PROCEEDINGS

VOLUME 61

WESTERN SECTION
American Society of Animal Science

Denver, Colorado
July 11–15, 2010

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2009-2010 WSASAS Committees

**Denote Committee Chair

Executive

1. G. E. Moss, President (11, University of Wyoming)**
2. D. H. Crews, Jr., President-Elect (12, CSU)
3. A. J. Roberts, Secretary-Treasurer (13, USDA-ARS, Ft, Keogh)
4. R. A. Battaglia, Past-President (10, University of Idaho)
5. B. W. Hess, ASAS Board Director (10, University of Wyoming)
6. C. K. Larson (12, Zinpro Corp.)
7. G. C. Duff (10, University of Arizona)

Awards

1. D. H. Crews, Jr. President-Elect (10, CSU)**
2. M. Du, (10, University of Wyoming)
3. M. E. Doumit (10, University of Idaho)
4. T. E. Engle (11, CSU)
5. J. M. Thompson (11, OSU)
6. M. D. MacNeil (11, USDA-ARS)

Symposium

1. S. I. Paisley (11), University of Wyoming)
2. J. B. Hall (11, University of Idaho)
3. A. Manuel (Manny) Encinias (12, NMSU, Clayton)
4. R. N. Funston (12, UNL)
5. J. R. Jaeger (12, KSU)

NOTE: No Symposium in 2010 – Paisley and Hall will serve another year

Advising and Coordinating

1. G. C. Duff (10, University of Arizona)**
2. P. A. Ludden (10, University of Wyoming)
3. J. G. P. Bowman (10, Montana State University)
4. C. J. Mueller (10, Oregon State University)
5. R. Mark Enns (10, CSU)
6. J. R. Carpenter (10, University of Hawaii)
7. A. J. Roberts (10, USDA-ARS, Miles City)
8. J. K. Ahola (11, CSU)
9. J. B. Taylor (11, USDA-ARS-USSES, Dubois, ID)
10. B. J. May (11, Angelo State University)
11. M. P. Shipka (12, U. Alaska)
12. J. E. Bruemmer (12, CSU)

Paper Competition

1. K. M. Cammack (10, University of Wyoming)**
2. D. L. Boss (11, Northern Ag Research Ctr, Havre, MT)
3. C. T. Parsons (11, Oregon State University)
4. H. L. Neibergs (12, WSU)
5. S. L. Ivey (12, NMSU)
6. R. L. Endecott (12 MSU)
7. R. K. Peel (12, CSU)

Academic Quadrathlon

1. D. C. Rule (University of Wyoming)**
2. J. B. Lamb (BYU - Idaho)
3. S. A. Soto-Navarro (New Mexico State University)
4. R. D. Wiedmeier (Utah State University)
5. H. Han (CSU)

Extension

1. R. Kott (10, Montana State University)**
2. C. T. Parsons (10, Oregon State University)
3. J. B. Glaze (11, University of Idaho)
4. S. L. Lake (11, University of Wyoming)
5. T. R. Whitney (12, Texas A&M, San Angelo)
6. C. P. Mathis (12, NMSU)

Necrology

1. R. A. Battaglia, Past-President (10, University of Idaho)**

Nominating

1. R. A. Battaglia, Past President (12, University of Idaho)**
2. K. C. Olson, (11, S. Dakota State University)**
3. T. T. Ross (10 New Mexico State University)

BUSINESS MEETING MINUTES
Western Section, American Society of Animal Science
June 18, 2009
Colorado State University, Fort Collins, CO

President Richard Battaglia called the meeting to order at 8:00 AM.

Acceptance of 2008 WSASAS Minutes.
After a call for additions or amendments, minutes of the 2008 WSASAS Business Meeting were accepted as printed in the 2009 Western Section ASAS Proceedings.

2008 Financial and 2009 Meeting Reports.
Denny Crews, Secretary-Treasurer, Colorado State University

The WSASAS financial report as of December 31, 2008 was summarized. In the 2008 calendar year, the Section total revenue was $44,878.05 and total expense was $51,636.53, leaving a balance of $55,896.42. The detailed report is included in these minutes as an appendix.

Pre-registrations for the Beef Symposium on June 16 totaled 107, and 15 registered on-site. Western Section ASAS meeting pre-registrations was 181 with 19 registering on-site. The final counts were 122 and 200 for the Beef Symposium and WSASAS, respectively. There were 106 papers submitted: 72 as oral and 34 as posters.

Necrology Committee Report.
Ken Olson, Past-President, South Dakota State University

Four WSASAS members passed away during 2008-09:
1. Joe B. Johnson, Oregon State University and Washington State University
2. Darrell Goll, University of Arizona
3. James (Jim) T. Elings, Oregon State University, University of California, Carnation Company, and Agricultural Industries, Inc.
4. Vern Swanson, Colorado State University

Following his report, Ken Olson called for a moment of silence in memory of our deceased members.

Nominating Committee Report.
Ken Olson, Past-President, South Dakota State University

Committee Members:
1. Ken Olson, South Dakota State University, Chair
2. James Thompson, Oregon State University
3. Tim Ross, New Mexico State University

Nominees for 2009 WSASAS elections were:

President-Elect:	Denny Crews, Colorado State University
Secretary-Treasurer:	Mike MacNeil, USDA-ARS-LARRL, Miles City, MT
	Andy Roberts, USDA-ARS-LARRL, Miles City, MT
Industry Director:	Connie Larson, Zinpro Corporation

Tim Bodine, Performix Nutrition Systems

Election results were:
President-Elect: Denny Crews, Colorado State University
Secretary-Treasurer: Andy Roberts, USDA-ARS-LARRL, Miles City, MT
Industry Director: Connie Larson, Zinpro Corporation

Ken Olson congratulated the new members of the Executive Committee and thanked all those who were willing to be nominees.

Extension Symposium Committee Report.
Jim Sprinkle, University of Arizona

Committee Members:
1. Jim Sprinkle, University of Arizona, Chair
2. Ben Bruce, University of Nevada – Reno
3. Rodney Kott, Montana State University
4. Cory Parsons, Oregon State University
5. Benton Glaze, University of Idaho
6. Scott Lake, University of Wyoming

On February 25, 2009, the Extension Committee was notified about the leadership structure of the committee. Prior to this time, the committee information was not properly linked on the ASAS Website and no communication was received from ASAS leadership. Given the late date at which we were informed as to the status of the committee chair, we decided it was impractical to expect speakers to have an abstract ready for the proceedings. Furthermore, it was improbable that the speakers we would choose would be able to complete a proceedings paper in the two or three weeks that would be available to them by the time speakers were finalized. After discussion, we informed the WSASAS Executive Committee that we would not require proceedings papers from speakers in our Extension Symposium and they supported our decision. We did decide that we would make any PowerPoint presentations that were given available on the WSASAS Website following the meeting. Dr. Denny Crews offered to assist us in having these presentations posted.

In 2008, the Extension Symposium was based somewhat on *Animal ID*. For the year before, the topic was *Disseminating information to the beef industry through the Extension Service.* In 2006, the topic was *Collaboration*.

As a committee, we decided that we wanted to have a topic theme rather than just opening it up to members. Given the current budget crisis that is present for most states, Dr. Benton Glaze suggested a topic related to how our institutions are coping with funding Extension. The committee decided that this was a good idea and that we would host a symposium on “Creative Funding for Extension Programming”. In particular, we were interested in partnerships that have enabled our Extension colleagues to continue delivering Extension programming. After several emails to flesh out some thoughts, a conference call was convened on April 3, 2009 and the following agenda was finalized.

Extension Symposium
Creative Funding for Extension Programming
Wednesday, June 17, 2009: 1:15 to 4:20
Colorado State University

1:15 - 1:20 Welcome & Introductions
Dr. Jim Sprinkle, Chair, Western Section, ASAS Extension Committee

Federal & State Funding Opportunities

1:20 - 1:40 How Can Cooperative Extension Continue Our Mission in the Midst of the Current Funding Climate?
Dr. Deborah Young, Director of Extension, Colorado State University

1:40 - 2:10 Funding Opportunities for Multi-State Extension Programming
Dr. Pete Burfening, National Program Leader, Competitive Programs, Cooperative State Research, Education, and Extension Service, Washington D. C.

National Funding Opportunities to Accomplish Mutual Educational Goals

2:10 - 2:40 Partnering with Extension to Deliver Producer Education
Dr. Tom Field, NCBA Director of Producer Education, National Cattlemen's Beef Association

Partnering with Allied Industries, Professional Societies, and Agencies to Deliver Programming

2:40 - 2:55 Oregon State University Annual Beef Cattleman's Workshop
Dr. Tim DelCurto & Mr. Cory Parsons, Oregon State University

2:55 - 3:15 BREAK

3:15 - 3:30 Targeted Grazing
Dr. Rodney Kott and Dr. Lisa Surber, Montana State University

3:30 - 3:45 Reading the Range
Dr. Jim Sprinkle, University of Arizona

3:45 - 4:00 Wyoming Master Cattleman Program
Mr. Bridger Feuz, University of Wyoming

Panel Discussion

4:00 - 4:20 Questions from Audience
Dr. Benton Glaze, University of Idaho, Moderator

Beef Symposium Committee Report.
Steve Paisley, University of Wyoming (Proxy report given)

Committee Members:
1. Steve Paisley, University of Wyoming, Chair
2. Shawn Archibeque, Colorado State University
3. Tim Delcurto, Oregon State University
4. Rachel Endicott, Montana State University
5. John Hall, University of Idaho

Steve Paisley was selected to replace Tom Field as Chair of the Beef Symposium Committee when Dr. Field moved from Colorado State University to the position of Director of Producer Education with the National Cattlemen's Beef Association.

Summary: Based on an initial conference call on March 20, the committee chose to develop a program focusing on two major concerns in the beef industry: 1) Nutrient/emissions issues, and 2) Animal well-being. Further refinement led to developing a morning program focusing on animal well-being topics, with the afternoon session focusing on nutrient/emissions issues.
In response to Mr. Avery's request for an honorarium, conference calls and email exchange focused on whether WSASAS was willing to pay honorariums to the level the Beef Symposium budget would allow. Subsequent requests to industry contacts for Symposium support were unsuccessful except for $100 from Ranch-Way Feeds by Jack Settlemire. A follow-up phone call with Dennis Avery resulted in a reduction in honorarium fees plus travel expenses.

Topics that need additional discussion may include:

a) What is the consensus of the group concerning honoraria
b) The Beef Symposium is self-sufficient, but depends heavily on ASAS contributions of $3,000
c) Better established emphasis on industry support of the Beef Symposium may help
d) Several requests for making CD or DVD of presentations after the meetings

Agenda, June 16:

8:45 AM	Bill Wailes	Welcome
9:00 AM	Steve Paisley	Introductions
9:15 AM	Ivan Steinke	Animal welfare: Finding solutions in all circumstances
10:00 AM	Tom Field	Raising beef in a first world country: science, media and politics
10:45 AM	Break	
11:00 AM	Temple Grandin	What I see as public relations concerns about animal welfare
11:45 AM	Lunch (on your own)	
1:15 PM	Andy Cole	Recent and upcoming rules related to air quality and cattle operations
2:00 PM	Terry Mader	Carbon credits and how they apply to the cattle industry
2:45 PM	Break	
3:00 PM	Wade Small	Beef marketing and cattle management that emphasizes animal welfare
3:45 PM	Dennis Avery	Current issues concerning animal agriculture and the environment

Academic Quadrathlon Committee Report.
Dan Rule, University of Wyoming

Committee Members:

1. Dan Rule, University of Wyoming, Chair
2. Sergio Soto-Navarez, New Mexico State University
3. Shawn Archibeque, Colorado State University
4. Brett Bowman, Montana State University
5. Jim Lamb, BYU – Idaho
6. Matt Kennedy, Oregon State University

The 2009 Western Section ASAS regional Academic Quadrathlon was held on April 17 and 18 on the Southern Utah University campus. This year's event was hosted by Dr. Chad Gasser, Assistant Professor of Animal Science and the Department of Agricultural and Nutritional Sciences, Southern Utah University. Many thanks go out to Dr. Gasser and his assistants, both members of the farm staff and faculty of Agricultural and Nutritional Sciences for their hours of hard work and planning to put this event together for the Western Section contest. There were six teams participating: New Mexico State University (Dr. Sergio A. Soto-Navarro, advisor); Colorado State University (Drs. Shawn Archibeque and

Hyungchul Han, advisors); University of Wyoming (Dr. Dan Rule, advisor); Utah State University (Dr. Brett Bowman, advisor); BYU-Idaho (Dr. Jim Lamb, advisor); and Oregon State University (Mr. Matt Kennedy, Advisor). Results were as follows: Oral Presentation winner was Oregon State University; Written Exam winner was Colorado State University; Laboratory Practicum winner was Oregon State University; Quiz Bowl winner was Colorado State University; and the Overall winner was Oregon State University. For each event's winner the school was awarded a recognition plaque, and for the overall winning team, each member was awarded a championship buckle from Montana Silversmiths.

The 2010 WS Academic Quadrathlon location has not been determined.

Awards Committee Report.
Gary Moss, President-Elect, University of Wyoming

Committee Members:
1. Gary Moss, University of Wyoming, Chair
2. Dave Bohnert, Oregon State University
3. Mike Tess, Montana State University
4. Min Du, University of Wyoming
5. Dale Zobell, Utah State University

Distinguished Service Award

Recipient:	Dr. Mike MacNeil, USDA-ARS-LARRL, Miles City, MT
Sponsor:	DSM Nutritional Products, Inc. c/o Scot Williams and Yvonne Towns 45 Water View Blvd. Parsippany, NJ 07054-1298
Nominator:	Dr. Sarah Northcutt, American Angus Association

Distinguished Teaching Award

Recipient:	Dr. Terry Engle, Colorado State University
Sponsor:	Elanco Animal Health c/o Dr. Todd Armstrong 2001 W. Main Street Greenfield, IN 46140
Nominator:	Dr. David Anderson, Colorado State University

Extension Award

Recipient:	Dr. James M. Thompson, Oregon State University
Sponsor:	Western Section ASAS
Nominator:	Dr. James Males, Oregon State University

Young Scientist Award

Recipient:	Dr. Joshua Bret Taylor, USDA-ARS, Dubois, ID
Sponsor:	Western Section ASAS
Nominator:	Dr. Greg Lewis, USDA-ARS, Dubois, ID

Gary Moss and Richard Battaglia presented awards at the banquet on the evening of June 17. Gary Moss thanked all who submitted nominations and encouraged nominators to get to work early and nominate our deserving colleagues in 2010.

Applied Paper Awards.
Gary Tibbetts, Chair

The results of the Applied Paper Competition were presented at the banquet on June 17. Individual awards were:

3rd Place. D. M. Larson
Estrous synchronization increases early calving frequency, which enhances steer progeny value. D. M. Larson and R. L. Funston, *University of Nebraska, West Central Research and Extension Center, North Platte, NE*.

2nd Place. A. J. Roberts
Implications of going against the dogma or feed them to breed them. A. J. Roberts, E. E. Grings, M. D. MacNeil, R. C. Waterman, L. Alexander, and T. W. Geary. *USDA-ARS Fort Keogh Livestock and Range Research Laboratory, Miles City, MT*.

1st Place. J. T. Mulliniks
Increasing glucogenic precursors in range supplements improves reproductive efficiency and profitability in your postpartum range cows in years 2000 to 2007. J. T. Mulliniks[1], S. H. Cox[1], M. E. Kemp[1], R. L. Endecott[2], R. C. Waterman[3], D. M. VanLeeuwen[1], and M. K. Petersen[3]. [1]*New Mexico State University, Las Cruces, NM;* [2]*Montana State University, Bozeman, MT;* [3]*USDA-ARS Fort Keogh Livestock and Range Research Laboratory, Miles City, MT*.

Graduate Student Competition Committee Report.
J. Bret Taylor, USDA-ARS, Dubois, ID

Committee Members:
1. J. Bret Taylor, USDA-ARS, Dubois, ID, Chair
2. Lance Baumgard, University of Arizona
3. Darrin Boss, Montana State University
4. Kristi Cammack, University of Wyoming
5. Cory Parsons, Oregon State University
6. Milan Shipka, University of Alaska
7. Ken Walburger, University of Saskatchewan

Lance Baumgard, Milan Shipka, and Bret Taylor will complete their 3-year terms this year. The Committee nominates Glenn Duff (University of Arizona), Rachel Endecott (Montana State University), and Shanna Ivey (New Mexico State University) as replacement committee members for the 2010-2012 term. The Committee nominates Kristi Cammack (University of Wyoming) as committee Chair for 2010.

