent fiber intake (NDFI) and crude protein intake (CPI) the data showed no statistical differences. However, a significant quadratic effect *(P=0.002)* was observed for digestible intake of acid detergent fiber (DIADF) with values of 72.0 (T1), 94.4 (T2), 98.6 (T3) and 87.3 (T4) g/animal/day (±15.5 S.E). Results indicated that their inclusion of zeolite in diets where the source of fiber is alfalfa hay, the intake and digestibility of nutrients have an important increment and can be used as a way to improve ruminal condition safely..

Keywords**:** Clinoptilolite, ruminants, digestibility, intake, alfalfa

Introduction

Inclusion of natural zeolites in animal feeds had been practiced several decades ago. This natural resource is composed by mobile minerals and interchangeable ions with a great selectivity for ammonia (Culfaz. and Yagiz, 2004), potassium, sodium, calcium and magnesium (Castaing, 1998), which are necessary for growth of several ruminal cellulolytic microorganisms (Galindo *et al*., 1990). The ammonia retained by zeolite is gradually liberated into the ruminal environment, which allows an ideal utilization of nitrogen by the ruminal microflora (Gutiérrez *et al*., 2004) and supports a high degradation of nutrients in the rumen with an improved passage of digesta and as a consequence a more desirable intake (Forouzani *et al*., 2004). However, little is known about the potentiality of the zeolites when included in rations based on hays with high digestibility and protein content. The objective was to evaluate intake and digestibility of nutrients in sheep with the inclusion of zeolite in a diet based on alfalfa hay and grains.

Materials and Methods

Four ruminally cannulated Pelibuey males (32.55±1.34 kg LW) were penned individually fed with a diet including 70% alfalfa hay and 30% grains, offering feed in a 10% level greater than consumed the day before. Treatments consisted of four levels of natural zeolite; 0.0% (T1), 1.5%(T2), 3.0% (T3) y 4.5% (T4) which were assigned to four animals in a Latin square design. Table 1 shows the chemical composition of the basal diet. zeolite was dosed ruminally every morning .

Table 1.Chemical composition of basal ration.

Composition	**(% DM)**
DM	93.6
OM	89.22
Ashes	10.78
CP	18.33
NDF	43.85
ADF	23.78

Intake was determined by difference between DM weigth of offered feed and DM weigth of refusals (Van Soest, 1994). Apparent DM digestibility (DMD), organic matter digestibility (OMD) and acid detergent fiber digestibility (ADFD), was determined using indigestible ADF as an internal marker, according to the methodology proposed by Penning and Johnson (1983). Feces were taken directly from the rectum of each animal and feeds were placed in nylon bags and suspended into the rumen of three animals during 12 days at the end of the experiment (Huhtanem *et al*., 1994) to measure IADF.

Data were statistically analyzed using Minitab (2000) and mean comparisons were made. To determine the effect of zeolite on digestible intake of ADF, effects of animal and period were eliminated from the model and a quadratic model was adjusted with the zeolite level as a predictor variable.

Results and Discussion

Results for DMD, OMD and ADFD are presented in Table 2. No significant effect was found for these variables (P>0.05). These results are lower than

[1] Mention of a proprietary product does not constitute a guarantee or warranty of the product by USDA, Montana AES, or the authors and does not imply its approval to the exclusion of other products that may also be suitable.USDA, ARS, Northern Plains Area, is an equal opportunity/ affirmative action employer. All agency services are available without discrimination.

those found by Forouzani *et al*. (2004). However, DMD and OMD values appeared to be higher for the zeolite treatment than for the control. This slight improvement could be attributed to the cationic interchange property of zeolite (Galindo *et al*., 1990) that could supply fair amounts of nitrogen to the ruminal microorganisms and partially satisfy their requeriments for growth and reproduction (Gutiérrez *et al*., 2004). ADFD also showed no statistical difference with the administration of zeolite, in agreement with Forouzani *et al*. (2004). However, a clear tendency for improvement (13%) was observed when 3.0% zeolita was used in comparison to 0% of zeolite, maybe due to the improvement of ruminal environment conditions (Galindo *et al*., 1984).

Table 2. Coeficients for DMD, OMD and ADFD in sheep influenced by different levels of zeolite in the diet

	Treatments (%)				
	0	**1.5**	**3.0**	**4.5**	**SE**
DMD (%)	67.9	66.9	69.3	70.8	2.8
OMD (%)	72.8	73.5	77.6	79.7	2.7
ADFD (%)	32.2	34.4	37.4	33.4	2.2

Results for DMI and OMI are presented in Figure 1, and those found for CPI NDFI and ADFI are showed in Figure 2. These variables were not affected (P>0.05) with inclusion of zeolite in the diet. However, this lack of significance could be due to the small sample used (large SE), as a consequence of characteristic of individuality and selectivity of each animal (McDonald *et al*., 2002). These results are in agreement wit the report by Coutinho *et al*. (2002) who also found no difference in intake when they included different levels of zeolita in a diet based on good quality hay and concentrate. Results observed for ADFI, NDFI and CPI tended to be improved as the level of zeolite was incremented.

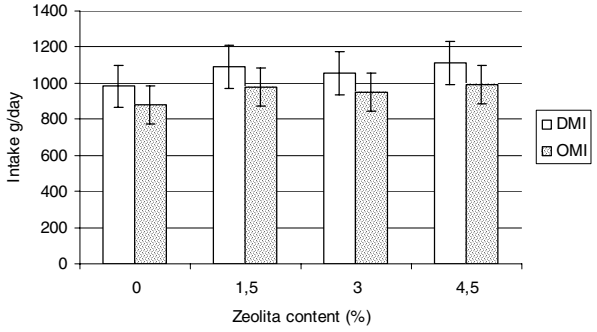

Figure 1. Effect of graded levels of zeolita on DMI and OMI

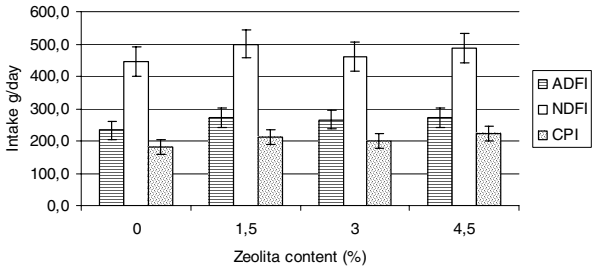

Figure 2. Effect of graded levels of zeolite on ADFI, NDFI and CPI

The effect of zeolite on the adjusted intake of digestible ADF showed a quadratic effect *(P=0.002),* with the best performance in T2 and T3 (increments of 26%). This response could be attributed to a better digestibility of the chemical components of ADF. The lower values found in T4 for this variable probably is a consequence of the diminution of the digestibility of ADF (Table 2). When zeolites are added in the diet with levels above 3%, conditions in the ruminal environment are altered, as reported by McCollum y Galyean (1983), explaining that doses of 5% of zeolita affected the ruminal fermentation causing a decrease in digestibility of nutrients due to lower values of pH and ammonia concentration, than for zeolitelevels below 5%.

Implications

Due to the known properties of zeolites as an improver of the ruminal environment, the results indicated that their inclusion in diets where the source of fiber is alfalfa hay, the intake of ADFI is improved and digestibility of DM, OM and ADF have substantial increments compared with the animals fed with 0% zeolite, indicating that this aditive can be safely utilized in ruminant nutrition. However, is recommended in the future to work with high sample sizes in order to decrease SE and obtain desirable results in DM consumption.

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PHOSPHORUS ABSORPTION OF FEED INGREDIENTS COMMONLY USED IN RUMINANT PRODUCTION SYSTEMS IN VENEZUELA

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ABSTRACT: Phosphorus digestibility of different feed ingredients, commonly used in ruminant production systems in Venezuela, was determined with 20 West African mature wethers with 30±3.3 kg live body weight. The animals were distributed in five treatments, with four animals each. In the experiment, cotton seed (CS), cotton cake (CC), bran and oil extracted corn germ (CBG), and rice polishing (RP) were evaluated, using a dicalcium phosphate (DCP) as a reference control. A balance trial was carried out in two periods of 10 days each. In both, P intake and excretion were determined. In the first period, animals were fed a basal diet containing 0.10% total P, and, in the second, a diet with 0.25% total P, by the addition of the different feed ingredients. These represented 80% of total dietary P. Phosphorus apparent absorption (AA), net utilization (NU), calculated by the difference between P levels, and true absorption (TA), by estimating fecal endogenous P, were measured. Phosphorus AA values (%) were higher (P<0.05) for CBG (41.8) and DCP (39.4) diets, in relation to CC (36.3), CS (33.3) and RP (30.0). Phosphorus TA and NU values (%) were 57.8 and 60.0; 51.1 and 46.4; 55.6 and 56.3; 61.9 and 70.7; and 48.5 and 41.0, respectively, for DCP, CS, CC, CBG and PA, being DCP and CBG higher (P<0.05) than the other feed ingredients. Digestibility values were highly correlated (r= 0.99). It is concluded, in this study, that the majority of vegetable feed ingredients had lower P bio-availability than DCP.

Key words: Absorption, Phosphorus, Sheep, Bioavailability

Introduction

Ruminants under intensive high milk and beef production systems, or in physiological conditions requiring greater nutrient intakes, even in non intensive management, require, in addition to forages, high concentrate diets, based on cereals, oil seeds and by-products, to satisfy nutrient requirements.

High concentrate diets have a great proportion of total P (Pt) as phytic P (Pph>70%). It has been demonstrated that, when diets contain approximately 50% P as phytate, more than 90% of this is hydrolyzed by rumen microbial phytases (Clark *et al*., 1986; Morse *et al*., 1992)

However, several authors (Lofgreen, 1960; Ellis and Tillman, 1960) suggest the hypothesis that in ruminants the microbial phytase activity, when high levels of concentrate are fed (>70%), is not sufficient to hydrolyze phytates, probably due to saturation of the enzyme to hydrolyze the substrate (Meschy and Gueguen, 1998; Godoy and Meschy, 2000). In addition, chemical and heat treatments used in the industrial processing of these materials may also affect the degradation of phytic phosphorus (Konischi *et al*., 1999; Park *et al*., 1999; Bravo *et al*., 2000).

Consequentely, this paper presents studies on phosphorus absorption of some ingredients commonly used in the animal industry in Venezuela. Mature wethers were used as experimental animals.

Materials and Methods

Twenty crossbred West African mature wethers of 30±3.3 kg live body weight, in a completely randomized experimental design, were assigned to five treatments with four animals each. Cotton cake (CC: 1.34% Pt), bran and corn oil extracted germ (CBG: 1.21% Pt), cotton seed (CS: 0.64% Pt) and rice polishing (RP: 1.57% Pt) were evaluated using dicalcium phosphate (DCP: 19.5 Pt) as a reference control.

Absorption was measured in a balance trial that was carried out in two periods of 10 days each. Wethers were kept in metabolism create, allowing a period of 14 days for adaptation followed by 10 days to measure intake and fecal excretions. Diet and fecal samples (10%) were taken for chemical analysis (AOAC, 1997).

In the first period, animal were fed a basal diet (B: 0.10% Pt). In the second, diets with the different ingredients were fed at an adequate level in order to satisfy P requirements (0.25% Pt). The ingredients under study represented 80% Pt (Table 1). One kg of the diet was offered daily with water *ad lib*.

Apparent absorption (AA), true absorption (TA) and net utilization (NU) were calculated as follows (Hurtwitz, 1964):

$$AA, \% = \frac{P\ intake - P\ fecal}{P\ intake} X\ 100$$

$$TA, \% = \frac{P\ intake - (P\ fecal - P\ endogenous)}{P\ intake} X\ 100$$

$$NU, \% = \frac{(P\ intake\ D - B) - (P\ fecal\ D - B)}{(P\ intake\ D - B)} X\ 100$$

D: experimental diet; B: basal

Phosphorus TA was estimated by subtracting from the total fecal excretion the metabolic fraction of

phosphorus, calculated by the following equation (Bravo *et al*., 2000):

P endogenous: Y (mg P/kg BW) = 13.6 + P intake (g/day)/BW (kg)

Data were treated by ANOVA and means were compared by Tukey test.

Table 1. Experimental diet (%)

Ingredients	B	DCP	CS	CC	CBG	RP
Corn cob	60.7	56.7	49.0	55.0	59.0	54.0
Cassava Starch	23.19	26.5	21.0	23.0	6.0	15.0
Hydrolyzed feather meal	6.22	6.60	-	-	-	-
Molasses	5.0	5.0	5.0	3.0	3.0	10.0
Calcium carbonate	2.00	1.50	2.00	2.00	2.00	2.00
Minerals	1.00	1.00	1,00	1.00	1.00	1.00
Urea	1.75	1.70	2.40	2.00	2.00	2.40
DCP[1]	0.15	1.00	-	-	-	-
CS[1]	-	-	22.0	-	-	-
CC[1]	-	-	-	14.0	-	-
CBG[1]	-	-	-	-	25.00	-
RP[1]	-	-	-	-	-	16.0
CP, %[2]	***1.41***	***14,1***	***1.40***	***14.1***	***14.0***	***14.0***
ME, Mcal[3]g[3]	***2.24***	***2.15***	***251***	***2.24***	***2.32***	***2,31***
Pt, %[2]	***0.11***	***0. 25***	***0.25***	***0.25***	***0.25***	***0.25***

[1]B: basal diet; DCP: dicalcium phosphate; CS: cotton seed; CC: cotton cake; CBG: bran and corn oil extracted germ; RP: rice polishing.

[2]Values determined by chemical analysis.

[3]Estimated metabolic energy.

Results and Discussion

Protein content, ether extract, neutral detergent fiber and mineral (Ca and P) values of the materials being evaluation (Table 2) are similar to those reported in the International Feed Composition Tables (NRC, 1998; FEDNA, 1999; Sauvant *et al*, 2002). Phytic P represented 77, 72, 65 and 63% of total P of CS, RP, CBG and CC, respectively.

Table 2 Chemical composition of ingredients

Item[2]	CP %	EE %	NDF %	Pt[1] %	Pph[1] %Pt	Ca %
CS	25.5 ±0.3	22.6 ±0.4	53.6 ±1.6	0.64 ±0.01	77	0.19 ±0.01
CC	34.3 ±1.3	5.63 ±1.5	45.2 ±1.8	1.34 ±0.01	63	0.16 ±0.02
CBG	16.6 ±0.2	0.52 ±0.1	20.5 ±1.4	1.21 ±0.1	65	0.02 ±0.01
RP	14.6 ±0.2	11.6 ±1.0	24.23 ±1.2	1.57 ±0.1	72	0.05 ±0.01

[1]Pt: Total phosphorus Pph: Phytic phosphorus

[2]CS: cotton seed; CC: cotton cake; CBG: bran and corn oil extracted germ; RP: rice polishing

Phosphorus (%) AA of the diets with the different ingredients (Table 3) was greater (P<0.05) than the average values of the basal ration (18.2). Diets with different feed ingredients had values (%) of 41.8, 30.4, 36.3, 33.2 and 30.0, respectively for CBG, DCP, CC, CS and RP. Phosphorus digestibility of CBG and DCP was higher (P<0.05) than the remaining ingredients**.**

Diet based on CBG had a P (%) TA (61.9) similar to DCP (57.8) and both were higher (P<0.05) than CC (55.6), CS (51.1) and RP (48.5). A similar tendency was registered for NU values, being P digestibility (%) higher (P<0.05) for CBG (70.7) and DCP (60.0) than CC (56.3), being the lowest (P<0.05) CS (46.6) and RP (41.0).

Table 3. Phosphorus absorption from diets with different ingredients in sheep

Item	DCP[3]	CS[3]	CC[3]	CBG[3]	RP[3]	SE
P intake g/day	2.66	2.81	2.49	2.39	2.69	0.01
P fecal, g/day	1.61	1.87	1.59	1.39	1.89	0.3
P end., g/day[1]	0.49	0.50	0.48	0.48	0.50	0.03
AA, %[2]	39.4^{a}	33.3^{c}	36.3^{b}	41.8^{a}	30.0^{c}	9.7
TA, %[2]	57.8^{ab}	51.1^{c}	55.6^{bc}	61.9^{a}	48.5^{c}	9.7
NU, %[2]	60.0^{a}	46.4^{c}	56.3^{b}	70.7^{a}	41.0^{d}	6.1

Basal diet: P intake: 1.32g/day; P fecal g/day: 1.08; AA: 18.2%

[1]P endogenous: Y (mg P/kg BW) = 13.6 + P intake (g/day)/BW (kg)

[2]AA: apparent absorption; TA: True absorption; NU: net utilization.

[3]DCP: dicalcium phosphate; CS: cotton seed; CC: cotton cake; CBG: bran and corn oil extracted germ; RP: rice polishing

a,b,c different letters in the same row are different (P<0.05)

SE: standard error

AA values are lower than TA and NU, since endogenous P is not subtracted from total P excretion. TA and NU values were highly correlated (r= 0.99; P<0.05).

The higher absorption values of CBG phosphorus are probably due to the fact that phytate is located mainly in the germ (Pointillart, 1994). This location might promote greater phytate degradation by microbial phytases. French feed composition tables (Sauvant *et al*, 2002) report a value of 64% of absorbable P for this product**.**

In the case of RP, phytates are present in both external and germ structures, probably causing a low breakdown by phytase activity. Data of this experiment are lower than the value of 64% presented by Sauvant *et al* (2002).

Phosphorus absorption values for CC are lower than the data reported by other authors (Field *et al*., 1984) for seed oil by-products (cotton, 64%; soybean, 67.9;

rapeseed, 60.5; sesame, 62.2; linseed, 63.8; sun flower; 59.7), probably due to greater chemical changes induced by industrial heat treatment (Han, 1989; Konischi *et al*., 1999; Park *et al*., 1999) which has an effect on protein and phytates degradability. In addition, heat treatment promotes the formation of cross linking between aldehyde groups and free amino acids, limiting the effect of microbial phytases to free inorganic P from phytate. In addition, in CC, the phytate molecule forms small globoid crystals (Han, 1989), which limits the time of contact between the enzyme and the phytate compounds (Park *et al*., 1999).

The registered values (TA and NU) for RP are lower than the ones (73%) reported by Sauvant *et al*. (2002).

Implications

Phosphorus true absorption and net utilization of different feed ingredients had significantly correlated values, suggesting that both methods are reliable to measure P bioavailability. Average P absorption coefficients, except for CBG, were lower than DCP, suggesting some changes in grain processing by the Venezuelan feed industry.

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EFFECT OF LEVEL OF UREA AND SOYBEAN MEAL AT SOLID STATE FERMENTATION OF APPLE BYPRODUCTS

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ABSTRACT. In order to evaluate the effect of the level of urea (UR) and soybean meal (SM) at solid state fermentation (SSF) of apple byproducts for microbial protein production, an experiment was carried out. Four treatments containing ground apple waste, 1.5 or 2% UR, and 0 or 3.5% of SM were prepared. A design factorial arrangement of 2 x 2 was used. All samples were added with 0.2% of ammonium sulfate and 0.5% of a mineral and vitamins supplement. Each treatment had 6 replicates consisting of 1 kg of sample, which were placed into a stove at controlled temperature of 28º C during 196 h. Replicates were mixed each 6 h taking samples each 12 h. The variables evaluated were pH, crude protein (CP), true protein (TP), and optic density of yeasts (OD). The results showed an increase in pH starting at 48 h of fermentation, and an effect of the addition of SM ($P<0.01$) was observed with values of 4.9 and 5.7 for the levels of 0 and 3.5% of SM in the mixture, respectively. The values detected for the effect of UR ($P>0.05$) were 5.5 and 5.1 for the levels of 1.5 and 2% of UR in the mixture, respectively. Crude Protein at the end of the fermentation showed difference ($P<0.01$) due to the addition of SM with values of 76.18 and 55.57% of CP for 0 and 3.5% of SM in the mixture, respectively. In addition, CP showed an effect ($P<0.01$) of the increment of UR to the mixture with values of 61.90 and 69.85% of CP for the levels 1.5 and 2% of UR in the mixture, respectively. There was an interaction of UR and SM on TP, indicating that there was an improvement in the production of TP by the addition of 3.5% SM to the mixture, only when the level of UR was 1.5%; although, with the levels of 2% UR and 3.5% SB on the mixture an OD at 196 h of fermentation time, a count of $450x10^6$ Ufc/ml of sample at the chamber of Newvauer, was observed. In conclusion, addition of UR at a 2% level in the SSF of apple waste, improves the production of CP and TP while the SM alone improves the TP, when the UR does not exceed from the 1.5% of the mixture.

Key words: Apple Byproducts, Microbial Protein, Solid State Fermentation

Introduction

The solid state fermentation (SSF) is a microbiologic process that occurs commonly in the surface of solids material that have the property of absorbing and containing water, with or without soluble nutrients. The yeasts are unicellular microorganisms of vegetative growth that, depending on the species, can utilize compounds as the pentose, metil-pentose, sugar alcohols, organic acid, polysaccharides and including compounds as i-inositol and almost all the species, with rare exceptions, utilize ions of ammonia for the synthesis of protein (Miller, 1977). In 2005, the northwest region of the Chihuahua State in Mexico produced around 409,778 ton of apple (SAGARPA, 2005). Near 120,000 ton were marketed as apple waste. Most of this apple waste is utilized in the juice industry; from where a byproduct known as waste pulp or pomasa is obtained. Pomasa production is approximately 25,000 ton per year, which is not taken advantage of, or in some cases, it is low used in the animal diets. During the process of substrates fermentation which are rich in sugars and cellulose, the microbial biomass is duplicated because it utilizes the contained energy together with the not protein nitrogen (NPN), added for the growth of the micro flora. Thus, an increment in the population of bacteria is produced and yeasts, still in the phase of dried without the utilization of inoculums in the system (Valiño et. al., 1992). The utilization of the apple waste has received very little attention, in spite of being considered like a cheap energy source, due to its great content of humidity (70-80%). These parameters could be taken advantage of by the native micro flora and nutritive value of byproducts could be increased by additions of NPN (Elías, 2004). Much of the apple waste that contributes the industrialization of this fruit represent a potential source of food for animals, with the advantage of being of under cost and the presence of nutrients highly fermentable by microorganisms as yeasts and bacteria. As result of this process, production of microbial protein of great utility in the animal nutrition could be obtained. The objective of this study was to evaluate the level of urea and soybean meal in the SSF of apple waste in aerobics condition with controlled temperature at 28 ºC. These results will allow to improvement diet value for beef and dairy cattle established in the northwest region of the Chihuahua State; offer options of utilization of the apple byproducts and to reduce the risk of contamination by these apple byproducts.

Material and Methods

Four treatments were utilized (T1 Apple waste with soybean meal 0% and urea 1.5%; T2 apple waste with 3.5% of soybean meal and urea 1.5%; T3 apple waste with 0% of soybean meal and urea 2%; T4 apple waste with soybean meal 3.5% and urea 2%). All the processing was added with 0.2% of ammonia sulfate and 0.5% of vitamins and minerals supplement to improve the growth of yeast. Each processing was comprised of 6 replicates in a plastic varnish with 1 kg of the mixture, which they were lodged for their fermentation in an incubator with controlled temperature of 28 ºC during 192 h. During the fermentation period of the apple waste, were taken 6 samples by processing in different times (0, 12, 15, 24, 36, 48, 60, 72, 84, 96,108, 120, 132, 144, 156, 168, 180 and 192 h). The pH was determined every sampling and was carried out a mixed in them to improve the oxygenation and the dried of the mixtures.
Each experiment consisted of apple waste of the variety *Golden delicious* that was molding in a mill of hammers without sieve, to subsequently prepare portions of 1 kg by varnishes, same that they were lodged in an incubator to constant temperature of 28 ºC during 192 h. Six samples of each processing of 10 g were taken of each one of them, they were placed in purses of plastic and they were kept in a temperature of -5 ºC, for their subsequent evaluation. The analyses that were carried out were: Humidity, Crude Protein (CP) and True Protein (TP) utilizing the techniques described in AOAC, (1984). For the optic density (OD) of yeasts, one gram of the dry sample was mixed in saline solution (0.1% of NaCl), agitating it during 10 minutes, subsequently, they were filtered in 4 gauzes and finally proceeded to the yeasts counting according to the number of dilutions required for its microscopic measure in the chamber of Neubauer^{MR} . The statistical design utilized was a completely randomized design with arrangement factorial of 2 x 2. The information was evaluated with the procedure General Linear Models of the Statistic Analysis System (2002).

Results and Discussion

The loss of humidity during the SSF was constant. Since the 0 h until the 150 h was observed that to the extent that the percentage was diminished of apple waste in the mixtures the loss of humidity went but slow. The results showed an increment in the pH beginning at 48 hours of the fermentation start. SM effect was observed (P<0.01), with values of 4.9 and 5.7 for 0 and 3.5% of SM in the mixture, respectively. There was no effect of UR (P>0.05), with values of 5.5 and 5.1 for the levels of 1.5 and 2% of UR in the mixture, respectively. In contrast (Elías and Lezcano, 1994), obtained values of pH similar when they utilized levels of urea lower to them evaluated in this work. They reported values of 4.18 and 5.8 for levels of 1 and 1.5% of UR with temperature of 37 ºC. The results of the present work suggest that the variations of pH seem to be related to the levels of UR and SM utilized. The greater values of pH obtained in this study, can be influenced by the presence of some species of yeasts and bacteria that develop to temperature of 28 ºC (Bergey 1984; Elías and Lezcano. 1993). The PC to the end of the SSF showed difference (P<0.01), by effect of the addition of SM with values of 76.18 and 55.57% of PC with levels of 0 and 3.5% of SM in the mixture, respectively (table 1). The decrease of PC from 76.18 to 55.57% upon adding the 3.5% of SM could be lead for a high population of bacteria that hydrolyzes UR in ammoniac such as *Staphylococcus epidermidis, Acinetobacter calcoacético* and *Proteus vulgaris*, they are bacteria that play a important role in the hydrolysis of the UR with the production of ammoniac. Ammoniac is an important metabolite for some of these species in the cellular synthesis, what produces an increase of total biomass in the product (Valiño et. al., 1994). The CP showed effect by the addition of UR to the mixture (P<0.01), with values of 61.90 and 69.85% of CP for the levels of 1.5 and 2% of UR in the mixture, respectively.

Table 1. Crude Protein of apple waste fermented to temperature of 28 ºC with two levels of urea and two of soybean meal at 196 h of fermentation time.

Soybean Meal Level	1.5% Urea	2% Urea	CP ± SE
0%	71.92	80.44	76.18±0.38 [c]
3.5%	51.89	59.25	55.57±0.38 [d]
CP ± SE	61.90± 0.38 [a]	69.85±0.38 [b]	

[a, b] Different Literal indicate difference (P<0.01) among column means.
[c, d] Different Literal indicate difference (P<0.01) among row means.

There was an interaction for TP among the factors UR and PS indicating that there is a positive response in the production of TP by the addition of 3.5% of SM to the mixture when the level of UR in the same one is of 1.5% (Figure 1). The best answer for growth of yeast was obtained with the levels of 2% of UR and 3.5% of SM, where was observed with aid of the chamber of Newvauer a OD at 196 h of fermentation a counting of 450x106 Ufc/ml of sample, with regard to the other processing, yeasts count were maintained around $300x10^6$ UFC/ml during the 100 to 150 h of fermentation time. This situation could be originated due to that this processing counted on the most maximum levels of both factors and a greater availability of nitrogen, in which the yeasts showed a better answer at the level of 2% of urea, 0.4% of ammonium sulfate and to 1% of the mineral supplement which the yeasts found its requirements for its growth (Elías and Lezcano, 1994).

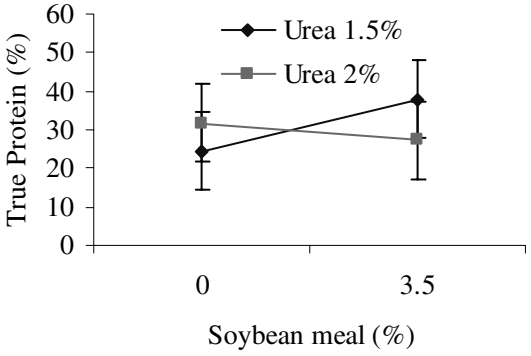

Figure 1. Effect of the addition of soybean meal to the mixture of apple waste fermented to controlled temperature of 28 ºC on true protein production at 240 h.

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EFFECT OF ORGANIC AND INORGANIC SELENIUM SUPPLEMENTATION ON WEIGHT PERFORMANCE OF EWES AND LAMBS

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ABSTRACT: Two selenium sources (organic and inorganic) were evaluated using 28 multiparous (M) and 18 uniparous (U) ewes, of 54.8 ± 9.4 and 39.7 ± 5.6 kg live weight, respectively. They were randomly assigned to two treatments: basal diet plus inorganic selenium (IS); and basal diet plus organic selenium, Sel-Plex 50® (OS). A split plot design in time was used because of the factorial nature of the treatment*maturity (2*2) of the main plot and time as sub-plot; Variables analyzed were : (1) post-partum weights of the ewes and, (2) the weight of the lambs from birth to weaning, with 14 days intervals. The variables were analyzed using PROC MIXED of SAS. Whereas results showed no differences (P>0.05) in the main effects: treatment, maturity and the weight of lambs in time (lactation days), the interaction treatment*time showed statistical difference (P<0.05). The maturity*time interaction was also significant (P<0.05). In conclusion, organic selenium could improve the weight of ewes after weaning; however lamb weight tended to be higher with inorganic selenium.

Key words: Selenium, Organic, Inorganic, Weight-Performance, Sheep.

Introduction

Selenium supplementation in animal nutrition has been a subject of research because it is an essential element in animal nutrition. Edens (2002) pointed out that there are two sources of selenium to offer in animal diets: inorganic (sodium selenite and selenate) and organic (Sel-Plex 50®); however the organic sources are potentially better sources of selenium for all animals because of their higher bioavailability, compared to inorganic sources (McDowell, 1997; Wolffram, 1999), since selenium's metabolic pathway in the animal body depends on its chemical structure (Cai *et al*., 1995).

At present there is abundant information on selenium for: serum levels, tissue and organ concentration, weight gains in dairy cattle and pigs; however, relevant information in small ruminants is lacking. The objective of the present research was to compare the effects of selenium sources (organic vs. inorganic) on weight gains of ewes and lambs fed a typical diet used in sheep production for lactating animals.

Materials and Methods

The research was carried out at Facultad de Zootecnia de la Universidad Autónoma de Chihuahua, located in Chihuahua, México. Forty-six pregnant Pelibuey x Blackbelly ewes were used; 18 were uniparous (U) and 28 were multiparous (M) with initial weights of 39.7 ± 5.6 and 54.6 ± 9.4 kg, respectively. Ewes were vaccinated against *Clostridium spp, Pasteurella haemolytica* A1 and *P. multocida* types A and D, using 2.5 ml per animal (TRIANGLE BAC 8V ®), and the animals were treated against internal parasites using 1% moxidectin (0.2 mg/kg of BW, CYDECTIN NR ®).

The treatments considered two variables 1) selenium source: inorganic selenium (IS) or organic selenium (OS; SEL-PLEX50®); and 2) maturity: multiparous (M) or uniparous (U) ewes. Based on these variables, ewes were randomly assigned to four groups: 1) uniparous inorganic selenium (UIS); 2) uniparous organic selenium (UOS), 3) multiparous inorganic selenium (MIS); and 4) multiparous organic selenium (MOS). All the animals received a basal diet, formulated according to their requirements (NRC, 1985) using ingredients available in the region (Table 1).

Selenium supplementation started in gestation at 6 and 12 weeks of pre-lambing for multiparous and uniparous, respectively, and continued until 22 d after the end of lactation. Ewes were weighed individually at lambing and every 14 d until 112 d postpartum. Lambs were individually weighed every 14 d until weaning (90 d). The weights were recorded in a digital balance (GALLAGHER 500 ®).

Results and Discussion

Ewes's weights from lambing (1d) to 22 d of post-weaning (112 d) were similar (P>0.05) for the main effects (treatment, maturity, and time). However, treatment*time interactions showed differences (P<0.05) among treatments (Figure 1); lambing weight was lower for organic selenium, but both sources had similar weights at 28 d, after which OS was more variable than IS, and at 112 d OS ewes showed higher weights.

The maturity*time interaction (Figure 2) was significant (P<0.05); at birth and 14 d the lower weights were for uniparous compared to multiparous ewes,

however at 28 d weights were similar; after that both groups increased in weight, which was maintained by M until 84 d, although U was more variable, they lost 3 kg by 70 d, ewes in both groups increased weight until 112 d, with lower weights in uniparous ewes.

The statistical model was:

$$Y_{ijk} = \mu + S_i + F_{ij} + (SF)_{ij} + A\ (SF)_{k\ (ij)} + T_l + (FT)_{jl} + (ST)_{il} + (SFT)_{ijl}$$

Where:
μ = Overall mean
S_i = Selenium effect
F_i = Maturity
SF_{ij} = Interaction effect of selenium with maturity
$A\ (SF)_{k(ij)}$ = Nested Effect of animal in each selenium level and maturity effect corresponding to main plot error
T_l = Time effect.
$(FT)_{jl}$ = Interaction effect of maturity and time
$(ST)_{il}$ = Interaction effect of selenium and time
$(SFT)_{ijl}$ = Interaction effect of selenium and maturity along time

The growth performance for both interactions, mainly in group U, has as a possible explanation that ewes in M have reached their adult body condition, although ewes in U are in that process. On other hand, through the lactation period there is a gradual diminution in body weight as a consequence of the large amounts of nutrients used for milk production, which are usually greater than those consumed in feed; after this physiological stage, the ewe restores its body reserves and gains weight (Pond *et al.,* 1995). As can be observed in both figures, at 28 d post-lambing there is a increase in weight gain, this in agreement with Godfrey *et al.* (1997) who reported that weight gain in ewes starts at 21 to 35 d of lactation. Awadeh *et al*. (1998) observed that selenium supplementation did not improve weight gain in ewes.

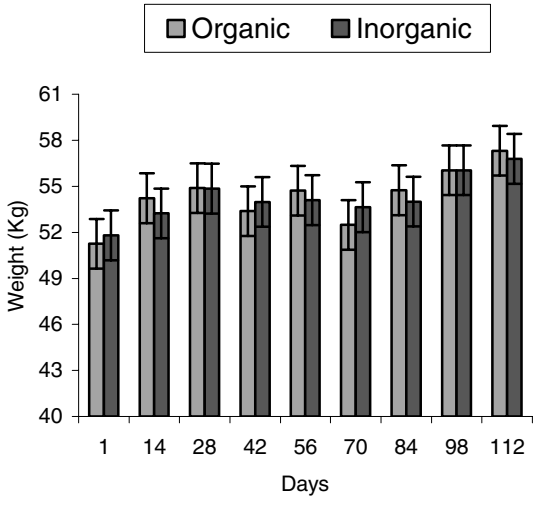

Figure 1. Weight performance of ewes from lambing (1 d) to 22 d post-weaning (112 d) for the treatment*time interaction.

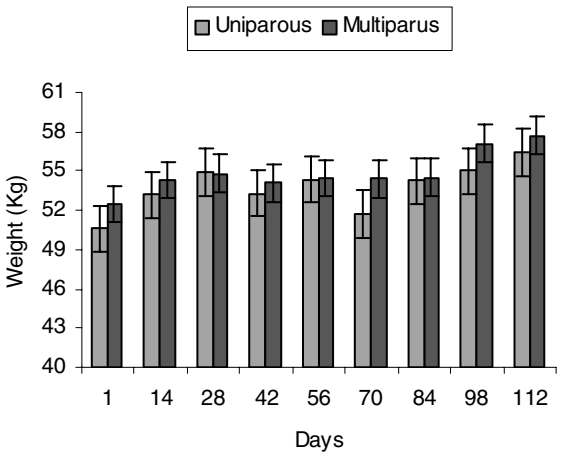

Figure 2. Weight performance of ewes from lambing (1 d) to 22 d post-weaning (112 d) for the maturity*time interaction.

The lamb weights were similar (P>0.05) for main effects (selenium source and maturity). The only difference (P<0.05) was for selenium source*litter size interaction, because the ewes suckled 1, 2, or 3 lambs; however data on parameters a, b, and k (growth model) there were not different (P>0.05) in weights of single and twin lambs (33.7 *vs.* 33.1 kg, respectively); however there were differences (P<0.05) between single and twin compared to triple lambs (33.4 vs. 27.3 kg, respectively).

Considering this effect, the selenium source*maturity*litter size interaction was analyzed (Table 2). The comparison of organic *vs.* inorganic selenium in uniparous ewes nursing 1 or 2 lambs showed is no difference (P>0.05) in weaning weight, or growth rate. However they are favourable in UIS, maybe because most lambs of this group were suckling single lambs, while ewes in UOS over 50% had 2 lambs (11 vs.14).

Weaning weights for lambs of mature ewes were 33.0 and 30.8 kg for MIS and MOS, respectively (P>0.05); their growth performance was similar to that observed in UIS and UOS, where weights favored MIS. Growth rate (k) was similar; this could have the same explanation with respect to the number on suckling lambs, since ewes in MOS were suckling 28 lambs versus 24 lambs in MIS; because of this, the milk per lamb is lower, which is indispensable in first weeks of life, because it is the main nutrient source for proper growth, development and health (Godfrey *et al.,* 1997). Parameters a and k were similar (P>0.05) among the four treatments for ewes nursing 1 or 2 lambs, although weaning weights favored UIS and MIS, maybe because of the litter size.

In the case of the 3 lambs per litter, the weights in MIS and MOS were 29.58 and 25.74 kg respectively (Table 2), without difference (P>0.05) between both groups, with numerical values higher for weights in MIS after showing the same growth rate (0.032) in both treatments. In MIS there was no difference (P>0.05)

between 3 vs. 1 and 2 lambs; however the parameters in MOS were different (P<0.05) respect to treatments UIS, MOS for 1 and 2 lambs, but was similar (P>0.05) to POS, maybe because of the milk productive capacity in each ewe and its ability to suckle 1, 2 or 3 lambs, and to the feed conversion of the lamb; in agreement with this, Godfrey *et al.* (1997) pointed that several factors could influence lamb growth, such as: milk production, environment, nutrition, parturition, and the number of suckling lambs.

In the evaluation of weight gains there are similar reports using selenium in 5-months-old grazing calves, with no significant effect (Lacetera *et al*.. 1996; Sweckert *et al.,* 1989; Ullrey *et al*.. 1977), however other report favorable effect (P<0.05) in weight gain in calves (Wichtel *et al.,* 1996) and 10-months-old sheep supplemented with selenium (Sang-Hwan *et al.,* 1976). In other study, Gunter *et al*. (2003) compared inorganic selenium (sodium selenite) vs. organic selenium (Sel-Plex) in 120 d pregnant cows fed alfalfa, and they did not find effects (P>0.05) on body weight, body condition, daily weight gains or dry matter consumption.

The results of the present research show that organic selenium does not improve weight gains of ewes at lambing or during lactation; however at 22 d post weaning the animals consuming organic selenium were heavier; this implicates that the organic form could propitiates faster recovery of the body condition after weaning. However, lamb weights tended to be lower in animals supplemented with organic selenium, which may be related to more lambs per ewe.

Acknowledgement

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Table 1. Ingredients and proximate analyses (%DM) of the diet used .

	STAGE			
	GESTATION		**LACTATION**	
INGREDIENTS	IS	OS	**IS**	**OS**
Corn, rolled	21.34	21.34	18.15	18.15
Oat bran	17.37	17.37	18.48	18.48
Alfalfa hay	57.20	57.20	57.44	57.44
Soybean meal	---	---	3.03	3.03
Molasses	3.63	3.63	2.46	2.46
Common salt	0.12	0.12	0.10	0.10
Mineral premix	0.34	0.34	0.34	0.34
Sel-Plex 50	---	0.20	---	0.20
Proximate analyses				
DM	92.20	92.10	91.50	91.80
Ash	7.50	7.50	7.50	7.50
CP	13.30	12.8	15.30	14.60
ADF	33.6	30.7	28.30	28.30
NDF	63.80	64.20	58.90	62.80

Table 2. Weights of lambs, adjusted values.

LITTER	**1 ó 2**		**1 ó 2**	**3**
TREATMENT	**K**			
PIS	35.48 ± 4.08[a]	---	0.036 ± 0.005[a]	---
POS	29.11 ± 4.34[a]	---	0.033 ± 0.006[a]	---
MIS	33.02 ± 2.66[a]	29.58 ± 8.03[ab]	0.033 ± 0.003[a]	0.032 ± 0.008[a]
MOS	30.81 ± 1.76[a]	25.74 ± 4.31[b]	0.035 ± 0.002[a]	0.032 ± 0.006[a]

UIS = Uniparous inorganic selenium
UOS = Uniparous organic selenium
MIS = Multiparus inorganic selenium
MOS = Multiparus organic selenium
a = Asymptotic weight at weaning
k = Growth rate
[ab] Means within the same row or column showing different superscript are significantly different (P<0.05).

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PROTEIN SUPPLEMENTATION OF LOW-QUALITY FORAGE: INFLUENCE OF FREQUENCY OF SUPPLEMENTATION ON RUMINANT PERFORMANCE AND NUTRIENT UTILIZATION

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ABSTRACT: Supplementation frequency (SF) of CP for ruminants consuming low-quality forage can be decreased to once every 7 d; however, no data are available describing the effects of decreasing SF to once every 10 d. Our objectives were to evaluate the influence of length of SF on forage intake, digestibility, N balance, digested N retained, and plasma concentration of urea-N in lambs and performance in pregnant ewes. Treatments included daily (D), once every 5 d (5D), or once every 10 d (10D) supplementation, and an unsupplemented control (CON). Sixteen wethers (31 ± 1 kg BW) were used in a digestibility study (n = 4/treatment). The amount of CP supplied by each supplement was approximately 0.15% of BW/d (averaged over a 10-d period) and formulated to meet CP requirements. Sixty pregnant Rambouillet ewes (75 ± 0.4 kg BW) in the last third of gestation were used in a performance study (n = 4/treatment). The amount of CP supplied by each supplement was approximately 0.11% of BW/d (averaged over a 10-d period) and formulated to meet CP requirements, but did not include CON. Basal diets consisted of low-quality (5% CP) barley straw. Total DMI and OM intake were not affected ($P \geq 0.93$) by supplementation. However, forage DMI, OM intake, and N intake by lambs decreased ($P \leq 0.06$) linearly as SF decreased. Apparent total tract digestibility of N for supplemented lambs was approximately 300% greater ($P < 0.001$) than the CON, with no difference ($P \geq 0.40$) among SF treatments. Digested N retained and N balance were greater ($P \leq 0.01$) for supplemented wethers than for CON, with no difference ($P \geq 0.27$) due to SF. Plasma urea (PU; m*M*) was measured over a 10-d period and supplemented lambs had increased ($P < 0.001$) PU compared with CON, but was not affected ($P \geq 0.28$) by SF. Crude protein SF had no affect ($P \geq 0.06$) on pre- and post-lambing BW and BCS change or lambing date and average lamb birth weight. Results suggest ruminants consuming low-quality forage can be supplemented with protein as infrequently as once every 10 days while not negatively affecting nutrient digestibility or livestock performance.

Key Words: Crude Protein, Lamb, Supplementation Frequency

Introduction

In the northern Great Plains, calculated winter feed costs are often $100 to 200 per animal unit per year. Management and nutritional practices that decrease winter feed costs, while maintaining rangeland health, may increase profitability for livestock producers. One management alternative that may decrease winter feed costs is to extend the grazing season through the winter months of December, January, and February. Protein supplementation may be necessary during this time period (Schauer et al., 2001), and the costs associated with providing supplemental protein can be substantial (labor, fuel, hours). Current research suggests that the frequency of protein supplementation may be able to be decreased to once every 7 days while maintaining livestock performance (Houston et al., 1999; Bohnert et al., 2002; Schauer et al., 2005). If supplementation frequency (**SF**) can be decreased from daily to once every 10 days, labor and fuel costs can be significantly decreased. Therefore, our objectives were to evaluate the influence of length of supplementation frequency on forage intake, digestibility, N balance, digested N retained, and plasma concentration of urea-N in lambs and performance in pregnant ewes.

Materials and Methods

Digestion Study

All experimental protocols were approved by the Institutional Animal Care and Use Committee at North Dakota State University. Sixteen wethers (31 ± 1 kg BW) were used in a completely randomized design to evaluate the efficacy of N use in lambs fed low-quality forage (5% CP) and supplemented with soybean meal (**SBM**) daily or infrequently. Treatments included daily (**D**), once every 5 d (**5D**), or once every 10 d (**10D**) supplementation, and an unsupplemented control (**CON**). Wethers were randomly allotted to treatments (n = 4) and housed in individual metabolism crates within an enclosed barn. All supplemented wethers received the same amount of supplement over a 10-d period; therefore, the 5D and 10D treatments received fivefold and tenfold the amount of supplement (N basis) on their respective supplementation day compared with D treatments. The amount of CP supplied by each supplement was 0.15% of initial BW/d (averaged over a 10-d period) based on intake and protein requirements (NRC, 1985). Wethers had continuous access to fresh water and chopped barley straw (4 to 8 cm length). Barley straw was provided (in two equal portions; 0700 and 1700) daily at 120% of the average intake for the previous 5 d, with feed refusals from the previous day determined before feeding. A trace mineral salt mix was available free choice and an intramuscular injection of vitamins A, D, and

E was administered to each wether at the onset of the trial. Ingredient and nutrient content of the barley straw and supplement are described in Table 1. The experimental period was 30 d. Forage intake was determined on d 19 to 28. Samples of barley straw, SBM, and orts were collected on d 19 to 28 and dried at 55°C for 48 h. On d 21 to 30, total fecal and urine output were collected. Urine was composited daily by wether (25% of total; weight basis) and stored at 4°C. Sufficient 6 *N* HCl (150 mL) was added to urinals daily to maintain urine pH < 3. A sub-sample of each daily fecal sample (7.5%; weight basis) was dried at 55°C for 96 h to calculate fecal DM. On d 21 to 30, 12 mL of blood was collected from the jugular vein at 4 h after feeding using a heparinized syringe. Blood samples were centrifuged (5000 × *g*, 15 min) and plasma harvested and stored (-20°C). Dried samples were ground through a Wiley mill (1-mm screen). Daily samples of barley straw and SBM were composited and daily ort samples composited by lamb on an equal weight basis (20% as-fed). Feed, orts, and fecal samples were analyzed for DM and OM (AOAC, 1990) and NDF and ADF (Ankom 200 Fiber Analyzer, Ankom Co., Fairport, NY). Feed, orts, fecal, and urine samples were analyzed for N using a Kjeltec Auto 1030 Analyzer (Tecator AB, Höganäs, Sweden). Plasma samples were assayed for urea-N using the Sigma Diagnostics Procedure 535 (Sigma Chemical Co., St. Louis, MO) and a UV/VIS spectrophotometer (Spectronic 710 Spectrophotometer, Bausch & Lomb, Inc., Rochester, NY). Data were analyzed as a completely randomized design using the GLM procedure of SAS (SAS Inst. Inc., Cary, NY) with animal serving as experimental unit. Plasma urea-N was analyzed using the REPEATED statement with the MIXED procedure of SAS. The model included wether and treatment. Contrast statements included: 1) CON vs. protein supplementation; 2) D vs. infrequent supplementation; 3) 5D vs. 10D; and 4) linear effect of supplementation frequency. Response variables included: 1) DM, OM, NDF, and N intake; 2) total tract digestibility of DM, OM, NDF, and N; 3) N balance; 4) digested N retained; and 5) plasma concentration of urea N.

Ewe Performance Study

Sixty pregnant Rambouillet ewes (75 ± 0.4 kg BW; 3.1 ± 0.1 body condition score) in the last third of gestation were stratified by age and body condition score (**BCS**) and assigned randomly within stratification to one of three treatments (as described in the digestion study, but not including CON) in a completely randomized design to evaluate ewe performance and lamb birth weight when consuming low quality forage (5% CP) and supplemented with SBM daily or infrequently. They were sorted by treatment and allotted randomly to 1 of 12 pens (n = 4). Protein supplements were offered as D, 5D, or 10D at 0800 to provide approximately 0.11% of BW/day of CP (averaged over a 10-d period; 145 g/d) until lambing based on intake and protein requirements (NRC, 1985). Ewes had continuous access to fresh water and chopped barley straw (4 to 8 cm length). A trace mineralized salt mix was available free choice. Ingredient and nutrient content of the barley straw and supplement are described in Table 1. Ewe BW and BCS were measured every 14 d until lambing and within 14 d following lambing for approximately 57 d. All weights were consecutive two-day unshrunk weights. Ewe BCS was evaluated independently by two observers. The same technicians measured BCS throughout the experiment. Forage and supplement samples (approximately 200 g) were collected weekly, dried at 55°C for 48 h, ground through a Wiley mill (1-mm screen), and composited by month for analysis of ADF and NDF, N, and OM as described in the digestion balance study. Ewe and lamb performance data were analyzed as a completely randomized design using the GLM procedure of SAS with pen serving as experimental unit. The model included treatment. Orthogonal contrast statements included: 1) D vs. infrequent supplementation; 2) 5D vs. 10D; and 3) linear effect of supplementation frequency. Response variables included: 1) ewe weight change; 2) ewe BCS change; and 3) lamb birth date and average lamb weight.

Results and Discussion

Digestion Study

Total DMI and OM intake were not affected ($P \geq 0.93$) by CP supplementation. However, intake of hay DM and OM was affected by CP supplementation ($P = 0.06$) with 5D and 10D SF linearly decreasing ($P \leq 0.06$) hay DM and OM intake (Table 2). Total DM and OM intake responded similarly, with total DM and OM intake exhibiting a linear decrease ($P = 0.06$) as SF decreased. Also, daily NDF and N intake decreased linearly ($P = 0.06$) as SF decreased; but all supplemented treatments had higher N intake than CON ($P < 0.001$; Table 2). Apparent total tract digestibility of N for supplemented lambs was approximately 300% greater ($P < 0.001$) than the CON, with no difference ($P \geq 0.40$) because of SF (Table 2). Daily fecal excretion of N was decreased ($P < 0.001$) and urinary excretion of N was increased ($P < 0.001$; Table 2) by CP supplementation. As SF decreased, fecal N excretion exhibited a linear decrease ($P < 0.001$); however, no difference was noted due to CP SF for urinary N excretion ($P \geq 0.70$). Daily N balance and digested N retained were greater ($P \leq 0.01$) with CP supplementation, with no difference observed for SF ($P \geq 0.27$). Treatment x time interactions ($P < 0.001$) were observed for plasma concentration of urea-N. However, after considering the nature of the interactions, we concluded that discussing treatment means while providing the treatment x time figure would aid in interpretation and discussion of the data (Figure 1). Lamb plasma urea-N was greater ($P < 0.001$) in CP-supplemented lambs than in CON (Table 2). No difference was observed due to CP SF ($P \geq 0.28$) for lamb plasma urea-N concentrations.

Ewe Performance Study

Pre-lambing (within 14 d pre-lambing) and post-lambing (within 14 d post-lambing) weight and BCS change were not affected by CP SF (Table 2). In fact, as SF decreased, pre-lambing weight change trended towards increasing linearly ($P = 0.06$). However, the rest of the weight and BCS change data indicate that SF had no affect on weight and BCS change ($P \geq 0.43$). Crude protein SF

had no affect ($P \geq 0.21$) on lambing date or average lamb birth weight (Table 2).

Implications

No negative affects on N balance, body weight and body condition score, lambing date, and birth weight were observed for once every 10-d supplementation of crude protein when compared to daily and once every 5-d supplementation. Livestock producers in the northern Great Plains may consider crude protein supplementation with soybean meal once every 10 d as a management alternative for reducing dormant season supplementation costs.

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Table 1. Dietary ingredient and nutrient composition of lamb and ewe diets (DM basis)

Item	Barley Straw	Soybean Meal
Supplement composition		
Soybean meal, %	---	100
Nutrient composition		
CP, %	4.99	52.6
OM, %	90.9	92.7
NDF, %	71.8	18.2
ADF, %	43.7	4.9

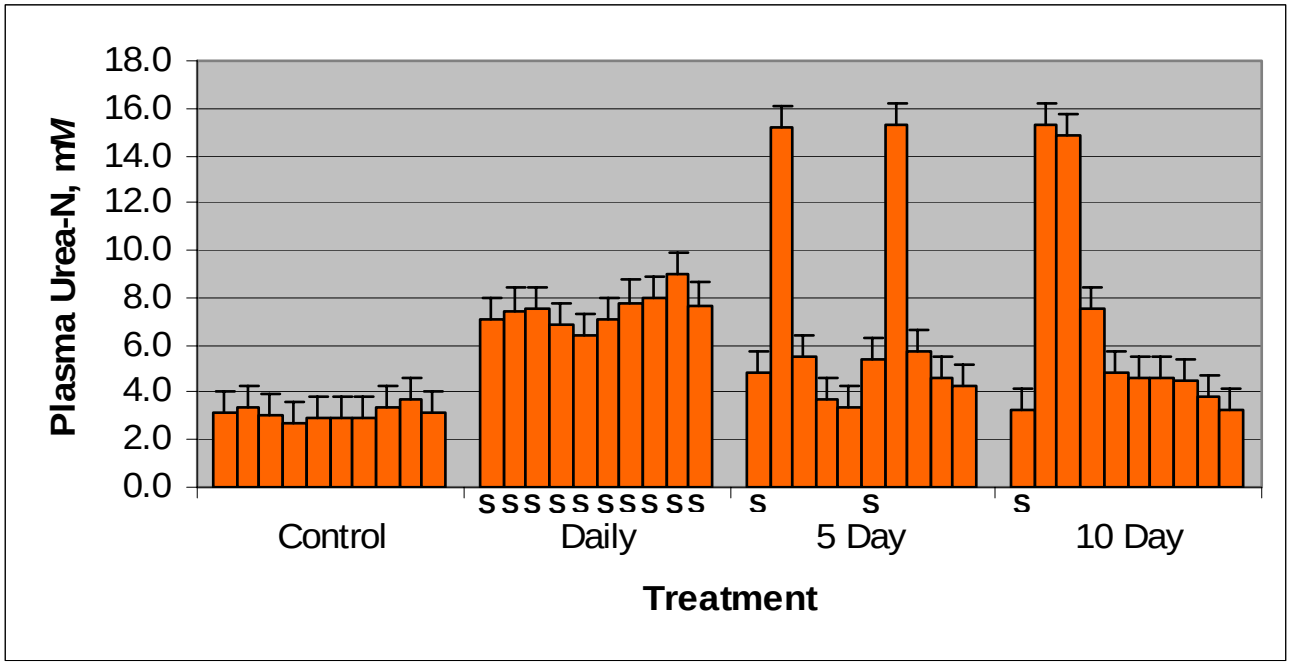

Figure 1. Effect of crude protein supplementation frequency on plasma urea-N (m*M*) of lambs. Columns from left to right for each treatment represent d 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 of a 10-d supplementation period, respectively. Treatments were as follows: Control; Daily = soybean meal every day; 5 Day = soybean meal every 5th day; 10 Day = soybean meal every 10th day. Each column with an S below represents a supplementation day. Treatment x time interaction ($P < 0.001$). SEM = 0.91.

Table 2. Effect of supplementation frequency on lamb intake, diet digestibility, and nitrogen balance and ewe performance and lamb birth weight

	Treatment[a]					*P*-value[c]			
Item	CON	D	5D	10D	SEM[b]	CON vs. supp.	D vs. 5D and 10D	5D vs. 10D	Linear SF
	Digestion Study								
Daily DM Intake, g/kg BW									
Hay	18.3	17.7	15.0	14.4	1.1	0.06	0.05	0.68	0.06
Supplement[d]	0.0	2.8	2.8	2.8					
Total	18.3	20.4	17.8	17.1	1.07	0.94	0.05	0.68	0.06
Daily OM Intake, g/kg BW									
Hay	16.7	16.1	13.7	13.1	1.0	0.06	0.05	0.68	0.05
Supplement[e]	0.0	2.5	2.5	2.5					
Total	16.7	18.7	16.2	15.6	1.0	0.93	0.05	0.68	0.06
Daily NDF Intake, g/kg BW	13.1	13.1	11.3	10.8	0.7	0.14	0.05	0.69	0.06
Daily N Intake, g/kg BW	0.147	0.373	0.344	0.335	0.012	<0.001	0.05	0.63	0.06
Total Tract Digestibility, %									
DM	43.8	50.7	51.6	52.1	0.01	0.001	0.46	0.75	0.43
OM	45.0	52.3	53.0	54.1	0.01	0.001	0.44	0.56	0.34
NDF	43.9	46.0	46.2	47.9	0.02	0.18	0.63	0.48	0.45
N	16.1	64.1	66.6	65.7	0.02	<0.001	0.40	0.74	0.57
Daily N Excretion, g/kg BW									
Fecal	0.123	0.134	0.115	0.116	0.009	<0.001	< 0.001	< 0.001	< 0.001
Urinary	0.096	0.247	0.256	0.248	0.014	<0.001	0.77	0.70	0.95
Daily N balance, g/kg BW	-0.072	-0.008	-0.027	-0.029	0.014	0.01	0.27	0.93	0.31
Daily Digested N retained, %[f]	-308.7	-3.4	-11.7	-13.8	9.0	<0.001	0.42	0.88	0.43
Plasam Urea-N, m*M*	3.12	7.49	6.80	6.69	0.55	<0.001	0.28	0.88	0.32
	Ewe Performance Study								
Weight change, kg									
Prelambing[g]	---	1.7	1.5	5.6	1.3	---	0.26	0.05	0.06
Postlambing[g]	---	-3.2	-1.7	-3.3	1.4	---	0.68	0.43	0.96
Body condition score change									
Prelambing[g]	---	-0.1	-0.1	-0.1	0.1	---	0.80	0.75	0.95
Postlambing[g]	---	-0.2	-0.3	-0.2	0.2	---	0.94	0.70	0.90
Lamb birth date, Gregorian d	---	265	267	264	2	---	0.75	0.36	0.85
Average lamb birth weight, kg	---	5	5	5	0.2	---	0.42	0.25	0.21

[a]CON = control; D = soybean meal every day; 5D = soybean meal every 5th day; 10D = soybean meal every 10th day.

[b]n = 4.

[c]CON vs. supp. = control vs. supplemented treatments; D vs. 5D and 10D = daily vs. once every 5 and 10 d treatments; 5D vs. 10D = 5 d vs. 10 d treatments; Linear SF = linear effect of supplementation frequency.

[d]Digestion study: D received 2.8 g/kg BW daily; 5D received 14 g/kg BW once every 5 d; 10D received 28 g/kg BW once every 10 d;
Ewe Performance Study: D received 1.95 g/kg BW daily; 5D received 9.75 g/kg BW once every 5 d; 10D received 19.5 g/kg BW once every 10 d.

[e]D received 2.5 g/kg BW daily; 5D received 12.5 g/kg BW every 5th d; 10D received 25 g/kg BW every 10th d.

[f]Calculated as (Daily N retention, g/kg BW/Daily N digested, g/kg BW) x 100.

[g]Within 14 d prior to or 14 d following lambing.

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LAMB MUSCLE SELENIUM CONCENTRATION PLATEAUS FOLLOWING 56 DAYS OF SELENIUM SUPPLEMENTATION

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ABSTRACT: Researchers have determined that dietary selenium (Se) affects the Se concentration of skeletal muscle in ruminants. Current research suggests that humans who consume 2 to 4 fold of the recommended dietary allowance (RDA = 55 μg Se/d) of Se may reduce their chance for developing lung, colorectal, and prostate cancer by 30, 50, and 70%, respectively. However, limited data are available describing the effects of length of supra-selenium supplementation to lambs on selenium status, feedlot performance, or carcass characteristics. Our objectives were to evaluate the influence of length of supra-selenium supplementation on muscle and plasma Se status, feedlot performance, and carcass characteristics of finishing lambs. One-hundred sixty wethers (35 ± 0.3 kg BW) were stratified by weight, randomly allotted to one of 20 pens, and assigned one of five treatments (n = 4): supra-selenium supplementation with selenoyeast for the final 84, 56, 28, 14, or 0 d (CON) of finishing. Diets were similar in ingredient composition (73% corn, 25% alfalfa, 2% supplement; DM basis), isonitrogenous and isocaloric, and offered once daily (0800) to provide ad libitum intake. Daily selenium intake for CON and supra-selenium supplemented wethers was 4 and 50 µg $Se \cdot kg^{-1}$ $BW \cdot d^{-1}$, respectively. On d 0 and 84, two-day weights were recorded and plasma samples collected for determination of circulating Se. On d 85, wethers were slaughtered; carcass data recorded; and foreshank samples collected for Se analysis. Treatment did not affect DMI, final BW, gain to feed, and ADG; fat depth, body wall thickness, longissimus muscle area, and hot carcass weight; or yield and quality grade ($P \geq 0.09$). Initial and final plasma Se concentrations were not different ($P \geq 0.06$). Muscle Se concentration increased quadratically ($P = 0.01$) as length of supra-Se supplementation increased, reaching a plateau between 56 and 84 d of supplementation. Results suggest that muscle Se concentration increases when lambs are supra-supplemented with Se without negatively affecting performance or carcass quality. However, muscle Se concentration may plateau following 56 d of Se supplementation.

Key Words: Lamb, Muscle, Selenium

Introduction

Recent research suggests that humans who consume in excess (2 to 4 fold) of the recommended dietary allowance (RDA = 55 μg Se/d) of selenium (**Se**) may reduce their chance for developing lung, colorectal, and prostate cancer by 30, 50, and 70%, respectively (Clark et al., 1996). Additionally, the American Dietetic Association encourages people to consume nutrients through food whenever possible, including meats and grains (ADA, 2005).

Results by Lawler et al. (2004) and Hintze et al. (2001) indicate that cattle fed feedstuffs high in Se may result in a moderate sized portion of high Se beef that would supply the Se necessary to achieve the cancer protection benefits described by Clark et al. (1996). Research by Schauer et al. (2005) indicates that feeding supranutritional levels of selenoyeast for 56 days to lambs prior to harvest can increase lamb muscle Se levels to concentrations suggested to prevent cancer in humans. However, a plateau in muscle Se concentration has not been reached following feeding supranutritional levels of Se in lambs. Research by Schauer et al. (2005) and Taylor (2005) report a linear increase in muscle Se concentration following 56 d of supranutritional Se supplementation, without reaching a plateau. Carcass quality and yield grade of beef steers and lambs has not been affected by supra-Se supplementation during the finishing time period (Lawler et al, 2004; Schauer et al., 2005).

Our team's goal is to develop feeding strategies for finishing lambs that increase the Se content of lamb skeletal muscle to levels that may provide cancer protection in humans. Therefore, our objectives were to evaluate the influence of length of supra-selenium supplementation on muscle and plasma Se status, feedlot performance, and carcass characteristics of finishing lambs as length of Se supra-supplementation extends beyond 56 d.

Materials and Methods

In year 2 of a two year study, a randomized complete design was used to evaluate the influence of duration of supra-Se supplementation in finishing rations on: a) lamb skeletal muscle Se concentration; b) finishing period body weight gain and feed efficiency; and c) carcass

characteristics. The North Dakota State University Institutional Animal Care and Use Committee reviewed and approved animal care and use protocols used during this study. One-hundred sixty Rambouillet wethers (35 ± 0.3 kg initial BW) were stratified by weight and assigned randomly to one of 20 pens (8 lamb/pen) for an 84 d finishing phase. Pens were then assigned to one of 5 treatments (n = 4); supra-selenium supplementation with selenoyeast for the final 84 d (**84 d**), 56 d (**56 d**), 28 d (**28 D**), 14 d (**14 d**), or 0 d (**CON**) of feeding prior to harvest. Wethers were wormed with Ivomec® on day 0. Diets were approximately 73% corn and 25% alfalfa provided daily at 0800 to ensure ad libitum intake (NRC, 1985; Table 1). Diets were isonitrogenous and isocaloric (Table 1). Feed offered was recorded daily and feed refusals collected and recorded when significant amounts of refused feed accumulated in the feeders. Selenium for supra-selenium supplementation treatments (14, 28, 56, and 84 d) was provided as selenoyeast to provide approximately 50 µg • kg^{-1} BW • d^{-1} Se (2.6 ppm ration concentration; Table 1). Initial and final BW were two-day un-shrunk weights, and single day interim weights were taken once every 28 d to aid in monitoring health and potential Se toxicity. Blood (jugular venipuncture into EDTA) was collected on day 0 and 84 to determine the change in circulating Se status. Blood samples were centrifuged, plasma collected, and frozen. Plasma samples were frozen at -30°C until analysis for Se. Wethers were harvested at Iowa Lamb Corp. in Hawarden, IA. Skeletal muscle samples (approximately 5 g of foreshank) were removed for the determination of Se concentration. Skeletal muscle samples were frozen at -30°C until analysis for Se. Skeletal muscle samples (0.3 - 0.5 g) and plasma samples were analyzed for Se by inductively coupled plasma-mass spectrometry after acid digestion (minimum detection limit = 10 ng/mL, inter assay CV = < 7%, intra assay CV = < 4%; Utah Veterinary Diagnostic Laboratory, Logan, UT). Additionally, carcass characteristics were evaluated following harvest. Hot carcass weight, backfat, bodywall thickness, and ribeye area (**REA**) were measured. Yield and quality grade were determined subjectively by a USDA grader. Gain to feed ratios, ADG, and % boneless closely trimmed retial cuts (**%BCTRC**; Savell and Smith, 1998) were calculated. Dry matter intake, BW, G:F, ADG, blood and skeletal muscle Se concentration, and carcass characteristic data were analyzed as a randomized complete design with the GLM procedure of SAS (SAS Inst. Inc., Cary, NY) using pen as the experimental unit. The model included treatment using the residual error term. Orthagonal contrast statements included: 1) Control vs. supra-Se supplementation; 2) linear effect of supra-Se supplementation; and 3) quadratic effect of supra-Se supplementation.

Results and Discussion

We observed no signs of potential Se toxicity. Length of supra-selenium supplementation did not affect performance measures of DMI, final weight, gain, ADG, and G:F ($P \geq 0.28$; Table 2), carcass characteristics (HCW, backfat thickness, and REA; $P \geq 0.09$; Table 2) or carcass quality ($P \geq 0.31$; Table 2). Initial and final plasma Se concentrations were similar for all lambs ($P \geq 0.06$; Table 3). Muscle Se concentration (wet and dry) increased quadratically ($P \leq 0.05$) as length of supra-Se supplementation increased (Table 3).

Lamb performance, carcass characteristics, and carcass quality of lambs in this study were not affected by length of supra-selenium supplementation. These results are similar to results in steers (Hintze et al., 2002; Lawler et al., 2004) and lambs (Schauer et al., 2005). Unlike the results reported by Schauer et al. (2005), we did not observe a decrease in DMI and HCW as length of supra-Se supplementation increased, suggesting the previous results for DMI and HWC may be misleading.

Muscle Se concentration in our trial increased as length of supra-selenium supplementation increased. These results are similar to results of other researchers for beef (Lawler et al., 2004) and sheep (Van Ryssen et al., 1989; Ehlig et al., 1967; Taylor, 2005). However, our trial indicates a plateau in muscle Se concentration may be reached, which has not been previously reported. Taylor (2005) reported that although gut tissue (kidney, lever, spleen, and duodenum) selenium concentration appeared to plateau after 56 d of supra-Se supplementation (2.9 ppm Se concentration of the diet), he did not observe a similar plateau in muscle Se concentration. Similarly, Schauer et al. (2005) observed a linear increase in muscle Se concentration following 56 d of supra-Se supplementation (1.89 ppm Se concentration of the diet), but did not observe a plateau in muscle Se concentration. These results suggest that supra-selenium supplementation for the purpose of enhancing muscle selenium concentration should be withheld until the final 56 days of lamb finishing, as muscle accumulation may slow down following 56 d.

North Americans acquire their daily Se requirement primarily from wheat grain and beef (Schubert et al., 1987; Holden et al., 1991; Hintze et al., 2001). A 0.11 kg (¼ lb) portion of lamb from lambs fed a supra-selenium supplemented diet in this trial would provide approximately 147, 146, 95, 64, and 42 µg Se/d (wet basis; 84, 56, 28, 14, and 0 d supra-selenium supplementation, respectively). While the 28 d supplemented treatment in this trial provided adequate selenium to meet the recommended dietary allowance for selenium in humans (RDA = 55 µg Se/d for females and 70 µg Se/d for males), the selenium concentration in lamb skeletal muscle tissue for the 84 and 56 d selenium supplemented treatment would provide approximately 200% of the RDA for selenium. This level falls within the range indicated by Clark et al. (1996; 2 to 4 fold the RDA) for humans to reduce their chance of developing lung, colorectal, and prostate cancer. Our results suggest that animals may prove to be an excellent "filter" for preventing Se toxicity in humans who are consuming diets with supranutritional levels of Se for the prevention of cancer. Because of the plateau in muscle Se concentration, humans may be prevented from consuming toxic levels of Se if red meat is the source of supra-Se in their diet.

Implications

Development of feeding protocols for achieving high selenium lamb will aid producers in developing a niche market for the sale of lamb as an organic selenium supplement, as well as adding value to locally grown forages through the finishing of lambs. Additionally, the beef industry may derive benefit from this research as a model of feeding beef cattle to achieve high selenium status for the purpose of niche marketing. Our results indicate the supplementing selenium during the finishing phase can result in a lamb product that is naturally high in selenium. Muscle selenium concentrations may plateau following 56 days of supra-selenium supplementation, indicating a need to concentrate the supra-supplementation of selenium into the final 56 days of finishing.

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Table 1. Dietary ingredient and nutrient composition of lamb finishing diets (DM basis)

Ingredient	Feedstuff Se concentration, ppm	Diets[a] CON	Diets[a] Selenium Diet
		%, DM basis	
Corn	0.12	73	73
Alfalfa	0.21	25	25
Trace Mineral[b]	---	0.44	0.44
Selenoyeast	614	---	0.24
CTC[c]	---	0.52	0.52
Limestone	---	0.87	0.87
Ammonium Chloride	---	0.44	0.44
Nutrient Composition of Diet			
CP, %		13	13
DE, Mcal/kg		0.75	0.75
ADF, %		10	10
Calcium, %		0.89	0.90
Phosphorus, %		0.27	0.30
Selenium, ppm		0.57	2.60
Selenium intake, $\mu g \cdot kg^{-1}$ BW$\cdot d^{-1}$		4.34	50.17

[a]CON = no supra-selenium supplementation with selenoyeast; Selenium diet = supplementation with selenoyeast for the final 14, 28, 56, or 84 d of finishing.
[b]Trace Mineral: 95.5% NaCl; 3,500 ppm Zn; 2,000 ppm Fe; 1,800 ppm Mn; 350 ppm Cu; 100 ppm I; and 60 ppm Co.
[c]CTC (4G) was formulated to provide 48 g/ton chlorotetracycline.

Table 2. The influence of supra-selenium supplementation on feedlot lamb performance and carcass characteristics

	Treatment[a]						*P*-value[c]		
Item	CON	14 d	28 d	56 d	84 d	SEM[b]	CON vs. Supp.	Linear	Quadratic
Dry Matter Intake, kg•hd^{-1}•d^{-1}	1.41	1.40	1.41	1.45	1.37	0.03	0.91	0.83	0.36
Final Weight, kg	55	55	55	57	55	0.5	0.39	0.52	0.29
Gain, kg	20	20	20	21	20	0.6	0.49	0.69	0.29
Average Daily Gain, kg/d	0.24	0.24	0.24	0.25	0.24	0.01	0.41	0.59	0.31
G:F	0.17	0.17	0.17	0.17	0.17	0.01	0.28	0.43	0.57
Hot Carcass Weight, kg	27	27	27	28	26	0.4	0.76	0.86	0.28
Backfat thickness, cm	0.46	0.53	0.46	0.48	0.46	0.05	0.82	0.74	0.78
Ribeye Area, cm^2	16.77	16.13	16.13	16.77	17.42	0.65	0.58	0.25	0.09
Quality Grade[d]	3.0	3.0	3.0	3.0	3.0	0.03	0.62	0.49	0.56
Yield Grade	2.4	2.3	2.2	2.4	2.4	0.11	0.53	0.76	0.31
% BCTRC[e]	45.8	45.6	45.7	45.8	45.8	0.18	0.65	0.82	0.56

[a]CON = no supra-selenium supplementation with selenoyeast; 14 d = supplementation with selenoyeast for the final 14 d of finishing; 28 d = supplementation with selenoyeast for the final 28 d of finishing; 56 d = supplementation with selenoyeast for the final 56 d of finishing; 84 d = supplementation with selenoyeast for the final 84 d of finishing.