Competition. Fourteen abstracts were submitted to the GSPC Committee for consideration. Each abstract received 3 reviews. Committee members with conflicts of interest were identified. The majority

of abstracts were scored "accept with revisions". One abstract was reassigned, per author's request, to Ruminant Nutrition, 1 abstract was withdrawn by the author, and 1 abstract was rejected. Of the 14 who submitted abstracts, 11 students submitted manuscripts to the GSPC Committee for review, and thus, were considered contestants. Competing students were C. M. McAllister from Colorado State University, J. L. Peterson and T. J. McDonald from Montana State University, L. E. Camacho and K. L. DeAtley from New Mexico State University, B. W. Neville from North Dakota State University, S. Wyffels from Oregon State University, J. L. Seale from Texas A&M University, R. R. Cockrum and P. Moriel from the University of Wyoming, and C. M. Williams from Utah State University. Montana State University, New Mexico State University and the University of Wyoming tied for institutions with the most competitors at 2 each.

Considerations. There was confusion among some advisors and authors about how the manuscripts should be prepared and if an Implications section is required. In an attempt to provide clarification, the GSPC Committee Chair sent an e-mail to each contestant on April 1 that described how to use and understand the instructions provided on the WSASAS website. Despite this effort 2 papers were submitted without an Implications section. The GSPC Committee will determine if the instructions to contestants, as posted on the WSASAS meeting website, are cumbersome, confusing, or misleading and make recommendations concerning this matter to the WSASAS Executive Committee on June 18.

According to the 2008 preliminary GSPC Committee report that was prepared by Amin Ahmadzadeh, the GSPC Committee made a recommendation to the Executive Committee to weight oral presentations greater than written when calculating final scores. As of June 14, the 2008 WSASAS Business Meeting minutes were not available on the WSASAS website, and thus, the Executive Committee decision could not be confirmed. Therefore, the GSPC Committee will weight oral and written scores equally when calculating the contestants' final scores unless directed otherwise. The minutes of the 2008 Business Meeting, as published in the 2009 Proceedings indicated that equal weight be assigned to oral and written presentations. In addition, it was recommended that the chair of the graduate student competition should provide a brief description of the scoring process prior to announcing the competition individual winners.

Results. The results of the GSPC were tabulated and awards were presented at the banquet on June 17. Individual awards were:

3rd Place. J. L. Peterson, Montana State University.
Metabolic and physical effects of psyllium supplementation on Quarter Horses. J. L. Peterson, S. J. Moreaux, J. G. P. Bowman, J. Olsen, and J. Berardinelli, *Montana State University, Bozeman*.

2nd Place. P. Moriel, University of Wyoming.
Camelina meal and crude glycerin as feed supplements for developing replacement beef heifers. P. Moriel, P. Price, V. Niyagihugu, and B. Hess, *University of Wyoming, Laramie*.

1st Place. C. M. McAllister, Colorado State University.
Genetic parameters for intramuscular fat percentage, marbling score, scrotal circumference and heifer pregnancy in Red Angus cattle. C. M. McAllister, S. E. Speidel, B. W. Brigham, D. H. Crews, Jr., and R. M. Enns, *Colorado State University, Fort Collins*.

Institutional Award. The institutional award for the highest average score with 2 or more contestants was presented to the University of Wyoming by Connie Larson from Zinpro Corporation. WSASAS

expresses its gratitude to Zinpro and Connie Larson for their continued support of the Graduate Student Competition and the Institutional Award.

Advisory and Coordinating Committee Report.
Mike Salisbury, Angelo State University

Committee Members:
1. Mike Salisbury, Angelo State University, Chair
2. Shanna Ivey, New Mexico State University
3. Glenn Duff, University of Arizona
4. Paul Ludden, University of Wyoming
5. Jan Bowman, Montana State University
6. C. Mueller, Oregon State University
7. Mark Enns, Colorado State University
8. James Carpenter, University of Hawaii
9. Andy Roberts, USDA-ARS-LARRL, Miles City, MT
10. Jason Ahola, University of Idaho
11. J. Bret Taylor, USDA-ARS, Dubois, ID
12. B. J. May, Angelo State University

For the 2008 WSASAS meeting the committee was charged with two items to make recommendation on. These two items are outlined in the minutes from the 2008 Executive Committee meeting as items 3 and 4. They are listed below.

3. Policy for publishing symposium papers.

   The A&C Committee will be working on recommendations for a draft policy statement that allows invited symposium speakers to publish symposium papers. Items to be considered include publication format (proceedings papers versus peer reviewed electronic JAS papers) and page charges.

4. Strategic plan.

   The A&C Committee will review the national ASAS strategic plan and will provide recommendations as to how WSASAS fits that plan.

<u>The Committee's Comments and Recommendations</u>

Policy for publishing symposium papers.
It is recommended that symposium papers should have the opportunity to be published with the WSASAS covering the expense of publication, but it should be noted that this could get expensive and might warrant applying a length limit to papers that are invited to be submitted for publication. However, the avenue to getting these symposia papers published is an area of much debate. The consensus of the committee is to allow an option for publication as either a proceedings paper or a JAS symposium publication. The place for publication should be determined by the symposium committee based on scientific merit of the paper because many of them are less scientific than others and would not be appropriate for publication in JAS resulting in rejection of the manuscript. In either publication, they should be peer reviewed prior to publication to preserve the merit of the publication. Additionally,

most speakers would not be able to have a paper prepared by the deadline for publication in WSASAS proceedings as most symposia presentations evolve shortly before they are presented and often should include information resulting from questions and discussion during the presentation. Therefore, if chosen to be published in JAS, the speakers would submit for normal publication, but if they are chosen to be published in WSASAS proceedings, they would need to be written and reviewed for publication in the following year's proceedings or the symposium program should be set at an earlier date so that the invited speakers (if chosen to submit a paper) would have adequate time to prepare a manuscript for publication in the current proceedings publication. In either venue, the quality of papers should be maintained by review and by choice of papers to invite for publication. Ultimately, the symposium committee would be responsible for determining the papers to be invited for publication, the review process and to make sure funding is secured for page charges. A list of responsibilities the Symposium Committee must take on are:

1. Determine each year if invited papers will be solicited
2. Determine publication venue for each paper
3. Make arrangements with the selected publication entity
4. Establish number of invitations and determine publication charges
5. Notify WSASAS President and/or Executive Committee of decisions
6. Make contact and invite authors to submit papers
7. Ensure papers are written and submitted in a timely manner
8. Serve as liaison between author and publication entity

Strategic plan.
In general, the committee feels WSASAS does a relatively good job in fitting most of the Strategic Directions set forward by ASAS. Yet, the committee also feels we can do more in several areas. The areas identified for improvement in the various Strategic Directions are:

#2 ASAS will market and make known to the larger public its value, knowledge and contributions as the leading comprehensive scientific information resource in the field of animal sciences. Have host site do a better job publicizing the annual meetings and symposia, and increase awareness of the symposium to other interested parties since it is being presented as a Webinar and could reach more people across the country. Additionally, we should work toward getting the WSASAS proceedings published on the main JAS website and not just the WSASAS website.

#3 ASAS will expand the numbers and diversity of its membership by actively recruiting, welcoming, and providing services that attract and engage all professionals who work with domesticated animals or animals in managed settings. We fit into this area quite well, but could increase participation by the Equine professionals by possibly adding scientific sessions focused on Equine Science. This would not only broaden our scientific areas, but would increase attendance and participation.

#4 ASAS will invest in its current and future members and leaders by providing professional and leadership development opportunities and by creating new structures and venues that better engage, represent, and meet diverse member needs and interests. WSASAS does a good job of this by continuing to keep costs down by holding the annual meetings on campuses rather than convention centers. However, to continue to maintain and even increase attendance we need to focus on location to keep it centrally located and have adequate travel options to the meetings.

#5 ASAS will develop and invest in cutting-edge communications technology and infrastructure that can effectively and efficiently facilitate scientific information exchange, dissemination, and networking to ASAS members and other interested audiences around the globe. We are currently working toward this with the Beef Symposium presented as a Webinar, but we should continue to increase this type of method for disseminating information.

#6 ASAS will partner and cooperate with other scientific societies, organizations, and government agencies to sponsor multi-disciplinary educational forums, symposia, and activities that address and problem-solve critical and timely issues in the animal sciences. WSASAS members have several ties to other meeting groups that could be partnered with our annual meetings and should be looked in to. Yes caution should be used when partnering with too much if we plan to continue to have the annual WSASAS meeting on campuses and keep the cost of the meetings down. Once we begin to partner with too many, our meeting location options change and price tends to increase.

#7 ASAS and the ASAS Foundation will work to insure that the society continues to be a vital, healthy, and financially sound, and growing organization that can raise the needed resources to implement this strategic plan and remain accountable to its members and their diverse needs. WSASAS does one of the best jobs of any section by continuing to focus on graduate students and the graduate student competition session. The can always continue to increase and may possibly be divided into two sections of M.S. level students and Ph.D. level students to possibly increase the interest by more M.S. students.

An additional committee recommendation for the Executive Committee would be to have committee assignments determined earlier and establish someone within the Advising and Coordinating Committee to serve as a contact person for suggestions to improve our annual meeting and compile these for the A&C Committee prior to the annual meeting so any recommendations can be conveyed to the Executive Committee prior to the annual meeting. This would allow improvements to our meetings to be made earlier rather than later and maybe even before the next meeting. Unfortunately, many suggestions and/or complaints are made in conversation after the meeting and are forgotten before the next meeting and thus never get expressed. We are not suggesting that there are changes that need to be made, but if there is a more accessible avenue of making suggestions, we might make more improvements to our section and annual meetings.

Report from the ASAS President.
Robert Wettemann, ASAS President
Meghan Wulster-Radcliffe, ASAS Executive Director

Dr. Robert Wettemann, ASAS President, and Dr. Meghan Wulster-Radcliffe, ASAS Executive Director, reported on activities and plans of the American Society of Animal Science at the national level. They reminded everyone of the upcoming Joint Annual Meetings in Montreal, Quebec.

Transfer of the Gavel.
Richard Battaglia transferred the WSASAS Presidency to Gary Moss and Past-President Battaglia was presented with the Presidential plaque.

The 2009 Western Section Business Meeting was adjourned by President Moss at 9 AM.

APPENDIX

WSASAS Detailed Financial Report: December 31, 2008.
Denny Crews, Secretary-Treasurer

Western Section
American Society of Animal Science
Financial Report as of December 31, 2008

	Revenue & Support	Expense	Balance
December 31, 2007			**62,654.90**
Donations – General	-		
Donations – Awards	4,800.00		
Donations – Symposium	7,645.00		
Meeting Registrations	31,302.00		
Ticketed Events	-		
Proceedings	11,489.34		
ASAS – Symposium Support	3,000.00		
ASAS – Dues	1,185.00		
Investment Gain/Loss	(14,766.37)		
Miscellaneous Income	223.08		
Total Revenue & Support	**44,878.05**		
Program		419.15	
Call for Papers/Abstracts		-	
Awards/Plaques		6,194.00	
Quadrathlon		2,500.00	
Convention Fees		26,649.47	
Proceedings		2,366.64	
Postage/Supplies		198.14	
Symposium Expense		2,321.00	
Travel – Speaker		-	
Travel		1,734.02	
Telephone		-	
Miscellaneous Expense		4,398.02	
Staff Support		4,856.09	
Total Expenses		**51,636.53**	
Net Revenue over Expense		**(6,758.48)**	
December 31, 2008			**55,896.42**

Proceedings, Western Section, American Society of Animal Science

Vol. 61, 2010

GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF CONVENTIONALLY RAISED LAMBS IMPLANTED WITH ZERANOL VERSUS NATURALLY RAISED LAMBS[1]

S. E. Eckerman*†, C. S. Schauer†, M. M. Thompson†, B. W. Neville*, M. L. Van Emon†*, P. T. Berg*, and G. P. Lardy*

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ABSTRACT: Our objective was to compare feedlot performance and carcass quality of conventional and naturally raised lambs. Two-hundred eighty-eight crossbred lambs (34 ± 0.1 kg) were assigned randomly to one of 12 pens (6 pens/treatment) and fed a finishing ration for 112 d. Treatments were conventional (CONV) or naturally raised (NAT). Naturally raised lambs were fed 80% corn and 20% commercial supplement ad libitum (DM basis; 87.9 % TDN and 15.8 % CP) with decoquinate included. The NAT lambs were not treated with antibiotics nor given growth promoting implants. Conventional lambs were fed a similar ration, with decoquinate, chlortetracycline and lasalocid included in the ration and were implanted with 36 mg zeranol on d 28 and treated with antibiotics as necessary, primarily for treatment of prolapse. Lambs were weighed and feed refusals collected every 28 d. Lambs were harvested on d 117 and carcass data collected 24 h post chill. Data were analyzed using the mixed procedures of SAS. Repeated measures was used to analyze period effects for ADG, DMI, and G:F. Treatment x period interactions were observed ($P \leq 0.02$). From d 29 to 56, CONV lambs had increased ADG, DMI, and G:F ($P \leq 0.02$) compared with NAT lambs. Conventional lambs had increased DMI and decreased G:F ($P \leq 0.008$). However, ADG, DMI, and G:F were not different between treatments ($P \geq 0.06$) for d 0 to 112. Naturally raised lambs had greater rib eye area ($P = 0.03$), decreased body wall thickness ($P = 0.05$), and a greater percentage boneless, closely trimmed retail cuts ($P = 0.05$). More CONV lambs prolapsed rectally or vaginally ($P = 0.001$; 8.3 vs 0 %) which increased mortality ($P = 0.01$; 2.8 vs 0 %). Lambs managed utilizing antibiotics, implants, and ionophores may have increased growth performance compared to lambs raised naturally, but may have diminished carcass quality and are more susceptible to prolapse and mortality.

Key Words: ionophore, lamb, naturally raised, zeranol

Introduction

Consumer demand for niche meat products has dramatically increased over the last two decades. In response, the USDA released voluntary standards for the production of naturally raised livestock. The Naturally Raised Marketing Claim standard promotes several guidelines regarding production of naturally raised livestock, primarily "…without growth promotants and antibiotics and that have never been fed mammalian or avian by-products…" (Agricultural Marketing Service, 2009). Livestock producers could take advantage of the growing market for niche meat products if the qualifications were discernible, and the economic advantages clearly demonstrated.

Growth promotants and antibiotics offer a considerable performance advantage to conventional management systems. The level of ionophores and antibiotics that can be supplemented to naturally raised lambs is restricted, and lasalocid and chlortetracycline (CTC) can be supplemented to conventional lambs to improve growth performance. Conventional lambs can also be implanted with zeranol, which has been shown to increase ADG and G:F in lambs (Hustfedler et al., 1996; Nold et al., 1992; Salisbury et al., 2007). Chlortetracycline has been shown to improve ADG, G:F, and survival rate in lambs (Bridges et al., 1953; Johnson et al., 1956; Kunkel et al., 1956). Lasalocid has also been reported to increase ADG and G:F in lambs (Funk et al., 1986). These factors benefit conventional management practices and may render naturally raised production systems less profitable. Our objective was to determine the effects of naturally raised and conventional management practices on carcass quality and feedlot performance. The hypothesis tested was that lambs raised using conventional management practices would have increased gain compared to naturally raised lambs without affecting carcass quality.

Materials and Methods

Animal Management and Treatments. All experimental protocols were approved by the North Dakota State University Animal Care and Use Committee. Two hundred eighty-eight spring born crossbred lambs (wethers and ewes, 34 ± 0.1 kg) were stratified by weight. Within stratification, lambs were assigned randomly to naturally raised (NAT) or conventional (CONV) treatment. Treatments were applied in a completely randomized design to evaluate lamb growth performance and carcass

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characteristics under naturally raised and conventional management practices. At the start of the trial, lambs were moved to 12 feedlot pens (n = 6). Each pen represented one experimental unit and contained 24 lambs. Lambs were offered feed ad-libitum via bulk feeders and had continuous access to fresh water. Refusals were collected every 28 d. Naturally raised lambs were offered 80% corn and 20% commercial supplement (Market Lamb 38-10 Supplement, CHS Nutrition, Sioux Falls, SD) ad libitum (DM basis; Table 1); the commercial supplement contained decoquinate (0.1432 g/kg, Deccox, Alpharma Inc., Bridgewater, NJ). Naturally raised lambs could not receive any antibiotics. If treatment with antibiotics was necessary, the treated lamb was removed from the pen as well as data set. Conventional lambs were raised using best management practices, including supplementation with decoquinate, lasalocid (Bovatec, Alpharma Inc., Bridgewater, NJ), and chlortetracycline (CTC; Table 1). Conventional lambs were offered 78.7% corn, 19.8% market lamb pellet, 1.2% Deccox, and 0.4% CTC ad libitum (DM basis; Table 1). The CONV market lamb pellet contained 0.15 g/kg lasalocid. Three 12 mg zeranol pellets (Ralgro, Schering-Plough Animal Health Corp., Union, NJ) were subcutaneously implanted in the ear on d 28. Conventional lambs were treated with antibiotics as necessary.