[b]Standard Error of Mean; n = 4 .

[c]*P*-value for CON vs. supra-selenium supplemented treatments and linear and quadratic affect of supra-selenium supplementation.

[d]1 = utility; 2 = good; 3 = choice; 4 = prime.

[e]% boneless closely trimmed retail cuts (49.936-(0.0848*HCW)-(4.376*backfat thickness)-(3.53*bodywall thickness)+(2.456*ribeye area)).

Table 3. The influence of supra-selenium supplementation on feedlot lamb muscle and plasma selenium concentration

	Treatment[a]						*P*-value[c]		
Item	CON	14 d	28 d	56 d	84 d	SEM[b]	CON vs. Supp.	Linear	Quadratic
Initial plasma Se concentration, ppm	0.17	0.15	0.16	0.17	0.16	0.005	0.06	0.54	0.23
Final plasma Se concentration, ppm	0.26	0.28	0.26	0.25	0.26	0.025	0.92	0.53	0.89
Muscle Se concentration, ppm; DM	1.41	2.12	3.25	4.73	4.80	0.09	< 0.001	< 0.001	0.01
Muscle Se concentration, ppm; wet	0.37	0.56	0.84	1.29	1.30	0.03	< 0.001	< 0.001	0.05

[a]CON = no supra-selenium supplementation with selenoyeast; 14 d = supplementation with selenoyeast for the final 14 d of finishing; 28 d = supplementation with selenoyeast for the final 28 d of finishing; 56 d = supplementation with selenoyeast for the final 56 d of finishing; 84 d = supplementation with selenoyeast for the final 84 d of finishing.

[b]Standard Error of Mean; n = 4 .

[c]*P*-value for CON vs. supra-selenium supplemented treatments and linear and quadratic affect of supra-selenium supplementation.

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PROFITABLE CALF BACKGROUNDING INTEGRATING ANNUAL FORAGE CROPS[1]

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ABSTRACT: In the four-state region of MT, ND, SD, and WY, cereal forages have become an increasingly important crop for livestock producers. Some small grains cut for hay have rough awns which can affect palatability and cause mouth irritation in cattle. New cereal forage cultivar development has only focused on the absence of awns or biomass production and not animal feeding performance. Our study objectives were to: 1) obtain animal performance comparisons of experimental and traditionally grown cereal forages; 2) demonstrate animal performance for an experimental awnless winter wheat cultivar; and 3) evaluate steer cost of gain for the experimental and traditionally grown cereal forages. A 57 d backgrounding performance study was conducted using 80 purchased crossbred weaned steer calves (308 ± 4 kg BW). Calves were stratified by BW, randomly allotted to pens, and assigned to one of four cereal forage dietary treatments (n = 4): 1) barley harvested as hay (BH); 2) barley harvested as silage (BS); 3) oat harvested as hay (OH); and 4) awnless winter wheat cultivar harvested as hay (WH). Steers were fed once daily (0900) and given ad libitum access to their roughage source, 3.6 kg•head^{-1}•d^{-1} of rolled barley grain, and 0.45 kg•head^{-1}•d^{-1} of a 30% CP supplement containing Rumensin®. Diets were formulated to target an ADG of 1.19 kg. Two-day un-shrunk weights were recorded on d 0, 28, and 57. Diet, ort, and fecal samples were collected on d 0, 28, and 57. Diet samples were composited by pen and analyzed for DM, OM, CP, ADF, and NDF. Steers consuming BH and BS had similar ($P > 0.10$) final BW. Dry matter intakes were not affected by treatment ($P = 0.11$). Calves consuming BS had the highest ($P < 0.01$) total gain and ADG of all four treatments. Calves consuming BS had the highest G: F ($P = 0.02$). Steers consuming WH had the highest feed cost of gain ($P = 0.04$) and total cost of gain ($P = 0.03$) of all four dietary treatments. Barley harvested as silage demonstrated greater potential as a backgrounding feedstuff as compared to the barley, oats or awnless winter wheat harvested as hay.

Key Words: Annual Forage, Backgrounding, Calf,

Introduction

In the four-state region of MT, ND, SD, and WY, cereal forages have become an increasingly important crop to livestock producers. Few statistics are available, but cereal hays are harvested on over 202,000 ha in this region. One explanation for the popularity of cereal forages may be reoccurring drought conditions and their use as an emergency hay crop. Small grains are used in crop rotations to renovate alfalfa stands and are an effective way to reduce costs associated with weed and disease control. Cereal hays are a significant source of winter forage for livestock producers in this area. Cereal forages can be an inexpensive, readily available feed source since they are easier to grow when compared to alfalfa regarding seed drills, herbicides, and risk and require similar harvesting techniques as legumes (Helsel and Thomas, 1987). Winter cereals have advantages over spring cereals concerning production, water use efficiency and seasonal distribution of workload.

Previous research has shown differences in feeding value among cereal forage species and across maturity stages at harvest. Barley forage has often been determined to have higher quality when compared to oat, wheat, or triticale forages (Cherney and Martin, 1982; Cherney et al., 1983; McCartney and Vaage, 1994; Khorasani et al., 1997). Some cereal grain seed heads contain rough awns. Awns can affect palatability and cause mouth irritation in livestock. Bolsen and Berger (1976) found lambs consuming awned wheat silage had decreased DMI compared to lambs consuming awnless wheat silage. New cultivar development has focused on awn absence or biomass production and not animal feeding performance.

We designed and conducted steer backgrounding feeding trials to evaluate the following objectives: obtain animal performance comparisons of experimental and traditional cereal forages; demonstrate animal performance for an experimental awnless winter wheat cultivar; and evaluate steer cost of gain for experimental and traditional cereal forages.

Materials and Methods

A backgrounding performance study was conducted using 80 purchased crossbred weaned steer calves (initial BW 308 kg ± 4 kg). Calves were stratified by BW, randomly allotted to one of 16 pens (5 steers/pen), and assigned to one of four cereal forage dietary treatments (n = 4): 1) barley harvested as hay (**BH**); 2) barley

[1] *Acknowledgements: We would like to thank the South Dakota Agricultural Experiment Station and the Four-State Ruminant Consortium for funding this project.*

harvested as silage (**BS**); 3) oat harvested as hay (**OH**) and 4) awnless winter wheat cultivar harvested as hay (**WH**). The barley variety used for silage and hay was 'Robust'; the oat variety used for hay was 'Loyal'; and the winter wheat variety used for hay was 'Willow Creek'. This awnless winter wheat was an experimental variety developed by Montana State University in Bozeman, MT. Cereal forages utilized in the feeding trial were seeded at the recommended rates for the soil types and environments of southwest ND and Miles City, MT. Barley hay, BS, and OH harvest were conducted at the same stage of maturity (soft dough stage) during the months of June and July 2005. The WH cultivar was grown and harvested at flowering near Miles City, MT by a commercial farmer and delivered to the Hettinger Research Extension Center prior to the start of the trial.

Upon arrival, steer calves were weighed and rectal body temperatures taken to determine the incidence of respiratory illness (BRD complex). Steers having a rectal body temperature of 40° C or greater were given a s. c. injection of Excede™ (Ceftiofur Crystalline Free Acid, Pfizer Animal Health, Exton, PA) antibiotic in the middle one-third posterior aspect of the ear. At processing, calves were vaccinated twice with Pyramid® 5 vaccine (Bovine Rhinotracheitis-Virus Diarrhea-Parainfluenza-3-Respiratory Syncytial Virus; modified live virus; Fort Dodge Animal Health, Ft. Dodge, IA) and Ultrabac® 7 Clostridial vaccine (Pfizer Animal Health, Exton, PA); vaccinated once with One Shot® bacterin-toxid for *Mannheimia haemolytica* (Pfizer Animal Health, Exton, PA), and poured with Dectomax® Pour-On dewormer (doramectin; Pfizer Animal Health, Exton, PA) for internal and external parasites. Calves were implanted with a Ralgro® implant (Schering-Plough Animal Health Corporation, Kenilworth, NJ) at the beginning of the backgrounding study.

Steers were fed once daily (0900) based on individual pen bunk calls and given ad libitum access to their roughage source, 3.64 kg of rolled barley grain, 0.45 kg of a 30% CP supplement containing Rumensin®, and fresh water (Table 1). Diets were formulated to target an ADG of 1.19 kg. Deccox® medicated crumbles were fed during the study for coccidiosis prevention. All hays were chopped to a 5.1 cm length prior to feeding. Two-day un-shrunk weights were recorded on d 0, 28 and 57. A health protocol was established through a local veterinary clinic which included a monthly pen walk-through by the attending veterinarian. Diet, ort, and fecal samples were collected on d 0, 28, and 57. Diet samples were composited by pen and analyzed for DM, OM, N (AOAC, 2000), NDF, and ADF (Van Soest et al, 1991).

Backgrounding performance, feed intake, and nutritional data were analyzed as a randomized complete design using the GLM procedures of SAS (SAS Inst. Inc., Cary, NC) to test the main effect of dietary forage source using pen as the experimental unit. Planned pairwise comparisons (LSD) were used to separate forage least square means when the protected *F*-test was significant ($P < 0.10$).

Results and Discussion

Steers consuming BH and BS had similar final weights; however, steers consuming BS had higher final weights as compared to the steers fed OH and WH ($P < 0.10$; Table 2). Both gain and ADG were influenced by dietary treatments ($P = < 0.01$; Table 2). Calves consuming BS diet had the highest gain and ADG of all four treatments, with no difference between BH, OH and WH fed steers ($P > 0.10$). Dry matter intake was not affected by treatment ($P = 0.11$); however, BH steers had DMI that was numerically higher than the other three treatments (Table 2). Gain to feed ratios were the highest for BS steers ($P = 0.02$; Table 2) as compared to the OH, BH and WH steers. Steers consuming WH had the highest feed cost of gain ($P = 0.04$; Table 2) and total cost of gain ($P = 0.03$; Table 2) of all four dietary treatments. One explanation for the high feed and total costs for WH may be due to transportation costs from Miles City, MT to Hettinger, ND. Transportation costs added an additional $0.04/kg to the final cost of WH, which the other three dietary treatments did not incur since they were grown and harvested at the Hettinger Research Extension Center.

Diets were formulated to achieve a 1.19 kg ADG; however, the BS treatment had higher NE_g values (Table 1) during the feeding trial as compared to the other three dietary treatments which may have resulted in higher gain and ADG (Table 2). McCartney and Vaage (1994) found ADG and subsequent animal performance was highest for growing beef heifers consuming barley silage as compared to oat or triticale silage. Todd et al. (2003) had similar DMI values (10.06, 9.61, and 8.08 kg/d, respectively) for steers consuming four different irrigated BH varieties (MT 981060, Valier, Haybet, and Westford). Umoh et al. (1982) reported similar DMI values for steers fed Horsford and Stepford barley hay. During our study, all three dry hay diets had large amounts of fines present in their feed bunks during ort collections as compared to the BS steers (data not reported). It appears that the BS steers possibly did not sort their daily feed allotment as much and consumed a more consistent diet of their daily feed allotment as compared to the other three treatments, thus improving BS steers G:F and ADG, despite having lower DMI.

Implications

In this backgrounding study, barley harvested as silage demonstrated greater potential as a backgrounding feedstuff as compared to barley, oats, or awnless winter wheat harvested as hay. More research is needed to further define the effects these cereal grain varieties have on backgrounding steer performance. Utilizing cereal grains as forage crops in post-weaning cattle rations offers unique business opportunities to producers in this region, especially in periods of drought.

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Table 1. Dietary ingredient and nutrient compositions of diets fed to crossbred steer calves (DM basis)

	Diets			
Ingredient	Barley Silage	Barley Hay	Oat Hay	Wheat Hay
Barley Silage, %	63.30	---	---	---
Barley Hay, %	---	56.08	---	---
Oat Hay, %	---	---	54.27	---
Wheat Hay, %	---	---	---	58.75
Barley grain, %	31.48	37.67	39.22	35.38
30% CP supplement[a], %	4.02	4.82	5.01	4.52
Deccox medicated crumbles, %	1.2	1.43	1.49	1.35
Nutrient Concentration				
DM, %	58.2	84.5	83.8	87.7
CP, %	13.6	12.4	9.56	11.2
NE_m, Mcal/kg	1.72	1.36	1.17	1.58
NE_g, Mcal/kg	1.1	0.79	0.59	0.99
OM, %	89.8	78.1	71.6	85.2
NDF, %	30.6	39.1	62.4	46.2
ADF, %	18.0	24.7	46	26.2
Ca, %	1.24	1.02	0.93	0.71
P, %	0.4	0.3	0.28	0.3
Nitrate, ppm	900	400	500	300
Deccox, mg	170	170	170	170
Rumensin, mg	213	213	213	213

[a] 30% Commercial supplement (as fed): 29.0% CP, Ca 17.0%, P 0.45%, K 1.2%, Mg 0.7%,Vitamin A 110,000 IU/kg, Vitamin D_3 11,000 IU/kg, Vitamin E 330 IU/kg, Cu 550 ppm, Zn 930 ppm, and Mn 1000 ppm.

Table 2. The influence of forage source on backgrounding steer performance

	Treatments[a]					
Item	BH	BS	OH	WH	SEM[b]	*P* -value[c]
Final Wt, kg	384^{xy}	389^{y}	375^{x}	372^{x}	5.3	0.07
Gain, kg	72^{x}	83^{y}	68^{x}	65^{x}	3.19	< 0.01
ADG, kg/d	1.26^{x}	1.46^{y}	1.20^{x}	1.14^{x}	0.055	< 0.01
DMI, kg/d	10.05	8.82	8.82	9.0	0.382	0.11
G:F	0.13^{x}	0.17^{y}	0.14^{x}	0.13^{x}	0.008	0.02
Feed cost of gain, $/kg	0.75^{x}	0.77^{x}	0.70^{x}	0.90^{y}	0.042	0.04
Total cost of gain, $/kg	1.12^{x}	1.08^{x}	1.14^{x}	1.36^{y}	0.062	0.03

[a] BH = Barley Hay; BS = Barley Silage; OH = Oat Hay; WH = Awnless Winter Wheat Hay.
[b] n = 4.
[c] *P*-value for *F*-test of treatment.
[x,y] Within a row, means without a common superscript differ ($P < 0.10$).

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EFFECTS OF ENERGY LEVEL ON POST-RUMINAL VALINE UTILIZATION BY SHEEP

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ABSTRACT: Valine is a limiting amino acid (**AA**) for growing lambs when fed a diet containing little ruminally undegradable protein. Increasing Val utilization may improve growth performance. Therefore, our objective was to evaluate effects of energy level on post-ruminal utilization of Val by four ruminally-cannulated wether lambs (47 ± 4.8 kg initial BW). Lambs were limit-fed (0.79 kg DM/d) twice daily a diet (80% soybean hulls, 15% alfalfa hay, 3.5% molasses, 0.35% urea, and 1.5% minerals/vitamins) low in ruminally undegradable protein. An AA mixture, devoid of Val, was continuously infused (500 mL/d) into the abomasum of lambs to ensure that all essential AA, except Val, did not limit protein accretion. Treatments (2 × 2 factorial) were two levels of supplemental energy (0 vs. 0.49 Mcal/d ME) and two levels of Val (0 vs. 4 g/d infused into the abomasum). Energy was supplied by ruminal infusions of acetate (41 g/d) and propionate (14 g/d), and abomasal infusions of glucose (75 g/d). The experiment was a 4 × 4 Latin square, and each period consisted of 7 d; 3 d for adaptation to treatments, and 4 d for collection of feces and urine to calculate N retention. Blood samples were collected 3 h after feeding on d 7. There were no energy × Val interactions ($P > 0.08$) for dietary intake, digestibility, and N balance. Infusion of Val increased ($P < 0.05$) total N intake, and energy infusion decreased ($P < 0.05$) OM, NDF, and N digestibility. Urinary N excretion decreased ($P < 0.05$), and N retention increased ($P < 0.05$) in response to Val infusion. Energy infusion did not affect ($P = 0.47$) N retention because it decreased ($P = 0.06$) urinary N excretion, but also increased ($P < 0.05$) fecal N excretion. Plasma Val concentrations increased ($P < 0.05$) in response to Val supplementation. An increase in N retention due to Val supplementation confirms that Val is a limiting AA for growing lambs. A decrease in urinary N excretion due to energy supplementation even when Val was limiting suggests that energy supply affects efficiency of AA utilization.

Key Words: Valine, Energy, Sheep.

Introduction

When dietary CP consists predominantly of ruminally degradable protein, microbial protein is the major source of amino acids (**AA**) available for absorption by ruminants (Merchen and Titgemeyer, 1992). Storm and Ørskov (1984) reported that microbial protein of sheep maintained by intragastric nutrition was limiting in Met, Lys, His and Arg. Research by Nolte et al. (2004) and Waggoner et al. (2005) demonstrated that Met and Val were limiting when growing lambs were fed diets containing predominantly ruminally degradable protein.

The efficiency of AA utilization for growth may be affected by energy supply. Schroeder et al. (2004) demonstrated that energy supplementation (from VFA, glucose, and fat) increased N retention of growing Holstein steers even when Met was limiting. Also, Schroeder et al. (2005) evaluated the effects of energy source (VFA vs. glucose and fat) on Met utilization, and concluded that level of energy supplementation increased Met utilization efficiencies by Holstein steers regardless of energy source. Because Val is a limiting AA for sheep (Waggoner et al., 2005), energy supply may alter the efficiency of Val utilization of growing lambs.

The objective of this study was to evaluate effects of energy level on post-ruminal utilization of Val by growing lambs fed a soybean hull-based diet low in ruminally undegradable protein.

Materials and Methods

Experimental procedures were approved by New Mexico State University's Institutional Animal Care and Use Committee. Four ruminally cannulated wether lambs (47 ± 4.8 kg BW) in a 4 × 4 Latin square were housed individually in metabolism crates under continuous lighting. The lambs had free access to fresh water and were limit-fed (0.79 kg DM/d) a soybean hull-based diet (Table 1) in equal portions twice daily. The diet was formulated to contain little ruminally undegradable protein so that microbial protein was the predominant source of metabolizable AA. Also, to ensure that all essential AA, except Val, did not limit protein accretion, an AA mixture devoid of Val, was continuously infused (500 mL/d) into the abomasum of lambs. This AA mixture supplied (g/d): DL-Met (2.0), L-Lys (7.0), L-His (3.4), L-Thr (3.3), L-Arg (6.6), L-Phe (3.7), L-Trp (0.5), L-Leu (8.2), L-Ile (2.0), L-Glu (11.0), and Gly (6.0). Infusions into the abomasum were made by placing flexible tubing through the rumen cannula and reticulo-omasal orifice. Infusion lines were secured in the abomasum with a rubber flange (3 cm in diameter).

Treatments were a 2 × 2 factorial arrangement; factors were two levels of supplemental energy (0 vs. 0.49 Mcal ME/d), and two levels of supplemental Val (0 vs. 4 g/d). The additional energy was supplied by ruminal infusions of acetate (41 g/d) and propionate (14 g/d), and abomasal infusions of glucose (75 g/d). Supplemental Val was infused into the abomasum.

Table 1. Diet composition

Item	% of DM
Ingredient	
Soybean hulls	79.6
Alfalfa hay	15.0
Cane molasses	3.5
Mineral/Vitamin premix[a]	0.80
Sodium bicarbonate	0.50
Urea	0.35
Salt	0.20
Elemental sulfur	0.05
Nutrient	
OM	92.4
CP	13.9
RDP[b]	11.8

[a] Composition: Ca (14.0 to 16.8%), P (≥ 11.0%), NaCl (11.0 to 13.2%), Mg (≥ 0.50%), K (≥ 0.10%), Cu (5.0 to 7.0 ppm), Se (≥ 15 ppm), Zn (≥ 1980 ppm), Vit A (660 KIU/kg), Vit D (165 KIU/kg), Vit E (1.32 KIU/kg).

[b] Ruminally degraded protein, calculation based on table values (NRC, 1996).

Experimental periods were 7 d, which allowed 3 d for adaptation to treatments, and 4 d for collection of feces and urine. Total feces and a representative sample of urine (5%) were saved, composited by period for each lamb, and frozen for later analysis. Urine was collected into bottles containing 50 mL 6 *N* HCl to prevent NH_3 loss. Feed and fecal samples were dried at 55°C in a forced-air oven and ground to pass a 1-mm screen. Dietary and fecal samples were analyzed for DM (105°C for 24 h), OM (500°C for 8 h), and NDF (ANKOM 200, ANKOM Technology Corp., Fairport, NY). Also, dietary, fecal, and urinary samples were analyzed for N (LECO FP-528, LECO Corporation, St. Joseph, MI). Samples of blood were collected via jugular venipuncture into vacuum tubes (Fisher Scientific, Pittsburg, PA) with and without sodium heparin at 3 h after feeding on d 7. Blood samples for plasma were immediately chilled on ice, whereas blood samples for serum were allowed to coagulate at room temperature for 30 min. Samples were then centrifuged at 2,000 × *g* for 20 min. Plasma was analyzed for AA by gas chromatography (Chen et al., 2002), and serum was analyzed for urea N by microtiter plate spectrophotometry (Synergy HT, BIO-TEK Instruments, Winooski, VT).

Data were analyzed statistically using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). The statistical model included effects of period, energy, Val, and energy × Val, with lamb as a random effect. Data are presented as least squares means, and differences were considered significant when $P < 0.05$.

Results and Discussion

No energy × Val interactions ($P > 0.08$) were observed for dietary intake, digestibility, and N balance of lambs (Table 2). Abomasal infusions of Val did not affect ($P = 0.36$) dietary intakes of DM, NDF, and N, but increased ($P < 0.05$) total N intake (dietary plus infusions) due to the supply of additional N from Val infusions. Infusion of Val decreased ($P < 0.05$) urinary N excretion and increased ($P < 0.05$) N retention, confirming that this AA is limiting for growing lambs as noted previously by Waggoner et al. (2005).

Infusions of energy did not affect ($P = 0.36$) dietary intakes, but increased ($P < 0.05$) fecal excretion of OM, NDF, and N, thus decreasing ($P < 0.05$) total tract OM, NDF, and N digestibility. A similar response was observed by Schroeder et al. (2004) when VFA were infused into the rumen, and glucose and fat were infused into the abomasum of Holstein calves. Decreased total tract digestibility in response to energy infusion is likely due to the effects of VFA on ruminal pH, which in turn affects rumen microbial activity. Also, abomasal infusions of glucose may have altered gastrointestinal passage. Although energy infusion decreased N digestibility, retained N was not affected ($P = 0.47$) by energy supply. This is because energy infusion decreased ($P = 0.06$) urinary N excretion, thus counteracting observed increases in fecal N excretion. A decrease in urinary N excretion due to energy supplementation even when Val was limiting suggests that energy supply affected post-absorptive AA utilization.

Assuming N retention responses were linear, every gram of infused L-Val increased retained N by 0.43 and 0.64 g for lambs supplemented with 0 and 0.49 Mcal ME/d, respectively. If protein deposition is estimated as retained N × 6.25, and deposited protein contained 4.9% Val, then the efficiencies of post-ruminal Val utilization was 13% and 20% for lambs infused daily with 0 and 0.49 Mcal of additional ME, respectively. These efficiencies for Val utilization by growing lambs are lower than the 65% efficiency value for Val reported by Löest et al. (2001) for growing Holstein steers. The lower efficiencies of Val utilization in this study are in part because the 4 g/d of infused Val exceeded the animals' requirements (based on plasma Val concentrations, see below), and N retention responses were likely not linear, thus decreases the efficiency of utilization.

Serum urea N concentrations of lambs were not affected ($P = 0.29$ to 0.50) by infusions of energy or Val (Table 3). However, energy × Val interactions ($P < 0.05$) were observed for plasma Phe, Trp, and Tyr concentrations. Also, plasma concentrations of His, Ile, Lys, Ala, Asp, and Ser tended ($P = 0.05$ to 0.10) to exhibit an energy and Val interaction. The interactions were similar for most of the AA; plasma concentrations were not affected or were greater when Val was infused without energy, but plasma concentrations were lower when Val was infused with energy. Due to the consistency of this pattern, energy and Val interactions were also observed for total AA ($P < 0.05$), total nonessential AA ($P < 0.05$), and total essential AA ($P = 0.07$). Lower plasma AA concentrations in response to Val infusion when additional energy was supplemented suggests that Val was limiting under these conditions, and that AA uptake for protein synthesis increased when more Val was supplied. However, the lack of a decrease in plasma AA concentrations in response to Val addition when energy was not infused suggests that energy was limiting.

Infusion of Val increased ($P < 0.05$) plasma concentrations of Val, and decreased ($P < 0.05$) plasma Thr concentrations. An increase in plasma Val concentrations demonstrates that abomasal infusions of 4 g/d L-Val in addition to that supplied by the basal diet exceeded the animals' requirements for Val.

Implications

The results of this experiment demonstrated that valine is limiting for growing lambs when fed a diet containing protein that is predominantly degraded in the rumen. Energy supply decreased urinary nitrogen excretion even when valine was limiting, which suggests that energy supply affects the efficiency of amino acid utilization in growing lambs.

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Table 2. Effects of energy and Val infusions on intake, digestibility, and retention of nutrients by growing lambs.

	Treatments[a]							
	0 Mcal ME		0.49 Mcal ME			*P*-value[b]		
Item	0 g Val	4 g Val	0 g Val	4 g Val	SEM	*E*	*V*	*E* × *V*
Dietary Intake, g/d								
OM	727.6	721.2	727.6	727.6	3.20	0.36	0.36	0.36
NDF	455.1	450.9	455.1	455.1	2.10	0.36	0.36	0.36
N	17.6	17.4	17.6	17.6	0.07	0.36	0.36	0.36
Dietary Intake + Infused, g/d								
N	25.9	26.2	25.9	26.3	0.07	0.36	<0.01	0.36
Fecal, g/d								
OM	97.1	102.7	148.2	132.2	11.2	0.01	0.65	0.36
NDF	54.1	47.6	93.6	69.5	11.9	0.03	0.23	0.48
N	5.64	6.22	7.53	6.99	0.38	<0.01	0.94	0.10
Urinary, g/d								
N	13.3	11.4	11.4	9.9	0.78	0.06	0.05	0.80
Digestibility, %								
OM	86.7	85.7	79.6	81.8	1.56	0.01	0.69	0.35
NDF	88.1	89.4	79.4	84.7	2.63	0.03	0.24	0.47
N	78.2	76.2	70.9	73.5	1.46	<0.01	0.79	0.08
Retention								
N, g/d	6.91	8.63	6.92	9.49	0.58	0.47	<0.01	0.48
N, %	26.7	32.9	26.7	36.0	2.27	0.50	0.01	0.52

[a] Factorial (2 × 2) arrangement of energy (0 vs 0.49 Mcal ME/d) and Val (0 vs 4 g/d). Energy was supplied by infusions of acetate (41 g/d ruminal), propionate (14 g/d ruminal), and glucose (75 g/d abomasal). Val was infused abomasally.

[b] *E* × *V* = probability of an energy and Val interaction; *E* = probability of an energy effect; *V* = probability of a Val effect.

Table 3. Effects of energy and Val infusions on serum urea N and plasma AA concentrations of growing lambs.

	Treatments[a]							
	0 Mcal ME		0.49 Mcal ME			*P*-value[b]		
Item	0 g Val	4 g Val	0 g Val	4 g Val	SEM	*E*	*V*	*E* × *V*
Serum urea N, mg/dL	19.28	16.79	16.36	16.08	1.84	0.29	0.41	0.50
Plasma AA, μ*M*								
His	59.78	71.93	73.25	72.35	3.44	0.07	0.12	0.08
Ile	53.98	73.38	58.35	56.48	5.70	0.30	0.16	0.09
Leu	135.18	169.98	128.60	131.58	16.57	0.21	0.28	0.36
Lys	189.15	232.42	180.83	156.65	22.34	0.05	0.61	0.10
Met	28.13	32.25	33.88	34.03	3.50	0.31	0.56	0.58
Phe	40.23	44.35	56.30	46.50	3.42	0.01	0.33	0.04
Thr	252.75	228.02	286.07	207.80	21.82	0.67	0.01	0.12
Trp	28.15	31.38	35.75	30.05	2.31	0.02	0.27	<0.01
Val	61.38	261.18	80.03	197.28	28.19	0.39	<0.01	0.14
Ala	113.92	131.98	121.60	114.73	6.52	0.45	0.38	0.08
Asn	22.73	33.25	36.80	63.02	15.42	0.19	0.26	0.62
Asp	2.89	4.43	4.71	3.91	0.88	0.28	0.52	0.07
Cys	6.99	7.46	5.49	10.88	1.88	0.62	0.15	0.22
Gln	315.08	362.48	384.08	349.98	29.69	0.33	0.81	0.18
Glu	85.00	101.02	85.37	84.50	16.10	0.47	0.50	0.45
Gly	468.30	513.65	668.95	636.48	46.86	0.01	0.87	0.35
Orn	126.48	145.85	114.02	116.55	19.75	0.27	0.54	0.64
Pro	62.13	69.53	71.98	61.98	5.46	0.82	0.80	0.13
Ser	77.10	89.08	133.32	113.10	7.99	<0.01	0.62	0.08
Tyr	38.55	45.28	55.43	44.73	4.82	0.03	0.53	0.03
Essential	848.5	1145.0	933.3	932.5	72.7	0.40	0.07	0.07
Nonessential	1319.3	1504.0	1681.5	1599.8	51.5	<0.01	0.27	0.02
Total	2167.8	2648.8	2615.0	2532.5	83.0	0.08	0.04	0.01

[a] Factorial (2 × 2) arrangement of energy (0 vs 0.49 Mcal ME/d) and Val (0 vs 4 g/d). Energy was supplied by infusions of acetate (41 g/d ruminal), propionate (14 g/d ruminal), and glucose (75 g/d abomasal). Val was infused abomasally.

[b] *E* × *V* = probability of an energy and Val interaction; *E* = probability of an energy effect; *V* = probability of a Val effect.

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EFFECTS OF MATERNAL SELENIUM SUPPLY AND DIETARY RESTRICTION ON CELLULARITY ESTIMATES OF FETAL JEJUNUM, HEART, AND SKELETAL MUSCLE[1]

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ABSTRACT: Pregnant Targhee-cross ewe lambs (n = 36; 53.8 ± 1.3 kg BW) were randomly allotted to one of four treatments in a 2 x 2 factorial arrangement to examine the effects of nutrient restriction and dietary Se on cellularity in fetal tissues. Treatments were: nutrition (maintenance [M] vs. 60% maintenance [R]) and dietary Se (no added Se, 7.4 μg/kg BW [NSe] vs. Se-enriched yeast, 81.5 μg/kg BW [HSe]). Selenium treatments were initiated 21 d before breeding and nutritional treatments on d 64 of gestation. All diets were similar in CP (16.0%) and energy density (2.12 Mcal/kg). On d 135 ± 5 of gestation, ewes were slaughtered and fetal tissues harvested. Maternal nutritional restriction resulted in decreased: fetal small intestinal weights (P = 0.01), fetal jejunal protein content (mg; P = 0.01) and protein:DNA (P = 0.06), fetal heart and skeletal muscle protein concentrations (mg/g; $P \leq 0.07$) and protein:DNA (P = 0.01), and fetal heart protein content (P = 0.01). Nutrient restriction also resulted in greater (P = 0.02) fetal heart RNA concentration. High maternal dietary Se resulted in increases in: fetal jejunal RNA:DNA (P = 0.07), fetal heart weight (P = 0.09) and RNA content (P = 0.04), and fetal skeletal muscle RNA concentration (P = 0.01). A nutrient restriction by dietary Se interaction (P = 0.04) was observed for fetal skeletal muscle DNA concentration, where R-HSe had greater ($P \leq 0.10$) DNA concentration compared with all other treatments (1.55, 1.52, 1.46, and 2.38 ± 0.16 mg DNA /g for M-NSe, M-HSe, R-NSe, and R-HSe; respectively). Results indicate that cellularity of fetal tissues are altered by changes in maternal selenium supply and dietary restriction.

Key Words: Nutrient Restriction, Pregnancy, Selenium

Introduction

Selenium is an essential trace element for normal growth and development (Sunde, 1997; McDowell, 2003). Both Se deficiency and excess have resulted in economic liabilities for livestock producers (Underwood and Suttle, 2001; McDowell, 2003). Recent work indicates that dietary supranutritional levels of Se from yeast (2- to 4-fold above normal requirements) can reduce the combined incidence of lung, colorectal, and prostate cancers in humans by as much as 50% (Clark et al., 1996; Combs and Lü, 2001). Additionally, research using rodent cancer models has demonstrated that the positive response to dietary supranutritional (2 to 3 ppm) Se levels may depend on the molecular form of Se (Whanger et al., 2000; Finley and Davis, 2001). Unfortunately, the effects of supranutritional levels of Se on growth and cellularity of normal rapidly proliferating tissues have not been investigated in detail.

In finishing steers fed supranutritional (3 ppm) levels of high-Se wheat, percentage of jejunal cellular proliferation was unaffected by high Se; however, jejunal mass was increased (Soto-Navarro et al., 2004). Consequently, when cellular proliferation data were coupled with jejunal mass, total number of jejunal proliferating cells almost doubled in high-Se wheat steers when compared with control steers consuming 0.4 ppm Se. Nutrient restriction during pregnancy resulted in maternal jejunal and total small intestinal mass reductions of 17 and 20%, respectively (Scheaffer et al., 2004a). High dietary Se was reported to reduce placentome weight and number in pregnant ewe lambs (Ward et al., 2004). Limited data is present evaluating combined effects of nutrient restriction and high Se on growth and cellularity of fetal tissues. Therefore, the objective of this study was to investigate the influence of maternal nutrient restriction and supranutritional Se in the diet on hypertrophy and hyperplasia in the jejunum, heart, and skeletal muscle tissues in fetuses from ewe lambs.

Materials and Methods

The North Dakota State University Institutional Animal Care and Use Committee approved experimental protocols, care, and management of animals used in this study. Thirty-six pregnant Targhee-cross ewe lambs (53.8 ± 1.3 kg) were randomly assigned to individual pens (0.91 x 1.2 m) and allotted to one of four treatments in a 2 x 2 factorial arrangement. Dietary treatments were nutrition (maintenance [M] vs. 60% maintenance [R]) and dietary Se (no added Se, 7.4 μg/kg BW [NSe] vs. 81.5 μg/kg BW [HSe]). All diets, consisting of alfalfa hay and the respective supplements, were similar in CP (16.0%) and energy density (2.12 Mcal/kg). Diets (Table 1) were fed once daily, with free access to water and Se-free salt. Supplements provided to HSe ewes contained Se enriched yeast (Alltech Inc., Nicolasville, KY) to meet targeted Se intakes, while NSe ewes were fed supplements without added Se.

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Dietary Se supplementation was initiated 21 d prior to breeding, and continued to slaughter (d 135 of gestation). Dietary restriction treatment was initiated on d 64 of gestation. Maintenance ewes were fed to perform within NRC (1985) guidelines.

One h prior to slaughter, ewes were injected with 5-bromo-2-deoxy-uridine (BrdU; 5 mg/kg BW), which is a thymidine analog that is incorporated into cellular DNA during the S-phase of the cell cycle (Jablonka-Shariff et al., 1993). Ewes were stunned via captive bolt and exsanguinated. Immediately following exsanguination, reproductive tract was removed. Fetuses were necropsied and fetal small intestine and heart were weighed. Small intestine, heart, and skeletal muscle were sampled. Samples were snap frozen in isopentane and stored at -80˚C until analyzed for DNA, RNA, and protein concentrations (Reynolds et al., 1990; Reynolds and Redmer, 1992). Tissue homogenates were analyzed for concentrations of DNA and RNA by using the diphenylamine (Johnson et al., 1997) and orcinol procedures (Reynolds et al., 1990). Protein in tissue homogenates was determined with Coomassie brilliant blue G (Bradford, 1976), with bovine serum albumin (Fraction V; Sigma, St. Louis, MO) as the standard (Johnson et al., 1997). Concentration of DNA was used as an index of hyperplasia and RNA:DNA and protein:DNA ratios were used as an index of hypertrophy (Swanson et al., 2000; Scheaffer et al., 2003; Soto-Navarro et al., 2004). Tissue DNA, RNA, and protein contents were calculated by multiplying DNA, RNA, and protein concentration by fresh tissue weights (Swanson et al., 2000; Scheaffer et al., 2003; Scheaffer et al., 2004b).

Data were analyzed as a 2 x 2 factorial using PROC GLM procedures of SAS (SAS Inst. Inc., Cary, NC). Because ewe lambs carried both singles and twins, fetal number was used as a covariate. Model contained effects of nutrition (M vs. R), level of Se (NSe vs. HSe), and nutrition x Se interaction. When interactions were present ($P < 0.10$) means were separated by least significant difference.

Results

Maternal nutrient restriction resulted in decreased fetal small intestinal weight (Table 2; $P = 0.01$), jejunal protein content (mg; $P = 0.01$) and protein:DNA ($P = 0.06$). Fetal heart RNA concentration was greater (mg/g; $P = 0.02$) for fetuses from R ewes while protein concentration (mg/g), content (mg), and protein:DNA decreased ($P \leq 0.07$) with dietary restriction. Skeletal muscle RNA concentration was lower (mg/g; $P = 0.01$) for fetuses from M ewes; however, protein concentration (mg/g) and protein:DNA were lower ($P \leq 0.02$) in offspring from R ewes.

High maternal dietary Se resulted in increases in fetal jejunal RNA:DNA (Table 2; $P = 0.07$), heart weight ($P = 0.09$) and RNA content (mg; $P = 0.04$), and skeletal muscle RNA concentration (mg/g; $P = 0.01$). A nutrient restriction by dietary Se interaction ($P = 0.04$) was observed for fetal skeletal muscle DNA concentration (mg/g). Fetuses from restricted ewes fed HSe had greater (Figure 1; $P \leq 0.10$) DNA concentration compared with all other treatments.

Discussion

Fetal jejunal mass was reduced by nutrient restriction, which is partially explained by lower protein and protein:DNA ratios in restricted ewes indicating reduced protein synthetic capacity and possibly smaller cell size. When Se was supplemented to ewes, fetal jejunal mass tended to increase. In addition jejunal RNA:DNA increased and RNA tended to increase in fetuses from Se supplemented ewes indicating that intestinal cells were larger compared with fetuses from control ewes. Scheaffer et al. (2004b) found reduced jejunal protein in mature ewes fed diets with restricted energy intake. Additionally, when steers were supplemented with high Se wheat jejunal DNA concentration increased compared with steers consuming control diets (Soto-Navarro et al., 2004). It appears that Se and maternal restriction have similar effects on mature and fetal jejunal samples.

Maternal nutrient restriction resulted in greater RNA and lower protein and protein:DNA ratios in fetal heart tissue indicating that protein synthetic rate was likely reduced. Fetal heart mass was greater when selenium was supplemented; however, DNA and RNA:DNA in fetal heart were unaffected by Se treatment. Changes in fetal heart mass may be a result of small undetected differences in cell size.

In fetal muscle there was nutrition level x Se interaction in DNA concentration. Fetuses from ewes restricted to 60% of maintenance and supplemented with high Se had muscle DNA concentrations nearly 1.6 times greater compared with fetuses from other treatments. Increased DNA concentration indicates increased hyperplasia (Baserga, 1985). Fetal muscle RNA concentrations were greater in ewes fed supplemental Se vs. NSe. Greater RNA concentrations may indicate increases in protein synthetic capacity. Like fetal jejunum and heart, fetal muscle tissue had lower protein and protein:DNA in response to nutrient restriction.

In summary, fetal tissues are responsive to maternal nutritional changes during gestation. Nutrient restriction reduced fetal jejunum mass and resulted in lower protein:DNA ratios in jejunum, heart, and muscle tissue. Elevated dietary Se increased fetal muscle DNA concentrations in nutrient restricted but not maintenance ewes. Additional research investigating mechanism and production implications of observed changes in fetal jejunum, heart, and muscle seems warranted.

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Table 1. Chemical composition of alfalfa hay and supplements (DM basis) fed to ewes at requirement or restricted (60% of requirement ewes) intakes

		Supplement[1]	
Item	Alfalfa Hay[2]	Control	Selenium
DM, %	87.4	85.6	86.1
Ash, %	9.9	1.95	2.3
CP, %	16.1	10.0	12.7
ADF, %	27.3	5.5	5.0
NDF, %	37.2	26.2	26.5

[1]Supplement was fed to provide 7.4 μg/kg BW or 81.5 μg/kg BW for control and high-Se fed ewes, respectively.
[2]Hay was chopped, averaging 3.8 cm in length.

Table 2. Main effect means of organ weight and cellularity estimates of fetal tissues as influenced by level of nutrition and dietary Se in pregnant ewe lambs

	Nutrition[1]		Selenium[2]			*P*-Value[3]		
Item	M	R	NSe	HSe	SEM	Nut	Se	Se x Nut
Fetal jejunum								
Weight, g	62.44	53.66	55.64	60.46	2.30	0.01	0.13	0.59
DNA, mg/g	3.98	3.69	4.10	3.84	0.25	0.95	0.47	0.50
DNA, mg	240.28	201.63	222.95	218.96	18.49	0.13	0.87	0.42
RNA, mg/g	3.65	4.14	3.75	4.03	0.24	0.14	0.40	0.94
RNA, mg	228.90	212.64	202.34	239.20	16.87	0.48	0.11	0.93
RNA:DNA	0.99	1.06	0.94	1.10	0.06	0.38	0.07	0.38
Protein, mg/g	29.58	22.65	28.46	23.78	3.22	0.13	0.32	0.73
Protein, mg	1974.99	1218.19	1680.85	1512.33	222.46	0.01	0.57	0.99
Protein:DNA	7.65	5.68	6.75	6.58	0.77	0.06	0.87	0.86
Fetal Heart								
Weight, g	29.38	26.85	26.44	29.80	1.42	0.20	0.09	0.93
DNA, mg/g	1.98	2.35	2.03	2.30	0.19	0.15	0.29	0.38
DNA, mg	59.21	58.15	53.24	64.12	5.67	0.89	0.17	0.24
RNA, mg/g	2.01	2.61	2.11	2.51	0.19	0.02	0.13	0.32
RNA, mg	59.51	63.78	54.07	69.22	5.35	0.56	0.04	0.13
RNA:DNA	1.21	1.22	1.24	1.19	0.12	0.94	0.80	0.81
Protein, mg/g	40.90	33.16	37.25	36.81	3.01	0.07	0.92	0.84
Protein, mg	1275.48	850.16	1010.58	1115.06	104.70	0.01	0.48	0.12
Protein:DNA	21.71	15.96	19.43	17.73	1.47	0.01	0.29	0.49
Fetal Muscle								
DNA, mg/g	1.54	1.92	1.50	1.95	0.16	0.09	0.05	0.04
RNA, mg/g	2.45	3.39	2.48	3.37	0.25	0.01	0.01	0.46
RNA:DNA	2.07	2.23	2.24	2.06	0.28	0.69	0.65	0.26
Protein, mg/g	38.93	27.61	29.92	36.62	3.36	0.02	0.16	0.54
Protein:DNA	32.09	18.33	25.58	24.85	3.70	0.01	0.89	0.23

[1]M = non-restricted ewes fed at requirements, R = ewes fed to 60% of M.
[2]7.4 µg/kg BW (NSe; no added Se) vs. 81.5 µg/kg BW (HSe).
[3]Probability values for effects of nutrition (Nut), selenium (Se) and the interaction.

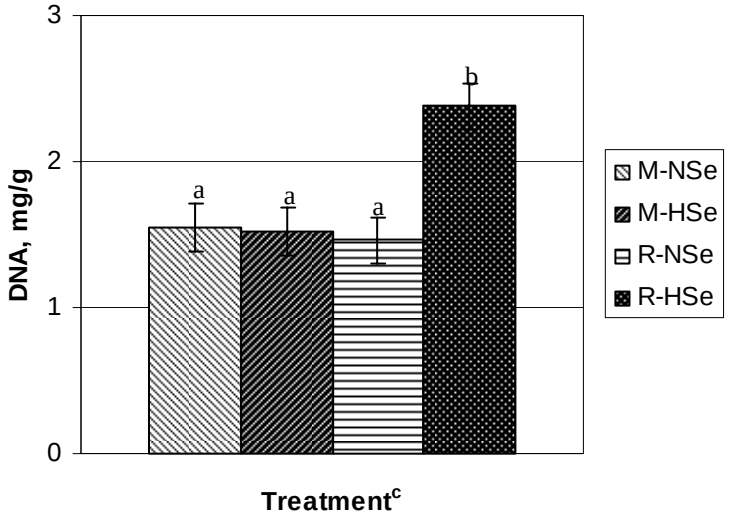

Figure 1. Interactive means for fetal muscle DNA as influenced by level of nutrition and dietary Se in pregnant ewe lambs ($P < 0.10$).
[c]M-NSe = non-restricted ewes fed adequate Se (7.4 µg/kg BW); M-HSe = non-restricted ewes fed high Se (81.5 µg/kg BW); R-NSe = restricted ewes to 60% of M and adequate Se; R-HSe = restricted ewes fed to 60% of M and high Se.

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INFLUENCE OF SLICE BAILING ALFALFA HAY ON HAY QUALITY AND DIGESTIVE FUNCTION OF STEERS CONSUMING A FEEDLOT FINISHING DIET

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ABSTRACT: A modification of the traditional alfalfa hay baling system has been developed. The new system is refered to as slice baling and consists of slice chopping the hay after suncuring and before baling. This method chops the length of alfalfa stems to 7.6 cm. Slicing is proposed to cause less damaged to the leaves compared to grinding after baling. Leaves should be more consistent. Also, less leaf material is lost with the slice bailing. Anecdotal information suggests that slice baling alfalfa results in a higher quality (higher proportion of leaves), improves rumen function in feedlot cattle because of less fines from leaves, results in better uniformity of the stem length, and saves cost associated with grinding. One hundred and seventy six crossbred steers (393.9 ± 10.81 kg initial BW) were used in an 84-d feeding experiment (4 pens/treatment) in a randomized block experimental design with a 2 x 2 factorial arrangement of treatments to evaluate effects of slice alfalfa (ground or slice) and forage level (8 or 14%) on growth performance. Experimental diets were based on steam-flaked corn. Daily weight gain was not affected ($P > 0.05$) by baling method the forage level. A baling method × forage level interaction ($P = 0.03$) was observed for DMI from d 28 to 56. Baling method did not affect ($P = 0.19$) DMI with 8% roughage, however, DMI was greater ($P = 0.05$) for ground alfalfa with 14% roughage. For the 84-d feeding period a baling method × forage level interaction tendency ($P = 0.07$) was observed. Baling method did not influence DMI with 8% roughage level. But with 14% roughage, DMI was greater ($P = 0.02$) for ground alfalfa. Gain to feed ratio for the first 56 d was affected ($P = 0.03$) by forage level (0.210 and 0.197 ± 0.004 for 8 and 14% forage, respectively) and by baling method ($P = 0.05$; 0.210, and 0.198 ± 0.005 for ground and slice alfalfa, respectively). However, over that 84-d feeding period, G:F was only affected ($P = 0.03$) by forage level (0.194, and 0.182 ± 0.003 for 8 and 14% roughage, respectively), but not ($P = 0.20$) by processing method (0.191, and 0.185 ± 0.003 for ground and slice alfalfa, respectively. We conclude that slice baling alfalfa does not improve feeding value of alfalfa used in feedlot finishing diets.

Keywords: Forage, Particle Size, Beef Cattle

Introduction

A modification of the traditional alfalfa hay baling system is available. The system is refered to as slice baling and consists of slice chopping the hay after suncuring and before baling. This system chops the length of alfalfa stems to 7.6 cm. Slicing is proposed to cause less damaged to the leaves compared to grinding after baling. Leaves should be more consistent. Also, less leaf material is lost with the slice baling. Anecdotal information suggests that slice baling alfalfa results in a higher quality (higher proportion of leaves), improves rumen function in feedlot cattle because of less formation of fines from leaves, results in better uniformity of the stem length, and saves cost associated with grinding.

Roughages are included in feedlot finishing diets to reduce digestive and metabolic problems (Galyean and Defoor, 2003). Most finishing diets generally contain 4.5 to 13.5% (DM basis) roughage with alfalfa hay and corn silage being the most common source (Galyean and Gleghorn, 2001). Forage is added to high-concentrate diets to stimulate chewing which is associated with increased saliva output (Balch, 1958), which plays a role in buffering acids produced during rumination. Both roughage concentration and physical form contribute to normal rumen function (Woodford et al., 1986). Dry matter intake increases with increasing roughage level but feed efficiency decreases because energy density of diets decreases with increasing roughage level (Bartle et al., 1994). With respect to physical form, forage particle size had no effect on finishing cattle performance (Shain et al., 1999). However, slice alfalfa has not been evaluated. Therefore, the objectives of this study were to evaluate the influence of baling method and roughage level on growth performance of cattle fed a steam-flaked corn-based finishing diet.

Materials and Methods

One hundred and seventy six crossbred steers (393.9 ± 10.81 kg initial BW) were used in an 84-d feeding experiment (4 pens/treatment) in a randomized block experimental design with a 2 x 2 factorial arrangement of treatments to evaluate effects of slice

alfalfa (ground or slice) and forage level (8 or 14%) on growth performance. Composition of experimental diets is shown in Table 1. Steers were blocked by BW and randomly assigned, within BW groupings, to 16 pens equipped with automatic waterers and fence-line feed bunks. Diets were prepared daily and were fed once daily, at approximately 110% of appetite. Individual steers were weighed (unshrunk) at initiation and completion of the study. In the calculation of the steer performance, BW was reduced 4% to adjust for digestive tract fill. Estimates of steer performance were based on pen means.

Data were analyzed as a randomized complete block design using the mixed procedures of SAS (SAS Inst. Inc., Cary, NC). The model included baling method, forage level, and baling method × forage level interaction. The random statement included block. When significant ($P < 0.05$) F-statistics were noted means were separated using the method of least significant difference.

Results and Discussion

The influence of alfalfa baling method and roughage level on performance of feedlot finishing steers is shown in Table 2. Daily weight gain was not affected ($P > 0.05$) by baling method or forage level. A baling method × forage level interaction ($P = 0.03$) was observed for DMI from d 28 to 56. Baling method did not affect ($P = 0.19$) DMI with 8% roughage, however, DMI was greater ($P = 0.05$) for ground alfalfa with 14% roughage. For the 84-d feeding period a baling method × forage level interaction tendency ($P = 0.07$) was observed. Baling method did not influence DMI with 8% roughage level. But with 14% roughage, DMI was greater ($P = 0.02$) for ground alfalfa. The greater DMI for the ground alfalfa agrees with the particle passage rate (4.77 and 3.76 ± 0.44%/h for ground and slice alfalfa hay, respectively; $P = 0.08$) observed in a companion digesta kinetics study (unpublished). Effects of baling methods were not observed probably because at such low level of roughage in the diet, the contribution of the different roughage source needs to be large to have a significant effect on the total diet. Galyean and Defoor, (2003) reported that feedlot cattle respond to roughage source and level by adjusting DMI to equal energy intake.

Gain to feed ratio for the first 56 d was affected ($P = 0.03$) by forage level (0.210 and 0.197 ± 0.004 for 8 and 14% forage, respectively) and by baling method ($P = 0.05$; 0.210, and 0.198 ± 0.005 for ground and slice alfalfa, respectively). However, over that 84-d feeding period, G:F was only affected ($P = 0.03$) by forage level (0.194, and 0.182 ± 0.003 for 8 and 14% roughage, respectively), but not ($P = 0.20$) by processing method (0.191, and 0.185 ± 0.003 for ground and slice alfalfa, respectively). The decrease in G:F with increasing roughage level from 8 to 14% agrees with previous data that indicate that increasing roughage level dilutes energy density and decreases feed efficiency (Bartle et al., 1994; Guthrie et al., 1996; Theurer et al., 1999). The lack of effect of baling method agrees with previous research where different particles size of roughage used in feedlot diets did not affect animal performance (Shain et al., 1999).

Implications

Slice baling alfalfa did not improve nutritional characteristics of alfalfa compared to traditional baling and grinding method. Because roughage level in feedlot finishing diets in only from 5 to 15% of total DM composition, nutritional improvements of roughage need to be large to impact performance of finishing cattle.

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Table 1. Ingredient composition of experimental diets fed to steers.

	Treatments[a]			
Item	Gr. 8%	Gr. 14%	Sl. 8%	Sl. 14%
Ingredients, % (DM basis)				
Ground alfalfa hay	8.00	14.00	0.00	0.00
Slice alfalfa hay	0.00	0.00	8.00	14.00
Flaked corn	75.88	75.88	69.22	69.22
Cottonseed meal	5.69	5.69	6.63	6.63
Urea	0.93	0.93	0.67	0.67
Tallow	3.00	3.00	3.00	3.00
Molasses	4.00	4.00	4.00	4.00
CLRC 2.5	2.50	2.50	2.50	2.50

[a]Treatments were a) Gr. 8% = ground alfalfa hay included at 8% (DM basis); b) Gr. 14% = ground alfalfa hay included at 14% (DM basis); c) Sl. 8% = slice bailed alfalfa hay included at 8% (DM basis); d) Sl. 14% = slice bailed alfalfa hay included at 14% (DM basis).

Table 2. Effects of bailing method and roughage level on performance of feedlot finishing steers consuming a concentrate diet

	Treatments[a]					P-values[b]		
Item	Gr. 8%	Gr. 14%	Sl. 8%	Sl 14%	SE	Bale	Level	B×L
BW, kg								
d 0	394.1	394.2	393.4	393.9	15.3	0.24	0.48	0.67
d 28	443.1	446.5	444.0	442.6	15.8	0.70	0.81	0.54
d 56	491.8	495.8	490.5	482.9	17.3	0.10	0.65	0.16
d 84	534.6	536.2	530.3	522.9	18.6	0.08	0.54	0.35
ADG, kg								
d 0 to 28	1.75	1.87	1.81	1.74	0.12	0.78	0.86	0.47
d 28 to 56	1.74	1.76	1.66	1.44	0.08	0.01	0.17	0.10
d 0 to 56	1.74	1.81	1.73	1.59	0.07	0.11	0.59	0.14
d 56 to 84	1.53	1.44	1.42	1.43	0.08	0.43	0.62	0.56
d 0 to 84	1.67	1.69	1.63	1.54	0.06	0.10	0.50	0.33
DMI, kg								
d 0 to 28	7.65	8.18	7.74	7.88	0.3	0.56	0.09	0.30
d 28 to 56	8.68	9.53	9.00	9.03	0.36	0.58	0.02	0.03
d 0 to 56	8.16	8.86	8.37	8.45	0.34	0.53	0.03	0.08
d 56 to 84	9.26	9.66	8.84	9.02	0.30	0.02	0.16	0.58
d 0 to 84	8.53	9.13	8.52	8.64	0.30	0.06	0.01	0.07
Gain:Feed								
d 0 to 28	0.23	0.23	0.23	0.22	0.014	0.95	0.62	0.61
d 28 to 56	0.20	0.18	0.18	0.16	0.006	0.01	0.01	0.57
d 0 to 56	0.21	0.21	0.21	0.19	0.006	0.05	0.03	0.37
d 56 to 84	0.18	0.15	0.16	0.16	0.008	0.52	0.12	0.14
d 0 to 84	0.20	0.19	0.19	0.18	0.005	0.20	0.03	0.81

Treatments were a) Gr. 8% = ground alfalfa hay included at 8% (DM basis); b) Gr. 14% = ground alfalfa hay included at 14% (DM basis); c) Sl. 8% = slice bailed alfalfa hay included at 8% (DM basis); d) Sl. 14% = slice bailed alfalfa hay included at 14% (DM basis). P-values for a) Bale = baling method; Level = roughage level; B×L = interaction of bailing level ×roughage level.

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EFFECTS OF UREA SUPPLEMENTATION LEVEL ON PERFORMANCE OF SUFFOLK LAMBS CONSUMING A HIGH CONCENTRATE DIET

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ABSTRACT: Optimal microbial synthesis requires OM and protein to be available for ruminal fermentation. Ruminal microbes have the ability to utilize NPN to synthesize protein. However, the ruminally degradable protein requirements of growing wethers consuming concentrate diets supplemented with NPN are not known. Sixteen Suffolk wethers lambs (40.8 ± 1.8 kg average initial BW, and 134 ± 22 d of age) were used in a 70-d feeding experiment to evaluate effects of dietary urea level (0, 0.69, 1.37, and 2.06%, DM basis) in 70 % ground corn concentrate diets on growth performance. Diets were formulated to be (DM basis) 9.5% CP (without inclusion of urea) 11.5% CP, 13.5% CP, and 15.5% CP with urea additions. The ratio of DIP: TDN was 0.073, 0.102, 0.131, and 0.16 for the 4 increasing levels of dietary CP, respectively. Average daily gain (125.9, 112.4, 119.2, and 67.1 ± 22.3 g/d for 9.5, 11.5, 13.5, and 15.5% CP diets, respectively) and G:F (92.5, 112.3, 96.7, 64.0 ± 47.54 g/kg for 9.5, 11.5, 13.5 and 15.5% CP diets, respectively) were not affected ($P > 0.05$) by urea level. However, DMI declined linearly ($P = 0.02$) with increasing level of urea supplementation (1,177, 1,117, 1,082, and 868 ± 77.4 g/d for 9.5, 11.5, 13.5 and 15.5% CP diets, respectively). Ruminal pH, ammonia concentration, and isobutyrate molar proportion increased ($P < 0.05$) linearly with urea supplementation. Increasing CP concentration using supplemental urea did not improve wether growth performance. Sheep may require true protein as a source of ruminally digestible protein.

Key words: Sheep, Ruminally Degraded N, Urea

Introduction

Metabolizable protein is the protein that reaches the small intestine for absorption and includes microbial protein synthesized in the rumen and feed protein that reaches the small intestine without being digested in rumen (NRC, 1996). Microbial protein synthesis is principally affected by ruminal concentration of N-containing compounds and the quantity of organic matter (OM) available for fermentation (Hespell, 1979), although other factors such as the rate at which digesta pass from the rumen also can have influence (Owens and Goetsch, 1986). Optimal microbial synthesis occurs when the appropriate synchrony between rumen digestible protein and rumen fermentable OM exist. Diets deficient in ruminally degraded intake N or protein (DIP) can limit microbial growth (Satter and Slyter, 1974), and excess DIP is also undesirable because of high excretion of N into the environment (Poos et al., 1979).

Although NRC (1996) recommendation for DIP requirement of beef cattle is 13% of TDN, Zinn and Shen (1998) found that the DIP requirements of feedlot cattle are not more than 10% of TDN. Because urea recycling seems to be different for sheep than for other ruminant species (Domingue et al., 1991), the beef cattle requirements for DIP may not be appropriate for sheep. Therefore, the objectives of this experiment were to determine the effects of level of CP and ratio of DIP to TDN on performance of weaned wether lambs consuming a high quality, high concentrate diet with urea as source of supplemental protein.

Materials and Methods

Sixteen Suffolk wethers lambs (40.8 ± 1.84 kg average initial BW, and 134 ± 22 d of age) were stratified by BW and randomly assigned to treatments within BW groups to 16 pens. Indoor pens were 3 × 1.5 m with inside temperature regulated, bucket waterers and 0.35 × 0.2 m feeder space. Treatments consisted of ground-corn based diets supplemented with 0, 0.69, 1.37, and 2.06% urea. Dietary CP levels were 9.5, 11.5, 13.5, and 15.5%, and the DIP:TDN ratios were 0.073, 0.102, 0.131, and 0.16 for the 0, 0.69, 1.37, and 2.06% urea supplementation level, respectively. All diets were composed of 30% sudangrass as the roughage source. The basal diet contained 62.2% ground corn with no supplemental urea yielding a CP content of 9.5%. The remaining diets had 60.6, 59.0, and 57.3% ground corn and were supplemented with 0.69, 1.37, or 2.06% urea, respectively, to yield respective CP (DM basis) levels of 11.5, 13.5, and 15.5%. Tallow was used to keep energy equal across diets (0.3, 1.3, 1.9, and 2.7 for 9.5, 11.5, 13.5, and 15.5% CP respectively). Other dietary ingredients were incorporated in similar amounts in all diets and included molasses (3%), ammonium chloride (1%), salt (1%), and a vitamin premix (1%; 2,200 IU/g vitamin A, 1,200 IU/g Vitamin D_3, and 2.2 IU/g vitamin E). The ratio of degradable intake protein to TDN was 0.073, 0.102, 0.131, and 0.16 for the diets containing 9.5, 11.5, 13.5, and 15.5% CP, respectively. Fresh feed was offered daily in amounts to stimulate ad libitum intake and orts were recorded daily. Orts were pooled weekly

and DM was determined. Lambs were weighed at 21-d intervals. The experiment last 70 d.

Ruminal fluid samples were collected on d 35 and 50 at 4 h after feeding using a stainless steel strainer passed through the mouth. Ruminal fluid samples were used to measure pH and analyze ruminal ammonia and VFA concentration.

Wethers were used as experimental units. Performance data were analyzed as a completely randomized design using GLM procedures of SAS (SAS Inst. Inc., Cary, NC). Treatment effects were tested for linear, quadratic, and cubic components by means of orthogonal polynomials (Hicks, 1973).

Ruminal fermentation data were analyzed split-plot analysis of variance using Mixed procedures of SAS. The model included CP level, day of collection, and the day by CP level interaction. The repeated effect was day of collection and animal within CP level was used to test treatment effects. Compound symmetry was the covariate structure that best fit the data. Linear, quadratic, and cubic treatment responses were evaluated.

Results and Discussion

Elemental S was added to diets to maintain N:S of 10.2:1 to prevent limitations of microbial growth as dietary urea increased. Maximal microbial growth has been demonstrated with maintaining N:S of 10:1(Hume and Bird, 1970). Effects of dietary urea level on growth performance of wether lambs are shown in Table 1. Average daily gain (125.9, 112.4, 119.2, and 67.1 ± 22.3 g/d for 9.5, 11.5, 13.5 and 15.5% CP diets, respectively) and G:F (92.5, 112.3, 96.7, 64.0 ± 47.5 g/kg for 9.5, 11.5, 13.5 and 15.5% CP diets, respectively) were not affected ($P > 0.05$) by urea level. However, DMI declined linearly ($P = 0.02$) with increasing level of urea supplementation (1,177, 1,117, 1,082, and 868 ± 77.4 g/d for 9.5, 11.5, 13.5 and 15.5% CP diets, respectively). These results disagree with the NRC (1996) DIP recommendations for beef cattle (13% of TDN as DIP), and with Zinn and Shen (1998). The reason why wether lambs did not respond to urea supplementation is uncertain. It is possible that at the age of these animals (134 ± 22 d) growth rate had already slowed and protein requirement had decreased. Alternatively, sheep may have a higher capacity to recycle N to the rumen and thus a lower requirements for DIP or they may simple require true protein as a source of DIP. Diets used in this experiment contained from 0 to 2.1% urea (DM base). Urea has been shown to cause toxicity with large amounts consumed in a short period of time (Helmer and Bartley, 1971), and to reduce intake when used at 1.7% of mixed diets (Van Horn et al., 1967). Therefore, DMI was expected to increase with the appropriate DIP level and to decrease with excess DIP. Production performances in this study might have been influenced also by supplemental fat. Tallow was added to compensate for the corn that was substituted by urea. Dietary fat level has also been shown to impact performance when used in concentrate diets (Hatch et al., 1972). Even though, fat supplementation increases feeding value of corn (Zinn 1992), decreased performance of beef cattle has been noted with levels of supplementation as low as 3% (Hatch et al., 1972). However, the greatest reductions in performance have been observed for fat levels > 5% of diet DM (Lofgreen , 1965; Hatch et al., 1972). Palatability problems as well as decreased fiber digestibility have been reported to be associated with feeding fats to ruminants (Johnson and McClure, 1973). Since the roughage level in the diets used in the present study were higher than roughage level in typical beef finishing diets, reductions in performance might occur with lower level of fat supplementation.

Ruminal ammonia concentration increased ($P < 0.05$) linearly with urea supplementation (3.7, 9.3, 14.1, and 16.9 ± 0.99 m*M* for 9.5, 11.5, 13.5, and 15.5% CP diets, respectively). These concentrations do not agree with previous result where dietary urea level in high-concentrate diets did not affect ruminal ammonia concentration in cattle (Thomas et al., 1984; Zinn 1995) or goats (Soto-Navarro et. al. 2003). On the other hand, these concentrations agree with those of Milton et al. (1997a, b) where finishing diets based on dry-rolled corn containing different levels of urea were evaluated using cannulated steers and they observed that ruminal ammonia concentration increased with increasing urea level in diets. Also, these concentrations agree with those of Brown et al. (2000) who found that dietary urea level increased ammonia concentration when incubated with corn as the substrate. The ruminal ammonia concentration for the 9.5% CP level (3.7 mM) is greater than 3.5 nM required for maximal microbial synthesis in vitro (Satter and Slyter, 1974). The accumulation of ruminal ammonia indicates that microbial requirements were exceeded. The linear decrease in DMI observed in this study with increasing urea supplementation level was probably due to the ruminal ammonia accumulation. The negative effects observed on ADG and G:F may be explained by the decreased DMI.

Ruminal pH increased ($P = 0.05$) linearly with increasing urea supplementation (6.27, 6.30, 6.49, and 6.58 ± 0.092 for 9.5, 11.5, 13.5, and 15.5% CP diets, respectively). These ruminal pH values agree with the ruminal ammonia concentration values. Since ammonia (weak base) acts as a buffer in the rumen (Visek, 1968). Ruminal VFA production decreases pH due to the acid load. Because urea supplementation level did not affect ($P = 0.61$) total VFA production, pH most likely was not affected by VFA production or absorption. The lack of effects of urea supplementation level on total VFA production indicates that DIP requirements were met with the lower protein level. An alternative explanation could be that sheep require true protein as source of DIP.

Implications

Urea supplementation did not improve growth or rumen fermentation characteristics of feedlot lambs consuming 70% concentrate diets. Lambs older than 150 d might not respond to ruminally degradable protein supplementation or might require true protein as source of ruminally degradable protein.

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Table 1. Effect of level of supplemental CP on feedlot performance of by lambs fed a 70% concentrate diet

	CP level (%)[a]					Contrast[b]		
Item	9	11	13	15	SME[c]	L	Q	C
Lambs, no (trt)	4	4	4	4				
Initial BW, kg	38.6	40.0	38.9	39.1	1.84	.98	.73	.66
Final BW, kg	46.8	47.3	46.7	43.4	2.83	.41	.51	.91
Daily gain, g								
d 0-21	182	114	135	109	37.9	.27	.59	.44
d 22-42	99	114	130	41	32.1	.29	.13	.48
d 0-42	140	114	132	75	35.2	.24	.63	.41
d 43-70	100	109	95	52	58.1	.41	.54	.98
d 0-70	126	112	119	67	22.3	.12	.40	.44
Daily DMI, g per day								
d 0-21	1262	1238	1218	1002	82.8	.05	.26	.60
d 22-42	1184	1107	1083	866	96.4	.04	.48	.58
d 0-42	1223	1173	1150	938	87.1	.04	.36	.58
d 43-70	1085	1004	944	736	69.4	.00	.38	.58
d 0-70	1177	1117	1082	868	77.4	.02	.34	.57
Gain to feed ratio.								
d 1-21	139	85	109	106	26.2	.54	.35	.38
d 22-42	76	94	118	49	26.4	.64	.12	.43
d 0-42	108	89	113	80	22.7	.54	.75	.34
d 43-70	93	112	97	64	47.5	.64	.59	.93
d 0-70	105	98	108	77	16.6	.33	.47	.45

[a]CP level (%) = The experimental treatments consisted of either 9, 11, 13 or 15% CP. The CP levels where obtained by supplemental urea.

[b]Probabilities for the linear (L), quadratic (Q), and cubic effects of level of CP.

[c]Standard error of treatment means; n = four lambs per treatment.

Table 2. Effect of level of supplemental CP on feedlot performance of by lambs fed a 70% concentrate diet

	CP level (%)[a]					Contrast[b]		
Item	9	11	13	15	SME[c]	L	Q	C
n	4	4	4	4				
pH	6.28	6.30	6.50	6.58	.09	.01	.73	.49
Ammonia N (mg/dl)	3.68	9.30	14.1	16.9	.98	.00	.18	.82
VFA								
Total (mM)	78.2	71.8	77.7	84.2	6.54	.39	.31	.69
mol/100mol								
Acetate	50.4	49.9	53.3	54.0	2.1	.12	.76	.46
Propionate	28.4	24.5	26.2	26.2	1.2	.37	.13	.21
Butyrate	6.58	6.75	5.37	5.55	.66	.59	.43	.17
Isobutyrate	.336	.354	.418	.515	.06	.01	.42	.95
Acetate: propionate ratio.	1.82	2.20	2.13	2.12	.15	.98	.19	.43

[a]CP level (%) = The experimental treatments consisted of either 9, 11, 13 or 15% CP. The CP levels where obtained by supplemental urea.

[b]Probabilities for the linear (L), quadratic (Q), and cubic effects of level of CP.

[c]Standard error of treatment means; n = four lambs per treatment.

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FEEDING VALUE OF CORN AND 'VALIER' BARLEY FOR FINISHING STEERS

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ABSTRACT: Eighty crossbred steers (average initial weight 358 kg) were used to evaluate the performance, nutrient digestibility, and grain energy content of finishing diets based on corn or 'Valier' barley. Barley was dry rolled prior to being fed and diets were formulated to be isocaloric (2.04 Mcal/kg NE_m and 1.43 Mcal/kg NE_g) and isonitrogenous (2.6% N). Diets were formulated (DM basis) to contain 80% grain, 6% straw, 3% soybean oil, and 11% vitamin/mineral supplement. Steers were weighed at the beginning and end of the 107-d study. Diet, ort, and fecal samples were collected on d 42, 77, and 107. Acid insoluble ash was used as an internal marker to estimate fecal output and calculate apparent nutrient digestibility. Steers were slaughtered when 70% were visually estimated to grade Choice and carcass measurements were collected after a 24-h chill. Weight and carcass data were analyzed using the GLM procedure of SAS with pen as the experimental unit. Intake and digestibility data were analyzed as repeated measures using PROC MIXED with pen as the experimental unit. Steer ADG did not differ (P = 0.64) between finishing diets based on corn or Valier. Gain:feed was lower (P = 0.03) for steers fed finishing diets based on Valier compared to corn. Percent KPH was lower (P = 0.05) from carcasses of steers fed Valier compared to carcasses from steers fed corn; however, all other carcass characteristics were not different (P > 0.30) between diets. Steers consuming Valier had higher (P = 0.09) DMI; but lower (P < 0.001) N, starch, and ADF intakes compared to steers consuming corn. Dry matter, N, and ADF digestibility were lower (P < 0.01) in the Valier-based finishing diet than the corn-based finishing diet; however, there was no difference (P = 0.40) in starch digestibility between diets. Corn grain had higher (P < 0.10) NE_m and NE_g content than Valier (2.27 vs. 2.12 Mcal/kg NE_m and 1.58 vs. 1.43 Mcal/kg NE_g). Slightly lower grain energy values were found for Valier compared with corn, however, there was no difference in steer performance.

Key Words: Barley, Corn, Finishing steers

Introduction

Starch digested in the small intestine may provide 42% more energy than starch digested in the rumen (Owens et al., 1986). A barley variety with lower DMD could shift more of the starch digestion from the rumen to the small intestine, in effect making barley more like corn in site of digestion (Bowman et al., 2001). Valier is a new barley variety developed from crossing Lewis and Baroness and released by the Montana Agricultural Experiment Station. In 1 finishing trail Valier had lower DM, starch, N and ADF digestibility compared to corn (Kincheloe et al., 2003); however, in 2 other studies Valier had lower DM and ADF digestibility, but similar starch and N digestibility compared to corn (Grove et al., 2006a,b). Energy values for Valier were similar to corn in 2 studies (Kincheloe et al., 2003; Grove et al., 2006a) and less than corn in another (Grove et al., 2006b). These studies had treatments other than corn and Valier and the feeding value of Valier compared to corn might be further elucidated by feeding more pens of cattle per treatment. The objective of the current study was to further evaluate the performance, digestibility, and energy value of corn and Valier barley.