Experimental Periods and Sampling Procedures. Lambs were weighed two consecutive days to determine body weight at the initiation and at the end of the trial. Lambs were weighed once every 28 days after initial weights. Lambs were harvested on d 117 and carcass data collected 24 h post chill by trained university personnel at Iowa Lamb Corporation in Hawarden, IA. Two-hundred forty-five lambs were harvested, 126 CONV and 119 NAT. Feed ingredient samples (approximately 0.2 kg) were collected approximately once every 28 d, dried at 55°C for 48 h, and analyzed for ADF, NDF, N, and OM by a commercial laboratory (Midwest Laboratories, Omaha, NE).

Statistics. Lamb performance data were analyzed as a completely randomized design using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC) with pen as experimental unit. Carcass data were analyzed with missing data points from underweight lambs not included in the data set, with pen serving as experimental unit. The model included treatment, day, and day x treatment interaction. Repeated measures was used to analyze period effects for ADG, DMI, and G:F. Each period consisted of 28 d, for a total of 4 periods. Data are presented as least squares means with differences considered significant at $P \leq 0.05$. The covariant structure used was Simple. Other structures were tested, however, Simple was the best fit.

Results

Results for lamb feedlot performance and carcass quality are reported in Table 2. Final weight, ADG, DMI, G:F, and gain were not different ($P \geq 0.06$) between treatments over the course of the trial (d 0-112). However, period effects were observed ($P < 0.05$). Conventional lambs exhibited increased ADG, DMI, and G:F ($P \leq 0.02$) from d 29-56 compared to NAT lambs. Naturally raised lambs had increased G:F ($P = 0.008$) and decreased DMI ($P = 0.006$) from d 85-112 compared to CONV lambs. Naturally raised lambs also had decreased body wall thickness, increased rib-eye area (REA), and increased percent boneless, closely trimmed, retail cuts (BCTRC) compared to CONV lambs ($P \leq 0.05$). No other carcass characteristics, including leg score, fat depth, quality and yield grades, and kg of lean were different ($P \geq 0.25$). Conventional lambs exhibited increased incidence of rectal and vaginal prolapses ($P = 0.001$) and increased incidence of mortality ($P = 0.01$).

Table 1. Ingredient and nutritional composition of diets fed to feedlot lambs

	Diets[1]	
Item	CONV	NAT
Ingredient, %	DM basis	
Whole Corn	78.7	80.0
CONV Market Lamb Pellet[2]	19.8	0.0
NAT Market Lamb Pellet[3]	0.0	20.0
Deccox	1.2	0.0
Chlortetracycline	0.4	0.0
Nutrient composition, %		
CP	15.7	15.8
TDN	87.5	87.9
Ca	1.10	0.94
P	0.40	0.40

[1] Treatments: CONV (conventional) and NAT (naturally raised).
[2] Conventional Market Lamb Pellet contained: 0.15 g/kg lasalocid, 38% CP, 4.25% Ca, 0.6% P, 3.5% salt, 1.2 mg/kg Se, 52,920 IU/kg Vitamin A, 5,292 IU/kg Vitamin D, and 154 IU/kg Vitamin E.
[3] Naturally raised Market Lamb Pellet contained: 0.1432 g/kg decoquinate, 38% CP, 4.25% Ca, 0.6% P, 3.5% salt, 1.2 mg/kg Se, 52,920 IU/kg Vitamin A, 5,292 IU/kg Vitamin D, and 154 IU/kg Vitamin E.

Discussion

The present study utilized 36 mg implants of zeranol, while previous lamb research was performed using 12 mg, implanted once or repeatedly. The lack of difference in feedlot performance over the course of the trial between treatments was not expected. Given that zeranol, CTC, and lasalocid have all been shown to promote improved feedlot performance, it was believed the CONV lambs would exhibit increased performance. The effects of zeranol on feedlot lamb performance are well documented. Previous research in lambs indicates that zeranol implants increase ADG and G:F (Hufstedler et al., 1996; Hutcheson et al., 1992; Salisbury et al., 2007) as well as DMI (Hutcheson et al., 1992). This agrees with the results from the present study for d 28-56. However, the decrease in G:F and increased DMI, and the trend of decreased ADG ($P = 0.09$), from d 85-112 in CONV lambs resulted in no differences over the course of the trial. Similar to Salisbury et al.

(2007), we observed no differences between treatments for ADG, DMI, and G:F at d 112. However, there was some evidence in our trial that lamb performance may have decreased because lambs had reached market weight and the incidence of rectal and vaginal prolapse. The increased performance observed after implantation (d 28-56) is expected for lambs implanted with zeranol.

Lasalocid has been demonstrated to increase ADG and G:F in lambs (Funk et al., 1986). The effects of CTC on feedlot lambs have been inconsistent, but some research has shown that it can improve feedlot performance. Various trials examining a range of inclusion levels have shown CTC can improve ADG (Johnson et al., 1956; Hatfield et al., 1954), improve feed efficiency (Bridges et al., 1953; Hatfield et al, 1954; Kunkel et al., 1956) and reduce DMI (Kunkel et al., 1956), although oftentimes not at significant levels.

The effects of zeranol on carcass characteristics are inconsistent. Over several different trials, zeranol has caused increased fat depth (Field et al., 1993), increased leg score (Hutcheson et al., 1992; Nold et al., 1992), decreased kidney and pelvic fat (Hufstedler et al., 1996), and increased carcass weight (Hutcheson et al., 1992; Wilson et al., 1972). These results were inconsistent with the present study. The increased body wall thickness in CONV lambs could be a result of overfinishing CONV lambs, although NAT lambs were most likely overfinished as well. The decreased %BCTRC in CONV is most likely a result of the decreased REA, which is accounted for in the %BCTRC calculation. Chlortetracycline is not typically believed to significantly alter carcass quality, but it has been proposed that CTC may improve carcass grades (Hatfield et al., 1954; Jordan et al., 1956).

A serious concern from this trial was the increased percent of vaginal and rectal prolapses in the CONV treatment. When lambs prolapsed, they were treated with antibiotics and sewn with purse string sutures to keep expelled tissue in place. Treated lambs often prolapsed repeatedly, and several eventually died as a result of complications from prolapses. This is similar to research reported by Salisbury et al. (2007). Increased incidence of prolapse has also been cited as a reason for decreased use of zeranol by lamb feeders (Lupton, 2008).

Implications

The results of the trial indicate a possible advantage in growth for conventionally raised lambs implanted with zeranol compared to naturally raised lambs. However, the high incidence of prolapse and mortality in the implanted lambs may negate any possible advantages in growth performance. The improved carcass characteristics exhibited by naturally raised lambs compared to conventional lambs may prove advantageous for producers interested in niche marketing, provided an appropriate premium is paid to offset any potential loss in production. Future research building on this trial should examine effects of lower doses of zeranol implants, and if the feedlot performance and carcass charcateristics of naturally raised lambs can be repeated.

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Table 2. Comparison of Conventional and Naturally Raised feeding practices on feedlot lamb performance and carcass characteristics

	Treatment[1]			
Item	CONV	NAT	SEM[2]	*P*-value[3]
Initial Wt, kg	34.1	34.1	0.13	0.96
Final Wt, kg	73.6	71.4	0.71	0.07
ADG[4], kg·d^{-1}				
d 0-112	0.35	0.33	0.005	0.06
d 0-28	0.35	0.36	0.02	0.95
d 29-56	0.47	0.39	0.02	<0.001
d 57-84	0.32	0.30	0.02	0.14
d 85-112	0.26	0.30	0.02	0.09
Intake[5], kg DM·hd^{-1}·d^{-1}				
d 0-112	1.64	1.58	0.02	0.09
d 0-28	1.39	1.47	0.05	0.08
d 29-56	1.68	1.57	0.05	0.02
d 57-84	1.75	1.67	0.05	0.08
d 85-112	1.77	1.64	0.05	0.006
G:F[6]				
d 0-112	0.21	0.21	0.003	0.47
d 0-28	0.26	0.25	0.01	0.30
d 29-56	0.28	0.24	0.01	0.004
d 57-84	0.18	0.18	0.01	0.53
d 85-112	0.15	0.18	0.01	0.008
Gain, kg	39.5	37.3	0.68	0.06
HCW, kg	37.0	36.5	0.36	0.35
Leg Score[7]	11.5	11.5	0.07	0.95
Conformation Score[7]	11.5	11.6	0.06	0.50
Fat Depth, cm[8]	0.84	0.79	0.03	0.25
Body Wall Thick, cm	2.82	2.69	0.03	0.05
Ribeye Area, cm^2	16.58	17.16	0.13	0.03
Flank Streaking[9]	351.03	356.89	5.85	0.50
Quality Grade[7]	11.4	11.4	0.06	0.85
Yield Grade[10]	3.72	3.55	0.1	0.25
BCTRC, %[11]	43.57	43.92	0.11	0.05
Lean, kg	16.1	16.0	0.13	0.69
Dress, %	49.26	49.26	0.15	0.99
Prolapse, %	8.3	0	1.0	0.001
Mortality, %	2.8	0	0.6	0.01

[1]Treatments: CONV (conventional) and NAT (naturally raised).
[2]Standard Error of Mean; n = 6.
[3]*P*-value for F-tests of mean.
[4]*P*-values for ADG TRT (*P* = 0.04), Pd (*P* < 0.001), TRT x Pd (*P* < 0.001).
[5]*P*-values for Intake TRT (*P* = 0.02), Pd (*P* < 0.001), TRT x Pd (*P* = 0.008).
[6]*P*-values for G:F TRT (*P* = 0.33), Pd (*P* < 0.001), TRT x Pd (*P* = 0.002).
[7]Leg score, conformation score, and quality grade: 1 = cull to 15 = high prime.
[8]Adjusted fat depth and yield grades.
[9]Flank streaking: 100-199 = practically devoid; 200-299 = traces; 300-399 = slight; 400-499 = small; 500-599 = modest.
[10]Yield Grade = 0.4 + (10 x adjusted fat depth, in).
[11]Boneless closely trimmed retail cuts (BCTRC), % = (49.936 – (0.0848 x 2.205 x HCW, kg) - (4.376 x 0.3937 x fat depth, cm) – (3.53 x 0.3937 x body wall thickness, cm) + (2.456 x 0.155 x ribeye area, cm^2)).

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EFFECTS OF RUMEN-PROTECTED ARGININE SUPPLEMENTATION ON EWE SERUM AMINO ACID CONCENTRATION, CIRCULATING PROGESTERONE, AND OVARIAN BLOOD FLOW

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ABSTRACT: Objectives were to determine if rumen-protected arginine supplemented to ewes on d 8 to 13 of the estrous cycle affected serum amino acid concentration, ovarian blood flow, and circulating progesterone. Nineteen multiparous Dorset ewes (63.8 ± 1.1 kg initial BW) were individually housed and randomly allocated to 1 of 4 rumen-protected arginine treatments: 0 (CON, n = 5), 90 (90 ARG, n = 4), 180 (180 ARG, n = 5), or 360 mg/kg BW supplemental arginine (360 ARG, n = 5). Following estrous synchronization, ewes were individually fed rumen-protected arginine blended into 150 g ground corn, which was immediately followed with 650 g of a pelleted diet (2.40 Mcal ME/kg and 12.9% CP, DM basis) on d 8 to 12 of the estrous cycle. Jugular blood samples were taken for amino acid and progesterone analysis. On d 12 color Doppler ultrasonography was used to determine ovarian hemodynamics. Ewes fed 360 ARG had greater serum arginine concentration than CON, 90 ARG, and 180 ARG on d 11 (175.5 vs. 153.2, 132.3, and 145.4 ± 8.6 nmol/mL, respectively; $P \leq 0.07$) and d 12 (166.4 vs. 142.7, 121.7, and 128.2 ± 7.4 nmol/mL, respectively; $P \leq 0.03$). On d 11, arginine as a percent of total amino acid concentration was increased in 360 ARG compared with CON and 90 ARG (7.16 vs. 6.19, 5.70 ± 0.34 nmol/mL, respectively; $P \leq 0.05$). Total essential amino acid concentration was elevated in 360 ARG compared with 90 ARG and 180 ARG ($P \leq 0.03$) on d 12. Arginine supplementation increased peak systolic velocity in the corpus luteum for 360 ARG and 90 ARG compared to CON (30.53 and 32.59 vs. 22.63 ± 2.48 cm/s, respectively; $P \leq 0.04$; Table 2). Flow time (milliseconds) in the ovarian hilus and corpus luteum was increased in 360 ARG compared to all other treatments ($P \leq 0.04$ and $P \leq 0.09$, respectively). Supplemental rumen-protected arginine had no effect on serum concentration of progesterone ($P > 0.50$). Results indicate that rumen-protected arginine supplemented to ewes at the rate of 360 mg/kg BW may increase circulating serum arginine concentration, in addition to increasing ovarian blood flow.

Key words: arginine, ovarian hemodynamics, sheep

Introduction

As a precursor for nitric oxide, polyamines, creatine, proteins, and glutamate, the amino acid arginine plays a vital role in metabolism and reproduction (Wu and Morris, 1998). Nitric oxide is the endothelium-derived relaxing factor essential for increasing systemic vasodilatation (Ignarro et al., 2001; Martin et al., 2001).

Supplemental arginine has been reported to increase the number of live piglets born per sow (Mateo et al., 2007). Furthermore, pregnant rats supplemented with arginine throughout gestation exhibited an increase in embryonic survival and litter size (Zeng et al., 2008). Recently Luther et al. (2008) observed increased ovarian blood flow, serum progesterone, and fetal number, despite similarities in ovulation rate, in ewes injected with L-arginine during the first 15 d post-breeding. Collectively, these studies would suggest that reproductive efficiency can be enhanced via supplementation of supranutritional levels of arginine.

In previous studies, arginine supplementation has been investigated primarily in monogastric species. Due to the lack of available rumen-protected arginine, research in ruminants has been limited. We hypothesize that feeding rumen-protected arginine will increase circulating levels of arginine, in addition to increasing systemic blood flow through its role in nitric oxide synthesis. Our specific objectives were to investigate the effects of feeding rumen-protected arginine on serum amino acids, ovarian hemodynamics, and serum progesterone.

Materials and Methods

All animal procedures were approved by the North Dakota State University Institutional Animal Care and Use Committee. Nineteen multiparous Dorset ewes (63.8 ± 1.1 kg initial BW) were individually housed and randomly allocated to 1 of 4 rumen-protected arginine treatments: 0 (**CON**, n = 5), 90 (**90 ARG**, n = 4), 180 (**180 ARG**, n = 5), or 360 mg/kg BW supplemental arginine (**360 ARG**, n = 5). Rumen-protected arginine (ARG 60; Eurhema Srl., Carviago, Itlay) was a 60% Arginine HCL product, calculated to have a minimum intestinal availability of 50%. Calculation of these doses used this assumption and that 40% of arginine reaching the small intestine is catabolized in this tissue (Wu, 1998), resulting in 30% of the rumen-protected arginine consumed reaching circulation. The 90 ARG treatment was estimated to deliver 27 mg arginine/kg BW to circulation.

All ewes received a vaginally inserted controlled internal drug release (CIDR-G®; 300 mg Progesterone; Pharmacia & Upjohn Limited Co., Auckland, New Zealand) device for 12 d. Following CIDR removal, a single injection of 400 IU equine Chorionic Gondotropin (eCG®; Novormon 5000, Syntex S.A., Buenos Aires, Argentina) was given to initiate follicular development. After synchronization, ewes were moved into the Animal Nutrition and Physiology Center at NDSU, where they were individually housed. The facility was temperature controlled with lighting timed to mimic daylight patterns.

Ewes were allowed a 7-d acclimation period to the facilty and diet before beginning rumen-protected arginine supplementation on d 8 of the estrous cycle (d 0 = estrus). For 5 d, ewes were fed rumen-protected arginine blended into 150 g of ground corn, which was immediately followed with 650 g of a pelleted diet (44.9% beet pulp, 25.0% alfalfa meal, 19.7% soyhulls, 6.7% corn, 3.7% soybean meal; pelleted diet: 2.23 Mcal ME/kg and 13.6% CP, DM basis; total diet: 2.40 Mcal ME/kg and 12.9% CP, DM basis).

Ovarian Hemodynamics. On d 12 of the estrous cycle, color Doppler ultrasonography (Aloka SSD 3500, Tokyo, Japan) was used to determine ovarian hilus and corpus luteum resistance index [(Peak systolic velocity – End diastolic velocity) / Peak systolic velocity], pulsatility index [(Peak systolic velocity – End diastolic velocity) / Time-averaged maximum velocity], peak systolic velocity, end diastolic velocity, mean velocity, and flow time.

Serum Analysis. Blood samples were collected via jugular venipuncture every 12 h from d 8 to 13 of the estrous cycle. Serum was analyzed for progesterone concentration using a solid-phase, competitive, chemiluminescent enzyme immunoassay (Immulite 1000, Diagnostics Products Corp. Diagnostic Products Corp., Los Angeles, CA). All samples were run on a single assay in duplicate form with the intraassay CV 9.1%. Amino acid concentration (20 AA, citrulline, and ornithine) was determined using the modified HPLC procedures of Wu et al. (1997).

Statistical Analysis. Ewe serum and ovarian hemodynamic data were analyzed as a randomized complete block design using the MIXED procedure of SAS (SAS Institute, Inc., Cary, NC) with arginine treatment as the fixed effect. Means were separated using the LSMEANS option of SAS and were considered significant when $P < 0.10$.

Results

Serum Arginine. Ewes fed 360 ARG had greater serum arginine concentration than CON, 90 ARG, and 180 ARG on d 11 (175.5 vs. 153.2, 132.3, and 145.4 ± 8.6 nmol/mL, respectively; $P \leq 0.07$; Figure 1) and d 12 (166.4 vs. 142.7, 121.7, and 128.2 ± 7.4 nmol/mL, respectively; $P \leq 0.03$). On d 11, arginine as a percent of total amino acid concentration was increased in 360 ARG compared with CON and 90 ARG (7.16 vs. 6.19, 5.70 ± 0.34 nmol/mL, respectively; $P \leq 0.05$; Table 1). Total essential amino acid concentration was elevated in 360 ARG compared with 90 ARG and 180 ARG ($P \leq 0.03$) on d 12. Supplemental rumen-protected arginine had no effect on citrulline or ornthine levels throughout the treatment period (data not reported; $P > 0.15$).

Ovarian Hemodynamics. Arginine supplementation increased peak systolic velocity in the corpus luteum for 360 ARG and 90 ARG compared to CON (30.53 and 32.59 vs. 22.63 ± 2.48 cm/s, respectively; $P \leq 0.04$; Table 2). Flow time (milliseconds) in the ovarian hilus and corpus luteum was increased in 360 ARG compared to all other treatments ($P \leq 0.04$ and $P \leq 0.09$, respectively). Pulsatility index and resistance index did not differ among treatments in the corpus luteum and ovarian hilus ($P \geq 0.18$).

Circulating Serum Progesterone. Supplemental rumen-protected arginine had no effect on serum concentration of progesterone (data not reported; $P \geq 0.50$).

Discussion

Arginine supplementation has primarily been evaluated in nonruminant species. Limited research investigating arginine supplementation in ruminants has been conducted because of the high degree of ruminal arginine catabolism and lack of rumen-protected products. Research in pigs (Wu et al., 1997) and sheep (Luther et al., 2008) has indicated that intravenous injection of arginine at the rate of 27 mg of arginine/kg BW increased serum arginine within one hour of injection. Data published herein represent industry and university collaborative efforts directed towards evaluating a rumen-protected arginine product on serum arginine concentrations and ovarian hemodynamics. The 90 ARG treatment used in this study was estimated to deliver 27 mg arginine/kg BW to circulation over a 24 h period. This is in contrast to other studies (Wu et al., 1997; Luther, 2008) which used intravenously injected arginine. Consequently, in the current study, only ewes supplemented the largest dose, 360 ARG, had greater serum arginine concentration, which occurred on d 11 and 12 after 3 and 4 d of supplementation, respectively.

As a precursor for nitric oxide and polyamines, arginine plays a unique role in metabolism and reproduction (Wu and Morris, 1998). Nitric oxide is the endothelium-derived relaxing factor essential for increasing systemic vasodilatation (Ignarro et al., 2001; Martin et al., 2001). Increased systemic vasodilatation has been reported to have many positive effects on steroidogenesis, ovulation, embryo implantation, and the maintenance of pregnancy (Gouge et al., 1998; Manser et. al., 2004). In the present study, rumen-protected arginine supplementation increased peak systolic velocity in the corpus luteum for 360 ARG and 90 ARG compared to CON on d 12 of the estrous cycle. These findings are similar to those of Luther et al. (2008), in which vascular resistance in the ovarian artery was reduced on d 12 following L-arginine injection.

Several studies have reported that low levels of progesterone can lead to a greater incidence of embryonic loss in sheep and ultimately result in decreased ewe productivity (Casida and Warwick, 1945; Dixon et. al., 2007). Rumen-protected arginine had no effect on serum progesterone concentration, which is in contrast to previous

research investigating the effects of arginine supplemented intravenously (Luther et al., 2008).

Implications

Results of this study indicate that rumen-protected arginine supplemented to ewes may increase circulating serum arginine concentration in addition to increasing ovarian blood flow. These preliminary data suggest that biological responses to rumen-protected arginine may be obtained without changing circulating arginine concentration. Additional work is needed evaluating the potential of rumen-protected arginine as a component of strategic supplementation programs. Moreover, the ability of rumen-protected arginine to successfully reach the small intestine and enter circulation needs further evaluation *in vivo*.

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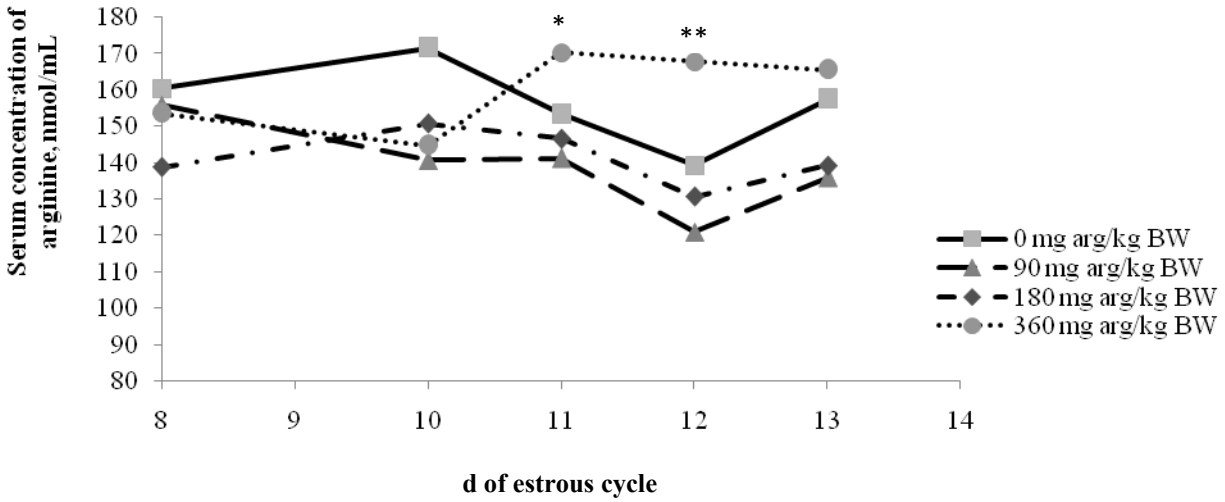

Figure 1. Effects of increasing level of rumen-protected arginine on serum arginine concentration (nmol/mL) in Dorset ewes (**P* = 0.01; ***P* = 0.002) from d 8 to 12 of the estrous cycle.

Table 1. Effects of rumen-protected arginine on serum amino acid concentration

	Treatment[1]					
Item	0	90	180	360	SEM[2]	*P*-value[3]
Day[4] 8						
Total essential amino acids, nmol/mL	1,030	915	938	949	82	0.78
Total amino acids, nmol/mL	2,447	2,196	2,264	2,360	163	0.72
Arginine, % of total essential amino acids	15.5	15.1	15.0	16.4	1.3	0.86
Arginine, % of total amino acids	6.43	6.32	6.08	6.55	0.49	0.92
Day 10						
Total essential amino acids, nmol/mL	1,085	920	973	1,081	79	0.39
Total amino acids, nmol/mL	2,600	2,323	2,422	2,599	187	0.66
Arginine, % of total essential amino acids	15.6	14.4	15.6	15.0	1.1	0.83
Arginine, % of total amino acids	6.47	5.70	6.13	6.27	0.39	0.54
Day 11						
Total essential amino acids, nmol/mL	987	932	895	1,055	63	0.34
Total amino acids, nmol/mL	2,502	2,345	2,260	2,464	125	0.51
Arginine, % of total essential amino acids	15.7	14.3	16.4	16.8	0.9	0.29
Arginine, % of total amino acids	6.19[a]	5.70[a]	6.44[ab]	7.16[b]	0.34	0.04
Day 12						
Total essential amino acids, nmol/mL	936[ab]	828[a]	809[a]	1,014[b]	58	0.08
Total amino acids, nmol/mL	2,320	2,057	2,037	2,378	118	0.12
Arginine, % of total essential amino acids	15.9	15.0	16.1	16.6	0.9	0.62
Arginine, % of total amino acids	6.21	5.99	6.34	7.02	0.32	0.15
Day 13						
Total essential amino acids, nmol/mL	963	943	885	1,028	95	0.77
Total amino acids, nmol/mL	2,430	2,384	2,260	2,443	185	0.89
Arginine, % of total essential amino acids	16.1	15.9	16.5	17.1	0.9	0.80
Arginine, % of total amino acids	6.34	6.19	6.37	7.14	0.35	0.26

[a, b]Means with different superscripts differ ($P \leq 0.10$) for each dose.
[1]Treatments: 0, 90, 180, and 360 mg/kg BW of rumen-protected arginine supplemented from d 8 to 12 of the estrous cycle (n = 5, 4, 5 and 5 respectively).
[2]Standard error of mean.
[3]*P*-value for F-test for treatment.
[4]Day refers to day of estrous cycle (day 0 = estrus). Day 8 is an initial sample taken prior to rumen-protected arginine supplementation.

Table 2. Effects of rumen-protected arginine on ovarian hemodynamics

	Treatment[1]					
	0	90	180	360	SEM[2]	*P*-value[3]
Corpus Luteum						
Peak sysolic velocity, cm/s	22.6[a]	32.5[b]	28.4[ab]	30.5[b]	2.4	0.07
Pulsatility index[4]	0.32	0.39	0.30	0.33	0.04	0.48
Resistance index[5]	0.26	0.32	0.25	0.28	0.03	0.42
Mean velocity, cm/s	20.1[a]	26.7[b]	24.4[ab]	25.7[b]	1.9	0.13
Flow time, ms	566[a]	596[a]	489[a]	753[b]	61	0.06
Hilus						
Peak sysolic velocity, cm/s	31.3	22.3	31.9	29.0	3.3	0.21
Pulsatility index[4]	0.40	0.51	0.40	0.47	0.046	0.30
Resistance index[5]	0.32	0.39	0.31	0.37	0.027	0.18
Mean velocity, cm/s	25.1[b]	17.0[a]	25.8[b]	22.5[ab]	2.5	0.12
Flow time, ms	579[a]	595[a]	514[a]	736[b]	43	0.02

[a, b]Means with different superscripts differ ($P \leq 0.10$) for each dose.
[1]Treatments: 0, 90, 180, and 360 mg/kg BW of rumen-protected arginine supplemented from d 8 to 12 of the estrous cycle (n = 5, 4, 5 and 5 respectively).
[2]Standard error of mean.
[3]*P*-value for F-tests for treatment.
[4]Pulsatility index = (Peak systolic velocity – End diastolic velocity) / Time-averaged maximum velocity.
[5]Resistance index = (Peak systolic velocity – End diastolic velocity) / Peak systolic velocity.

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EFFECT OF WET DISTILLER'S GRAINS WITH SOLUBLES ON RUMEN BACTERIAL COMMUNITY PROFILES IN INDIVIDUALLY FED CATTLE

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ABSTRACT: Despite the growing use of wet distiller′s grains with solubles (WDGS) in the US, very few data are available that describe potential rumen fermentation and microbial ecology alterations that may occur by feeding higher concentrations of WDGS. The objective of this experiment was to evaluate the effects of WDGS on ruminal bacterial communities. Twenty-three steers that had been acclimated to steam-flaked corn finishing ration (average BW = 340 ± 29.6 kg) were randomized and assigned to one of three treatment groups. Cattle were individually fed via calan gates once per day. Treatments were replacement of steam-flaked corn with 0, 30, or 60% WDGS (DM basis; n = 7, 8, and 8, respectively). Ruminal fluid was collected once per wk for 5 wk via esophageal tubing before feeding. Samples were frozen and stored at -20°C for further analysis. Ruminal fluid community DNA was extracted, 16S rDNA was amplified using PCR and analyzed by denaturing gradient gel electrophoresis (DGGE). Clustering of DGGE banding patterns was normalized to an external standard and compared based on binary and numerical coefficients of Dice and Pearson, respectively. Binary banding patterns for all samples were 59.8% similar and total number of bands per sample was not influenced by treatment (P = 0.96). Analysis of treatment dendrograms for binary banding pattern revealed a decrease in similarity from 30 to 60% WDGS, with 0% being intermediate (68.5, 71.2, and 59.2 ±7.09% for 0, 30, and 60% WDGS, respectively). Banding pattern similarity decreased during the duration of the experiment (73.4, 80.4, 72.8, 60.0, and 61.9 ± 8.65% for wk 1-5, respectively). Construction of dendrograms based on band intensity resulted in a dramatic reduction (19.2 ± 12.32%) of similarity across treatments. These results indicate feeding high levels of WDGS does not decrease the richness of the bacterial population but shifts in individual bacterial community members do occur.

Key words: Cattle, Wet distiller's grains, rumen bacteria

Introduction

Ethanol industry coproducts, such as dried distiller's grains with soluble (**DDGS**), wet distiller's grains with soluble (**WDGS**) and condensed distiller's solubles (syrup) are becoming increasingly available as the ethanol industry expands. In 2009 alone 40.1 billion liters of ethanol was produced throughout the United States. A bushel of corn has the potential to yield 10.6 liters of ethanol and 7.7 kg of distiller's coproducts (Renewable Fuels Association, 2010). Wet distiller's grains with solubles can be used as a source of protein and energy in cattle feedlot diets and has been shown to increase feed efficiency over a traditional feedlot diets based on dry rolled corn (Larson et al., 1993; Vander Pol et al., 2006). Furthermore, inclusion of WDGS reduces the amount of starch while increasing the amount of fiber present in a feedlot diet. This has the potential to decrease incidence of acidosis in feedlots (Klopfenstein et al., 2008). Much research has been done to examine the overall usefulness of WDGS as a feedstuff in both cattle feedlots and dairies; however, very few data are available that describe potential alterations of rumen fermentation and microbial ecology that may occur by feeding WDGS in concentrations higher than 30%. With the industry's increasing dependence on the use of distiller's grains as an affordable energy and protein source, a greater understanding of the possible impacts WDGS have on the microflora of the ruminant animal is important. Due the difference in nutrient composition of WDGS to steam-flaked corn, we hypothesize that microbial populations will change with the inclusion of increasing levels of WDGS to a concentrate diet to reflect an increased level of protein, fiber and fat in the diet. However, the impact of those changes on animal performance is unknown. Our objective was to evaluate the effects of WDGS on ruminal bacterial communities using denaturing gradient gel electrophoresis (DGGE).

Materials and Methods

Animals and Experimental Design. All animal procedures were approved by the West Texas A&M Institutional Care and Use Committee. Twenty-three steers (average BW = 340 $\pm$ 29.6 kg) previously acclimated to steam-flaked corn finishing ration and trained to a calan gate system (American Calan; NH) were randomly allotted to one of three treatment groups. Cattle were individually fed via calan gates once per day.

Diets and Sampling. In experimental diets WDGS (average grain composition: 22% sorghum grain and 78% corn grain) replaced steam-flaked corn at 0, 30, or 60% (DM basis; n = 7, 8, and 8, respectively). Diet ingredients and nutrient composition is in Table 1. Cattle were acclimated to WDGS levels over 3d with incremental

increases of 15%. Ruminal fluid was collected once per wk for 5 wk via esophageal tubing with a suction strainer before feeding (Ivey et al., 2009) when WDGS was first added to the ration. All samples were placed on ice immediately after collection and then stored frozen at -20°C until being analyzed for pH, VFA and ammonia concentrations and extraction of community DNA.

Laboratory analysis. Ruminal ammonia was analyzed using the phenol–hypochlorite procedure of Broderick and Kang (1980), adapted to a microtiter plate (BioTek Instruments, Winooski, VT). Volatile fatty acid concentration was determined by high performance liquid chromatography. Community rumen DNA was extracted from ruminal fluid using the bead beating and column method described by Yu and Morrison (2004b). The quality of the DNA was assessed by electrophoresis on 1.0% agarose gel. Extracted DNA was used as template for subsequent PCR-DGGE.