Materials and Methods

Eighty crossbred steers (average weight 358 kg) were assigned by weight to 16 pens in a completely randomized design. Steers were fed finishing rations based on corn or 'Valier' barley. Chemical composition of the grains is presented in Table 1. Barley was dry rolled prior to being fed and diets were formulated to be isocaloric (2.04 Mcal/kg NE_m and 1.43 Mcal/kg NE_g) and isonitrogenous (2.6% N). Diets were formulated (DM basis) to contain 80% grain, 6% straw, 3% soybean oil, and 11% vitamin/mineral supplement. Animals were cared for under protocols approved by the Montana State University Animal Care and Use Committee.

Steers were weighed on 2 consecutive days at the beginning and end of the 107-d study. Steers were fed once daily at 0800 and were given ad libitum access to water. Steers were gradually brought up to ad libitum intake of their respective treatment diets over 28 days. Steers were implanted on d 0 and 56 with Synovex S (Fort Dodge Animal Health, Fort Dodge, IA). Diet, ort, and fecal samples were collected from individual steers and composited by pen on d 42, 77, and 107. Diet and fecal samples were dried in a 60° C forced-air oven, ground through a Wiley mill (1-mm screen), and analyzed for DM (AOAC, 1999), N (Leco Corporation, St. Joseph, MI), ADF (Van Soest et al., 1991), starch (Megazyme, Sidney, Australia), and AIA (4N HCl method; Van Keulen and Young, 1977). Acid insoluble ash was used as an internal marker to estimate fecal output and calculate apparent nutrient digestibility. Grain energy content (NE_m and NE_g) was calculated based on steer average weight, DMI, and ADG using NRC (1984) equations.

Steers were slaughtered when 70% were visually estimated to grade Choice, and hot carcass weights were collected. All other carcass measurements were taken after

a 24-h chill. A USDA grader assigned quality grades and marbling scores.

Weight and carcass data were analyzed using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC) with pen as the experimental unit. Intake and digestibility data were analyzed as repeated measures using PROC MIXED with pen as the experimental unit. Least square means were separated using the Least Significant Difference method when $P < 0.10$.

Results and Discussion

Steer final weights and ADG did not differ ($P > 0.64$) between steers fed finishing diets based on corn and Valier (Table 2). Percent KPH was lower ($P = 0.05$) from carcasses of steers fed Valier compared to carcasses of steers fed corn. All other carcass characteristics were not different ($P > 0.30$) between treatments. Gain:feed was lower ($P = 0.03$) for steers fed finishing diets based on Valier compared to corn. In agreement with our results, ADG was similar between Valier and corn-fed cattle in 3 other finishing trials (Kincheloe et al., 2003; Grove et al. (2006a,b). Valier-fed cattle had similar G:F to corn-fed cattle in 2 studies (Kincheloe et al. 2003; Grove et al., 2006a) but lower G:F than corn-fed cattle in another (Grove et al., 2006b). Cattle fed Valier had less backfat, lower yield grades, and tended to have lower quality grades compared to cattle fed corn (Kincheloe et al., 2003). These and our data suggest that steers fed Valier-fed cattle may deposit less external fat compared to steers fed corn. In contrast, Grove et al. (2006a,b) reported no differences in carcass characteristics between corn- and Valier-fed finishing cattle. Early researchers reported that cattle fed barley gained as well as cattle fed corn, but did not have as much finish Weber (1936); however, others have reported few differences between corn and barley diets in final weights or carcass characteristics (Miller et al., 1996).

Corn had higher ($P < 0.10$) NE_m and NE_g content than Valier (2.27 vs 2.12 Mcal/kg NE_m and 1.58 vs 1.43 Mcal/kg NE_g). In contrast to our data, Kincheloe et al. (2003) and Grove et al. (2006a) reported no differences in energy value between corn and Valier, averaging 2.19 Mcal/kg NE_m and 1.53 Mcal/kg NE_g and 2.28 Mcal/kg NE_m and 1.58 Mcal/kg NE_g, respectively. Similar to our data, Grove et al. (2006b) reported that corn had higher energy content than Valier (2.28 vs. 2.05 Mcal/kg NE_m and 1.59 vs. 1.37 Mcal/kg NE_g). While results differed, actual energy values were similar between all 4 finishing trials.

Steers consuming Valier had higher ($P = 0.09$) DMI; but lower N, starch, and ADF intakes compared to steers consuming corn ($P < 0.001$). Similar to our data, Grove et al. (2006a) reported greater DMI by steers consuming Valier compared to corn; however, Kincheloe et al. (2003) and Grove et al. (2006b) reported similar DMI between steers consuming corn and Valier finishing diets. These differences in DMI help explain G:F results. Droughty conditions during the years these studies were conducted resulted in high protein content of Valier compared to corn; therefore, large proportions of hydrolyzed feather meal and urea were used to balance the diets for protein. Hydrolyzed feather meal and urea were 73 and 4% of the corn supplement in Grove et al. (2006b) and the current study, 23 and 3% in Kincheloe et al. (2003), and 10 and 8% in Grove et al. (2006a). In contrast the Valier diets contained no feathermeal and 0 to 2% urea in all studies. The feeder noted palatability problems with the corn supplement which could explain differences in intake and may have influenced G:F between studies. We are currently conducting a study in which no feathermeal was used in the corn supplement.

Dry matter, N, and ADF digestibility was lower ($P < 0.001$) for Valier- than corn-based finishing diets; however, there was no difference ($P = 0.40$) in starch digestibility between diets. Similar to our data, Valier diets also had lower apparent DM and ADF digestibility yet similar starch digestibility compared to corn diets (Kincheloe et al., 2003; Grove et al., 2006a,b). Apparent N digestibility of Valier diets was similar to that of corn diets in 2 studies (Grove et al., 2006a,b) and lower than apparent N digestibility of corn diets in the other study (Kincheloe et al., 2003).

Implications

Nutrient digestibility was lower for Valier- than corn-based finishing diets; however, animal performance was not different. Future research should evaluate ruminal and post-ruminal digestion of new barley varieties.

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Table 1. Nutrient composition of corn and 'Valier' and ingredient composition of finishing diets fed to steers

Item	Corn	Valier
DM, %	84.7	93.9
N, %	1.33	2.42
ADF, %	2.72	3.82
Starch, %	73.1	56.2
ISDMD, % at 3 h[a]	26.4	28.87
Particle size, um	-	1324
Bulk density, kg/hL	64.4	61.8
Ingredient, % of DM		
Corn	80	-
Cracked barley	-	80
Barley straw	6	6
Oil	3	3
Supplement[b]	11	11
Feather meal	73.3	-
Canola meal	1.25	-
Wheat midds	-	57.7
Bentonite	-	21.6
Calcium sulfate	-	0.85
Urea	3.8	-
Calcium carbonate	9.4	8.9
Sodium chloride	1.8	1.3
Potassium chloride	1.36	0.65

[a] ISDMD = in situ DM disappearance.

[b] All supplements contained 7.4% sodium bicarbonate, 0.18% trace mineral premix, 0.025% Vitamin A, D, E premix, 1% mineral oil, 0.125% Rumensin, 0.075% Tylan, 0.28% Selenium, and 0.05% Agrisweet flavor.

Table 2. Animal performance and carcass characteristics of steers fed finishing diets based on corn or 'Valier' barley

Item	Corn	Valier	SE	*P*-value
No. of pens	8	8		
No. of animals	40	40		
Weight, kg				
Initial	358	358	0.3	0.19
Final	579	582	2.6	0.59
ADG	2.08	2.09	0.026	0.64
FE, kg gain/100 kg feed	17.1	15.5	0.46	0.03
Carcass wt, kg	340	339	1.7	0.71
KPH fat, %	2.2	2.1	0.04	0.05
Fat thickness, cm	1.6	1.5	0.03	0.15
REA, cm^2	71.21	71.27	0.720	0.95
Marbling score	450	461	15.1	0.61
USDA quality grade[a]	12.0	12.2	0.14	0.42
USDA yield grade	3.8	3.7	0.06	0.30
Diet NE_m, Mcal/kg	2.16	2.01	0.048	0.05
Diet NE_g, Mcal/kg	1.48	1.35	0.042	0.05
Grain NE_m, Mcal/kg	2.27	2.12	0.060	0.09
Grain NE_g, Mcal/kg	1.58	1.43	0.052	0.05

[a] 11 = Select, 12 = Choice$^-$, 13 = Choice^o, 14 = Choice$^+$

Table 3. Nutrient intake and apparent digestibility by steers fed finishing diets based on corn or 'Valier' barley

	Treatment			
Item	Corn	Valier	SE	*P*-value
Intake				
DM, kg	12.0	12.7	0.27	0.09
N, g	312	274	6.5	0.001
Starch, kg	6.2	5.3	0.13	0.0002
ADF, kg	1.53	1.30	0.032	0.0002
Apparent digestibility, %				
DM	76.6	67.2	1.32	0.0002
OM	77.4	69.9	1.33	0.001
N	70.6	64.0	1.43	0.006
Starch	92.8	91.9	0.79	0.40
ADF	65.5	2.1	2.61	0.0001

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DIGESTIBILITY OF BARLEY BETA-GLUCAN IN CATTLE

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ABSTRACT: Oral administration of barley beta-glucans has been shown to stimulate the mammalian immune system. Beta-glucans are assumed to be completely digested in the rumen and few researchers have evaluated the effects of oral beta-glucan administration on immune response in cattle. The objective of the current study was to estimate the *in situ* and *in vivo* digestibility of beta-glucan from different barley varieties in beef cattle. Valier (feed barley, 3.6% beta-glucan), Harrington (2-row malting barley, 4.6% beta-glucan), Hockett (2-row malting barley, 4.2% beta-glucan), Legacy (6-row malting barley, 4.5% beta-glucan), and purified barley beta-glucan (67.2% beta-glucan) were incubated *in situ* for 0, 3, and 6 h. Diet and fecal samples from steers fed a finishing diet containing 80% Valier were also analyzed for beta-glucan in order to calculate *in vivo* beta-glucan digestibility. Data were analyzed using the GLM procedure of SAS. *In situ* beta-glucan disappearance at 3 h of ruminal incubation tended ($P = 0.11$) to be lowest for Legacy and Valier (average 31.6%), intermediate for purified barley beta-glucan (42%), and highest for Harrington and Hockett (average 61.8%). At 6 h of ruminal incubation, Valier had lower ($P = 0.06$) *in situ* beta-glucan disappearance compared to all other treatments (45.6 vs. average of 79.7%). *In vivo*, apparent digestibility of beta-glucan from a Valier barley-based finishing diet was lower ($P < 0.001$) at 42- than 107-d on feed (91.6 vs. 98.1%, respectively). We recovered 0.03 to 0.11 g beta-glucan/kg BW from the feces of mature cattle consuming Valier barley-based finishing rations at 42 d on feed. Other researchers have stimulated the mammalian immune system with oral beta-glucan doses as little as 0.11 to 0.22 g beta-glucan/kg BW. By feeding Valier, it may be possible to get enough beta-glucan through the rumen early in the finishing period in order to stimulate the immune system of ruminants.

Key Words: Barley beta-glucan, Beef cattle, Digestibility, Immunity

Introduction

Beta-glucans are naturally occurring forms of carbohydrate found in yeast, fungi, oats, and barley that have been shown to stimulate the mammalian immune system (Williams, 1997; Taylor et al., 2002). Barley varieties evaluated in our lab contained 3.6 to 9.4% beta-glucan while beta-glucans content of corn was 0.1%. Research has shown that cells of the immune system have specific receptors that recognize beta-glucan (Williams, 1997), including beta-glucans from barley (Czop and Austen, 1985). Oral administration of purified beta-glucans from barley has had immune modulating activities in rats (Delaney et al., 2003a). In addition, mice consuming barley-based diets had increased levels of antibodies and improved weight recovery after a viral infection compared to mice consuming corn-based diets (Kaiser et al., 2005). Sealey et al. (2006) also reported fish fed diets based on barley varieties containing 5.2 or 8.2% beta-glucan had improved survivability compared to fish fed wheat-based diets (~1% beta-glucan) after a viral challenge.

Few researchers have evaluated the immune response from oral administration of beta-glucans in cattle because beta-glucans are assumed to be completely digested in the rumen. However, only one researcher has published *in situ* and *in vivo* digestion coefficients for beta-glucans from barley: 95% and 98.6%, respectively (Engstrom et al., 1992). These authors evaluated Bonanza (malting) and Klondike (feed) barleys; however, there is a considerable amount of variation in digestibility between barley varieties (Bowman et al., 2001). Valier is new barley variety with low ruminal digestibility that could slow digestibility of other nutrients such as beta-glucan. It is the desire of this research group to evaluate the efficacy of barley beta-glucans as an immunostmulant in cattle; however, before doing so it is important to characterize the digestibility of barley beta-glucans in ruminants. The objective of the current study was to evaluate the *in situ* and *in vivo* digestibility of beta-glucans from different barley varieties.

Materials and Methods

In Situ Experiment. Valier (feed barley, 3.6% beta-glucan), Harrington (2-row malting barley, 4.6% beta-glucan), Hockett (2-row malting barley, 4.2% beta-glucan), Legacy (6-row malting barley, 4.5% beta-glucan), and purified barley beta-glucan (67.2% beta-glucan) were incubated *in situ* for 0, 3, and 6 h. Barleys were cracked using a Bühler mill (Bühler AG, Uzwil, Switzerland) and 5 g of sample weighed into 50 µm-pore-size polyester bags (Ankom Technology, Macedon, NY). Samples were incubated in duplicate in each of 2 ruminally cannulated cows consuming low quality grass hay ad libitum and 3.6 kg/d of dry rolled barley. One standard bag and 1 blank bag were also incubated in each cow at each time point. Samples for 0 h were not placed in the rumen, but were simply rinsed in warm water. After incubation, bags were hand washed in cold water and dried in a 60° C forced-air oven for 48 h. Dry matter disappearance was determined and the dried residue was also analyzed for beta-glucan using McCleary Kits (Megazyme, Sidney, Australia) in order to calculate *in*

situ DM and beta-glucan disappearance. Data were analyzed at each time point using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC). Least square means were separated using the Least Significant Difference method when $P < 0.10$.

In Vivo Experiment. Samples from a feedlot trial (Iversen et al., 2006) in which an 80% Valier barley finishing diet was fed were used to calculate total tract apparent digestibility of DM and beta-glucan. Diet, ort, and fecal samples were collected and composited by pen on d 42 and 107 of the feeding trial. Diet and fecal samples were dried in a 60° C forced-air oven, ground through a Wiley mill (1-mm screen), and analyzed for DM (AOAC, 1999), beta-glucan (as previously described), and AIA (4N HCL method; Van Keulen and Young, 1977). Acid insoluble ash was used as an internal marker to estimate fecal output and calculate apparent nutrient digestibility. Data were analyzed using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC) with pen as the experimental unit in order to compare DM and beta-glucan digestibility at 42 versus 107 d on feed. Least square means were separated using the Least Significant Difference method when $P < 0.10$.

Results and Discussion

In Situ Experiment. In situ DM disappearance did not differ ($P = 0.23$) between treatments at 3 h of incubation; however, at 6 h of incubation, *in situ* DM disappearance was lower ($P = 0.08$) for Valier compared to Hockett and purified barley beta-glucan (Table 1). Our data supports the fact that Valier is a feed quality barley with low DM disappearance. Numerically, Legacy had lower DM disappearance than Harrington and Hockett, which is in agreement with Bowman et al. (2001) who reported that 6-row barley varieties had lower DM disappearance compared to 2-row barley varieties.

Fifteen percent of the beta-glucan in purified barley beta-glucan disappeared in water at 0 h (Table 1). *In situ* beta-glucan disappearance at 3 h of ruminal incubation tended ($P = 0.11$) to be lowest for Legacy and Valier (average 31.6%), intermediate for purified barley beta-glucan (42%), and highest for Harrington and Hockett (61.7%). At 6 h of ruminal incubation, Valier had lower ($P = 0.06$) *in situ* beta-glucan disappearance compared to all other treatments (45.6% vs. average of 79.1%). Our values for beta-glucan disappearance are lower than those reported by Engstrom et al. (1992; 95% at 8 h of *in situ* incubation); however, these differences are most likely due to barley variety. Suppose a 454 kg feedlot steer consumes 12 kg DM of a Valier-based finishing diet containing 3.0% beta-glucan. If 46% beta-glucan disappears in 6 h (or 54% remains), then assuming a rapid passage rate, 0.43 g beta-glucan/kg BW may escape the rumen and become available to the animal.

In Vivo Experiment. Dry matter and beta-glucan digestibility were lower ($P = 0.001$) at 42 d on feed than at 107 d (65.8 vs. 72% DM digestibility and 91.6 vs. 98.1% beta-glucan digsetibility; Table 2). Our data at 107 d on feed is similar to Engstrom et al. (1992) who reported total tract *in vivo* digestibility of beta-glucans in Bonanza (malting) and Klondike (feed) barleys to be 98.6%. In the current study, 0.03 to 0.11 g beta-glucan/kg body weight were present in the feces of mature cattle consuming Valier barley-based finishing rations at 42 d on feed. Other researchers have stimulated the immune system with oral beta-glucan doses as low as 0.10 to 0.22 g beta-glucan/kg body weight (Yun et al., 1997; 2003; Davis et al., 2004). It has been hypothesized that mucosal cells in the intestine may be able to pick up beta-glucan (or beta-glucan fragments) and transport it to the blood and immune system while preserving the original active conformation of beta-glucan (Delaney et al., 2003b based on work by Owen, 1999). However, most orally administered beta-glucan has been found in the gastrointestinal tract suggesting that beta-glucans can act directly from the gut to stimulate the immune system (Miura, 2005). While the exact mechanism is unknown, oral beta-glucan administration has stimulated the mammalian immune system (Yun et al., 1997; 2003; Davis et al., 2004).

Implications

Barley beta-glucan digestibility varied between barley varieties. By feeding Valier it may be possible to get enough beta-glucan through the rumen early in the finishing period in order to stimulate the immune system of ruminants. This is the most critical and stressful time for feedlot cattle and would be the best time to stimulate the immune system.

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Table 1. *In situ* disappearance of DM and beta-glucan (BG) in 4 barley varieties and purified barley beta-glucan at 3 time points

	Beta-glucan treatment						
	Harrington	Hockett	Legacy	Valier	Purified BG	SE	*P*-value
DM disappearance, %							
0 h	1.9^{ab}	5.1^{b}	-1.5^{a}	3.8^{b}	2.6^{b}	1.31	0.10
3 h	44.9	46.9	27.9	32.2	43.3	5.96	0.23
6 h	63.5^{ab}	65.2^{bc}	54.8^{ab}	45.9^{a}	83.2^{c}	6.83	0.08
BG disappearance, %							
0 h	-9.5^{b}	-18.0^{a}	-11.2^{ab}	-18.1^{a}	14.7^{c}	2.58	0.001
3 h	58.6^{b}	64.9^{b}	32.9^{a}	30.2^{a}	42.0^{ab}	8.48	0.11
6 h	82.3^{b}	78.1^{b}	72.7^{b}	45.6^{a}	85.7^{b}	7.26	0.06

^{abc} Within a row, means without a common superscript letter differ ($P < 0.10$)

Table 2. *In vivo* digestibility of DM and beta-glucan in Valier barley-based diets at 2 dates in a finishing experiment

	Days on feed			
	42 d	107 d	SE	*P*-value
Apparent digestibility, %				
DM	65.8	72.0	0.80	0.001
Beta-glucan	91.6	98.1	0.83	0.001

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FEEDING VALUE OF CORN, 'HAXBY', 'VALIER', AND 'H3' BARLEY VARIETIES FOR FINISHING STEERS

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ABSTRACT: Eighty crossbred steers (average initial weight 392 kg) were used to compare the feedlot performance, nutrient digestibility, and grain energy content of 4 finishing rations based on: corn, or 'Valier,' 'Haxby,' and 'H3' barley. Grain was dry rolled prior to being fed and diets were formulated to be isocaloric (2.07 Mcal/kg NE_m and 1.40 Mcal/kg NE_g) and isonitrogenous (2.0% N). Diets were formulated (DM basis) to contain 80% grain, 6% straw, 3% soybean oil, and 11% vitamin/mineral supplement. Steers were weighed at the beginning and end of the 106-d study, and diet, ort, and fecal samples were collected on d 25, 53, 81, and 106. Acid insoluble ash was used as an internal marker to estimate fecal output and calculate apparent nutrient digestibility. Steers were slaughtered when 70% were visually estimated to grade Choice and carcass measurements were collected after a 24-h chill. Weight and carcass data were analyzed using the GLM procedure of SAS with pen as the experimental unit. Intake and digestibility data were analyzed as repeated measures using PROC MIXED with pen as the experimental unit. Average daily gain ($P = 0.25$) and G:F ($P = 0.12$) did not differ between treatments, averaging 1.8 kg/d and 15.5 kg gain/100 kg feed, respectively. Carcass characteristics did not differ ($P > 0.13$) between steers fed corn, H3, Haxby, or Valier. Starch intake was greatest ($P = 0.0001$) by steers fed corn, intermediate by steers fed Haxby and Valier, and lowest by steers fed H3; however, there was no difference ($P > 0.12$) in DM or N intake between diets. Dry matter digestibility tended to be lower ($P = 0.11$) for Valier and H3 diets compared to the corn diet. Digestibility of ADF was greater ($P = 0.01$) for the corn diet than the barley diets. Corn grain had higher ($P < 0.06$) NE_m and NE_g content than H3 and Haxby, while Valier had NE_m and NE_g content similar to corn and H3 but higher than Haxby. Differences in grain energy content, starch intake, and DM digestibility did not affect steer weight gains or carcass characteristics.

Key Words: Barley, Beef cattle, Corn

Introduction

Barley grain characteristics that can be used to predict feed quality for beef cattle have been identified (Surber et al., 2000) and new barley varieties have been selected based on these feed quality characteristics. Valier is an improved feed barley variety with low DMD that has been released by the Montana Agricultural Experiment station. Valier had energy values similar to corn (Kincheloe et al., 2003) but higher NE_m and NE_g than reported for barley by NRC (1996). Haxby is another Montana Agricultural Experiment station release with high crop yields that could replace Harrington as a malting variety; however, since malting barley often ends up as animal feed, it seems prudent to evaluate the effect of Haxby on animal performance. Finishing steers fed Haxby had similar ADG, carcass characteristics, digestibility, and energy values compared to steers fed Valier in 2 finishing trials (Grove et al., 2006); however, Haxby has never been compared to corn in a finishing trial. H3 is a barley variety that retains its kernel weight under droughty growing conditions common to the West and steers fed H3 had greater ADG and higher energy content than steers fed corn (Kincheloe et al., 2002). The objective of this study was to evaluate the performance, digestibility, and energy value of corn and these three barley varieties, Haxby, Valier, and H3, in a finishing trial.

Materials and Methods

Eighty crossbred steers (average initial weight 392 kg) were assigned by weight to 16 pens in a completely randomized design. Steers were fed finishing rations based on corn, Valier, Haxby, and H3 barleys. Chemical composition of the barley cultivars is presented in Table 1. Valier was developed from crossing Lewis and Baroness, Haxby is a cross between Gallatin/Bellona and Clark/Lamont, and H3 is a cross between Lewis and Apex. Grains were dry rolled prior to being fed and diets were formulated to be isocaloric (2.07 Mcal/kg NE_m and 1.40 Mcal/kg NE_g) and isonitrogenous (2.0% N). Diets were formulated (DM basis) to contain 80% grain, 6% straw, 3% soybean oil, and 11% vitamin/mineral supplement. Animals were cared for under protocols approved by the Montana State University Animal Care and Use Committee.

Steers were weighed on 2 consecutive days at the beginning and end of the 106-d study. Steers were fed once daily at 0800 and were given ad libitum access to water. Steers were gradually brought up to ad libitum intake of their respective treatment diets over 25 d. Diet, ort, and fecal samples were collected from individual steers and composited by pen on d 25, 53, 81, and 106. Diet and fecal samples were dried in a 60° C forced-air oven, ground through a Wiley mill (1-mm screen), and analyzed for DM (AOAC, 1999), N (Leco Corporation, St. Joseph, MI), ADF (Van Soest et al., 1991), starch (Megazyme, Sidney, Australia), and AIA (4N HCl method; Van Keulen and Young, 1977). Acid insoluble ash was used as an internal marker to estimate fecal output and calculate apparent nutrient digestibility. Grain energy content (NE_m and NE_g)

was calculated based on steer average weight, DMI, and ADG using NRC (1984) equations.

Steers were slaughtered when 70% were visually estimated to grade Choice, and hot carcass weights were collected. All other carcass measurements were taken after a 24-h chill. A USDA grader assigned quality grades and marbling scores.

Weight and carcass data were analyzed using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC) with pen as the experimental unit. Intake and digestibility data were analyzed as repeated measures using PROC MIXED with pen as the experimental unit. Least square means were separated using the Least Significant Difference method when $P < 0.10$.

Results and Discussion

Steer final weight was greater ($P = 0.06$) by steers fed corn and Valier than Haxby, with steers fed H3 being intermediate and similar to all other treatments (Table 2). Steer ADG did not differ ($P = 0.25$) between diets, averaging 1.8 kg/d. This is the first time Haxby has been compared to corn in a finishing trial. Similar to our results, ADG by steers fed H3 was similar to or greater than ADG by steers fed corn (Kincheloe et al., 2002). In addition, ADG was similar between steers fed H3, Valier, or corn (Kincheloe et al., 2003) and steers fed Valier also had similar ADG compared to steers fed Haxby (Grove et al., 2006).

Gain:feed did not differ ($P = 0.12$) between treatments, averaging 15.5 kg gain/100 kg feed. In agreement with our results, G:F was similar between steers fed H3, Valier, or corn (Kincheloe et al., 2002; 2003) and steers fed Valier also had similar G:F compared to steers fed Haxby (Grove et al., 2006).

All carcass characteristics were not different ($P > 0.13$) between diets. In agreement with our data, Bergner et al. (2002) reported that all carcass traits were similar between H3- and corn-fed steers. In contrast, Kincheloe et al. (2003) reported that carcasses from steers fed corn had higher yield grades and more backfat than carcasses from steers fed H3 and Valier. Steers fed Valier had similar carcass traits compared to steers fed Haxby in two finishing trials (Grove et al., 2006).

Dry matter and N intake did not differ ($P > 0.12$) between treatments averaging 11.6 kg/d and 239 g/d, respectively (Table 3). Starch intake was greatest ($P = 0.0001$) by steers fed corn, intermediate by steers fed Haxby and Valier, and lowest by steers fed H3. Intake of ADF was lowest ($P = 0.002$) by steers fed corn, intermediate by steers fed Haxby, and highest by steers fed H3 and Valier. In agreement with our results, intake of DM was similar between steers fed corn and H3 (Kincheloe et al., 2002) or corn, H3, and Valier (Kincheloe et al., 2003); however, corn-fed steers consumed more starch than steers fed either of barley. Steers fed Valier and Haxby had similar intakes of all nutrients (Grove et al., 2006).

Dry matter digestibility tended to differ ($P = 0.11$) between treatments being lower for Valier and H3 than corn with DM digestibility of Haxby being intermediate and not different from the other diets. There was no difference ($P > 0.35$) in N or starch digestibility between dietary treatments averaging, 81.7 and 96.0%, respectively. Digestibility of ADF was greater ($P = 0.01$) in corn diets than in barley diets. In 1 finishing trial, H3-based finishing diets had similar DM and starch digestibility, but lower ADF digestibility, compared to corn; however, in another finishing trial H3-based finishing diets had greater DM and starch digestibility, but similar ADF digestibility compared to corn-based finishing diets (Kincheloe et al., 2002). Kincheloe et al. (2003) reported that H3- and Valier-based finishing diets had similar DM and starch digestibility, but were lower compared to corn-based finishing diets. Finishing diets based on Valier and Haxby had similar digestibility of all nutrients (Grove et al., 2006).

Corn grain had higher ($P < 0.06$) NE_m and NE_g content than H3 and Haxby, while Valier had NE_m and NE_g content similar to corn and H3, but higher than Haxby. In one study, the NE_m and NE_g content of H3 was greater than or equal to corn (Kincheloe et al., 2002) while others reported that H3, Valier, and corn had similar NE_m and NE_g values (Kincheloe et al., 2003). Valier and Haxby also had similar energy contents (Grove et al., 2006).

Implications

Slight differences in grain energy content and starch intake by steers between finishing diets did not affect cattle gains or carcass characteristics.

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Table 1. Composition of grains and finishing diets based on corn, 'H3', 'Haxby', and 'Valier' barleys

Item	Corn	H3	Haxby	Valier
DM, %	87.5	90.5	90.7	90.2
N, %	1.54	2.29	2.14	2.17
ADF, %	1.35	3.94	3.70	5.82
Starch, %		58.2	58.9	58.0
ISDMD, % at 3 h[a]	31.4	45.7	56.3	51.3
Particle size, um	-	1270	1158	1236
Ingredient, % of DM				
Corn	79	-	-	-
Cracked barley	-	80	79	79
Barley straw	6	6	6	6
Oil	3	3	3	3
Supplement[b]	11	11	12	12
Feather meal	10	-	-	-
Wheat midds	35.8	52.3	52.3	52.3
Urea	8.7	2.2	2.2	2.2

[a] ISDMD = in situ DM disappearance.

[b] All supplements contained 19.6% calcium carbonate, 3.9% sodium chloride, 3.9% potassium chloride, 10.2% bufferite, 0.25% trace mineral premix, 0.295% Vitamin A, D, and E premix, 1% EZ flow, 0.14% Rumensin, 0.075% Tylan, and 6.1% dicalcium phosphate.

Table 2. Performance and carcass characteristics of steers fed finishing diets based on corn, 'H3', 'Haxby', and 'Valier' barleys

Item	Corn	H3	Haxby	Valier	SE	*P*-value
No. of pens	4	4	4	4		
No. of animals	18	20	20	20		
Weight, kg						
Initial	392	392	388	393	1.5	0.19
Final	578[c]	574[bc]	564[b]	582[c]	4.3	0.06
ADG, kg	1.8	1.7	1.7	1.8	0.046	0.25
G:F, kg gain/100 kg feed	16.4	15.3	14.6	15.6	0.48	0.12
Carcass wt, kg	335	321	328	324	4.0	0.13
KPH fat, %	2.1	2.1	2.1	2.1	0.06	0.94
Fat thickness, cm	1.24	1.22	1.46	1.18	0.101	0.25
REA, cm^2	77.1	78.3	75.5	75.6	1.36	0.43
Marbling score	480	427	471	432	20.5	0.22
USDA quality grade[a]	12.4	11.9	12.3	11.8	0.19	0.15
USDA yield grade	3.2	3.1	3.5	3.2	0.12	0.13
Diet NE_m, Mcal/kg	2.14[c]	2.04[bc]	1.99[b]	2.09[c]	0.038	0.09
Diet NE_g, Mcal/kg	1.46[c]	1.38[bc]	1.33[b]	1.42[c]	0.033	0.09
Grain NE_m, Mcal/kg	2.32[d]	2.16[bc]	2.10[b]	2.23[cd]	0.048	0.05
Grain NE_g, Mcal/kg	1.61[d]	1.49[bc]	1.43[b]	1.55[cd]	0.042	0.06

[a]11 = Select, 12 = Choice$^-$, 13 = Choice^o, 14 = Choice$^+$

[bcd] Means within a row lacking a common superscript letter differ ($P < 0.10$)

Table 3. Nutrient intake and apparent digestibility by steers fed finishing diets based on corn, 'H3', 'Haxby', and 'Valier' barleys

	Treatment					
Item	Corn	H3	Haxby	Valier	SE	*P*-value
Intake						
DM, kg	11.7	11.4	11.4	11.7	0.16	0.33
N, g	238	246	231	240	4.0	0.12
Starch, kg	6.6[c]	5.3[a]	5.6[b]	5.5[b]	0.10	0.0001
ADF, kg	0.71[a]	0.89[c]	0.81[b]	0.92[c]	0.031	0.002
Apparent digestibility, %						
DM	85.8[b]	80.0[a]	83.8[ab]	81.8[a]	1.58	0.11
N	83.6	79.5	82.9	80.8	2.12	0.51
Starch	95.3	95.6	96.9	96.0	0.63	0.35
ADF	65.8[b]	39.5[a]	47.1[a]	45.3[a]	4.82	0.01

[abc] Means within a row lacking a common superscript letter differ ($P < 0.10$)

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FEEDING VALUE OF 'HAXBY', 'VALIER', 'MT960099', AND 'ESLICK' BARLEY VARIETIES FOR FINISHING STEERS

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ABSTRACT: Two feedlot studies (Bozeman and Havre, MT) were conducted in order to evaluate 4 finishing diets based on: Haxby, Valier, MT960099, and Eslick barley varieties. At each location, 80 Angus steers were allotted by weight to 16 pens with 4 pens per treatment. Barley was dry rolled prior to being fed and diets were formulated to be isocaloric (2.07 Mcal/kg NE_m and 1.41 Mcal/kg NE_g) and isonitrogenous (2.3% N). Diets were formulated (DM basis) to contain 80% grain, 6% straw, 3% soybean oil, and 11% vitamin/mineral supplement. Steers were weighed at the beginning and end of the 112-d study, and diet, ort, and fecal samples were collected on d 28, 56, 84, and 112. Acid insoluble ash was used as an internal marker to estimate fecal output and calculate apparent nutrient digestibility. Steers were slaughtered when 70% were visually estimated to grade Choice and carcass measurements were collected after a 24-h chill. Data from each location was analyzed separately. Weight and carcass data were analyzed using the GLM procedure of SAS with pen as the experimental unit. Intake and digestibility data were analyzed as repeated measures using PROC MIXED with pen as the experimental unit. Steer final weights and ADG were not different ($P > 0.73$) between diets at Bozeman; however, final weight and ADG was lower ($P < 0.09$) by steers fed Eslick than by steers fed all other barleys at Havre. Gain:feed was similar ($P > 0.32$) between diets at both locations averaging 15.1 and 15.4 kg gain/100 kg feed at Bozeman and Havre, respectively. Steers fed Eslick had lower ($P = 0.008$) carcass weights compared to steers fed the other 3 barleys at Havre, but there was no difference ($P = 0.67$) in carcass weight between diets at Bozeman. There was no difference ($P > 0.33$) in the other carcass characteristics between barley diets at both locations. Grain energy value was similar ($P > 0.35$) between barleys in both studies averaging 2.21 Mcal/kg NE_m and 1.53 Mcal/kg NE_g at Bozeman and 2.13 Mcal/kg NE_m and 1.45 Mcal/kg NE_g at Havre. In Bozeman, intake of DM, N, starch, and ADF were similar ($P > 0.50$) between barley varieties. In contrast, DM, N, and starch intakes were lower ($P < 0.10$) for steers fed Eslick than all other barleys at Havre. Apparent digestibility of nutrients was similar ($P > 0.14$) between all barley varieties at both locations. Few differences were found in performance, digestibility, and energy content between Haxby, Valier, MT960099, and Eslick barley varieties.

Key Words: Barley, Beef cattle, Carcass traits, Feedlot

Introduction

Montana State University has been actively developing new barley varieties with improved feed quality characteristics. 'Valier', 'Eslick', and 'Haxby' are all barleys with improved feed quality that have been released by the Montana Agricultural Experiment Station, and 'MT960099' is an experimental line that also shows promise as a new barley variety with improved feed quality. The feeding value of Eslick and MT960099 has not been previously evaluated in the feedlot. Haxby had lower energy content but resulted in similar animal performance compared to Valier (Grove et al., 2006). The objective of this study was to evaluate the performance, digestibility, and energy value of these 4 barley varieties in 2 feedlot trials.

Materials and Methods

Eighty Angus crossbred steers were allotted by weight to 16 pens with 4 pens per treatment at 2 locations: Bozeman and Havre, MT (average initial weight 410 and 402 kg, respectively). Steers were fed finishing rations based on 'Eslick', 'Haxby', 'Valier', and 'MT960099' barley varieties. Eslick is a cross between Stark and Baroness, Haxby is a cross between Gallatin/Bellona and Clark/Lamont, Valier is a cross between Lewis and Baroness, and MT960099 is a cross between Manly and Baronesse. Chemical composition of the barley cultivars is presented in Table 1. Barley was dry rolled prior to being fed and diets were formulated to be isocaloric (2.07 Mcal/kg NE_m and 1.41Mcal/kg NE_g) and isonitrogenous (2.3% N). Diets were formulated (DM basis) to contain 80% barley, 6% straw, 3% soybean oil, and 11% vitamin/mineral supplement. Animals were cared for under protocols approved by the Montana State University Animal Care and Use Committee.

Steers were weighed on 2 consecutive days at the beginning and end of the 112-d study. Steers were fed once daily at 0800 and were given ad libitum access to water. Steers were gradually brought up to ad libitum intake of their respective treatment diets over 28 days. Steers at Bozeman were implanted with Synovex S (Fort Dodge Animal Health, Fort Dodge, IA) on d 56, but steers at Havre were not implanted. Diet, ort, and fecal samples were collected from individual steers and composited by pen on d 28, 56, 84, and 112. Diet and fecal samples were dried in a 60° C forced-air oven, ground through a Wiley

mill (1-mm screen), and analyzed for DM, (AOAC, 1999), N (Leco Corporation, St. Joseph, MI), ADF (Van Soest et al., 1991), starch (Megazyme, Sidney, Australia), and AIA (4N HCl method; Van Keulen and Young, 1977). Acid insoluble ash was used as an internal marker to estimate fecal output and calculate apparent nutrient digestibility. Grain energy content (NE_m and NE_g) was calculated based on steer average weight, DMI, and ADG using NRC (1984) equations.

Steers were slaughtered when 70% were visually estimated to grade Choice, and hot carcass weights were collected. All other carcass measurements were taken after a 24-h chill. A USDA grader assigned quality grades and marbling scores.

Data from each trial were analyzed separately since trials were conducted in different years. Weight and carcass data were analyzed using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC) with pen as the experimental unit. Intake and digestibility data were analyzed as repeated measures using PROC MIXED with pen as the experimental unit. Least square means were separated using the Least Significant Difference method when $P < 0.10$.

Results and Discussion

Steer final weights and ADG were not different ($P > 0.73$) between diets at Bozeman; however, final weight and ADG was lower ($P < 0.09$) by steers fed Eslick than by steers fed all other barleys at Havre (Table 2). Gain:feed did not differ ($P > 0.32$) between diets at both locations averaging 15.1 and 15.4 kg gain/100 kg feed at Bozeman and Havre, respectively. Steers fed Eslick had lower ($P = 0.008$) carcass weights compared to steers fed the other 3 barleys at Havre, but there was no difference ($P = 0.67$) in carcass weight between diets at Bozeman. There was no difference ($P > 0.33$) in the other carcass characteristics between barley diets in both studies. This is the first time Eslick and MT960099 have been evaluated in a finishing trial. Differences in performance results between studies could be due to different implant strategies between locations. In agreement with our results, steers fed Valier had similar ADG and carcass characteristics compared to steers fed Haxby (Grove et al. 2006).

Grain energy value was similar ($P > 0.35$) between barleys in both studies averaging 2.21 Mcal/kg NE_m and 1.53 Mcal/kg NE_g at Bozeman and 2.13 Mcal/kg NE_m and 1.45 Mcal/kg NE_g at Havre. These energy values for Haxby and Valier are similar to those reported by Grove et al. (2006); however, these authors reported that steers fed Valier had higher energy values compared to steers fed Haxby.

At Bozeman, intake of DM, N, starch, and ADF were not different ($P > 0.50$) between diets (Table 3); however, at Havre, DM and starch intakes were lower ($P < 0.05$) by steers fed Eslick than by steers fed all other diets. In addition, N intake was lowest ($P < 0.001$) by steers fed Eslick, intermediate by steers fed Haxby and MT960099, and highest by steers fed Valier at Havre. At Havre, ADF intake was also higher ($P < 0.01$) by steers fed Eslick and MT960099 than by steers fed Haxby and Valier. Differences in results between studies could be due to feeding management or weather conditions between locations. Lower DM, N, and starch intakes by steers fed Eslick at Havre could be responsible for their lower ADG and carcass weights. In agreement with the Bozeman data, Grove et al. (2006) also reported similar DM, N, and starch intake by steers fed Haxby and Valier.

Apparent digestibility of DM, N, starch, and ADF was similar ($P > 0.14$) between diets in both studies. Similarly, Grove et al. (2006) also reported no difference in nutrient digestibility between Haxby and Valier.

Implications

This is the first time Eslick and MT960099 have been evaluated in the feedlot. There were few differences in performance, digestibility, and energy content between Haxby, Valier, MT960099, and Eslick barley varieties when evaluated at 2 different locations.

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Table 1. Composition of 4 barley varieties used in finishing diets at 2 locations

	Bozeman				Havre			
Item	Eslick	Haxby	MT960099	Valier	Eslick	Haxby	MT960099	Valier
DM, %	88.94	87.98	88.37	88.38	91.61	92.10	91.62	92.08
N, %	2.03	2.05	2.11	2.03	2.19	2.21	2.24	2.33
ADF, %	5.41	4.18	5.91	7.76	6.01	4.56	4.23	4.23
Starch, %	59.30	57.88	56.71	60.45	52.79	53.14	56.78	53.90
ISDMD, % at 3 h[a]	53.05	41.34	45.13	45.71	42.28	44.66	31.07	35.59
Particle size, um	1314	1352	1481	1467	1341	1191	1377	1265
Bulk density, kg/hL	62	66	59	66	64	67	63	64

[a] ISDMD = in situ DM disappearance

Table 2. Performance and carcass characteristics of steers fed finishing diets based on 4 barley varieties at 2 locations

Item	Eslick	Haxby	MT960099	Valier	SE	*P*-value
Bozeman						
Initial weight, kg	403	402	402	401	0.68	0.37
Final weight, kg	576	577	573	567	7.2	0.73
ADG, kg	1.6	1.6	1.5	1.5	0.07	0.76
G:F, kg gain/100 kg feed	15.1	15.1	15.1	15.0	0.40	0.99
Carcass wt, kg	332	333	328	326	4.8	0.67
KPH fat, %	2.2	2.2	2.2	2.1	0.08	0.96
Fat thickness, cm	1.33	1.32	1.37	1.22	0.100	0.74
REA, cm^2	77.9	76.0	77.4	76.1	1.01	0.48
Marbling score	448	441	498	453	23.0	0.33
USDA quality grade[a]	12.1	12.0	12.5	12.1	0.26	0.56
USDA yield grade	3.3	3.4	3.3	3.2	0.15	0.82
Diet NE_m, Mcal/kg	2.07	2.08	2.04	2.07	0.043	0.92
Diet NE_g, Mcal/kg	1.41	1.42	1.38	1.41	0.038	0.92
Grain NE_m, Mcal/kg	2.22	2.23	2.18	2.22	0.054	0.92
Grain NE_g, Mcal/kg	1.54	1.54	1.50	1.53	0.048	0.92
Havre						
Initial weight, kg	409	411	410	411	1.1	0.65
Final weight, kg	570[b]	584[c]	580[c]	583[c]	3.8	0.09
ADG, kg	1.4[b]	1.5[c]	1.5[c]	1.5[c]	0.03	0.08
G:F, kg gain/100 kg feed	15.9	15.4	15.3	14.8	0.41	0.32
Carcass wt, kg	320[b]	332[c]	338[c]	333[c]	3.0	0.008
KPH fat, %	1.7	1.7	1.7	1.7	0.04	0.78
Fat thickness, cm	0.98	1.11	1.04	1.12	0.082	0.60
REA, cm^2	72.9	75.4	74.1	75.0	1.75	0.75
Marbling score	436	442	433	458	16.0	0.70
USDA quality grade[a]	12.5	12.6	12.5	12.8	0.15	0.42
USDA yield grade	2.9	3.0	3.0	3.0	0.14	0.87
Diet NE_m, Mcal/kg	2.09	2.06	2.04	2.00	0.035	0.36
Diet NE_g, Mcal/kg	1.43	1.39	1.38	1.34	0.031	0.36
Grain NE_m, Mcal/kg	2.19	2.14	2.12	2.08	0.044	0.35
Grain NE_g, Mcal/kg	1.50	1.46	1.44	1.40	0.039	0.36

[a] 11 = Select, 12 = Choice$^-$, 13 = Choice^o, 14 = Choice$^+$

[bc] Means within a row lacking a common superscript letter differ ($P < 0.10$)

Table 3. Nutrient intake and apparent digestibility by steers fed finishing diets based on 4 barley varieties at 2 locations

	Treatment					
Item	Eslick	Haxby	MT960099	Valier	SE	Pr > F
Bozeman						
Intake						
DM, kg	11.1	11.0	11.4	10.6	0.52	0.71
N, g	240	242	255	238	11.8	0.73
Starch, kg	5.12	5.20	5.16	4.88	0.274	0.84
ADF, kg	1.00	0.93	1.07	0.91	0.076	0.50
Apparent digestibility, %						
DM	73.6	71.0	71.1	73.1	0.92	0.14
N	72.7	68.9	70.7	71.4	1.13	0.17
Starch	95.1	93.3	95.2	95.3	0.72	0.21
ADF	15.9	4.0	9.9	7.9	5.58	0.53
Havre						
Intake						
DM, kg	11.2[a]	11.8[b]	11.8[b]	11.9[b]	0.17	0.03
N, g	266[a]	289[b]	292[b]	312[c]	5.7	0.001
Starch, kg	4.78[a]	5.46[b]	5.23[b]	5.37[b]	0.085	0.002
ADF, kg	1.19[b]	1.14[a]	1.22[b]	1.13[a]	0.018	0.01
Apparent digestibility, %						
DM	76.4	78.0	77.8	76.8	1.55	0.85
N	76.8	78.3	79.9	77.2	1.53	0.51
Starch	94.7	95.7	96.0	92.3	0.94	0.14
ADF	28.1	28.9	28.5	28.9	4.71	1.0

[abc] Means within a row lacking a common superscript letter differ ($P < 0.10$)

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FEEDING VALUE OF CORN, 'VALIER' BARLEY, AND CORN/VALIER COMBINATIONS FOR FINISHING STEERS

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ABSTRACT: Eighty crossbred steers (average weight 383 kg) were used to evaluate the performance, nutrient digestibility, and grain energy content of 4 finishing rations based on: corn, 'Valier' barley, 2/3 corn + 1/3 Valier (**66CORN**), or 1/3 corn + 2/3 Valier (**33CORN**). Grain was dry rolled prior to being fed and diets were formulated to be isocaloric (2.04 Mcal/kg NE_m and 1.43 Mcal/kg NE_g) and isonitrogenous (2.6% N). Diets were formulated (DM basis) to contain 80% grain, 6% straw, 3% soybean oil, and 11% vitamin/mineral supplement. Steers were weighed at the beginning and end of the 100-d study, and diet, ort, and fecal samples were collected on d 28, 56, 84, and 100. Acid insoluble ash was used as an internal marker to estimate fecal output and calculate apparent nutrient digestibility. Steers were slaughtered when 70% were visually estimated to grade Choice and carcass measurements were collected after a 24-h chill. Weight and carcass data were analyzed using the GLM procedure of SAS with pen as the experimental unit. Intake and digestibility data were analyzed as repeated measures using PROC MIXED with pen as the experimental unit. Final weight and ADG were not different ($P > 0.48$) between diets, averaging 569 kg and 1.9 kg/d, respectively. Steers fed corn and 66CORN had greater ($P = 0$ 07) G:F compared to steers fed Valier. Carcass characteristics did not differ ($P > 0.15$) between diets. Dry matter intake was greater ($P = 0.05$) by steers consuming Valier than by steers consuming corn and 66CORN. Starch intake was greater ($P = 0.01$) by steers consuming corn and 66CORN than the other two diets. Apparent DM ($P = 0.06$) and ADF ($P = 0.002$) digestibilities were lower by steers consuming Valier than all other diets; however, apparent N and starch digestibilities did not differ ($P > 0.21$) between diets, averaging 71.7 and 90.4%, respectively. Corn grain had a higher NE_m ($P = 0.09$) and NE_g ($P = 0.07$) content than Valier (2.28 vs. 2.05 Mcal/kg NE_m and 1.59 vs. 1.37 Mcal/kg NE_g). There was little benefit to feeding corn and Valier barley in combination compared to feeding each grain alone.

Key Words: Barley, Beef cattle, Corn, Grain mixtures

Introduction

Barley is commonly fed in finishing rations in Canada and throughout the Pacific Northwest; however, it is widely believed that corn has superior feeding value compared to barley. Barley has a faster rate of DM and starch digestion compared to corn (Surber and Bowman, 1998) making cattle on high barley-concentrate diets more prone to ruminal acidosis and bloat (Hunt, 1996).

Early researchers suggested that finishing cattle often tired of eating barley and recommended feeding barley in combination with other grains such as corn or oats in order to increase palatability and reduce the incidence of bloat (Morrison, 1956). Weber (1936) reported that a 50:50 mix of corn and barley was more palatable than either grain fed alone. It has also been hypothesized that feeding combinations of grains having high and low ruminal starch degradability may maximize the benefits of ruminal and intestinal starch digestibility while minimizing the negative effects (Noon et al., 1998). 'Valier' barley was selected for reduced rate of ruminal DM digestion. The objective of this study was to evaluate the performance, digestibility, and energy value of corn, Valier, and combinations of corn and Valier when fed to finishing steers.

Materials and Methods

Eighty crossbred steers (average weight 383 kg) were assigned by weight to 16 pens in a completely randomized design. Steers were fed finishing diets based on corn, Valier barley, 2/3 corn + 1/3 Valier (66CORN), or 1/3 corn + 2/3 Valier (33CORN). Chemical composition of the grains is presented in Table 1. Grains were dry rolled prior to being fed and diets were formulated to be isocaloric (2.04 Mcal/kg NE_m and 1.43 Mcal/kg NE_g) and isonitrogenous (2.6% N). Diets were formulated (DM basis) to contain 80% grain, 6% straw, 3% soybean oil, and 11% vitamin/mineral supplement. Animals were cared for under protocols approved by the Montana State University Animal Care and Use Committee.

Steers were weighed on 2 consecutive days at the beginning and end of the 100-d study. Steers were fed once daily at 0800 and were given ad libitum access to water. Steers were gradually brought up to ad libitum intake of their respective treatment diets over 28 d. Steers were implanted on d 28 with Synovex S (Fort Dodge Animal Health, Fort Dodge, IA). Diet, ort, and fecal samples were collected from individual steers and composited by pen on d 28, 56, 84, and 100. Diet and fecal samples were dried in a 60° C forced-air oven, ground through a Wiley mill (1-mm screen), and analyzed for DM (AOAC, 1999), N (Leco Corporation, St. Joseph, MI), ADF (Van Soest et al., 1991), starch (Megazyme, Sidney, Australia), and AIA (4N HCl method; Van Keulen and Young, 1977). Acid insoluble ash was used as an internal marker to estimate fecal output and calculate apparent nutrient digestibility. Grain energy

content (NE_m and NE_g) was calculated based on steer average weight, DMI, and ADG using NRC (1984) equations.

Steers were slaughtered when 70% were visually estimated to grade Choice, and hot carcass weights were collected. All other carcass measurements were taken after a 24-h chill. A USDA grader assigned quality grades and marbling scores.

Weight and carcass data were analyzed using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC) with pen as the experimental unit. Intake and digestibility data were analyzed as repeated measures using PROC MIXED with pen as the experimental unit. Least square means were separated using the Least Significant Difference method when $P < 0.10$.

Results and Discussion

Steer final weights and ADG were not different ($P > 0.48$) between diets (Table 2). Gain:feed was greater ($P = 0.07$) in steers fed corn and 66CORN compared to steers fed Valier, with steers fed 33CORN having similar G:F to steers fed 66CORN and Valier. Carcass characteristics did not differ ($P > 0.15$) between diets. Early researchers reported that cattle fed barley gained as well as cattle fed corn, but that cattle fed corn or a mix of corn and barley were a little fatter than cattle fed barley alone (Weber, 1936). Dyer and Weaver (1955) reported that cattle fed a 50:50 mix of corn and barley had intermediate ADG, but poorer feed conversion compared to cattle fed either corn or barley alone. More recently, Miller et al. (1996) reported that cattle fed corn, barley, or a corn/barley mix had similar end weights and carcass quality grades. Kincheloe et al. (2003) reported average daily gain and G:F by cattle consuming finishing diets based on corn or Valier barley were similar, but cattle consuming Valier tended to have lower quality grades compared to cattle fed corn. Differences between studies could be due to the variety and/or chemical composition of barley fed and ratio of corn to barley in the mixed diets.

Dry matter intake was greater ($P = 0.05$) by steers consuming Valier than by steers consuming corn and 66CORN, with DMI by steers consuming 33CORN being intermediate and not different from the other diets (Table 3). Nitrogen intake was not different ($P = 0.33$) between diets; however, starch intake was lower ($P = 0.01$) by cattle consuming Valier and 33CORN than by cattle consuming corn and 66CORN. In contrast to our results, Weber (1936) reported that rations containing a mix of corn and barley were more palatable compared to feeding either grain alone and Dyer and Weaver (1955) reported that cattle fed a 50:50 mix of corn and barley consumed more feed than cattle fed only corn or barley. Martín-Orue et al. (2000) reported greater DMI by cattle consuming a 75% concentrate diet composed of 66% barley and 23% corn compared to cattle fed a 75% concentrate diet composed of 23% barley and 66% corn. Kincheloe et al. (2003) also reported similar DMI between steers consuming corn and Valier.

Apparent DM digestibility was lower ($P = 0.06$) for Valier than all other diets (Table 3); however, there was no difference ($P > 0.21$) in apparent N or starch digestibility between diets, averaging 71.7 and 90.4%, respectively. Apparent ADF digestibility was lowest ($P = 0.002$) for the Valier diet, intermediate for the 33CORN and 66CORN diets, and highest for the corn diet. Kincheloe et al. (2003) reported that Valier barley had lower apparent digestibility of DM, OM, N, and ADF compared to corn, while starch digestibility was similar. Martín-Orue et al. (2000) reported similar apparent total tract DM digestibility between 75% concentrate diets containing 66% barley+23% corn or 23% barley+66% corn.

Corn grain had a higher NE_m ($P = 0.09$) and NE_g ($P = 0.07$) content than Valier (2.28 vs. 2.05 Mcal/kg NE_m and 1.59 vs. 1.37 Mcal/kg NE_g). Kincheloe et al. (2003) reported NE_m and NE_g values for corn and barley that were similar to ours; however, they observed no differences in energy content between the 2 grains.

Implications

Greater energy content and higher starch intakes by cattle fed primarily corn were associated with improved feed conversions compared to cattle fed Valier. Lower total tract digestibility of Valier may have reduced the amount of nutrients available to the animal; however, there were no differences in ADG or carcass characteristics between diets. There was little benefit to feeding a mix of corn and Valier in finishing diets compared to feeding the grains alone.

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Table 1. Composition of corn and 'Valier' barley, and finishing diets based on corn and Valier

Item	Corn	66CORN[a]	33CORN	Valier
DM, %	85.4	-	-	90.1
N, %	1.32	-	-	2.93
ADF, %	4.14	-	-	6.9
Starch, %	76.9	-	-	48.1
ISDMD, % at 3 h[b]	35.7	-	-	26.2
Particle size, um	-	-	-	1324
Bulk density, kg/hL	55	-	-	72
Ingredient, % of DM				
Corn	80	53.6	26.4	-
Cracked barley	-	26.4	53.6	80
Barley straw	6	6	6	6
Oil	3	3	3	3
Supplement[c]	11	11	11	11
Feather meal	73.3	32.3	0.75	-
Canola meal	1.25	30.0	30.0	-
Wheat midds	-	13.0	44.7	57.7
Bentonite	-	-	-	21.6
Calcium sulfate	-	-	-	0.85
Urea	3.8	3.8	3.8	-
Calcium carbonate	9.4	9.2	9.4	8.9
Sodium chloride	1.8	1.9	2.0	1.3
Potassium chloride	1.36	0.72	0.32	0.65

[a] 66CORN = 66.7% corn + 33.3% 'Valier' barley; 33CORN = 33.3% corn + 66.7% 'Valier' barley.

[b] ISDMD = in situ DM disappearance

[c] All supplements contained 7.4% sodium bicarbonate, 0.18% trace mineral premix, 0.025% Vitamin A, D, E premix, 1% mineral oil, 0.125% Rumensin, 0.075% Tylan, 0.28% Selenium, and 0.05% Agrisweet flavor.

Table 2. Performance and carcass characteristics of steers fed finishing diets based on corn, 'Valier' barley, or combinations of corn and Valier barley

Item	Corn	66CORN[a]	33CORN	Valier	SE	*P*-value
No. of pens	4	4	4	4		
No. of animals	20	18	20	19		
Weight, kg						
Initial	383	384	382	383	1.0	0.82
Final	567	576	563	570	4.8	0.34
ADG, kg	1.8	1.9	1.8	1.9	0.05	0.48
G:F, kg gain/100 kg feed	16.8[e]	16.4[de]	15.2[cd]	14.8[c]	0.57	0.07
Carcass wt, kg	334	340	333	338	3.1	0.39
KPH fat, %	2.0	2.1	2.0	2.1	0.06	0.36
Fat thickness, cm	1.7	1.5	1.5	1.6	0.09	0.66
REA, cm^2	73.3	76.0	75.4	72.7	1.70	0.48
Marbling score	432	445	429	482	18.0	0.19
USDA quality grade[b]	12.0	12.0	11.8	12.5	0.19	0.15
USDA yield grade	3.7	3.5	3.4	3.7	0.16	0.61

[a] 66CORN = 66.7% corn + 33.3% 'Valier' barley; 33CORN = 33.3% corn + 66.7% 'Valier' barley.
[b]11 = Select, 12 = Choice$^-$, 13 = Choice^o, 14 = Choice$^+$.
[cde] Means within a row lacking a common superscript letter differ ($P < 0.10$).

Table 3. Nutrient intake and apparent digestibility by steers fed finishing diets based on corn, 'Valier' barley, or combinations of corn and Valier barley

	Treatment					
Item	Corn	66CORN[a]	33CORN	Valier	SE	*P*-value
Intake						
DM, kg	11.6[b]	12.2[b]	12.3[bc]	13.1[c]	0.32	0.05
N, g	323	302	313	323	9.0	0.33
Starch, kg	6.4[c]	6.1[c]	5.6[b]	5.5[b]	0.18	0.01
ADF, kg	0.89[b]	0.93[bc]	1.01[c]	1.20[d]	0.044	0.001
Apparent digestibility, %						
DM	76.0[c]	74.8[c]	75.3[c]	68.1[b]	2.01	0.06
N	72.2	73.1	73.9	67.5	2.17	0.21
Starch	91.3	89.2	90.9	90.0	0.85	0.35
ADF	41.2[d]	33.9[cd]	30.2[c]	12.3[b]	4.15	0.002

[a] 66CORN = 66.7% corn + 33.3% 'Valier' barley; 33CORN = 33.3% corn + 66.7% 'Valier' barley.
[bcd] Means within a row lacking a common superscript letter differ ($P < 0.10$).

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FEEDLOT PERFORMANCE AND SERUM METABOLIC HORMONE PROFILES IN LAMBS RECEIVING FOUR LEVELS OF SOYBEAN MEAL SUPPLEMENTATION

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ABSTRACT: Twenty Rambouillet wether lambs (initial BW = 27.6 ± 0.5 kg, age = 103 ± 1.2 d) were assigned randomly to 1 of 4 treatments (5 lambs/treatment) to examine effects of dietary CP level on intake, growth, and serum hormone profiles. Lambs were penned individually (3 x 9 m) and fed a 70% corn-based concentrate diet with sudangrass as the roughage source and soybean meal to supply CP levels of 9.5, 11.5, 13.5, and 15.5% (ratio of ruminally degradable intake protein:TDN = 0.073, 0.091, 0.11, 0.129, respectively) . Lamb BW were recorded every 21 d, orts were weighed daily, serum was collected weekly, and ruminal fluid was collected twice during the 84-d feeding period. Animal BW tended to increase linearly (P = 0.09*)* with increasing dietary CP (39.3, 42.9, 43.9, 44.1 ± 1.9 kg for lambs receiving 9.5, 11.5, 13.5, and 15.5% CP on d 84, respectively). Likewise, ADG and G:F tended to improve (P = 0.10) in a linear fashion as CP level increased. Daily DMI also increased (quadratic, P = 0.10) over the 84-d feeding period (1.22, 1.37, 1.34, 1.30 kg/d for lambs fed 9.5, 11.5, 13.5, and 15.5 % CP, respectively). Total ruminal VFA production tended (P = 0.09) to increase with increasing CP level. Ruminal ammonia concentration increased linearly (P < 0.01) with increasing CP level (1.8, 6.0, 7.3 and 10.9 ± 0.87 m*M* for 9.5, 11.5, 13.5 and 15.5% CP, respectively). Serum growth hormone and triiodothyronine did not differ (P > 0.30) among dietary treatments while serum IGF-1 increased (linear, P = 0.03) with increasing levels of CP (138, 176, 180, and 180 ± 11.6 ng/mL in lambs receiving 9.5, 11.5, 13.5, and 15.5% CP, respectively; CP x week, P = 0.66). Serum prolactin also differed (cubic, P = 0.03) among CP levels (187, 344, 262, and 258 ± 29 ng/mL for 9.5, 11.5, 13.5, and 15.5% CP, respectively; CP x week, P = 0.97). Within week (CP x week, P = 0.04), serum thyroxine responded to dietary CP by increasing linearly (P < 0.10) from wk 4 through 9 of the 12-wk experiment. Increasing dietary CP from 9.5 to 15.5% tended to improve DMI, ADG, and G:F in Rambouillet lambs with the largest improvement resulting from 11.5% CP. This performance response may have partially resulted from altered serum concentrations of IGF-1 and prolactin.

Key Words: Dietary Protein, Growth, IGF-1, Prolactin, Sheep, Thyroid Hormones

INTRODUCTION

Feedlot performance in lambs is influenced by nutrient intake and the metabolic hormones that regulate growth. Understanding dietary protein requirements and the relationship of dietary protein and metabolic hormones has the potential to improve efficiency of production in feedlot lambs. Increasing dietary CP is generally believed to increase ADG and feed intake (Hudson et al., 1969; Craddock et al., 1974; Woolley et al., 2005). Protein requirements in feedlot lambs vary from 10.0 to 14.7% (NRC, 1985) but specific levels and protein sources have not been thoroughly examined. Ruminants require degradable protein for ruminal fermentation to digest OM and synthesize microbial protein (NRC, 1996). Therefore, protein available for absorption depends not only on CP level in the diet but also on the efficiency with which the CP is used by rumen microbes to synthesize protein and the feed protein that reaches the small intestine undigested in the rumen. The relationship between CP level and metabolic hormone profiles has not been greatly explored. Hersom et al. (2004) reported that an increased rate of gain was associated with an increased serum IGF-1, triiodothyronine (T3), and thyroxine (T4) over values determined in finishing steers having a low rate of gain. Ellenberger et al. (1989) reported similar results showing that nutrient restriction decreased concentrations of IGF-1 and T4 while an increase in growth hormone (GH) was noted. Previous work from our laboratory (Garcia et al., 2005) detected correlation coefficients greater than 0.40 between serum T3 and T4 values at 14 d of age and weaning weight. Prolactin (PRL) has also been reported to have an effect on growth (Turner and Bagnara, 1976), and GH and PRL are homologous hormones that arose from gene duplication (Bolander, 1994). Objectives of this study were to examine effects of increasing levels of dietary CP using soybean meal as source of ruminally degradable protein on feedlot performance and metabolic hormone profiles in Rambouillet lambs.

MATERIALS AND METHODS

Twenty spring-born Rambouillet wether lambs born on the main campus at New Mexico State University were used in this study. All procedures were approved by the Institutional Animal Care and Use Committee. Lambs were docked at 1 d of age, castrated at 28 d of age, and vaccinated against tetanus and enterotoxemia at 28 d of age and again at weaning (approximately 60 d of age). During the preweaning period, lambs had free access to alfalfa hay and cracked corn was offered at levels appropriate for age and BW. After weaning, lambs were

fed alfalfa hay and cracked corn until they were approximately 80 d of age at which time they began an adaptation period to the basal experimental diet. When lambs weighed 27.6 ± 0.5 kg and were 103 ± 1.2 d of age, they were stratified by BW and randomly assigned to 1 of 4 dietary treatments. During the 84-d experiment, lambs were maintained outdoors in individual pens (3 x 9 m) and had free access to water and their experimental diet.

All diets were composed of 30% sudangrass as the roughage source. The basal diet contained 62.2% ground corn with no supplemental soybean meal, yielding a CP content of 9.5%. The remaining diets had 58.2, 54.2, and 50.2% ground corn and were supplemented with 4.2, 8.4, or 12.6% soybean meal, respectively, to yield respective CP (DM basis) levels of 11.5, 13.5, and 15.5%. Other dietary ingredients were incorporated in similar amounts in all diets and included molasses (3%), tallow (approximately 0.3%), ammonium chloride (1%), salt (1%), and a vitamin premix (1%; 2,200 IU/g vitamin A, 1,200 IU/g Vitamin D_3, and 2.2 IU/g vitamin E). The ratio of degradable intake protein to TDN was 0.073, 0.091, 0.11, and 0.129 for the diets containing 9.5, 11.5, 13.5, and 15.5% CP, respectively. Fresh feed was offered daily in amounts to stimulate ad libitum intake and orts were recorded daily. Orts were pooled weekly and DM was determined. Lambs were weighed at 21-d intervals.

Ruminal fluid samples were collected on d 35 and 50 at 4 h after feeding using a stainless steel strainer passed through the mouth. Ruminal fluid samples were used to measure pH and analyze ruminal ammonia and volatile fatty acid (VFA) concentration.

Blood samples were collected from each lamb weekly before feeding. Samples were obtained by jugular venipuncture into sterile vacuum tubes (Corvac Serum Separator, Kendall, St. Louis, MO). Blood was allowed to clot at room temperature for approximately 30 min after which serum was harvested by centrifugation at 1,500 g for 15 min at 4º C. Serum was transferred to plastic vials and stored frozen until analyzed. Hormone concentrations were determined by RIA. Serum T4 and T3 were determined by solid phase RIA using components of commercial kits (Coat-A-Count, Diagnostic Products Corp., Los Angeles, CA) and validated for ruminant serum in our laboratory as described by Richards et al. (1999) and Wells et al. (2003), respectively. Concentrations of GH, IGF-1, and PRL were quantified by double antibody RIA as described by Hoefler and Hallford (1987), Berrie et al. (1995), and Spoon and Hallford (1989), respectively. Within and between assay CV for all determinations were less than 15%.

Lamb performance responses (BW, ADG, ADFI, and G:F) were subjected to ANOVA appropriate for a completely random design with animal as the experimental unit. Analyses were computed using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC). Because treatments were arranged with increasing levels of dietary CP, linear, quadratic, and cubic responses were also examined.

Ruminal fermentation and hormone data were analyzed by split-plot analysis of variance using Mixed procedures of SAS. The model included CP level, day of collection, and the day by CP level interaction. The repeated effect was day of collection and animal within CP level was used to test treatment effects. Compound symmetry was the covariate structure that best fit the data. When treatment by sampling day interactions were detected, treatment effects were examined within sampling day. Linear, quadratic, and cubic treatment responses were evaluated.

RESULTS AND DISCUSSION

Growth Responses

Weight and growth responses of lambs receiving 4 levels of dietary CP are shown in Table 1. At the beginning of the experiment, lamb BW was similar (P = 0.86) among the 4 diets. Likewise after 42 d, lamb BW did not differ (P = 0.36) among groups but actual values began to suggest that lambs consuming 9.5% CP may not have been responding to the extent of lambs receiving the other diets. At the end of the experiment (d 84), lamb BW tended to increase with increasing dietary CP (linear, P = 0.10). This trend was also apparent in ADG over the entire 84-d period in that lambs receiving 9.5, 11.5, 13.5, and 15.5% CP gained 147.5, 184.9, 188.0, and 192.2 g/d, respectively (linear, P = 0.10). A similar linear trend (P = 0.10) was also observed for G:F while DMI tended to respond in a quadratic fashion (P = 0.11) to increasing dietary CP levels. These growth responses indicate that dietary CP levels for lambs may need to be in the range of 11% to provide optimum ruminally degradable intake protein for support of ruminal microbial populations. Satter and Syter (1974) reported that diets deficient in ruminally degradable intake protein may limit microbial growth. Other researchers also reported positive weight responses to increasing dietary protein (Craddock et al., 1974; Dabiri and Thonney, 2004) although Woolley et al. (2005) observed no benefit to ADG and G:F.

Ruminal Fermentation

Individual ruminal VFA molar proportions were not affected (P > 0.40) by dietary CP level. However, total ruminal VFA production tended (P = 0.09) to increase with increasing CP level. This tendency implies that rumen fermentation tended to increase with increasing CP level.

Ruminal ammonia concentration increased linearly (P < 0.01) with increasing CP level (1.8, 6.0, 7.3 and 10.9 ± 0.87 mM for 9.5, 11.5, 13.5 and 15.5% CP, respectively). Net microbial synthesis in vitro is maximized with an ammonia concentration of 3.5 mM (Satter and Slyter, 1974) and in vivo with a ruminal ammonia concentration of 1.6 mM (Slyter et al., 1979). Brown et al. (2000) observed that increasing urea levels increased ammonia concentration in in vitro incubation with corn as the substrate. Accumulation of ruminal ammonia indicates that microbial requirements were exceeded. In the present study, the greater increment in ammonia concentration occurred from 9.5 to 11.5%

dietary CP, which agrees with the growth responses that seem to be optimized with CP level of 11.5%.

Serum Hormone Profiles

The tendency for growth responses to increase with increasing dietary CP levels was investigated further by examining profiles of several metabolic hormones across the 84-d feeding period. Serum GH was quantified in samples collected weekly (before feeding). No dietary CP by sampling day interaction was detected (P = 0.95) and values pooled across weeks were 2.5, 2.9, 2.2, and 2.9 (± 0.4) ng/mL for lambs receiving 9.5, 11.5, 13.5, and 15.5% CP, respectively (P = 0.56). The authors realize that the pulsatile nature of GH secretion limits the value of these data and they are provided only as reference values for these types of animals under the conditions of this experiment.

Because a dietary CP by sampling week interaction was detected for serum IGF-1 concentration (P = 0.06), treatment values for each sampling day are shown in Figure 1. The data demonstrate that IGF-1 in lambs fed 9.5% CP was generally lower on most sampling days than in lambs fed the 3 higher levels of CP. If the IGF-1 values are pooled over all sampling days, lambs fed 9.5, 11.5, 13.5, and 15.5% CP had 138, 176, 180, and 180 (± 12) ng/mL, respectively (linear, P = 0.03). Hersom et al. (2004) also reported elevated IGF-1 concentrations in steers fed to support a high rate of gain compared with those having a low rate of gain. Ellenberger et al. (1989) suggested that increased dietary protein appeared to increase serum IGF-1 which then resulted in improved growth rates.

The 4 respective dietary CP groups had serum PRL concentrations of 187, 344, 263, and 258 (± 29) ng/mL (quadratic, P = 0.02; treatment by day, P = 0.98). Although PRL is generally thought to influence reproduction and(or) lactation in various species, the effects of this hormone on growth responses are also well recognized (Turner and Bagnara, 1976).

Concentrations of the I-containing hormones from the thyroid gland were also determined. Serum T3 did not differ (P = 0.30) among dietary CP groups (1.54, 1.40, 1.56, and 1.50 ± 0.06 ng/mL, respectively; treatment by day, P = 0.66). Figure 2 shows serum T4 concentrations on each sampling day (treatment by sampling day, P = 0.04). As with IGF-1, serum T4 was generally lower in lambs receiving 9.5% CP than in lambs fed the other 3 diets. If the values are examined across days, lambs receiving 9.5, 11.5, 13.5, and 15.5% CP had serum T4 values of 47, 51, 52, and 55 ± 3 ng/mL, respectively (linear, P = 0.10). As with IGF-1, Hersom et al. (2004) observed elevated serum T4 in steers having high rates of gain. Likewise, Hayden et al. (1993) reported that elevated T4 was positively associated with energy consumption. Previous work from our laboratory (Garcia et al., 2005) also detected positive relationships between serum T3 and T4 and weaning weight of lambs during the preweaning period.