Each PCR reaction was performed in 25 µL and amplified on DNA Engine PTC-200 (MJ Research, Watertown MA) for each PCR-DGGE analysis. The PCR mixture contained 1.25 U Platinum taq (Invitrogen, Carlsbad CA) 60 mM Tris-SO4 (pH 8.9), 18 mM ammonium sulfate,1.75 mM MgCl2, 250 µM of each deoxynucleoside triphosphate, 0.0674%BSA, 0.5 µM each primer and approximately 100 ng of template DNA. The V3 reigion of the *rrs* gene was amplified using primers 357f (5'-CCTACGGGAGGCAGCAG-3') and 519r (5'-ATTACCGCGGCKGCTGG-3'). The 357f primer has a 40-bp GC clamp attached to the 5' end (CGC CCGCCGCGCGCGGCGGGCGGGGCGGGGGCACGGG GGG) to prevent dissociation of the DNA strands (Yu and Morrison, 2004a). To reduce the production of spurious PCR products, touchdown PCR was performed. The PCR cycle consisted of an initial denaturing at 94ºC for 4 minutes, 10 cycles of touchdown PCR wherein the starting annealing temperature of 61ºC was decreased 0.5°C per cycle for ten cycles to 56ºC. This was followed by 25 cycles with denaturing step at 94°C for 30 s, annealing at 56ºC 30 s, and a final primer extension at 72º for 30 s. Quality of the PCR products was confirmed visually using a 1.5% agarose gel stained with ethidium bromide.

Using the Bio-Rad D-Code system (BioRad, Hercules, CA), DGGE was performed as described by Simpson et al., 1999. To separate PCR fragments, 30 µL of PCR product was resolved on 7.5 % polyacrylamide gel (37.5:1) containing a 30 to 60% gradient denaturants (100% denaturants consisting of 40% [vol/vol] formamide and 7 M urea). Electrophoresis was performed at 60°C and 82 V for 16 hrs. Additionally, a standard sample was included in each gel to allow for normalization of band migration and gel curvature among different gels (McCracken et al., 2001). After electrophoresis, gels were stained with GelStar (Cambrex, Rockland, ME) according to manufacturer's specifications and the images were captured using Kodak Imaging Systems (New Haven, CT).

Statistical analysis of DGGE banding patterns. Images of DGGE gel patterns were imported as TIFF files into Bionumerics software (version 5.2; Applied Maths, Applied Maths, Inc., Austin, TX). Lanes of each DGGE gel were converted to densiometric curves and an automatic band search was performed on normalized patterns. Gels were normalized using five bands from a 1 kb DNA ladder and a standard sample to ensure the location of bands was consistent across all gels. After visual control of the assigned bands, a band-based analysis was performed using two methods. For the Dice coefficient all bands are divided into classes of common bands and for each band pattern, a particular band class can have two state: present or absent (binary matrix). A 1% band position tolerance was used and is an arithmetic determination of the degree to which banding patterns are alike, (i.e. contain the same bands in similar locations). The Pearson correlation coefficient was used to calculate similarities of banding patterns based on band intensities by correlating the intensities between densitometric curves. For cluster analysis of both methods similarities were displayed graphically as a dendrogram. The clustering algorithms used to calclulate the dendrograms was an unweighted pair group method with average linkages (UPGMA). Clusters (groups) were determined by sequentially comparing patterns and the construction of a related dendrogram reflected relative similarities.

Shannon-Wiener diversity index. Richness (*S)* was determined from the number of bands in each lane using the band matching table generated during the Dice analysis of the DGGE profiles. The Shannon-Wiener index (*H'*) of diversity was used to determine the proportional abundances of bacterial taxa present in the rumen samples of cattle fed increasing levels of WDGS. Shannon-Wiener index was calculated for binary (band presence or absence) and band intensity using the following equation: $H' = -\Sigma P_i \ln P_i$, where P_i is the importance probability of the bands in a lane, calculated from n_i/N where n_i is the peak height of a band and N is the sum of all peak heights in the densitometric curve.

Statistical analysis. Richness, Shannon-Wiener index, ruminal ammonia and VFA concentrations were analyzed as a completely random design with repeated measures using the Proc MIXED procedure of SAS version 9.1 (SAS Inst. Inc., Cary, NC). Model included the effect of treatment. The repeated variable was sampling week and the error term was animal within treatment. Compound symmetry was used as the variance structure. Mean comparisons with *P*-values less than or equal to 0.05 were declared significant, and values less than or equal to 0.10 were considered tendencies. Means were calculated using LSMEANS and separated using PDIFF. Single degree of freedom contrasts evaluated the means of cattle fed 0% WDGS compared to 30% and 60% WDGS.

Results

Ruminal ammonia had a tendency to differ by treatment (P = 0.08) with addition of 60% WDGS resulting in the greatest ammonia concentration (1.86, 1.36, and 3.13 ± 0.57 for 0, 30, and 60% WDGS respectively). Treatment had no effect on total VFA production (P = 0.26), acetate (P =0.29), propionate (P = 0.19), or butyrate (P =0.23) concentrations and acetate:propionate ratio (**A:P**; P = 0.43). Ruminal pH tended to decrease as the level of WDGS treatments increased (P = 0.11). Ruminal pH levels were highest in 0% WDGS (7.77, 7.68, and 7.52 ± 0,09 for 0, 30, and 60% WDGS respectively) with a tendency for no WDGS to be statistically different than inclusion of WDGS in the diet (P = 0.11). Treatment had no effect on richness (P = 0.83) or Shannon-Wiener index evaluated for either binary (P = 0.29) or intensity (P = 0.71). Banding pattern similarity was assessed using two differing coefficients, Dice and Pearson. When dendrograms were constructed using banding pattern based on band presence or absence all samples were more uniform when compared to dendrograms based on band intensity (59.8 vs 19.2 ± 12.32% for binary and intensity dendrograms respectively). Similarities of dendrograms were compared by treatment. The 30% WDGS treatment yielded the most similar dendrograms (71.20 ± 7.09 and 21.53 ± 12.79, binary and intensity, respectively).

Discussion

While a large amount of research has been conducted involving ethanol industry coproducts and animal productivity, very little data exist to show the effect of these coproducts the rumen microbial environment. It was our hypothesis that bacterial populations would change with the inclusion WDGS in a concentrate diet to reflect an increased level of protein, fiber and fat in the diet. The WDGS used in this experiment averaged 22% sorghum grain and 78% corn grain (DM basis). In our study, dietary CP increased with addition of WDGS (13.4, 16.7, 22.2% CP for 0, 30, and 60% WDGS respectively) and ruminal ammonia tended to increase as WDGS were added to the diet agrees with this increase in protein. The degradability of the protein fraction of WDGS is a reflection of the grains in the fermentation mix. Degradability of zein, the main protein in corn distiller's grains, is approximately 40% (Aines, 1987) and sorghum protein is 23% more degradable than corn protein in the rumen (NRC, 2000) therefore the CP in the WDGS used in this study should be greater than 40% due to the combination of sorghum and corn grains. In 2009, Leupp et al. showed a quadratic increase in ruminal ammonia concentration with corn DDGS from levels of 0 to 1.2% of BW with a moderate quality diet. This same study also showed no difference in rumen pH with differing DDGS levels. Anderson et al., (2006) also showed an increase in ammonia concentrations with an increase from 10% to 20% WDGS. They also compared ammonia levels to a control containing no distiller's grains as well as 10% and 20% DDGS and the control treatment tended to yield higher ammonia concentrations than WDGS treatments. Anderson et al., (2006) attributed this to an increase in ruminally degradable soybean meal in the control diet. They showed that WDGS had higher ammonia concentrations than did DDGS treatments.

Volatile fatty acids are the end product of rumen microbial fermentation and represent the main supply of metabolizable energy for ruminants (Van Soest, 1982). Our data showed no affect of treatment on VFA production and agree with experiments of Anderson et al., (2006) as well as Al-Suwaiegh et al., (2002) which showed no change in total VFA production when ethanol co-products were fed.

Our data indicates that WDGS do have some impact on rumen bacterial community structure. Differences bacterial concentrations have been observed when animals are fed either a high-concentrate or high-forage diet (Leedle and Hespell, 1980). Mackie and Gilchrist (1979) showed an increase in amylolytic bacteria from 1.6% to 21.2% during the stepwise adaptation of sheep to a 71% concentrate diet. Previous work from Nebraska by Fron et al., (1996) showed that inclusion of 15% condensed distiller's byproducts in a dry-rolled corn diet increased both fibrolytic and lactilytic bacteria. These changes in bacterial populations are a sign of ability of the rumen microbial population to adaptation to efficiently utilize available nutrients. The changes observed in our study in bacterial community structure may have not reached the magnitude to influence ruminal VFA or ammonia concentrations and the short duration of our sampling protocol does not allow us to determine the impact of these changes on animal performance. However, they do imply that ruminal VFA and ammonia may not be sensitive enough to detect slight shifts in the bacterial population. The impact of these shifts in bacterial populations on animal productivity needs further investigation and further research is needed to evaluate the types of bacteria that are changing in quantity with these changes in diet.

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Table 1. Ingredient and chemical composition (DM basis) of experimental diets containing wet distiller's grains with solubles fed to steers.

	Wet distiller's grains with solubles concentration		
Ingredient, %[1]	0%	30%	60%
Steam-flaked corn	78.25	56.22	28.74
Cottonseed meal	5.58	-	-
Wet distiller's grains with solubles[2]	-	30.16	60.19
Supplement[3]	3.17	2.65	2.13
Yellow grease	4.02	2.00	-
Alfalfa hay	8.98	8.97	8.94
Chemical composition, %[4]			
CP	13.4	16.7	22.2
Non-protein N, % CP	2.5	1.4	0.3
ADF	8.3	11.7	17.0
NDF	13.8	20.4	28.9
EE	5.9	5.9	7.7
Ca	0.8	0.7	0.7
P	0.3	0.4	0.5

[1]Determined based on actual DM determined for each ingredient throughout the study.
[2]Wet distiller's grains with soluble averaged 22% sorghum grain and 78% corn grain.
[3]Supplements were formulated to provide 1.06, 0.53, and 0% urea for 0, 30, and 60% wet distiller's grains with solubles.
[4]Data represent the mean of duplicate analyses for each analyte from a composite of weekly samples for each diet collected from the bunk.

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FORAGE SELECTION PREFERENCES BY MULTIPAROUS AND PRIMIPAROUS BEEF COWS GRAZING NATIVE TALLGRASS RANGE DURING WINTER

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ABSTRACT: Our objective was to evaluate diet selection preferences of 18 experienced multiparous and 20 naive primiparous beef cows (9 and 2 yr old, respectively) grazing dormant, native tallgrass pastures during winter. The study was analyzed as a 4-period, 8-pasture (average size = 28 ha) Latin rectangle. Predominant pasture forage species were *Andropogon geradii* and *Schizachyrium scoparium*, which were grouped together for analysis (BL); *Bouteloua curtipendula* (SO); *Bouteloua gracillis*, (BG); *Panicum virgatum* (SG); *Sorghastrum nutans* (IG); *Amorpha canescensi* (LP); *Symphyotrichum ericoides* (HA); *Liatris punctata* (DG); and *Dalea purpurea* (PP). Animals were grouped randomly by parity status (n = 4 or 5) and grazed 1 of 4 assigned pastures during 4 consecutive 48-h periods. Fecal samples were collected from each animal at the end of each period. Range-plant fragments in fecal samples were quantified using a modified microhistological technique; plant fragment prevalence in fecal material was assumed to be equivalent to diet composition on a DM basis. Primiparous cows selected more forbs and fewer grasses (main effect of parity; P = 0.09) than multiparous cows. Multiparous cows ate more (P = 0.07) BL and less (P = 0.05) DG than primiparous cows. Consumption of all forbs, PP, LP, and DG by both classes of cows declined ($P \leq 0.04$) over time, while consumption of all grasses, BL, and BG increased ($P \leq$ 0.02) over time, indicating possibly that forb availability diminished during the study. Occasional differences in consumption of IG, SG, SO, and HA between primiparous and multiparous cows occurred; however, differences were inconsistent (parity x period effect; $P \leq$ 0.02) over time. Differences in diet selection patterns between multiparous and primiparous cows during a short-term winter grazing period could be indicative of differences in long-term foraging strategies. We interpreted these data to suggest that foraging strategies associated with cow stayability may be related to selection preferences during periods of poor forage quality.

Key Wor ds: botanical composition, cows, grazing, heifers

Introduction

Estimating the nutritive value of a grazing animal's diet is a significant challenge. Description of the botantical composition of a grazed diet is vital in that regard (Holechek et al., 1982b). Microhistological analysis of fecal material has been used for estimating the botanical composition of wild and domestic ungulate diets since first described by Baumgartner and Martin in 1939 (Holechek and Vavra, 1981; Holechek et al., 1982a; Alipayo et al., 1992). The primary weakness of microhistological analyses of fecal material for estimating botanical composition of cattle diets is that it may over-estimate consumption of grasses and shrubs and underestimate consumption of forbs compared with microhistological analyses of ruminal contents. The primary strengths of fecal microhistology are that it is non-invasive and it does not disrupt animal grazing behavior. In addition, sample collection is not constrained by the availability of fistulated animals (Soder et al., 2009). Little research has been conducted on the diet selection preferences of multiparous beef cows compared to primiparous beef cows. We hypothesized that foraging strategies associated with cow longevity may be related to selection preferences during periods of poor forage quality. To that end, our objective was to characterize differences in diet selection between experienced multiparous and naïve primiparous beef cows grazing dormant, native Tallgrass pastures during winter.

Materials and Methods

All procedures used in the care and handling of animals in our study were approved by the Kansas State University Institutional Animal Care and Use Committee.

Design and Treatments. The study was analyzed as a 4-period, 8-pasture (average size = 28 ha) Latin rectangle. Multiparous cows (n = 18; average initial BW =

589 ± 50 kg; average initial body condition score = 4.9 ± 0.5) were all 9 y of age and had grazed dormant, native Tallgrass pastures during each winter of their lives. Primparous cows (n = 20; average initial BW = 301 ± 25 kg; average initial body condition score = 4.1 ± 0.4) were all 2 y of age and had never grazed dormant, native Tallgrass pastures. Cows were grouped randomly into grazing cohorts by parity status (n = 4 or 5); cohorts were then assigned randomly to graze 4 pastures in sequence during 4 consecutive 48-h periods. Cows were allowed to adapt to their cohort groupings and to graze separate dormant, native Tallgrass pastures for 9 d before the study began. No supplemental feed or mineral was offered to cows during the study.

The study was conducted at the Kansas State University Beef Stocker Unit. Predominant pasture forage species were described by Towne and Owensby (1984) and Haddock (2005) and included big bluestem (*Andropogon geradii*) and little bluestem (*Schizachyrium scoparium*), which were grouped together for the purposes of microhistological analysis (BL); sideoats gramma (*Bouteloua curtipendula,* SO); blue gramma (*Bouteloua gracillis,* BG); switch grass (*Panicum virgatum,* SG); indian grass (*Sorghastrum nutans,* IG); lead plant (*Amorpha canescensi,* LP); heath aster (*Symphyotrichum ericoides,* HA); dotted gayfeather (*Liatris punctata,* DG); and purple prairie clover (*Dalea purpurea,* PP). Average chemical composition of the pasture forage during the study was 93.5% DM, 2.98% CP, 71.6% NDF, and 50.8% ADF.

Collections. Individual grazing cohorts were gathered into a corral at the end of each 48-h collection period. Fecal grab samples were collected from each animal. Each grab sample was hand mixed to ensure homogeneity and a 40-g subsample was retained for analysis.

Sample Preparation. Sample preparation methods were described by Holechek (1982), as modified by Eckerle et al. (2009). Samples were soaked overnight in 50% EtOH (v/v). The EtOH was removed and samples were homogenized and washed with de-ionized H_2O through a No. 200 US-standard sieve to remove contaminants. Samples were then re-homogenized, strained, and dried at 55°C for 96 h. Dried samples were ground (#4 Wiley Mill, Thomas Scientific, Swedesboro, NJ, USA) to pass a 1-mm screen and stored for slide preparation (Bennett et al., 1999).

Slide Preparation. Slide preparation methods were described by Eckerle et al. (2009). Subsamples (0.5 g) of dried, ground plant material were soaked in de-ionized H_2O for 1 h to soften them. Approximately 20 mL of NaOH (0.05M) was then added to each sample. Samples were incubated for 20 min at room temperature to destroy plant pigments. Samples were rinsed with de-ionized H_2O over a No. 200 US-standard sieve to remove NaOH and then homogenized in a blender with 20 mL of de-ionized H_2O for 1 min. Samples were then rinsed a second time over a No. 200 US-standard sieve.