IMPLICATIONS

Soybean meal can be used to meet the ruminally undegradable protein requirements of growing lambs. The most appropriate CP level of 70% concentrate corn-based diets appeared to be around 11.5% with soybean meal as the supplemetal ruminally degradable protein source.

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Table 1. Feedlot performance of Rambouillet wether lambs fed increasing levels of dietary crude protein during an 84-d period

	Dietary CP, %[1]				
Item	9.5	11.5	13.5	15.5	SE[2]
Weight, kg					
Day 0[3]	26.9	27.4	28.1	27.9	1.1
Day 42	34.5	37.1	38.2	36.9	1.5
Day 84[4]	39.3	42.9	43.9	44.1	1.9
Performance[5]					
ADG, g/d[4]	147.5	184.9	188.0	192.2	17.7
DMI, kg/d[6]	1.22	1.37	1.34	1.30	0.06
G:F[4]	120.9	133.9	139.6	147.8	10.2

[1]Diets contained (DM basis) 30% sudangrass hay with ground corn at 62.2, 58.2, 54.2, and 50.2% and soybean meal at 0, 4.2, 8.4, and 12.6% in the 9.5, 11.5, 13.5, and 15.5% CP treatments, respectively.
Row values without superscripts do not differ ($P > 0.20$).
[2]Based on 5 individually fed lambs/treatment.
[3]Day 0 was the first day that experimental diets were fed.
[4]Linear ($P = 0.10$).
[5]Performance data based on the entire 84-d feeding period.
[6]Quadratic ($P = 0.11$).

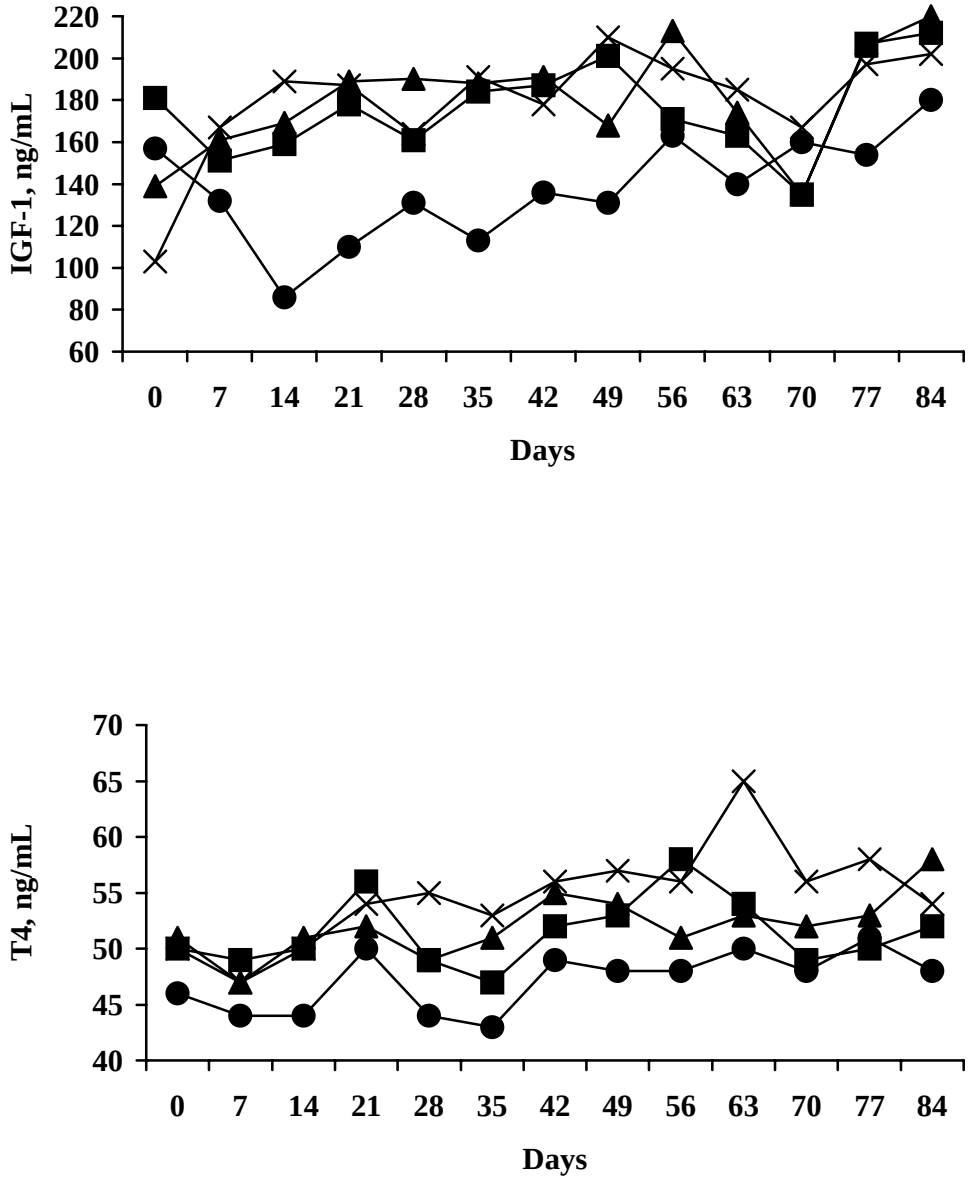

Figure 1. Serum IGF-1 (top panel, SE ranged from 12.0 to 28.7 ng/mL on individual days) and thyroxine (T4; bottom panel, SE ranged from 2.9 to 4.1 ng/mL on individual days) profiles in Rambouillet wether lambs fed increasing levels of dietary crude protein: 9.5% (--●--; n = 5), 11.5% (--■--; n= 5). 13.5% (--▲--; n = 5), and 15.5% (--x--; n= 5). Diets were fed for 84 d and serum samples were obtained weekly.

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EVALUATION OF ANIMAL PERFORMANCE IN CROSSBRED HAIR LAMBS FED WITH A HIGH CONCENTRATE DIET[1]

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ABSTRACT: This study was conducted to evaluate performance of hair crossbred lambs in terms of dry matter intake (DMI), average daily gain (ADG) and gain efficiency (GE) under production conditions of lambs for the mexican market . Forty two post weaning lambs with an average age of 90 d and an average body weight of 24 kg were used. Lambs came from Suffolk (SF), Charollais (CH), Blackbelly (BB), Pelibuey (PB), and Katahdin (KH) rams and BB and PB ewes. Lambs were housed in individual stalls, fed *ad libitum* a diet consisting of (as-fed basis %): alfalfa hay (20.82), dry rolled corn (57.58), cotton seed meal (11.79), corn gluten meal (4.95), cane molasses (3.57), salt (.44), mineral and vitamin premix (.44), and calcium carbonate (.37). Amounts of feed and orts were recorded daily and lambs were weighed every 14 d until slaughter weight (45 to 50 kg for SF and CH, 40 to 45 kg for KH, and 35 to 40 kg for BB and PB), in a feeding period of 56 to 112 d. A model including fixed effects of ram breed, weaning type (singles, twins and triplets), ewe age, and their double and triple interactions was adjusted for measured variables. For GE there were a difference between BB and SF, CH and PB ($P < 0.10$). For ADG at 56 d of test, BB was lower than CH and SF ($P < 0.10$). However, for ADG through slaughter weight the mean was lower for BB than for CH and SF ($P < 0.10$). There were not differences for GE due to lamb age ($P > 0.05$), but there were for lamb breed group ($P < 0.10$) in the whole test. Crossbreeding of hair type ewes with terminal wool type rams improves average daily gain and feed efficiency compared to straight bred hair sheep.

KEYWORDS: Hair sheep, Growth, Feed efficiency

Introduction

Sheep meat production is an alternative to supply animal protein to a bigger population as that of Central Mexico. There exist different options to increase sheep production, one being crossbreeding programs. However, there is little information in Mexico regarding crossbreeding wool and hair breeds in order to obtain the better weaned crossbred lamb that uses feed more efficiently, while being more resistant to climate and diseases. Crossbreeding is used to increase fertility and productive parameters like average daily gain, feed efficiency, as well as more lambs per ewe (Brown and Jackson, 1995; Bores et al., 2002). Bunge (1995) reported that hair ewes have bigger lamb production than wool ewes and Bunge et al. (1993) mention that crossbred lambs must be more productive than their progenitors compensating for their crossing. Studies conducted with lambs receiving high concentrate diets have shown improved average daily gain, feed efficiency and carcass traits (Borton et al., 2005), however this is not a common practice in Chihuahua sheep units. This study was conducted to evaluate performance of hair crossbred lambs receiving a high concentrate diet under production conditions for the mexican market.

Materials and Methods

The study was conducted in the metabolic facilities of the Facultad de Zootecnia of the Universidad Autonoma de Chihuahua, located at Chihuahua City.

Forty two weaned lambs with an average age of 90 d and an average body weight of 24 kg were used. Lambs came from Suffolk (**SF**), Charollais (**CH**), Black belly (**BB**), Pelibuey (**PB**), and Katahdin (**KH**) rams and BB and PB ewes primiparous and multiparous. Lambs per sire breed group were **SF**, 10; **CH**, 10; **BB**, 10; **PB**, 7; and **KH,** 5. Received a vitamin A injection and were treated for internal and external parasites and then were housed in individual stalls. They have an adaptation period of 15 d starting with a 50:50 forage : concentrate until they receive *ad libitum* the finishing diet consisting of (as-fed basis, %): alfalfa hay (20.83), dry rolled corn (57.58), cotton seed meal (11.8), corn gluten meal (4.96), cane molasses (3.57), salt (.44), mineral and vitamin premix (.44), and calcium carbonate (.37). amounts of feed and orts were recorded daily and lambs were weighed every 14 d with a 12 h feed withdrawal, until they reached the market live weight (kg) which was as follows: **BB** and **PB**, 35-40; **KH,** 40-45; and **SF** and **CH** 45-50.

Statistical analysis. The data were analyzed as a completely randomized design (Steel and Torrie, 1988) with the GLM of SAS, using a model that included fixed effects of ram breed, weaning type (singles, twins and triplets), ewe age, and their double and triple interactions (SAS, SAS Inst. Inc., Cary, NC).

Results and Discussion

There was no difference in initial body weight of lambs (P > 0.05) being **SF** and **BB** lower (Table 1) because most of the lambs were twins and triplets (Bunge et al., 1995). However, final body weight or 112 d on test (Table 1) was different (P < 0.05), **CH** and **SF** were the heaviest followed by **KH** and **PB**, and **BB** was the lightest (Bunge et al., 1993; Noter et al., 2004). Our results indicate that there was no difference in dry matter intake (P > 0.05) but **BB** had the lower intake (0.95 kg) and **KH**, **SF** and **CH** had a higher DMI than **BB**; 20, 20 and 25 %, respectively (Table 1).

Results for ADG at 56 d and 112 d on test showed that **BB** had again the poorer performance although it was similar to **PB** and **KH**, while **CH** and **SF** had the highest weight gain (P< 0.10).

On the other hand, gain efficiency at 56 d indicates that **SF** was the more efficient breed group and **PB** had similar performance; **PB**, **CH** and **KH** were similar, the least efficient was **BB**. Final GE was different (P< 0.10), **SF** was the most efficient crossing but equal to **CH, PB** and **KH** and the latter had a similar performance to **BB** and this showed the lowest efficiency (Table 1). Our results indicate a general trend to lose gain efficiency as days on feed increases within breed group (Borton et al., 2005).

Implications

Crossbreeding of hair type ewes with terminal wool type rams improves average daily gain and feed efficiency compared to straight bred hair sheep while maintaining desirable reproductive traits of hair ewes.

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Table 1. Performance of crossbred lambs fed a high concentrate diet

	Breed Group				
Item	PB	BB	KH	CH	SF
Initial BW	25.60	22.64	24.40	25.02	23.02
Final BW (kg)	39.10^{b}	35.97^{c}	41.77^{b}	45.66^{a}	46.09^{a}
AVG days on test	62	78	73	77	87
DMI (kg)	1.07	0.95	1.14	1.19	1.14
ADG 56 d (kg)	0.24^{ab}	0.18^{b}	0.24^{ab}	0.27^{a}	0.29^{a}
Final ADG (kg)	0.23^{ab}	0.17^{b}	0.24^{ab}	0.27^{a}	0.29^{a}
GE 56 d	4.30^{ab}	5.45^{c}	4.87^{b}	4.32^{b}	3.29^{a}
Final GE	4.64^{a}	5.91^{b}	5.09^{ab}	4.66^{a}	3.91^{a}

^{abc} Means within a row lacking a common superscript differ (P < 0.05) for BW and DMI, all other (P < 0.10).

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Effect of white corn processing method on some digestion indicators of Brahman cross finishing bulls

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ABSTRACT. With the objective to determine the influence of steam-flaking processing of white corn on some digestion indicators of Brahman cross finishing bulls, a digestion experiment was performed. Eighty four bulls (324.61 ± 1.7 kg) proximately 75% of Brahman blood, placed in 12 pens and involved in a feedlot experiment were used. Animals were fed with a finishing diet (88% concentrate), containing 68.61% (DM basis) of dry-ground white corn (DGC); or diet similar to previously described, but containing 68.61% of steam-flaked white corn, that substituted entirely the dry-ground corn (SFC). On d 56 to 60, grab samples and feed samples were taken from each pen, fecal pH was measured in fresh feces samples. For feed and feces samples, content of DM, OM and acid insoluble ashes was determined, and apparent digestibility was calculated. Postmortem rumen pH was measured. The experiment was analyzed as a completely randomized design, and each pen was considered as an experimental unit. Corn processing method had not effect (P = 0.14) on *postmortem* rumen pH. SFC diminished (P < 0.01) 17% DM of feces. SFC increases (P = 0.04) 6.4% DM digestibility, and 6.6% OM digestibility. Fecal pH was augmented (P < 0.01) 4.5% by SFC. Fecal starch was reduced (P < 0.01) in 84% by SFC. Apparent starch digestibility was enhanced (P < 0.01) 14% by SFC (85.86 *vs*. 98.19%, for DGC and SFC, respectively). It is concluded, that steam-flaking processing of white corn, improves the apparent dry matter, organic matter and starch digestibility of the diet of finishing cattle, in magnitudes near that obtained with dent yellow corn.

Key words: White corn, steam-flaking, Digestibility.

Introduction

White corn is the type of grain mainly used to integrate the diets for feedlot cattle in the Northwest of Mexico. Is known that steam-flaking processing of yellow corn, increases dry matter and organic matter digestion (Lee *et al*., 1982; Ramirez et al., 1985), as well improves apparent starch digestion (Ramirez *et al.,* 1985; Zinn, 1987), and augmenting fecal pH (Zinn, 1987; Barajas and Zinn, 1998), however, there is little information about the influence of steam-flaking processing method on digestion indicators. This experiment was conducted with the objective of determine the influence of steam-flaking processing of white corn on some digestion indicators of Brahman cross finishing bulls.

Material and Methods

Location

The experiment was conducted in the Experimental Station for Beef Cattle of the Universidad Autónoma de Sinaloa, inside of Feedlot yard "Ganadera Los Migueles, S.A. de C.V." in Culiacán, Sinaloa, localized in the Northwest of Mexico (20º 48' N. and 107º 23' W. ; 60 m o.m.s.l.; mean temperature 25 ºC, and 645 mm of raining fall).

Animals

Eighty four bulls (324.61 ± 1.7 kg) proximately 75% Brahman blood with remainder of Simmental, Charolais, Brown Swiss, or Angus in indeterminate proportions, involved in a feedlot performance experiment were used.

Treatments

Animals were blocked by body weight, and in groups of seven were housed in ground flour pens (6 x 12 m). After a ten days adaptation period, agreement with a complete randomized block design experiment (Hicks, 1973), were assigned to receive one of two diets in that consisted the treatments: 1) Finishing diet (88% concentrate), containing 68.61% (DM basis) of dry-ground white corn (DGC); or 2) Diet similar to previously described, but containing 68.61% of steam-flaked white corn (SFC), substituting entirely the dry-ground corn.

Experimental Procedure

The bulls were fed under free access condition (105% of voluntary food intake of previous week), offering once a day (1600 h) the diets that appear in table 1. Animals had permanently access to fresh and clean drinking water.

After 56 eating experimental diets, dietary and fecal grab samples were taken during four consecutive days. Diet samples consisted in 2,000 g of food obtained directly from feed-bunk immediately after diet was served. In each pen, four grab samples; proximately 200g each, were taken directly from the flour just was excreted by the animals. The fecal sampling procedure was performed at 600 h, 1000 h, 1400 h, and 1800 h on days 57, 58, 59, and

60, respectively. Fecal pH was measured immediately as excreta sample was obtained, mixing 50 g of fecal sample with 50 g of deionized water and inserting general-purpose pH electrode (Haaland *et al*., 1982). Dietary and fecal samples were oven dried (110 ºC for 48 h), after that were ground. Fecal samples (16) from a same pen were mixed to integrate a pooled representative sample, and then 100 g analytical sample was obtained. Food and fecal samples were burned (550 ºC by 3 h); the resulting ashes were boiled during 15 min in a 4 N HCl-solution to determine acid insoluble ashes content (Van Keulen and Young, 1977). Using acid insoluble ashes (AIA) as internal digest marker, apparent dry matter digestibility and apparent organic matter digestibility were calculated using the equations proposed by Schneider and Flatt (1975). From fecal pH values, fecal starch content was calculated using the equations: Fecal starch in DRC diets, % = 100.05 - (13.3766 * fecal-pH); r = -.58, P < 0.01, and Fecal starch in SFC diets, % = 28.056 – (3.8809 * fecal-pH); r = -.39, P < 0.02, (Barajas and Zinn, 1998). Apparent starch digestibility was derivate from fecal starch content, using the equations: Starch apparent digestibility, % = 101 – (0.78 * fecal starch); r = - 0.99, P < 0.01 (Barajas and Zinn, 1998). Once complete 70 d feedlot experiment, animals were sacrificed in a slaughterhouse, proximately 6 h after was removed from its respective pen. Immediately after cattle were death, rumen samples were taken and pH value was obtained by inserting general-purpose pH electrode.

Table 1. Composition of the diets used in the experiment.

Ingredients	Dry-ground Corn	Steam-flaked Corn
Dry-ground corn	68.61	-
Steam-flaked corn	-	68.61
Corn straw	12.20	12.20
Soybean meal	6.01	6.01
Sugar cane molasses	4.17	4.17
Tallow	4.41	4.41
Pork meat and bone meal	2.00	2.00
Ganamin Total [1]	2.78	2.78
Total	100%	100%
Calculated Analyses DM basis [2]		
CP, %	13.17	13.17
NEm, Mcal/kg	2.048	2.153
NEg, Mcal/kg	1.385	1.467

[1] Ganamin Total ® (Técnica Mineral Pecuaria, S.A. de C.V.; Guadalajara, Jalisco), vitamin and mineral premix.
[2] Calculated from tabular values (NRC, 1996).

Statistical Analysis.

As block did not have significant effect, was removed from the model, and the results of experiment were analyzed as a completely randomized design (Hicks, 1973), each pen was considered as the experimental unit, using ANOVA/COV of GLM procedures of Satistix 8 ® (Analytical Software; Tallahassee, FL).

Results and Discussion

The results of the influence of white corn processing method on some indicators of digestion metabolism are presented in table 2.

The corn processing method had not effect (P = 0.14) on postmortem ruminal pH. In despite that usually SFC diminished rumen pH during the first 3 h after feeding, is common that 6 h after feeding there are not difference on rumen pH value due to corn processing method (Lee et al., 19821; Barajas and Zinn, 1998). SFC decreased (P < 0.01) 17% the DM content of the feces. Organic matter content of the feces was diminished (P = 0.02) in 9% by SFC. SFC processing, increased (P < 0.05) 6.4% apparent dry matter digestibility. This result is agreement with the 6.7 % of improvement observed by Johnson *et al*. (1968). The steam-flaked processing of white corn improved (P < 0.05) in 6.6% apparent organic matter digestibility. This value is intermediate between the 4.6% and the 8.3% observed by Ramirez et al. (1985) and Zinn *et al*. (1995), respectively.

Fecal pH was augmented (P < 0.01) 4.5% by SFC. This value is in close agreement with the 4.5% found by Barajas and Zinn (1998), and near to 8% observed at day 56 by Lee *et al.* (1982). Fecal pH has been shown an inverse relationship with fecal starch content (Barajas and Zinn, 1998). Calculated fecal starch content was reduced (P < 0.01) 84% due to SFC. Similar reductions on fecal starch has been previously observed by Lee *et al*. (1982), and Barajas and Zinn (1998), then fecal starch values near of 20% and 3% for dry corn processed diets and steam-flaked corn diets, respectively, are in concordance with expected. Estimated apparent starch digestibility was enhanced (P < 0.01) in 14 % by SFC. The 98.1% of starch digestibility for SFC-diets is agree with results of mostly experiments conducted using dent yellow corn that ranking from 97% (Zinn, 1987) to 99.1 (Zinn *et al*., 1995); while the 85.8% of starch digestibility for dry-ground white corn diets, appears intermediate across wide spread values observed for dry-processed yellow corn, ranking since 78.3% (Lee *et al*., 1982) until 95.8% (Cole et al., 1976).

Implications

The results of this study, suggest steam-flaking processing of white corn, improves the apparent dry matter, organic matter and starch digestibility of the diet of finishing cattle, in magnitudes near that obtained with dent yellow corn.

Acknowledgments

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Table 2. Effect of white corn processing method on several indicators of digestive metabolism of finishing Brahman cross bulls.

Variable	Treatments		SEM [1]	*P-Value*
	Dry ground corn	Steam-flaked corn		
Bulls, n	42	42		
Pen, n	6	6		
Days in trial, n	70	70		
Days at fecal sampling, n	56	56		
Rumen pH (*postmortem*)	5.71	5.76	0.16	0.14
DM in feces, %	25.05	20.74	0.80	< 0.01
Moisture in feces, %	74.95	79.26	0.80	< 0.01
MO in fecal DM, %	82.45	75.00	2.32	0.02
Apparent DM digestibility, % [2]	67.41	71.75	1.62	0.04
Apparent OM digestibility, % [2]	68.77	73.34	1.67	0.04
Fecal pH	6.03	6.30	0.08	< 0.01
Starch in feces, % [3]	19.39	3.06	0.79	< 0.01
Apparent starch digestibility, % [4]	85.86	98.19	0.62	< 0.01

[1] Standard error of the means.
[2] Estimated using acid insoluble ashes as internal marker.
[3] Estimated from pH-values using equations proposed by Barajas and Zinn (1998).
[4] Estimated from fecal starch using the equation proposed Barajas and Zinn (1998).

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Effect of white corn processing method on feedlot performance of Brahman cross finishing bulls

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ABSTRACT. The objective of this study was to determine the influence of steam-flaking processing method of white corn on the feedlot performance of Brahman cross finishing bulls. A 70 d feedlot experiment was conducted using eighty four bulls (324.61 ± 1.7 kg), proximately 75% of Brahman blood with remainder of Simmental, Charolais, Brown Swiss, or Angus in indeterminate proportions. This was a complete randomized block design experiment, and treatments were assigned to receive one of two diets in that consisted of: 1) Finishing diet (88% concentrate), containing 68.61% (DM basis) of dry-ground white corn (DGC); or 2) Diet similar to previously described, but containing 68.61% of steam-flaked white corn, substituting entirely the dry-ground corn in to the diet (SFC). SFC did not affect (P = 0.69) ending weight. ADG was similar (P = 0.41) in both treatments. DMI was diminished (P < 0.01) in 8.8% by steam-flaked corn (8.35 *vs*. 7.61 kg/d). Feed/gain ratio was improved (P < 0.01) 11.9% by SFC (5.835 *vs.* 5.139 kg/kg). Diet NEm was enhanced (P < 0.01) in 9.9% by SFC (2.059 *vs.* 2.264 Mcal/kg). Diet NEg was increased (P < 0.01) in 12.8% with inclusion of SFC (1.396 *vs.* 1.576 Mcal/kg). The NE content of steam-flaked white corn was estimated to be 2.479 and 1.762 Mcal/kg for NEm and NEg, respectively. It is concluded, that steam-flaking processing of white corn, improves its energy availability nearly 13%, with respect to dry ground white corn. The benefits of steam-flaked processing on feedlot performance are beyond those attributed by tabular values.

Key words: White corn, steam-flaking, feedlot cattle.

Introduction

White corn is the type of grain mainly used to integrate the diets for feedlot cattle in the Northwest of Mexico. Is known that steam-flaking processing of yellow corn, decreased dry matter intake (Lee *et al*., 1982; Ramirez et al., 1985), improves feed/gain ratio (Ramirez *et al.,* 1985; Zinn, 1987), and increases the energy content of the corn (Zinn, 1987; Barajas and Zinn, 1998). However, there are little information about the impact of steam-flaking processing method of white corn and its influence on performance of finishing cattle.

This experiment was conducted with the objective of determine the influence of steam-flaking processing method of white corn on the feedlot performance of Brahman cross finishing bulls.

Material and Methods

Location

The experiment was conducted in the Experimental Station for Beef Cattle of the Universidad Autónoma de Sinaloa, inside of Feedlot yard "Ganadera Los Migueles, S.A. de C.V." in Culiacán, Sinaloa, localized in the Northwest of Mexico (20º 48' N. and 107º 23' W. ; 60 m o.m.s.l.; mean temperature 25 ºC, and 645 mm of raining fall).

Animals

Eighty four bulls (324.61 ± 1.7 kg) proximately 75% Brahman blood with remainder of Simmental, Charolais, Brown Swiss, or Angus in indeterminate proportions, were used. Animals becomes from a same feedlot group, and were re-implanted (Component ES with Tylan ®; Elanco Animal Health), proximately 80 d before of sacrifice date.

Treatments

Animals were blocked by body weight, and in groups of seven were housed in ground flour pens (6 x 12 m). After a ten days adaptation period, agreement with a complete randomized block design experiment (Hicks, 1973), were assigned to receive one of two diets in that consisted the treatments: 1) Finishing diet (88% concentrate), containing 68.61% (DM basis) of dry-ground white corn (DGC); or 2) Diet similar to previously described, but containing 68.61% of steam-flaked white corn (SFC), substituting entirely the dry-ground corn.

Feedlot Performance

The bulls were fed under free access condition (105% of voluntary food intake of previous week), offering once a day (1600 h) the diets that appear in table 1. Animals had permanently access to fresh and clean drinking water. Food intake was considerate as food offered minus weekly refusals, feed samples (4 kg) were taken weekly directly from mixer wagon, and were oven dried (110°C by 48 h), and dry matter intake was calculate. Animals were weighed at starting the experiment (initial weight) and immediately before trucked to slaughterhouse (ending weight). 4% of live

body weight was pencil discounted as digestive tract fill (NRC, 1984). Retained energy (RE, mega calories) was derivate from measurements of BW and ADG, agreement with the equation: Bull calves RE = (0.0562 $LW^{.75}$) $ADG^{1.097}$ (NRC, 1984). The net energy of the diets was calculated assuming a constant heat increment production (MQ) of 0.077 $LW^{.75}$ Mcal/day (Lofgreen and Garrett, 1968). From the estimating of RE and MQ, the values of NEm and NEg of the diet were obtained by an iterative process (Zinn, 1987), fitting a NEg = (.877 ENm) - .41 (NRC, 1984).

Statistical Analysis.

The results of experiment were analyzed as a complete randomly blocks design (Hicks, 1973), considering each pen as the experimental unit, using ANOVA/COV of GLM procedures of Satistix 8 ® (Analytical Software; Tallahassee, FL).

Table 1. Composition of the diets used in the experiment.

Ingredients	Ground Corn	Steam-Flaked Corn
Dry-ground corn	68.61	-
Steam-flaked corn	-	68.61
Corn straw	12.20	12.20
Soybean meal	6.01	6.01
Sugar cane molasses	4.17	4.17
Tallow	4.41	4.41
Pork meat and bone meal	2.00	2.00
Ganamin Total [1]	2.78	2.78
Total	100%	100%
Calculated Analyses DM basis [2]		
CP, %	13.17	13.17
NEm, Mcal/kg	2.048	2.153
NEg, Mcal/kg	1.385	1.467

[1] Ganamin Total ® (Técnica Mineral Pecuaria, S.A. de C.V.; Guadalajara, Jalisco), vitamin and mineral premix.
[2] Calculated from tabular values (NRC, 1996).

Results and Discussion

The results of the influence of corn processing method on feedlot performance are summarized in table 2. SFC not affected (P = 0.69) ending weight. ADG was similar (P = 0.41) in both treatments. Absence of effect of corn processing method on ADG has been described previously (Zinn, 1987; Barajas and Zinn, 1998). DMI was diminished (P < 0.01) in 8.8% by steam-flaked corn, this is agreement with reduction on DMI from 4.28% to 12.5% observed with yellow corn in steers (Lee *et al*., 1982; Ramirez et al., 1985; Zinn, 1987), and 8.4% found in heifers (Barajas and Zinn, 1998). Feed conversion (feed/gain) was improved (P < 0.01) 11.9% by SFC. Using yellow corn-based diets for beef steers, Ramirez *et al*. (1985), found an improvement of 9.96%, in other experiment Zinn (1987) reported an enhancement of 6.83%. In beef heifers, Barajas and Zinn (1998), observed 14% of benefice on feed efficiency. Diet NEm was enhanced (P < 0.01) 9.9% by SFC. Zinn (1987) found an increment on diet NEm of 7.65% using steam-flaked yellow corn, respect to diets containing DRC offered to beef steers. Barajas and Zinn (1998), found an increment of 10% on diet NEm when feed beef heifers diets containing 64% of SFC. Diet NEg was increased (P < 0.01) in 12.8% with inclusion of SFC. Barajas and Zinn (1998), observed an improvement of 12.85% on NEg of the diet by inclusion of 64% of steam-flaked yellow corn. Observed NEm and NEg of dry-ground corn diet was close to expected (1.01), while steam-flaked corn-diet observed NEm and NEg were respectively 5% (P = 0.08) and 7% (P = 0.06) higher than expected, this results are similar to observed by Barajas and Zinn (1998), feeding beef heifers with diets containing 64% of SFC substituting DRC. Estimated NE values for dry-ground white corn, calculated from performance response of cattle were 2.181 and 1.500 Mcal/kg, for NEm and NEg, respectively; they are in close agreement with values of 2.18 and 1.50 Mcal/kg assigned by NRC (1996), to ground yellow corn. Usually is accepted that white corn due to contain mainly vitreous endosperm, its starch is less available for rumen microbial and intestine enzymes, so that its energy content for beef cattle is lower, however, Szasz et al. (2005), comparing corn kernel containing vitreous or floury endosperm, found that ruminal starch digestion and total tract starch digestion were higher for vitreous endosperm ground corn, and attributes this response to the more brittle and shattered particles of vitreous corn when was dry rolled, that increases surface area of smaller particles and improves starch utilization. Because SFC, was substituted for an equal quantity of ground corn (DM basis) in the diet (table 1), it may be assumed that the NE of SFC is equal to the NE of ground corn it replaced plus the change in NE of the complete diet brought about by replacement. Accordingly, given that ground corn has NEm and NEg values of 2.18 and 1.5 Mcal/kg, respectively (NRC, 1996); the corresponding NEm and NEg values for steam-flaked white corn in this experiment would be 2.479 and 1.762 Mcal/kg, respectively. Zinn (1987), from beef steers response estimated the NE content of SFC in 2.54 and 1.77 Mcal/kg, for NEm and NEg, respectively. Barajas and Zinn (1998), using beef heifers, calculated the NE content of SFC in 2.63 and 1.85 Mcal/kg, for NEm and NEg, respectively. The value of NEm of SFC observed in this experiment is 6 % higher than the 2.33 Mcal/kg suggested by NRC (1996), and the value for SFC NEg content is 8 % higher than 1.62 Mcal/kg assigned by NRC (1996). Improvement of energetic value (P < 0.01) of white corn as consequence of steam-flaked-process was estimated to be 13.7% in NEm and 17.4% for NEg, respectively, respect to 2.18 and 1.5 Mcal/kg assigned by NRC tables (1996) to ground corn. The results of this experiment are in agreement with the 13.4% and 14.2% of improvement for NEm and NEg, respectively observed by Zinn (1987), and the 17% and 19% found by Barajas and Zinn (1998).

Implications

The results of this study, suggest steam-flaking processing method of white corn, improves its energy availability nearly 13%, respect to dry-ground white corn. The benefits by steam-flaking processing method on feedlot performance are beyond those attributed by tabular values.

Acknowledgments

The authors give thanks to Ganadera Los Migueles, S.A. de C.V., to CECYT-Sinaloa, and Universidad A. de Sinaloa by the financial support.

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Table 2. Effect of white corn processed method on feedlot performance of Brahman cross finishing bulls.

Variable	White corn processing method		SEM[1]	*P-Value*
	Dry-ground	Steam-flaked		
Bulls, n	42	42		
Pen, n	6	6		
Days in trial	70	70		
Initial weight, kg [2]	324.61	324.61	1.77	0.77
Ending weight, kg [2]	424.41	426.21	4.35	0.69
Average daily gain, kg/day	1.451	1.490	0.04	0.41
Dry matter intake, kg/day	8.350	7.614	0.44	< 0.01
DMI/gain, kg/kg	5.835	5.139	0.20	< 0.01
Re-implant failure, %	0.00	0.00	0.00	1.00
Diet Net Energy, Mcal/kg				
Maintenance	2.059	2.264	0.05	< 0.01
Gain	1.396	1.576	0.04	< 0.01
Diet Net Energy, Observed/Expected				
Maintenance	1.01	1.05	0.02	0.08
Gain	1.01	1.07	0.03	0.06
Corn observed Net Energy, Mcal/kg				
Maintenance	2.181	2.479	0.07	< 0.01
Gain	1.500	1.762	0.06	< 0.01
Corn Net Energy, observed/expected				
Maintenance	1.00	1.06	0.03	0.08
Gain	1.00	1.09	0.04	0.06
Grain NE as proportion of tabular values for ground corn, % [3]				
Maintenance	100.02	113.69	3.06	< 0.01
Gain	99.98	117.44	3.89	< 0.01

[1] Standard error of the means.
[2] From live weight values, 4% was pencil discounted as digestive tract fill (NRC, 1984)
[3] Tabular values from NRC (1996).

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Effect of white corn processing method on carcass characteristics of Brahman cross finishing bulls

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ABSTRACT. With the objective to determine the influence of steam-flaking processing method of white corn on carcass characteristics of Brahman cross finishing bulls, an experiment was conducted. Eighty four bulls (324.61 ± 1.7 kg) proximately 75% of Brahman blood with remainder of Simmental, Charolais, Brown Swiss, or Angus in indeterminate proportions, were used in a 70 d feedlot performance experiment. This was a complete randomized block design experiment, and treatments assigned to receive one of two diets that consisted of: 1) Finishing diet (88% concentrate), containing 68.61% (DM basis) of dry-ground white corn (DGC); or 2) Diet similar to previously described, but containing 68.61% of steam-flaked white corn, substituting entirely to dry-ground corn (SFC). Upon completetion of a 70 days finishing period, the bulls were harvested. Corn processing method did not affect (P > 0.20) hot carcass weight (268 ± 2.91 kg), carcass dressing percentage (63.09 ±0.31%) nor back fat thickness (0.72 ±0.06 cm). LMA was similar (P = 0.21) across treatments (67.73 *vs.* 71.24 cm^2, for DGC and SFC, respectively). Marbling score (453 ± 12) was not affected (P = 0.42) by treatments. KPH fat was not altered (P = 0.38) by corn processing method. Percentage choice was similar (P = 0.60) across treatments (39.13 vs. 45.06% for DGC and SFC, respectively). Meat pH was diminished (P < 0.01) by SFC (5.83 *vs.* 5.65, for DGC vs. SFC, respectively). Preliminary yield grade and retail cuts were not affected (P > 0.20) by treatments. Its is concluded, that processing method of white corn, did not alter most carcass characteristics of finishing bulls, but the modification that induced muscle pH change, could indicates that it is able to modify muscle-cells glycogen content at harvest.

Key words: White corn, Steam-flaking, Carcass Characteristics.

Introduction

White corn is the type of grain mainly used to integrate the diets for feedlot cattle in the Northwest of Mexico. Is known that steam-flaking processing of yellow corn, decreases dry matter intake (Lee *et al*., 1982; Ramirez *et al*., 1985) improves feed/gain ratio (Ramirez *et al.,* 1985; Zinn, 1987) and increases the energy content of the corn (Zinn, 1987; Barajas and Zinn, 1998). However, there is little information about the impact of steam-flaking processing of white corn on carcass characteristics of Brahman cross finishing bulls.

This experiment was conducted with the objective of determine the influence of steam-flaked processing method of white corn on the carcass characteristics of Brahman cross finishing bulls.

Material and Methods

Location

The experiment was conducted in the Experimental Station for Beef Cattle of the Universidad Autónoma de Sinaloa, inside of Feedlot yard "Ganadera Los Migueles, S.A. de C.V." in Culiacán, Sinaloa, localized in the Northwest of Mexico (20º 48' N. and 107º 23' W. ; 60 m o.m.s.l.; mean temperature 25 ºC, and 645 mm of raining fall).

Animals

Eighty four bulls (324.61 ± 1.7 kg) proximately 75% of Brahman blood with remainder of Simmental, Charolais, Brown Swiss, or Angus in indeterminate proportions, were used. Animals becomes from a same feedlot group, and were re-implanted (Component ES with Tylan ®;Elanco Animal Health), proximately 80 d before of sacrifice date.

Treatments

Animals were blocked by body weight, and in groups of seven were housed in ground flour pens (6 x 12 m). After a ten days adaptation period, agreement with a complete randomized block design experiment (Hicks, 1973), were assigned to receive one of two diets in that consisted the treatments: 1) Finishing diet (88% concentrate), containing 68.61% (DM basis) of dry-ground white corn (DGC); or 2) Diet similar to previously described, but containing 68.61% of steam-flaked white corn (SFC), substituting entirely to dry-ground white corn.

Carcass Measurements

Upon complete the 70 days finishing period, the bulls were sacrificed in a slaughter house supervised by the sanitary authority of Culiacan City. Hot carcass weights were recorded, and after 24 hours chilling period in a cold room (2 ºC), left carcass side *Longissimus* muscle was cross sectioned between the 12th and 13th rib, back fat thickness (cm) and *Longissimus* muscle area (LMA) was measured by direct grid reading, marbling score and percentage of KPH fat were visually estimated.

Preliminary yield grade and retail cuts were estimated using procedures proposed by USDA (1996). Meat pH was measured in *Pectoralis profundus* muscle using a pH-meter fitted with a penetration electrode (HI8314 membrane pH-meter; Hanna Instruments).

Statistical Analysis.

The results of experiment was analyzed as a complete randomly blocks design (Hicks, 1973), considering each carcass as the experimental unit, using ANOVA/COV of GLM procedures of Satistix 8 ® (Analytical Software; Tallahassee, FL).

Table 1. Composition of the diets used in the experiment.

Ingredients	Dry-Ground Corn	Steam-Flaked Corn
Dry-ground corn	68.61	-
Steam-flaked corn	-	68.61
Corn straw	12.20	12.20
Soybean meal	6.01	6.01
Sugar cane molasses	4.17	4.17
Tallow	4.41	4.41
Pork meat and bone meal	2.00	2.00
Ganamin Total [1]	2.78	2.78
Total	100%	100%
Calculated Analyses DM basis [2]		
CP, %	13.17	13.17
NEm, Mcal/kg	2.048	2.153
NEg, Mcal/kg	1.385	1.467

[1] Ganamin Total ® (Técnica Mineral Pecuaria, S.A. de C.V.; Guadalajara, Jalisco), vitamin and mineral premix.
[2] Calculated from tabular values (NRC, 1996).

Results and Discussion

The influence of white corn processing method on carcass characteristics is shown in table 2. Hot carcass weight was not altered (P = 0.68) by treatments. Barajas and Zinn (1998) not found effect of processing method of yellow corn on carcass weight. Carcass dressing percentage was similar (P = 0.92) in both treatments, this results is agreement with observed by Barajas and Zinn (1998). Back fat thickness was not modified (P =0.76), this fact is accord to previous findings (Barajas and Zinn, 1998). KPH fat was not affected (P = 0.38) by treatments. This result is opposite to observed by Barajas and Zinn (1998) who found a higher KPH fat in heifers fed SFC-based diets respect to heifers that received dry-rolled yellow corn-based diets. The area of *Longissimus dorsi* muscle was not affected (P = 0.21) by treatments. Similar result obtained Barajas and Zinn, in carcass of heifers. Marbling score was unchanged (P = 0.42) by corn processing method. The absence of effect of corn processing method on marbling score is agreement with previous reports in heifers (Barajas and Zinn, 1998). The proportion of choice grade carcass was similar (P = 0.60) between treatments, other authors has been observed similar quality grade in carcass from steers fed dry-rolled corn or steam-flaked corn (Lee *et al*., 1982; Ramirez et al., 1985; Dunbar *et al*., 1987). Preliminary yield grade was equal (P =0.95) for both treatments, agreement with previous results using yellow corn (Lee *et al*., 1982; Ramirez *et al*., 1985; Dunbar *et al*., 1987). Retail cuts was not modified (P = 0.94) by corn processing method, this result is in concordance with observed by Barajas and Zinn (1998). Meat pH, measured in *Pectoralis profundus* muscle, was reduced (P < 0.01) 3% by steam-flaked processing of white corn, there are not available information to compare directly this observation as consequence of corn processing method, but considering that postmortem muscle pH is relationship to muscle glycogen reserves (Egbert, and Cornforth, 1986), is possible hypothesize that the higher availability of propionate from rumen fermentation of steam-flaked corn (Zinn, 1987; Zinn *et al*., 1995), increases muscle glycogen stored at death time.

Implications

The results of this study suggest steam-flaking processing of white corn, did not alter most carcass characteristics of finishing bulls, but the modification that induced muscle pH changes, could indicates that it is able to modify muscle-cells glycogen content at harvest. More research is required to clarify the influence of extensive processing methods of grains on ultimate muscle pH.

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Table 2. Influence of white corn processing method on carcass characteristics of Brahman cross finishing bulls.

Variable	White corn processing method		SEM[1]	*P-Value*
	Dry-ground	Steam-flaked		
Bulls, n	42	42		
Days in trial	70	70		
Ending weight, kg [3]	424.41	426.21	4.35	0.69
Hot carcass weight, kg	267.65	268.92	2.91	0.68
Hot carcass dressing, %	63.07	63.10	0.31	0.92
Back fat thickness, cm	0.72	0.72	0.06	0.76
KPH fat, %	2.25	2.32	0.08	0.38
Longissimus muscle area, cm^2	67.73	70.24	2.11	0.21
Marbling score [4]	448	458	12.16	0.42
Choice, %	39.13	45.06	5.13	0.60
Yield grade	2.48	2.49	0.12	0.95
Retail cuts, %	51.08	51.06	0.27	0.94
Muscle pH	5.83	5.65	0.06	< 0.01
Dark cuts, %	0.00	0.00	0.00	1.00

[1] Standard error of the mean.
[3] 4% of full weight was pencil discounted as digestive tract fill (NRC, 1984)
[4] Code: 400 = slight^{00}; 500 = small^{00}

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PERFORMANCE AND RESIDUAL FEED INTAKE ARE SIMILAR IN ANGUS-HEREFORD STEERS HOUSED IN INDIVIDUAL OR GROUP PENS

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ABSTRACT: Residual feed intake (**RFI**) calculations require individual measurements of feed intake offered and average daily gain for at least 70 d. Animals may be housed in individual or group pens, but housing type may affect the results (Paulino et al., 2004, J. Anim. Sci. 82 (Suppl. 1): 43). To re-evaluate the effect of housing type, 60 Angus x Hereford crossbred steers (296 kg initial BW) were fed a corn-based finishing ration (2.27 Mcal NEm/kg, 13% CP on a DM basis) during two periods of 60 d each. In the first phase, 30 steers were fed in individual pens and 30 in six pens containing five steers each. In the second period, the animals were switched from group to individual pens and vice versa. Cattle were weighed monthly, and feed offered and refused estimated weekly. Dry matter intake, average daily gain, gain:feed and residual feed intake were analyzed using the GLM procedure (Minitab Inc, State College, PA), with period and housing type as main effects. For both phases, the regression equation fitted without the intercept (not statistically significant) was: DMI (kg/d) = 0.0652 x $BW^{0.75}$ + 2.06 x ADG, r^2 = 0.64. There were differences ($P < 0.001$) across periods for ADG (1.49 vs. 1.33 kg/d for periods 1 and 2, respectively) and gain:feed (0.154 vs 0.132 for periods 1 and 2, respectively), but not for DMI (8.70 vs. 9.01 kg/d for periods 1 and 2, respectively, $P > 0.05$). None of these variables was affected by housing type ($P > 0.05$). Effects of period are likely due to increasing physiological maturity as animals become fatter, gain more slowly and become less efficient. The lack of effect of housing type contrast with our previous results using similar cattle and the same pens. The difference between present results and previous work may be due to a change in personnel and feeding practices. Housing type effects may be more evident under once daily feeding rather than the multiple feedings adopted in the present study.

Keywords: residual feed intake, housing type, beef steers

Introduction

Feed is the most expensive input within any livestock production system, including beef cattle. The relative importance of the cost of feeding in beef operations is due to the fact that 70-75% of the total dietary energy cost in beef production is used for maintenance (Ferrell and Jenkins 1985; NRC 1996).

There is a clear need for genetic selection strategies to improve feed efficiency without adversely impacting other traits, such as performance, reproduction, and meat quality.

The most widely used index of feed efficiency in the literature is gross efficiency or its inverse, feed conversion ratio (feed intake/weight gain). However, this is highly correlated with body weight and weight gain (Arthur et al., 2001c).

By contrast, residual feed intake (**RFI**), presented initially by Koch et al. (1963) as an efficiency parameter, is not correlated with body weight or weight gain. Thus, RFI should be a more sensitive and precise measurement of feed utilization, since it is based on energy intake and energy requirements. RFI can be defined as the difference between actual feed intake and the expected feed requirements for maintenance of body weight and for weight gain. Residual feed intake is an individual measurement; therefore animals must be fed individually or in groups using electronic devices that measure each animal's intake individually. Obtaining RFI data is laborious and expensive, and this has limited its adoption as a feed efficiency measurement. Moreover, there are some questions as to the validity of feed intake data obtained in individual pens (Paulino et al., 2004).

The purpose of the present study was to re-evaluate the effect of housing type on average daily gain (**ADG**), gain:feed, dry matter intake (**DMI**) and RFI.

Materials and Methods

The study was conducted at the UC Davis feedlot, during summer and fall of 2005. Sixty growing Angus-Hereford steers were allowed to adapt to the new environment, personnel and concentrate ration for one month. Following this they were weighed, and placed in 30 individual pens and five group pens (six animals each). After a 60 day test period, animals were switched form group to individual pens and vice versa. Steers were weighed monthly. All pens were fed once per day during the morning and in the afternoon they were stimulated to come to the bunk by calling and mixing the feed. The same ration was used throughout the trial (Tables 1 and 2). All procedures were approved by the UC Davis Animal Use and Care Committee.

Methodology for measuring RFI

The amount of feed offered was measured daily and the refusals weekly. Dry matter intake was regressed on mid-test metabolic BW ($W^{0.75}$) and ADG:

$$DMI = \beta 0 + \beta 1\ W^{0.75} + \beta 2\ ADG + \varepsilon$$

where β0 is the intercept, β1 and β2 are the coefficients of the equation, and ε is the residual (i.e., RFI). The intercept of the equation was tested and if not significant a new equation was fitted without the intercept. The actual DMI minus the predicted DMI corresponds to the residual feed intake. This means that a more efficient animal has a negative RFI (observed feed intake is lesser than predicted feed intake) and a less efficient animal has a positive RFI (observed feed intake is greater than predicted feed intake). Separate equations were fitted to individual data for each period.

Statistical Analyses

Differences in DMI, ADG, gain:feed and RFI among housing types were analyzed by one way ANOVA using the GLM procedure (Minitab Inc, State College, PA).

Results and Discussion

Figure 1 shows the relationship between RFI and predicted feed intake. The points are evenly distributed above and below zero, as expected, indicating that the regression was unbiased.

There were differences ($P < 0.001$) between periods for ADG (1.49 vs. 1.33 kg/d) and gain:feed (0.154 vs 0.132), but not for DMI (8.70 vs. 9.01 kg/d, $P > 0.05$) for periods 1 and 2, respectively (Figure 2).

The effects of period were likely due to increasing physiological maturity as animals became fatter, gained more slowly and became less efficient. As animals mature, adipose tissue may have a feedback role in controlling feed intake (National Research Council, 1987). One possible mechanism may be increasing plasma leptin concentrations (Morrison et al., 2001). Regardless of the mechanism, the percentage of body fat is often considered in equations to predict feed intake by beef cattle.

None of the variables studied was affected by housing type ($P > 0.05$). The lack of effect of housing type contrasts with our previous results using similar cattle and the same pens (Paulino et al., 2004). The difference between present results and previous work may be due to a change in personnel and feeding practices. Housing type effects may be more evident under once daily feeding rather than the multiple daily interactions adopted in the present study.

Conclusions

Given the problems associated with selection for ratio traits and the fact that residual feed intake is strongly correlated with feed conversion ratio, residual feed intake should be the preferred trait for genetic improvement of post-weaning feed efficiency. The feeding protocol adopted during a study appears to be very important, because a small change in personnel or feeding practices may change feed intake and therefore performance. This study shows that individual pens may be used as long as animals are stimulated to come to the bunk more than once daily.

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Table 1. Diet Composition

Ingredients	Percentage (as is basis)
Flaked Corn	80%
Alfalfa Hay	5%
Oat Hat	5%
Molasses	4%
Fat	2.5%
Sodium bicarbonate	1.25%
Urea	1%
Oyster shell	0.5%
Trace mineralized salt	0.5%
Ammonium chloride	0.25%
Potassium chloride	1%
Rumensin	per label
Rabon™	per label

Table 2. Chemical Composition

Dry matter, %	89
ME, Mcal/kg DM	33.27
NEm, Mcal/kg DM	2.27
NEg, Mcal/kg DM	1.57
Crude Protein, %DM	13.00
Ether Extract, %DM	6.04
Neutral Detergent Fiber, %DM	12.51

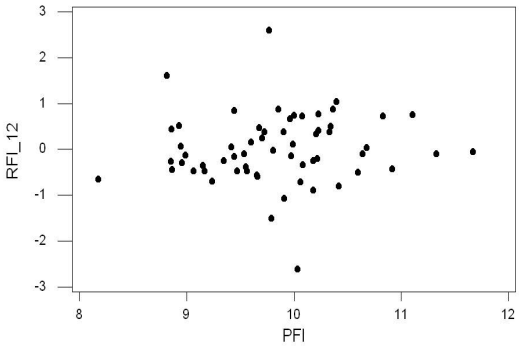

Figure 1. Relationship between RFI and predicted FI

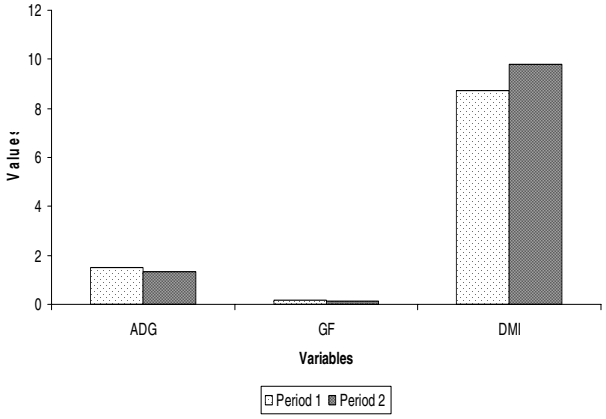

Figure 2. Differences in ADG, gain:feed and DMI across both periods

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CARCASS COMPOSITION AND VISCERAL ORGANS ARE SIMILAR AT HARVEST IN LOW- AND HIGH-RESIDUAL FEED INTAKE GROUPS OF ANGUS-HEREFORD STEERS

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ABSTRACT: Residual feed intake (RFI) measurements reflect individual deviations above or below the intake expected for a given weight and rate of gain. These deviations may be due to differences in the animals' maintenance energy requirements, which in turn are often related to visceral organ mass. In order to determine if RFI was related to carcass composition and visceral mass at harvest, 60 Angus x Hereford crossbred steers (296 kg initial BW) were fed a corn-based finishing ration (2.27 Mcal NEm/kg, 13% CP on a DM basis) for 60 d. Cattle were weighed monthly, and feed offered and refused estimated weekly. The highest and lowest 15 RFI steers were classed as high- and low-RFI groups. After the RFI measurement period, all cattle were returned to group pens and fed until reaching market finish. At harvest, carcasses were evaluated according to USDA standards, the 9-10-11 rib section was dissected to estimate carcass fat percentage, and internal visceral organs were dissected and weighed. RFI groups were compared using one-way ANOVA (Minitab Inc, State College, PA). There were differences ($P < 0.01$) between low- and high-RFI groups for DMI (9.19 vs. 10.95 kg/d), gain:feed (0.151 vs. 0.125) and RFI (-0.955 vs 0.977 kg/d), but not for ADG (1.43 vs. 1.44 kg/d, $P > 0.05$). There were no differences ($P > 0.05$) between low- and high-RFI groups for final BW (511 vs. 513 kg), hot carcass wt (324 vs. 321 kg), longissimus muscle area (75.5 vs. 75.5 cm^2), backfat (1.29 vs. 1.26 cm), KPH (3.6 vs. 4.0%), marbling score (average Choice for both groups) or carcass fat (33.0 vs. 33.8%). Visceral organ masses and abdominal fat were generally similar (31.44 vs. 31.01 kg and 30.11 vs. 29.59 kg, respectively, $P > 0.05$). These results do not support the existence of major differences in composition and organ mass between low- and high-RFI steers at harvest.

Keywords: residual feed intake, beef steers, viscera

Introduction

For many years, genetic selection programs have focused on production (output) traits, with little attention given to production costs (inputs). Recently, this view has begun to change, and the efficiency of conversion of feed (i.e., the amount of product per unit of feed input) has been recognized as more important. Residual feed intake (RFI), defined as actual feed intake minus the expected feed intake of each animal, was first proposed as an alternate measure of feed efficiency by Koch et al. (1963). It can be defined, in other words, as the difference between actual feed intake and the expected feed requirements for maintenance of body weight and for weight gain. RFI has been adopted more intensively in other countries, such as Australia and Canada, but in the US more attention has been given to understand the biological issues around this concept (Archer et al., 1997; Arthur et al., 2001). Genetic selection to reduce RFI can result in progeny that eat less without sacrificing growth performance (Herd et al. 2003; Richardson et al. 1998). In contrast to gain:feed, residual feed intake is independent of growth and maturity patterns. Therefore, RFI should be a more sensitive and precise measurement of feed utilization, since it is based on energy intake and energy requirements.

The mechanisms responsible for differences among animals in RFI are still unknown. One possibility is that the composition of gain is different, so that low RFI animals might have less fat and therefore greater feed efficiency. Another is that differences in maintenance energy requirement result in the observed variations in RFI. We have previously observed that maintenance energy requirement is often related to the mass of visceral organs, which have a greater metabolic intensity than non-visceral tissues (Sainz et al., 1995). Therefore, the purpose of the present study was to evaluate differences in final carcass composition and visceral organ mass between low and high RFI steers.

Materials and Methods

The study was conducted at the UC Davis feedlot, during summer and fall of 2005. Sixty growing Angus-Hereford steers were allowed to adapt to the new environment, personnel and concentrate ration for one month. Following this they were weighed, and placed in 30 individual pens and five group pens (six animals each). After a 60 day test period, animals were switched form group to individual pens and vice versa. Steers were weighed monthly. All pens were fed once per day during the morning and in the afternoon they were stimulated to come to the bunk by calling and mixing the feed. The same corn-based ration was used throughout the trial (2.27 Mcal NEm/kg DM, 13% crude protein). The amount of feed offered was measured daily and the refusals weekly. Dry matter intake was regressed on mid-test metabolic BW ($W^{0.75}$) and ADG:

$$DMI = \beta0 + \beta1\ W^{0.75} + \beta2\ ADG + \varepsilon$$

where $\beta0$ is the intercept, $\beta1$ and $\beta2$ are the coefficients of the equation, and ε is the residual (i.e., RFI). Separate equations were fitted to individual data for each period. Further details of the study are given in Cruz et al. (2006).

After the conclusion of the RFI tests, all animals were returned to group pens and fed the same finishing ration until reaching market finish (12 mm backfat measured by real-time ultrasound). At harvest, carcasses were evaluated according to USDA standards, the 9-10-11 rib section was dissected to estimate carcass fat percentage, and internal visceral organs were dissected and weighed. All procedures were approved by the UC Davis Animal Use and Care Committee.

Statistical Analyses

Steers were assigned to Low or High RFI groups if they exceeded 0.5 standard deviations below or above the mean RFI, respectively. Differences among RFI groups were analyzed by one way ANOVA using the GLM procedure (Minitab Inc, State College, PA).

Results and Discussion

As expected, low-RFI steers consumed less DM and had lower RFI than high-RFI animals ($P < 0.01$, Table 1). There was no difference between RFI groups in ADG, therefore gain:feed was greater ($P < 0.01$) in the low RFI group as compared to the high RFI group. There were no differences ($P > 0.05$) between low- and high-RFI groups for final BW, hot carcass wt, longissimus muscle area, backfat, KPH, marbling score or carcass fat percentage. Visceral organ masses and abdominal fat were also similar between low- and high-RFI groups. Therefore, low and high RFI steers reached market finish at similar weights and carcass compositions, as indicated by carcass characteristics assessed by the grader as well as through dissection.

Visceral organs such as the gastrointestinal tract, liver, heart and kidneys have higher oxygen consumption per unit mass than non-visceral tissues (Baldwin and Sainz, 1995). Numerous reports have demonstrated the relationship between maintenance energy expenditure and visceral organ mass (e.g., Sainz et al., 1995; Hersom et al., 2004; Rompala et al., 1991). The present results do not support the existence of major differences in composition and organ mass between low- and high-RFI steers at harvest. It should be noted that the RFI test was conducted early during the feeding period (two to four months pre-harvest), therefore the results may not reflect the body compositions of the steers during the test. Alternatively, it is possible that other mechanisms, such as differences in metabolic patterns or digestive efficiency, are responsible for the observed variations in RFI. Further studies will be required to examine alternative hypotheses.

Conclusions

Residual feed intake is a heritable trait that is closely related to feed efficiency and profitability. Low and High RFI steers reached market finish at similar body weights and compositions. Further research is needed to elucidate the mechanisms responsible for differences in RFI.

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Table 1. Performance and composition of Low and High RFI steers

Measurement	Low RFI	High RFI
DM intake, kg/d	9.19[b]	10.95[a]
ADG, kg/d	1.43	1.44
Gain:feed	0.151[a]	0.125[b]
RFI, kg/d	-0.955[b]	0.977[a]
Final BW, kg	511	513
Hot carcass wt, kg	324	321
Longissimus muscle area, cm^2	75.5	75.5
Backfat, cm	1.29	1.26
KPH[1] fat, %	3.6	4.0
Quality grade	Choice	Choice
Carcass fat[2], %	33.0	33.8
Abdominal fat, kg	31.44	31.01
Visceral organ[3] mass, kg	30.11	29.59

[a,b]Means in the same row not sharing a superscript differ ($P < 0.01$)

[1]Kidney, pelvic and heart fat, dissected and weighed from one side of each carcass.

[2]Carcass fat determined by dissection of the 9-11th rib section, according to Hankins and Howe (1946).

[3]Viscera include liver, heart, lungs, trachea, spleen, reticulorumen, omasum, abomasum, small and large intestines, empty and free of dissectible fat.

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WHEY SILAGE FOR BEEF COWS UNDER MAINTENANCE CONDITIONS

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ABSTRACT: Two studies were conducted with the objective of evaluating the effects of feeding liquid whey ensiled with wheat straw and wheat middlings to beef cows under maintenance conditions. Whey silage was produced by combining liquid whey, barley straw and wheat middlings at levels of 28.7, 46.8 and 24.6 % for study one (DMB) and 30.3, 45.8 and 23.9 % for study two (DMB) respectively. Dry, pregnant beef cows, initial weight 613.0 kg and 578.0 kg for studies one and two respectively, were randomly assigned to either a control (C) or treatment (T) group with five head per pen and three pens per treatment. Length of study was 56 days for study one and 140 days for study two. In study one the C cows received grass hay and the T ration that consisted of 83.3, 16.0 and .70% whey silage, barley grain and limestone respectively. Study two C cows received a diet consisting of 27.6% alfalfa hay, 55.2% barley straw and 17.2% barley grain and T cows received whey silage and a small amount of limestone. In both studies a TM salt was provided free choice to all cows. Feed intake was recorded daily on a pen basis and adjusted after each weighing such that cows from both treatments gained approx. .20 kg.d-1. Cows in study one gained weight equally between treatments (P>.05), with no differences in change of body condition score (P>.05). In study two, C cows gained 88.0 kg versus 107.4 kg for the T cows (P<.05) although the change in body condition score was not different (P>.05) between treatments. Dry matter digestibility was not different between treatments (P>.05) with values of 63.1% and 67.8% for the C and T groups respectively. Neutral detergent fiber digestibility differed (C-60.4% and T-49.9%; P<.05). For both studies the T cow's diets were approximately 30% lower in cost than C diets. This study confirms that whey silage is a viable alternative to more traditional diets for beef cows under maintenance conditions.

Key Words: Whey, Silage, Cattle, Beef

Introduction

Feed accounts for the highest input cost for beef cows. Traditional feedstuffs consist of predominantly harvested forages which are either produced on the farm or purchased. Forage prices fluctuate depending on supply, which can be affected by a number of factors and can vary from year to year.

The use of agricultural and industrial by-products for beef cattle are well documented (Clerk et al., 1987; Belyea et al, 1989, Givens et al., 1993). Residue feeds such as wheat straw, liquid whey and wheat middlings have been combined and ensiled to produce a whey silage that provided a nutritious and palatable feedstuff for growing and finishing cattle (ZoBell et al., 2004 and ZoBell et al., 2005). The objective of two studies was to evaluate whey silage as a feedstuff for beef cows under maintenance conditions.

Materials and Methods

Silage Preparation

Whey silage was produced for two studies using the nutrient profiles and proportions of the feedstuffs as shown in Tables 1 and 2. The cheese whey used for each study varied little in dry matter percent and nutrient content and came from the same cheese plant. The feedstuffs whey, wheat straw and wheat middlings were ensiled in a bunk type silo to produce the whey silage. The whey silage was sampled 3-4 weeks later for nutrients, fermentation characteristics, and analyses were continued throughout each feeding trial. All nutrient and feedstuff analyses reported in these studies were conducted at a commercial laboratory using procedures of Bull (1981), AOAC (2000) standard procedures and those outlined by ZoBell et al. (2003).

Fermentation properties of the whey silage are shown in Table 3.

Feeding Trials

British-based crossbred beef cows were used in the two studies. Initial weights for study 1 were 603.4 kg and 623.3 kg, and for study 2, 571.5 kg and 585.5 kg for C and T cows respectively. There was no difference between treatments for initial weight in both studies (P>.05). In study 1 there were 5 cows per pen and three pens per treatment and in study 2, 6 cows per pen and three pens per treatment. All cows had been pregnancy tested prior to trial initiation. Cows were fed at 08:00 h daily with about 5% orts. Individual cow weights were recorded at the start of the tests, every 28 days and at trial termination (study 1-56 d; study 2- 140d) . Feed intake was adjusted after each weighing such that cows from both treatments gained approximately .20 $kg.d^{-1}$. In study 1, C cows were fed grass hay and T cows, whey silage with barley grain. In study 2, C cows received a mixed ration of alfalfa hay, barley grain and barley straw and T cows, whey silage (Table 4).

Digestibility Trials

The C and T diets that were used in the cow diets in Study 2 were fed to four ruminally cannulated beef cows in a digestibility trial using a replicated 2 x 2 Latin square design. Cows were individually housed in open front 4 m x 10 m pens with concrete floors. All feedstuffs were fed once daily at 0800 for a 21-d adaptation period followed by a 6-d collection period. Diets were fed to appetite such that there were no refusals. During the collection periods, fecal grab samples (300g) were obtained at 0800 from each cow. Samples of the total mixed ration (TMR), feces and individual feedstuffs were also obtained throughout the collection period. Feed samples were weighed and dried at 60º C for 72 h and ground in a Wiley mill to pass a 1- mm screen and the ground material analyzed for DM (AOAC 2000; 934.01). Total N was determined using a LECO CHN-1000 Combustion Analyzer (Sweeney 1989; Yeomans and Bremmer 1991), and ADF determined using an Ankom Fiber Analyzer (Ankom Technology, Fairport, NY). The ADF was assayed without sodium sulfite, with alpha amylase, and without residual ash. Acid insoluble ash (AIA) (Van Keulen and Young, 1977) was used as an internal marker to estimate apparent nutrient digestibility. Net energy for maintenance and net energy for gain was calculated using DE values following NRC (1989) procedures and the DE values were calculated from measured percent ADF (Bull 1981). Calcium and phosphorous were analyzed using methods described by Isaac and Johnson (1985). Fecal samples were weighed and dried at 60º C for 72 h and ground to pass through a 1-mm screen and proportionately composited by cow for each of the two collection periods. DM was determined after grinding. Analysis of fecal samples followed the same procedures and methodologies as those used for the feed samples.

Volatile fatty acid (VFA) concentrations in Study 2 were measured in acidified samples using gas chromatography (Hewlett Packard 5890, Avondale, PA) with a 1.83 m X 2 mm ID glass column packed with GP 10% SP-1200/1% H_3PO_4 on 80/100 mesh Chromosorb W-AW. The study was approved and conducted according to the protocol established by the Institutional Animal Care and use Committee (IACUC) at Utah State University.

Statistical Analysis

Data were statistically analyzed in a completely randomized design using the MIXED procedure of SAS (SAS Institute, Cary, NC). Pens were the experimental units. Cow BW and BCS were analyzed using diet treatments and weigh date as fixed effects in a factorial treatment structure. Weigh date was designated a repeated measure. The Kenward-Roger option was used to estimate denominator degrees of freedom. The variance-covariance matrix was chosen in an iterative process wherein best fit was chosen based on the Schwarz's Bayesian Criterion. Cow change in BCS and weight, and DM intake during each experiment were analyzed with diet treatment as the only independent variable. In this model, pens were designated as random effects. Least squares means were calculated for main effects and, when significant, interactions. Dry matter

and NDF digestibility in Study 2 were analyzed as a replicated 2 × 2 Latin square design by using animals as the experimental units with periods of the Latin square incorporated as repeated measures of feed treatments. Treatment and period were fixed effects and animal was a random effect. Volatile fatty acid and pH data for Study 2 were analyzed using the same model as DM and NDF digestibility, except hour of ruminal sampling was incorporated as an additional repeated measure. Sampling hour and its interaction with feed treatment were considered fixed effects. Significance was interpreted at $P \leq 0.05$ for all tests unless otherwise indicated.

Results and Discussion

Fermentation properties are shown in Table 3 for studies 1 and 2. The whey silage had adequate levels of essential silage characteristics for adequate fermentation. The T cows consumed their ration well each day and palatability appeared to be adequate.

In study 1, all cows (C and T) gained weight equally and there was no treatment effect (P=.281). This carried over into BCS with similar results for the C and T treatments (P=.91).). In study two, C cows gained 88.0 kg versus 107.4 kg for the T cows (P<.05) although the change in body condition score was not different (P>.05) between treatments (Table 5). Dry matter digestibility was not different between treatments (P>.05) with values of 63.1% and 67.8% for the C and T groups respectively. Neutral detergent fiber digestibility differed (C-60.4% and T-49.9%; P<.05).

An economic analysis was conducted for both studies and results showed that the T cow's diets were approximately 30% lower in cost than C diets.

Implications

The whey silage was a combination of three residual feeds commonly found in agricultural areas of the US. When these residual feeds were combined and ensiled, a nutritious and economical feedstuff was produced. Production and economic data demonstrated that feed costs can be decreased when whey silage is fed, compared to more traditional harvested forage.

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Table 1. Feedstuff nutrient levels for Study 1 and 2 (DMB)

Feedstuff	Study	DM (%)	NE_m (Mcal/kg)	NE_g (Mcal/kg)	CP (%)	Ca (%)	P (%)
Whey	1	16.8	1.98	1.19	5.20	1.60	2.10
	2	20.9	2.09	1.41	8.30	.55	1.18
Wheat Straw	1	92.1	.77	.24	4.20	.40	.22
	2	80.0	.73	.20	6.00	.36	.20
Wheat Middlings	1	88.5	1.39	.81	14.9	.15	.62
	2	90.3	1.85	1.21	18.2	.11	.56
Alfalfa Hay	2	91.4	1.25	.68	18.0	1.07	.30
Grass Hay	1	90.8	1.21	.64	8.70	.46	.17
Barley Grain	2	88.5	2.02	1.36	12.5	.07	.38

Table 2. Composition of silage on a dry matter basis, energy values and nutrient analysis for Study 1 and 2.

	Silage composition % (DM)			Nutrient[Z]					
Study[Y]	Whey	Straw	WM[X]	DM	NEm	NEg	CP	Ca	P
1	28.7	46.8	24.5	42.0	1.47	.90	8.1	.39	.38
2	30.3	45.8	23.9	43.1	1.58	.99	10.6	.41	.63

[Z]DM=Dry matter (%); NEm=Net energy for maintenance (Mcal kg^{-1}); NEg=Net energy for gain (Mcal kg^{-1}); CP=Crude protein (%); Ca=Calcium (%); P=Phosphorus (%).[Y]Study 1 Whey DM=16.8%; Study 2 Whey DM=20.9%.[X] WM=Wheat middlings

Table 3. Fermentation properties of whey silage for Study 1 and 2

Study	pH	Lactic acid (% DM)	Acetic acid (% DM)	Total VFA (% DM)	Ammonia (% DM)
1	4.39	4.6	.28	4.90	.50
2	4.20	6.1	.48	6.82	.90

Table 4. Feedstuffs and composition of diets used for Study 1 and 2 (DMB)

		Study 1		Study 2	
Feedstuff[Z]	Units	Control	Treatment	Control	Treatment
AH	%	-	-	27.6	-
GH	%	100	-	-	-
WS	%	-	83.3	-	99.3
BG	%	-	16.0	17.2	-
BS	%	-	-	55.2	-
Lim	%	-	.70	-	.70

[Z]AH=Alfalfa hay; GH=Grass hay; WS=Whey silage;
BG=Barley grain; BS=Barley straw; Lim=Limestone

Table 5. Study 2 weights and body condition score for control and treated cows

Treatment	Initial Weight (lbs)	Final Weight (lbs)	P	SEM	Δ Weight (lbs)
C	571.5	649.4	<.0001	6.41	88.0
T	585.5	679.5	<.0001	9.32	107.4
P	.57	.24			.02
SEM	22.2	22.2			4.68

	Initial BCS	Final BCS	P	SEM	Δ BCS
C	4.86	4.93	.60	.13	.07
T	4.94	5.07	.39	.13	.09
P	.78	.65			.30
SEM	.28	.28			.02

Table 6. Fermentation and digestibility properties of treatments in Study 2

	Treatment			
	Control	Whey Silage	SEM	P
Rumen parameters[a]				
pH	6.47	6.37	.08	.38
Acetate (mol 100 mol^{-1})	62.10	45.30	1.66	<.0001
Propionate (mol 100 mol^{-1})	15.60	17.10	.95	.24
Butyrate (mol 100 mol^{-1})	7.68	11.60	.81	.0004
Total (mmol l^{-1})	88.32	75.45	2.22	.0013
Whole tract digestibility (%)[b]				
DM digestibility	63.10	67.80	1.27	.07
NDF digestibility	60.40	49.90	1.98	.04

[a] VFA = volatile fatty acids, [b] DM = dry matter; NDF = neutral detergent fiber

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