Samples were placed on a slide, 1 – 3 drops of Hertwig's solution was applied, and the slide was placed over a propane flame until dry. One to 2 drops of Hoyer's solution was added to mount a cover slip. Slides were dried for 96 h in a 55°C-oven before viewing.

Slides were viewed on a compound microscope at 10 × magnification. The microscope was equipped with a digital camera; each slide field was photographed for comparison with standard slides (Eckerle et al., 2009). Twenty fields per slide were selected randomly from the entire slide view and were used to measure the frequency with which plant fragments appeared (Holechek and Vavra, 1981). Plant fragment prevalence in slide fields was assumed to be equivalent to prevalence in fecal samples and in grazed diets on a DM basis (Sparks and Malechek, 1968). Plant fragments that were not among the 10 predominant range plants for which standards were prepared were classified as either an unknown grass or an unknown forb.

Statistics. Data were analyzed as a Latin rectangle using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). Class variables included parity, grazing cohort, animal, period, and pasture. The model included terms for parity, period, and parity x period. Period × pasture × cohort within parity was used as the error term. Type-3 error rates were used to test for differences between treatments and periods. Means were separated using the method of Least Significant Difference and were reported with pooled standard errors. Means were considered different when $P < 0.10$.

Results and Discussion

The objective of our study was to characterize differences in diet selection between experienced multiparous and naïve primiparous beef cows grazing dormant, native Tallgrass pastures during a short-term winter grazing bout. Villalba and Provenza (2009) indicated that nutritional status of grazing herbivores and their capability to persist in a range-based production system (i.e., stayability) was a function of cumulative experience as a grazer. We speculated that, under conditions of poor forage quality, differences in the capability of animals to alter nutrient intake by selectively grazing specific forage species would be magnified. Furthermore, we speculated that foraging strategies learned through extensive experience (e.g., mature multiparous cows) may contrast with foraging strategies

formed through limited experience (e.g., naïve primiparous cows).

Relatively few plant species comprise the majority of diets selected by beef cows grazing the Kansas Flint Hills during winter (Eckerle et al., 2009). The prevalence of unidentifiable grasses and forbs in each period × grazing cohort observation was ≤ 0.14% in our study; moreover, there were no effects ($P \geq 0.32$) of treatment or period on the amount of unidentified grasses or forbs in beef cow diets (Table 1).

Primiparous cows selected more ($P = 0.09$) forbs and fewer ($P = 0.09$) grasses than multiparous cows (Table 2). The average magnitude of the difference was modest (i.e., 4.03%) but typical of previous reports comparing botanical composition of diets grazed by different classes of beef cattle (Grings et al., 2001; Clark et al., 2009). In addition, multiparous cows ate more ($P = 0.07$) BL and less ($P = 0.05$) DG than primiparous cows (Table 2). Grass consumption by the cows in our study was less and forb consumption greater than that reported for spring and summer grazing seasons in the northern US (Grings et al., 2001; Clark et al., 2009; Wyffels et al., 2009). Conversely, Mohammad et al. (1996) and Eckerle et al. (2009) reported similar grass:forb in cattle diets in the southern US.

Greater consumption of forbs by primiparous cows compared with multiparous cows was unexpected. Soder et al. (2009) indicated that preference for broadleaf plants generally increases with grazing experience; however, these conclusions were based on research with greater-quality forages than those evaluated in our study. The post-ingestive consequences of consuming dry, dormant broadleaf plants may be different from those associated with consumption of actively-growing broadleaf plants.

Towne and Owensby (1984) reported that forbs comprised only 2.5 to 6% of all range plants on Kansas Tallgrass prairie. Forb consumption in our study ranged from a high of 39.62% in period 1 to a low of 27.05% in period 4 (Table 3). Consumption of all forbs, PP, LP, and DG by both classes of cows declined ($P \leq 0.04$) over time, while consumption of all grasses, BL, and BG increased ($P \leq 0.02$) over time. Cows appeared to actively seek certain forb species during foraging. Similar observations were reported by Mohammad et al. (1996). The pastures in our study were subject to repeated grazing bouts over an 8-d period. The decline in forb consumption over time may have indicated that forb availability diminished during the study.

Occasional differences in consumption of IG, SG, SO, and HA between primiparous and multiparous cows occurred; however, differences were inconsistent (parity × period effect; $P \leq 0.02$) over time (Table 1). The significance of these differences was judged to be relatively minor.

Implications

Differences that we observed in diet selection patterns between multiparous and primiparous cows during a short-term winter grazing period could be indicative of differences in long-term foraging strategies. We interpreted these data to suggest that foraging strategies associated with cow stayability in a range-based production system may be related to selection preferences during periods of poor forage quality. Further research in this area appears warranted.

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Table 1. Effects of collection period on botanical composition of diets selected by multiparous or primiparous beef cows grazing the Kansas Flint Hills during winter

						P-Values		
Item	Period 1	Period 2	Period 3	Period 4	SEM	Parity	Period	Parity x Period
Grasses, % of diet DM								
Multiparous	61.74	66.51	73.02	74.55	2.532	0.09	< 0.01	0.55
Primiparous	59.02	64.59	64.75	71.35				
Andropogon geradii + *Schizachyrium scoparium*, % of diet DM								
Multiparous	27.24	15.20	19.62	17.77	1.491	0.07	< 0.01	0.58
Primiparous	26.39	10.54	17.02	15.99				
Sorghastrum nutans, % of diet DM								
Multiparous	19.44	34.17	37.23	40.89	1.728	0.24	< 0.01	< 0.01
Primiparous	16.38	44.74	36.23	41.79				
Panicum virgatum, % of diet DM								
Multiparous	9.97	11.78	11.59	10.05	1.145	0.01	0.60	0.03
Primiparous	9.34	5.09	7.01	7.54				
Bouteloua gracillis, % of diet DM								
Multiparous	3.57	3.91	2.60	4.30	0.508	0.79	0.02	0.13
Primiparous	4.62	2.90	2.79	3.64				
Bouteloua curtipendula, % of diet DM								
Multiparous	1.47	1.64	1.84	1.57	0.244	0.82	0.22	0.04
Primiparous	2.23	1.06	1.48	1.60				
Unknown Grasses, % of diet DM								
Multiparous	0.03	0.05	0.03	0.02	0.055	0.32	0.74	0.60
Primiparous	0.04	0.09	0.10	0.14				
Forbs, % of diet DM								
Multiparous	38.26	33.48	26.97	25.44	2.532	0.09	< 0.01	0.55
Primiparous	40.98	35.41	35.25	28.65				
Dalea purpurea, % of diet DM								
Multiparous	14.23	13.66	11.70	9.99	1.117	0.15	< 0.01	0.22
Primiparous	15.93	16.22	10.10	12.06				
Amorpha canescensi, % of diet DM								
Multiparous	10.83	10.32	5.58	6.16	1.559	0.42	0.04	0.14
Primiparous	10.62	9.05	10.60	7.39				
Liatris punctata, % of diet DM								
Multiparous	7.06	6.48	6.17	5.35	1.051	0.04	0.01	0.28
Primiparous	11.24	8.44	7.77	5.63				
Sympyotricum ericoides, % of diet DM								
Multiparous	6.15	3.00	3.71	3.87	0.858	0.88	< 0.01	< 0.01
Primiparous	3.18	1.98	6.89	4.18				
Unknown Forbs, % of diet DM								
Multiparous	0.03	trace	0.01	0.01	0.014	0.58	0.60	0.38
Primiparous	trace	trace	trace	0.02				

Table 2. Effect of parity status on botanical composition of diets selected by beef cows grazing the Kansas Flint Hills during winter

Item	Primiparous	Multiparous	SEM	*P*-Value
Grasses, % of diet DM	64.93	68.96	1.404	0.09
Andropogon geradii + *Schizachyrium scoparium*, % of diet DM	17.49	19.96	0.791	0.07
Forbs, % of diet DM	35.07	31.04	1.404	0.09
Liatris punctata, % of diet DM	8.26	6.26	0.579	0.05

Table 3. Effect of collection period on botanical composition of diets selected by beef cows grazing the Kansas Flint Hills during winter

Item	Period 1	Period 2	Period 3	Period 4	SEM	*P*-Value
Grasses, % of diet DM	60.38	65.55	68.89	72.95	1.779	< 0.01
Andropogon geradii + *Schizachyrium scoparium*, % of diet DM	26.82	12.87	18.32	16.88	1.040	< 0.01
Bouteloua gracillis, % of diet DM	4.10	3.41	2.70	3.97	0.350	0.02
Forbs, % of diet DM	39.62	34.45	31.11	27.05	1.779	< 0.01
Dalea purpurea, % of diet DM	15.08	14.94	10.90	11.02	0.775	< 0.01
Amorpha canescensi, % of diet DM	10.72	9.68	8.09	6.77	1.093	0.04
Liatris punctata, % of diet DM	9.15	7.46	6.97	5.49	0.737	0.01

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DRY MATTER INTAKE IS REPEATABLE OVER PARITIES AND RESIDUAL FEED INTAKE IS NEGATIVELY CORRELATED WITH DRY MATTER DIGESTIBILITY IN GESTATING COWS

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ABSTRACT: Feed costs account for approximately two-thirds of total cash inputs for cow/calf producers. Selecting cows that consume less DM, but maintain production, would lower breakeven costs. The objectives of these two experiments were to determine repeatability of DMI over parities, calculate residual feed intake (RFI), and examine the relationships between RFI and diet DM digestibility. Nichols et al. (2010, these proceedings) previously determined individual DMI for 120 gestating, primiparous heifers in 2008. In Exp. 1, twenty-four of these heifers that had the highest and lowest DMI were selected for this 2009 experiment. Cows (3-yr-old, BW = 593 ±50 kg, second trimester gestation) were fed a diet composed of 74% grass hay and 26% grain-based supplement (104% of MP requirement) to determine the correlation of DMI per $BW^{0.75}$ between heifers (2008) and later as cows (2009). Animals were in a similar gestational state both years. Diets were limit fed at 12.7 kg $DM \cdot cow^{-1} \cdot d^{-1}$ using a GrowSafe system. Cows were adapted to the diet for 10 d followed by a 70 d trial to determine individual feed intakes and weight gain. Residual feed intake was calculated as the residual from the linear regression of DMI on $BW^{0.75}$ and ADG. Dry matter intake per $BW^{0.75}$ was highly correlated ($r = 0.71$, $P < 0.01$) between first and second parities. Residual feed intake ranged from 4.46 kg/d to -4.58 kg/d. Immediately following Exp. 1, cows were fed for an additional 5 d for collection of feces (Exp. 2). Grab samples were collected daily at 0600 and 1800, and indigestible ADF was used to estimate DM digestibility. Residual feed intake was negatively correlated with DM digestibility ($r = -0.51$, $P = 0.03$, range = 62.6% to 74.2%) but had no relationship with digestible DMI ($P = 0.32$). Results showed that DMI was repeatable over parities, and as RFI increased, DM digestibility of a forage-based diet decreased.

Key Words: residual feed intake, gestation, digestibility

Introduction

Genetic selection in the cattle industry during the past three decades has focused on growth and carcass traits. As a result, there has been a significant increase in mature cattle weights and consequently, DM consumption per animal. Breakeven costs could be lowered if input costs (feed) were reduced without a negative effect on output (eg. weaning weights and reproduction; Archer et al. 1999). Selection for improved feed efficiency using G:F ratios has been questioned because of the correlation of ADG and G:F ratios. Therefore, animals have indirectly been selected for growth (Crews 2005).

Koch et al. (1963) first proposed using residual feed intake (RFI) as an alternative measure of feed efficiency because it is independent of growth. RFI is the difference between an animal's actual DMI and its expected DMI necessary to meet requirements for maintenance and production. Residual feed intake is calculated by a phenotypic regression of actual intake or DMI on $BW^{0.75}$ and predicted ADG (Crews et al. 2006).

Several questions remain unanswered regarding the biological factors which can be attributed to RFI results described in the literature. Richardson et al. (1996) reported that young bulls and heifers (sorted by low and high RFI) differed slightly in diet DM digestibility. The low RFI group exhibited only a 1% improvement in DM digestibility when compared to the high RFI group. Similarly, Cruz et al. (2010) reported no differences in DM digestibility between high and low RFI steers.

Additional questions have been raised regarding the repeatability of RFI. For example, do cows with a negative RFI early in their productive lives retain this trait after producing several progeny? Herd et al. (2006) and Arthur et al. (1999) both reported a significant correlation of RFI with heifers tested as calves post-weaning and again as 4-yr-old cows.

The objectives of this research were to determine repeatability of DMI over first and second parities, determine RFI, and determine if a significant relationship existed between RFI and diet DM digestibility.

Materials and Methods

Animal care and handling techniques were approved by the Montana State University Institutional Animal Care and Use Committee (AA-301).

Exp. 1

Twenty-four cows (3-yr-old, BW = 593 ±50 kg, second trimester of gestation) with previously determined DMI differences (Nichols et al. 2010, these proceedings) were transported to the Bozeman Agricultural Research and Teaching Farm in 2009 to investigate the correlation of DMI between heifers (2008) and later as cows (2009). Animals were in a similar gestational (2^{nd} and 3^{rd} trimesters) stage both years. Twelve cows with the highest and twelve cows with the lowest DMI were assigned to one pen (30 x 11 m) which held eight GrowSafe (Airdrie, Alberta, Canada) pods which are designed to determine individual feed intakes.

Cows were offered a total mixed ration comprised of 74% native grass hay and 26% supplement (Table 1) and were fed at approximately 12.7 kg $DM \cdot cow^{-1} \cdot d^{-1}$. The grass

hay was chopped to a length of 10 cm through a hammer mill. Cows had ad libitum access to water and trace mineralized salt blocks (White Block, North American Salt Company; Overland Park, KS). The rations were mixed daily in a Roto-Mix TMR Mixer/Feeder (Dodge City, KS) and fed at 0730.

The experiment consisted of a 10 d adaptation period to the GrowSafe pods followed by a 70 d feeding trial. Body weight measurements were recorded on d 1, 2, 14, 28, 42, 56, 69, and 70. Initial and final weights were recorded as the average of d 1 and 2 and d 69 and 70. Average daily gain and initial weight were predicted from a regression of BW on animal and the animal x day interaction. Predicted end weight was calculated by multiplying the predicted initial weight by the predicted ADG and days on feed. Then, $BW^{0.75}$ was computed by averaging the predicted initial and end BW and raising that result to the three quarter power. RFI was calculated as the residual from the linear regression of DMI on $BW^{0.75}$ and ADG.

Results of DMI over parities were compared by a Pearson correlation coefficient (Statistix 9, 2008). Coefficients were considered significant at the $P < 0.05$ level.

Table 1. Diet[1] composition fed to gestating cows to determine DMI, residual feed intake (RFI), and diet DM digestibility.

Item	% of DM
Chopped Native Grass Hay	74.20
Dried Distillers Grains	12.60
Soybean Meal	6.10
Cracked Corn	5.40
Calcium Carbonate	1.00
Mineral supplement[2]	0.70

[1] 15.1% CP, 104% of NRC (1996) MP requirement, 0.57 NE_m, 0.34 NE_g

[2] Calcium – 11.5%, Phosphorus – 10%, Salt – 14.5%, Sodium – 5.8%, Magnesium – 1%, Potassium – 1.5%, Cobalt – 20 parts per million (ppm), Copper – 2,000 ppm, Iodine – 200 ppm, Manganese – 4,000 ppm, Added Selenium – 26 ppm, Zinc – 4,500 ppm

Exp. 2

Immediately following Exp. 1, cows were fed an additional 5 d for collection of feces to determine diet DM digestibility. Grab samples were collected daily at 0600 and 1800. Feed and fecal samples were composited within animal and dried with a forced air oven at 60°C for 48 h. Samples were then ground to pass through a 1.0 mm screen in a UDY Cyclone Sample Mill (UDY Corporation, Fort Collins, CO) and analyzed for DM (AOAC, 1999). Feed and fecal samples were then analyzed for indigestible ADF using the procedures outlined by Bohnert et al. (2002). Relationships between RFI, DMI per $BW^{0.75}$, performance traits, and DM digestibility were analyzed as Pearson correlation coefficients (Statistix 9, 2008) with correlation coefficients considered significant at the $P < 0.05$ level.

Results and Discussion

One cow was removed from the analysis of Exp. 1 and 2 due to an abnormally low intake (failed to consume diet). Additionally, four cows were removed from the analysis of Exp. 2 due to the following reasons: one late term abortion, two contaminated fecal samples, and one determined to be an outlier using the rationale described by Cook (1977).

In Exp. 1, the correlation of DMI per $BW^{0.75}$ was 0.71 ($P < 0.01$) between first and second parities. There is limited literature discussing parity differences for DMI. However, Herd at al. (2006) reported that the calculation of RFI for post-weaned heifers and again as 4 yr old cows were significantly correlated (r = 0.39). However, in those studies, cows were fed a pelleted diet with ad libitum access and were not pregnant. In the current study, cows were in the second and third trimesters of gestation and were limit fed a chopped forage diet.

Additionally, Arthur et al. (1999) showed that weaned female calves, which were determined to be highly efficient (negative RFI), required less feed as 4-yr-old cows while maintaining the same level of performance as inefficient (positive RFI) cows. In that study, the correlations between parities for RFI and DMI were 0.36 and 0.30, respectively (both significant at $P < 0.05$ level). However, 4-yr-old cows had ad libitum access to a pelleted diet (15-17% CP) consisting of 70% lucerne hay and 30% wheat.

The RFI for cows in the present study ranged from 4.46 kg/d (less efficient) to -4.58 kg/d (more efficient). Table 2 shows the relationship of RFI to DMI and diet utilization. RFI had a correlation of -0.51 ($P < 0.03$) to diet DM digestibility (Figure 1) but no relationship with digestible DMI. Dry matter digestibility ranged from 62.6% for the high RFI cows to 74.2% for the low RFI cows. This suggests that cows with a higher RFI consumed more DM but digested less. The net effects were similar digestible DM intakes.

Present results differ from the findings of Cruz et al. (2010) who reported no differences between RFI and diet DM digestibility for feedlot steers. Steers were fed a corn-based finishing ration and placed on two separate 60 d trials. In the first 60 d, half of the steers were placed in individual pens while the other half was placed in one of six group pens. After the first 60 d trial, steers were switched. Steers were assigned to low or high RFI groups if they reached or exceeded 0.5 SD below or above the RFI mean. DM digestibility ranged from 70 to 75% for the low RFI group and averaged 74% for the high RFI group over both periods.

Discrepancies between Cruz et al. (2010) and the results of the present study may be attributed to the 60 d test period which was less than the recommended 70 d (Archer et al. 1997). Additionally, differences could be credited to composition of diets (high concentrate vs. high roughage) and the mechanisms which control feed intake (chemostatic vs. gut fill). Furthermore, different techniques were used to determine DM digestibility.

Implications

The repeatability of DMI over parities helps to prove the significance of RFI as cows that exhibit lower DMI early in their life retain that characteristic as they continue to produce progeny. Furthermore, differences in RFI can now be partially attributed to increased intakes and decreased DM digestibility. However, further research with a greater number of animals is warranted to verify these results.

Table 2. Pearson correlation coefficients for residual feed intake (RFI) and selected traits when 3-yr-old gestating cows[1] were limit fed a forage-based diet.

Measurement	RFI	*P* – Value
DMI per $BW^{0.75}$	0.81	0.01
ADG	0.11	0.61
G:F	0.77	0.01
Mid – Test BW	0.22	0.31

[1] n = 23

Acknowledgements

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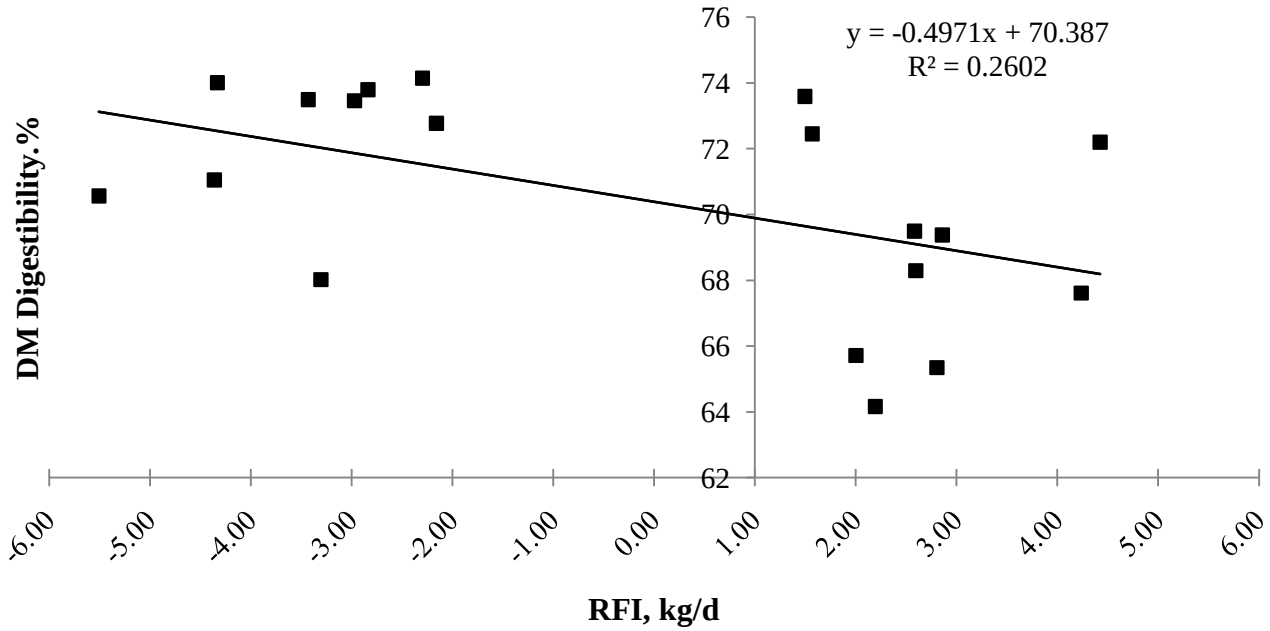

Figure 1. The linear relationship of residual feed intake (RFI) vs. DM digestibility for 3-yr-old cows selected for high and low DMI.

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THE RELATIVE IMPORTANCE OF WEANING MANAGEMENT AND VACCINATION HISTORY ON PERFORMANCE BY RANCH-DIRECT BEEF CALVES DURING WEANING AND RECEIVING

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ABSTRACT: Angus × Hereford calves (n = 437; average initial BW = 208 ± 25 kg) were stratified by BW, sex, and age and assigned randomly to 1 of 3 treatments that corresponded to length of time between weaning and shipping to a feedlot: 45, 15 or 0 d. Within each weaning period length, calves were assigned randomly to 1 of 2 bovine respiratory disease (BRD)-vaccination treatments: vaccinated 14 d prior to weaning and again at weaning (PRE) or vaccinated on the d of arrival at the feedlot and again 14 d later (POST). On a common shipping date, calves were transported 3 h to an auction market and held for 12 h. Calves were then transported 1 h to a feedlot. Calves were fed the same diets ad libitum throughout the study. Incidence of undifferentiated fever 15 d after weaning was greater ($P < 0.01$) for calves weaned 45 d before shipping than for calves weaned 15 d before shipping; however, ADG before shipping was greater ($P < 0.01$) for calves weaned 45 d than those weaned 15 d. Incidence of undifferentiated fever and ADG before shipping were similar ($P > 0.66$) between PRE and POST. Average DMI before shipping by 45-d calves was less ($P < 0.01$) than that by 15-d calves. Also, DMI by PRE calves was less ($P = 0.03$) than that by POST calves. Incidence of undifferentiated fever during receiving was similar ($P \geq 0.73$) between weaning and vaccination treatments. Calf ADG during receiving tended to be greater ($P < 0.07$) for 45- and 15-d calves than for 0-d calves. Receiving DMI increased ($P < 0.01$) as length between weaning and shipping increased. Conversely, the timing of vaccination did not affect ($P \geq 0.51$) ADG or DMI during receiving. Growth efficiency was similar ($P \geq 0.36$) among weaning and vaccination treatments. Weaning more than 15 days before shipping did not improve health or growth of cattle that were moved from their ranch of origin to a feedlot within 16 h and were not commingled with market-sourced cattle. Pre-shipment BRD vaccination may not change health or performance of ranch-direct cattle relative to BRD vaccination deferred until feedlot arrival.

Key Words: health, preconditioning, weaning

Introduction

Preconditioning is a term used in the beef industry to describe management practices that are applied during the weaning period in order to optimize calf nutrition, health, and growth performance during the feedlot receiving period (Duff and Galyean, 2007). The primary goal of preconditioning is to minimize damage to growth potential and carcass merit that occurs as a result of the bovine respiratory disease complex. Cole (1985) reported that preconditioned cattle had reduced mortality and morbidity and increased feedlot performance compared with cattle that were not preconditioned. Conversely, Pritchard and Mendez (1990) indicated that the effects of preconditioning on calf growth and health were variable due to interactions between management, year, and ranch of origin. Bovine respiratory disease (BRD) is the leading cause of morbidity and mortality according to a survey of US feedlots (Woolums et al., 2005).

Many BRD-vaccination strategies are practiced by cow-calf producers in the US. The most cautious strategy involves vaccination against BRD pathogens 2 to 4 weeks prior to maternal separation followed by a booster at weaning. This strategy is used in instances where time, labor, and facilities are available to gather and process calves while they are still suckling. Another BRD-vaccination strategy is to defer vaccination until after calves have been shipped to a feedlot. Deferring BRD vaccination to the receiving period is thought to increase BRD incidence compared to vaccination that is implemented on the ranch of origin; however, this assumption has not been widely scrutinized for cattle that are moved directly from their ranch of origin to a feedlot and undergo little or no commingling with market-sourced cattle.

Bolte et al. (2008a, 2008b, 2009a and 2009b) reported that length of the ranch-of-origin weaning period influenced growth and health of beef calves during the receiving period at a feedlot. Therefore, it is reasonable to expect that vaccination strategy and the length of the ranch-of-origin weaning period may have synergistic effects on calf performance during the receiving phase. The objective of our experiment was to compare the effects of BRD vaccination administered prior to weaning on the ranch of origin or after arrival at a feedlot for calves weaned 45, 15, or 0 days prior to feedlot arrival.

Materials and Methods

Angus x Hereford calves (n = 437; average initial BW = 208 ± 25 kg) were used for this experiment. Calves originated from Kansas State University commercial cow-calf herds at Manhattan (n = 263) and Hays (n = 174). At the time of maternal separation, calves were 175 to 220 days of age. All calves were de-horned and steer calves were castrated before 60 d of age.

Approximately 60 d before weaning, animals were stratified by BW, sex, and birth date and assigned randomly to a pre-shipment weaning period (i.e., 45,15, or 0 days). Within each pre-shipment weaning period, calves were assigned randomly to 1 of 2 BRD-vaccination treatments. One group was vaccinated 14 d prior to maternal separation and again at weaning (PRE). A second group was vaccinated on the d of arrival at the feedlot and again 14 d later (POST).

Initial and booster vaccinations against IBR, BVD, PI3, and BRSV were administered using a modified live product (Bovi-Shield Gold FP®, Pfizer Animal Health Exton, PA). All calves were treated for internal and external parasites using Dectomax® (Pfizer Animal Health Exton, PA) and were vaccinated against clostridial diseases (Vision 7 with SPUR®, Intervet Inc., Millsboro, DE) at the time of weaning. Calves were then transported a short distance (< 15 miles) to a central home-ranch weaning facility.

Calves were weaned in earth-floor pens (4 pens / treatment) and fed a common weaning diet that was formulated to achieve an ADG of 0.91 kg at a DMI of 2.5% of BW (Table 1). Feed intake was recorded daily on a pen basis.

Calves were monitored for symptoms of respiratory disease at 0700 and 1400 daily during the ranch-of-origin weaning period. Calves with clinical signs of BRD, as judged by animal caretakers, were removed from home pens and evaluated. Each calf with clinical signs of BRD was weighed, rectal temperature was measured, and a clinical illness score was assigned (scale: 1 to 4; 1 = normal, 4 = moribund). Calves with a clinical illness score greater than 1 and a rectal temperature greater than 40.0ºC were treated. Cattle were evaluated 72 h post-treatment and re-treated based on observed clinical signs.

All calves were individually weighed and transported 4 h from their respective ranch-of-origin weaning facilities to an auction market located in Hays, Kansas on a common shipping date. Calves from both origins were commingled with respect to gender and treatment and were maintained on the premises of the auction market for 12 h. This commingling was employed to simulate the pathogen exposure typically encountered by market-ready calves.

The following day, calves were shipped a short distance (< 15 miles) to a feedlot. Upon arrival, calves were weighed individually and assigned to a receiving pen based on their weaning and vaccination treatments. The cattle were adapted to a receiving ration (Table 2) and daily DMI was recorded throughout a 60-day receiving period.

Calves were monitored for symptoms of BRD daily at 0700 and 1400. Clinical symptoms of disease were evaluated and treated as during the ranch-of-origin weaning phase. Calf BW was measured 60 d after arrival at the feedlot.

Results and Discussion

Health. Incidence of undifferentiated fever during the 15 d immediately after maternal separation was greater ($P < 0.01$) for calves assigned to the 45-d weaning treatment compared to those assigned to the 15-d weaning treatment (Table 3). Reasons for this response were unclear. In contrast, length of the ranch-of-origin weaning period did not affect ($P = 0.73$) incidence of undifferentiated fever during the receiving period (Table 4). Similarly, Bolte et al. (2008a and 2008b) reported that health of calves during receiving was similar for calves weaned 15, 30, 45, or 60 d prior to feedlot placement.

Undifferentiated fever during the pre-shipment period was similar ($P = 0.66$) between PRE and POST calves (Table 5). Evidently, the pathogen challenge and the stress associated with maternal separation were insufficient to increase incidence of BRD among unvaccinated calves during the ranch-of-origin weaning periods.

Incidence of undifferentiated fever during the receiving period was similar ($P = 0.80$) between calves that were vaccinated against BRD-causing organisms on the ranch of origin and those that were not vaccinated until feedlot arrival (Table 6). Richeson et al. (2009) indicated that delaying vaccination for BRD for 14 d after feedlot arrival improved receiving performance compared with vaccinating at the time of feedlot arrival.

Only 4 of 437 calves on our study were treated for presumptive BRD during this period. This result was surprising and seemed to indicate that labor and time savings might be realized by deferring BRD vaccination until feedlot arrival without sacrificing animal performance; however, more research is needed to confirm this finding.

Step et al. (2008) reported that during the receiving period performance of ranch-direct calves weaned on the ranch of origin for 45 d without preshipment vaccinations was similar to that of ranch-direct calves weaned on the ranch of origin for 45 d with preshipment vaccinations. This report called into question the relative importance of pre-shipment vaccination and pre-shipment weaning to receiving growth and health.

The calves in our study had excellent overall health during the receiving period. In addition, these ranch-direct calves could be considered lower risk than is typical for market-sourced cattle.

Growth Performance. Pre-shipment ADG was greater ($P < 0.01$) for calves weaned 45 d before shipping to the feedlot compared to calves weaned either 15 or 0 d before shipping to the feedlot (Table 3). This occurred because calves weaned for 45 d before shipping consumed, on average, a more energy-dense diet than calves that suckled their dams for all or part of this period. Calf ADG during the pre-shipping period was similar ($P = 0.66$) between PRE and POST calves (Table 5).

Calf ADG during the 60-d feedlot receiving period was similar ($P = 0.62$) between calves weaned for 45 or 15 d prior to feedlot placement; however, both groups of calves tended to have greater ($P < 0.07$) ADG during the receiving period than those shipped directly to the feedlot after maternal separation (i.e., the 0-d weaning treatment; Table 4). Bolte et al. (2008a and 2008b) reported that calves weaned for 15, 30, 45, or 60 days before feedlot placement had similar ADG during receiving; however, calves weaned for any length of time prior to feedlot placement had greater ADG than calves placed in a feedlot immediately after maternal separation.

Calf ADG during the 60-d feedlot receiving period was similar ($P = 0.51$) between calves vaccinated on their ranch of origin or calves not vaccinated until feedlot arrival. Richeson et al. (2009) reported similar results for calves vaccinated at feedlot arrival and calves vaccinated 14 d after feedlot arrival.

Intake. Feed intake (DM basis) and gain:feed by calves weaned for 45 d was greater ($P < 0.01$) during the pre-shipment period than that by calves weaned for 15 d (Table 3). Similarly, DMI increased ($P < 0.03$) successively with length of the weaning period during receiving; however, gain:feed was not affected ($P \geq 0.36$) by length of the weaning period (Table 4). Experience consuming dry diets from a feed bunk prior to shipping translated to greater feed intake and greater ADG during the receiving period. Feed efficiency during receiving was not influenced ($P = 0.36$) by length of the ranch-of-origin feeding period (Table 4). Furthermore, the timing of vaccination against BRD-causing organisms did not affect ($P \geq 0.35$) feed intake or feed efficiency during the receiving period (Table 6).

Implications

Ranch-of-origin weaning periods that were at least 15 d in length improved receiving DMI and growth performance during receiving of cattle that were moved from their ranch of origin to a feedlot within 16 h and were not commingled with market-sourced cattle. Significantly, receiving performance was similar during receiving for calves weaned 15 d or 45 d before shipping. This study raised the possibility that pre-shipment BRD vaccination may not improve health or performance of ranch-direct cattle relative to BRD vaccination that is deferred until feedlot receiving. Further research will be necessary to verify this finding.

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Table 1. Ingredient and nutritional composition of the weaning diet

Ingredient composition*	DM %
Alfalfa extender pellets	41.82
Corn gluten feed	18.22
Wheat middlings	14.68
Cracked corn	10.78
Cottonseed hulls	7.68
Dried distiller's grain	3.01
Molasses	1.67
Limestone	1.85
Nutrient composition	DM %
CP	15.31
Ca	0.56
P	1.43
NE_m, Mcal/kg	1.44
NE_g, Mcal/kg	0.85

* Diet also contained Salt, Zinc Sulfate, and Rumensin® 80

Table 2. Average ingredient and nutritional composition of the receiving diet

Ingredient composition*	DM %
Ground sorghum grain	59.43
Sorghum silage	25.47
Soybean meal	11.04
Limestone	2.08
Ammonium sulfate	0.44
Urea	0.06
Salt	0.06
Nutrient composition	DM %
CP	15.90
Ca	1.01
P	0.33
NE_m, Mcal/kg	1.75
NE_g, Mcal/kg	1.13

* Diet also contained Rumensin® 80, Tylan® 40, and trace minerals

Table 3. Performance of beef calves during ranch-of-origin weaning periods lasting 0, 15, or 45 days

	Length of Weaning Period, d				
Item	0	15	45	SEM	*P* value
Incidence of undifferentiated fever (weaning to d 15), %	-	0.00[a]	0.70[b]	-	< 0.01
ADG (weaning to shipping) , kg	0.58[a]	0.50[a]	0.93[b]	0.031	< 0.01
DMI (weaning to shipping), kg/d	-	3.79[a]	5.27[b]	0.133	< 0.01
Gain:feed (weaning to shipping)	-	0.49[a]	0.23[b]	0.001	< 0.01
Shrink (shipping to feedlot arrival), % BW	8.86[a]	5.29[b]	8.79[a]	0.749	< 0.01

[a, b] Treatment means within row that share common superscript are similar.

Table 4. Performance of beef calves weaned for 0, 15, or 45 days before shipping during a 60-d receiving period

	Length of Weaning Period, d				
Item	0	15	45	SEM	*P* value
Incidence of undifferentiated fever, %	1.37	0.00	1.40	-	0.73
ADG, kg					
Arrival to d 30	1.10	1.26[b]	1.32[b]	0.038	< 0.01
Arrival to d 60	1.26	1.32[b]	1.30[b]	0.025	0.07
DMI, kg/d	7.37	7.85[b]	8.09[c]	0.072	< 0.01
Gain:feed	0.17	0.17	0.16	0.005	0.36

[a, b,c] Treatment means with row that share common superscript are similar.

Table 5. Performance of beef calves vaccinated against respiratory-disease pathogens prior to shipping or at feedlot arrival during a ranch-of-origin weaning period

	Vaccination Timing			
Item	Pre-shipment	Feedlot arrival	SEM	*P* value
Shrink (shipping to feedlot arrival), % BW	8.14[a]	7.16[b]	0.606	0.02
Incidence of undifferentiated fever (weaning to d 15), %	1.40	0.90	-	0.66
ADG (weaning to shipping) , kg	0.68	0.66	0.025	0.17
DMI (weaning to shipping), kg/d	4.33[a]	4.74[b]	0.141	0.03
Gain:feed (weaning to shipping)	0.36	0.36	0.015	0.64

[a, b] Treatment means within row that share common superscript are similar.

Table 6. Performance of beef calves vaccinated against respiratory-disease pathogens prior to shipping or at feedlot arrival during a 60-d receiving period

	Vaccination Timing			
Item	Pre-shipment	Feedlot arrival	SEM	*P* value
Incidence of undifferentiated fever, %	0.93	0.90	-	0.80
ADG, kg				
Receiving to d 30	1.17[a]	1.27[b]	0.029	0.02
Receiving to d 60	1.30	1.28	0.020	0.51
DMI, kg/d	7.79	7.76	0.059	0.72
Gain:feed	0.16	0.17	0.004	0.35

[a, b] Treatment means with row that share common superscript are similar.

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EFFECTS OF SUN-CURING AND HARVEST MATURITY ON CONCENTRATION AND PROTEIN-BINDING CAPACITY OF CONDENSED TANNINS IN SERICEA LESPEDEZA (*LESPEDEZA CUNEATA*)

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ABSTRACT: A study was conducted to evaluate the effects of sun-curing and harvest maturity on concentrations of condensed tannins (CT) and protein-precipitable phenolics (PPP) in sericea lespedeza (SL). Samples of SL (n = 200 plants/sample) were collected from a single native tallgrass pasture at 1 to 4-wk intervals from June 24 to October 11 that corresponded to single-stem, branched-stem, budding, flowering, and senescent stages of plant phenology. Samples were divided randomly into 2 equal portions that were either dried via sun-curing or were frozen immediately after harvest and later freeze dried. Total phenolics were extracted from dried, ground SL samples using a modified methanol-extraction technique and were analyzed for CT and PPP. Concentrations of CT in sun-cured SL were less (main effect of treatment - $P < 0.01$) than that in fresh SL. Concentration of CT in SL responded cubically ($P < 0.01$) over time; CT was least during June and October and peaked during August. Peak CT concentration corresponded to the flowering stage of the SL life cycle. Concentrations of PPP in SL also changed over time but the magnitude of the effect was influenced by treatment (treatment × period – $P < 0.01$). Concentrations of PPP in sun-cured SL responded cubically ($P < 0.01$) as the growing season advanced; PPP was least during June and October and peaked during August. In contrast, PPP in fresh SL responded quadratically ($P < 0.01$) over time, indicating that significant concentrations of PPP remained in SL late into the growing season. Concentration of CT and PPP in SL decreased dramatically during drying and storage. These data may explain why sharp avoidance of SL by grazing livestock is not observed when SL is fed in the form of sun-cured hay. Understanding how drying and plant growth stage influence tannins in SL could lead to more effective research models for the study of SL intake by ruminants.

Key W ords: condensed tannin, noxious weed, sericea lespedeza

Introduction

Sericea lespedeza (*Lespedeza cuneata*) is a noxious weed that infests approximately 600,000 acres of native Tallgrass range in Kansas (Eddy et al., 2003). Intake of sericea lespedeza by grazing livestock is poor, due presumably to the presence of tannins in the plant (Terrill et al., 1989; Mantz et al., 2009). Condensed tannins reduce protein digestion by ruminants (Jones and Mangan, 1977); condensed tannins may also decrease plant palatability.

Prolific seed production, in combination with little or no grazing pressure, has contributed to the rapid spread of sericea lespedeza on Kansas rangelands (Eddy et al., 2003). Increasing grazing pressure on sericea lespedeza may reduce seed production and slow its advance; however, development of appropriate research models to study sericea lespedeza intake by ruminants has been slow. Tannin concentration in sericea lespedeza changes dramatically during drying and storage (Terrill et al., 1989, 1990, and 1994). Therefore, sharp avoidance of sericea lespedeza by grazing livestock is not generally observed when sericea lespedeza is fed to livestock in the form of sun-cured hay (Terrill et al., 1989; Mantz et al., 2009). Little is known about how harvest maturity and sun-curing influence the concentration of condensed tannins in sericea lespedeza or the degree of protein-binding by condensed tannins over the course of an entire growing season. Such information could lead to more effective research models for the study of sericea lespedeza intake by ruminant livestock. Therefore, the objective of our study was to examine changes in condensed-tannin concentrations and in protein-binding capacity of condensed tannins throughout the growing season in both sun-cured and fresh sericea lespedeza.

Materials and Methods

Sample Collection and Preparation. Samples were collected during the summer and fall of 2009, from a single 65-ha pasture in Greenwood County, Kansas. Plant-species composition on the study site was estimated using a modified step-point technique described by Owensby (1973); sericea lespedeza comprised 19.3% of all plants encountered during the procedure. Above-ground biomass of sericea lespedeza averaged 0.1 kg/m^2.

Individual sericea lespedeza plants were collected from the study site at 1 to 4-wk intervals from June 24 to October 11 (n = 200 plants / sampling date) that corresponded to single-stem, branched-stem, budding, flowering, and senescent stages of the plant (Koger et al., 2002). Plants were clipped approximately 1 cm above the soil surface.

At the time of collection, samples were either allowed to sun cure in burlap bags or were flash-frozen as described by Terrill et al. (1990). Frozen samples were later freeze dried. All dried samples were ground with dry ice (0.5-mm screen; #4 Wiley Mill, Thomas Scientific, Swedesboro, NJ, USA) to preserve tannin structure and bioactivity (Makkar, 2003).

Extraction of Condensed Tannins. Extraction of condensed tannins was adapted from methods described by Makkar (2003). Each ground sericea lespedeza sample was thoroughly mixed and a 200 mg subsample was collected. Ten ml of 50% Methanol (v/v) was added to each sample in a 50-ml beaker and the mixture was stirred. Samples were agitated in an ultrasonicator (Blackstone Ultrasonics, Sheffield, PA) for 2 x 10-min periods. Samples were allowed to stand for a period of 5 min between agitations. The resulting solution was transferred to 15-ml polyethylene tubes and centrifuged at 3,000 x *g* (4°C) for 15 min. The supernatant was decanted into a clean 50-ml beaker and chilled; the pellet was washed 2 × with 5 ml of 50% Methanol (v/v). The centrifugation step was repeated after each wash and supernatant was decanted. All supernatant from a single sample was combined for tannin analysis.

Measurement of Condensed Tannins. Methods used for determining the amount of condensed tannins in harvested forages were adapted from Makkar (2003). A 100-µl aliquot of supernatant from each sample was placed into individual 1.5-ml Eppendorf tubes; 600 µl of Butanol-HCl and 20 µl of ferric reagent, which was used to increase the sensitivity and reproducibility of this assay (Makkar, 2003), were added to each tube. Samples were incubated for 60 min in a 100°-C water bath. Samples were allowed to cool and then placed in a 96-well microplate. Sample absorbance at 550 nm was measured using a UV spectrophotometer equipped with Gen5 software (Biotech Inc., Winooski, VT). Absorbance was adjusted to condensed-tannin concentration using leucocyandin as a standard (Makkar, 2003).

Measurement of Protein-Precipitable Phenolics. Standards (200 µl) containing 0, 50, 100, and 150 µl tannic acid in 50% Methanol (v/v) were prepared from a standard solution (0.5 mg tannic acid/ml). These mixtures were added to 400 µl of bovine serum albumin (BSA). Aliquots of extracted tannins (20 ml) were mixed with 400 µl of BSA solution (100 mg BSA in 100 ml acetate buffer) and a complementary amount of 50% Methanol (v/v) [e.g. 25 µl extract: 175 µl methanol] and mixed thoroughly. This dilution allowed for measurement of tannic acid in the tannin-protein complexes of sericea-lespedeza leaf. Samples and standards were allowed to stand at 4° C for 16 h and then centrifuged for 10 min at 3000 x *g* (4° C). The supernatant was discarded and the pellet was dissolved using 300 µl of 1% sodium dodecyl sulfate (w/v) solution. A 200 µl aliquot was removed from each sample and added to 600 µl of sodium dodecyl sulfate-triethylamine solution and 200 µl of Ferric-chloride reagent. Iron in the form of Ferric-chloride reacted with tannin phenolics to express a pink chromatophore that was measurable spectrophotometrically (Makkar, 2003). The resulting solution was allowed to stand at room temperature for 30 min before being placed into a 96-well microplate together with standards.

Absorbance was measured at 510 nm using a UV spectrophotometer equipped with Gen5 software (Biotech Inc., Winooski, VT). Concentrations of tannic acid in the tannin-protein complexes were determined using a standard curve. Values were multiplied by 1.5 (each sample was dissolved in 1.5 ml of 1% sodium dodecyl sulfate solution) to calculate the amount of tannin in the tannin-protein complex (Makkar, 2003).

Statistical Analysis. Data were subject to 2-way ANOVA using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC). Class variables included harvest date and treatment. The model included terms for harvest date, treatment, and harvest date × treatment. F- tests were constructed using the type-3 error mean squares. Treatment × harvest date interactions were detected; therefore, treatment effects were reported by harvest dates. Within harvest dates, treatment means were separated using the method of Least Significant Difference. Least Squares Means were considered to be different when $P \leq 0.05$. Trends in concentrations of condensed tannins and in protein-binding capacity of condensed tannins over time were characterized using orthogonal polynomial contrasts.

Results and Discussion

Condensed Tannins. Condensed tannin concentrations in sun-cured forage were 105.69, 107.04, 155.09, 154.39, 172.09, and 81.26 ± 3.06 g/kg (DM basis) for samples harvested on 6/24, 7/3, 7/25, 8/24, 9/15, and 10/11, respectively (Figure 1). In contrast, condensed-tannin concentrations in fresh sericea lespedeza samples that were frozen immediately after harvest were 123.04, 198.99, 228.04, 217.87, 222.48, and 158.13 ± 3.06 g/kg (DM basis) for samples harvested on 6/24, 7/3, 7/25, 8/24, 9/15, and 10/11, respectively (Figure 1). Allowing forage to sun cure substantially decreased detectable condensed tannins at all stages of sericea lespedeza maturity (main effect of treatment - $P < 0.01$). Terrill et al. (1989) suggested that such differences were due to reduced solubility of tannins, caused by polymerization reactions between tannins and other compounds in the forage as the plant dries. Alternatively, wilting and maceration of the forage may have disrupted the 3-dimensional structure of condensed tannins.

Concentration of condensed tannins was different (main effect of harvest date - $P < 0.05$) at each successive growth stage of sericea lespedeza. Concentration of condensed tannins in fresh and sun-cured samples responded cubically ($P < 0.01$) over time; it was least during June and October and peaked during mid August. Peak concentrations corresponded to the flowering stage of the sericea lespedeza life cycle. Previous reports indicated condensed-tannin concentrations were maximal immediately prior to seed dispersal (Cope et al., 1971; Cope and Burns, 1974). This was the case in our study as well.

Protein-Binding Capacity. Protein-binding capacity of condensed tannins in sericea lespedeza was estimated from the concentration of protein-precipitable phenolic compounds in purified samples of condensed tannins prepared from each of our samples. Concentrations of protein-precipitable phenolics in sun-cured forage were 12.2, 20.0, 18.0, 22.0, 37.5, and 10.0 ± 0.002 μg/200μg of condensed tannin, respectively (Figure 2). Concentrations of protein-precipitable phenolics in fresh sericea lespedeza samples that were frozen immediately after harvest were 12.5, 40.0, 43.0, 43.5, 41.0, and 15.0 ± 0.002 μg/200μg of condensed tannin, respectively (Figure 2).

Terrill et al. (1989) indicated that the concentration of protein-precipitable phenolics in sun-cured sericea lespedeza may be underestimated because of polymerization between condensed tannins and certain other plant compounds during drying. A similar underestimation may also occur in fresh sericea lespedeza because of maceration and any wilting while sampling.

Allowing forage to sun cure appeared to decrease the protein-binding capacity of condensed tannins in sericea lespedeza (Figure 2). Protein-binding capacity of condensed tannins was different ($P < 0.01$) at each successive growth stage. Concentrations of protein-precipitable phenolics changed over time but the magnitude of the effect was influenced by treatment (treatment × period – $P < 0.01$; Figure 2). Concentrations of protein-precipitable phenolics in sun-cured sericea lespedeza responded cubically ($P < 0.01$) as the growing season advanced; protein-precipitable phenolics were least during June and October and peaked during August. In contrast, protein-precipitable phenolics in fresh sericea lespedeza responded quadratically ($P < 0.01$) over time, indicating that condensed tannins in sericea lespedeza retained significant protein-binding capacity late into the growing season.

Implications

Results from this study were interpreted to suggest that allowing sericea lespedeza to sun cure after harvest decreased dramatically the amount of extractable condensed tannins and the capability of condensed tannins to bind proteins; moreover, condensed tannin concentration and protein-binding capability peaked near the flowering stage of sericea lespedeza. We believe these data explain why sharp avoidance of sericea lespedeza exhibited by grazing livestock is difficult to replicate in a laboratory setting when the plant is offered to livestock in the form of sun-cured hay. Understanding how drying and plant growth stage influence condensed tannin concentrations and protein-binding capacity of sericea lespedeza could lead to more effective research models for the study of sericea lespedeza intake by ruminant livestock. Finally, our adaptations to established procedures for extracting and isolating condensed tannins and protein-precipitable phenolics reduced generation of hazardous byproducts by approximately 80%.

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Figure 1. Effects of sun-curing and harvest date on concentration of condensed tannins in sericea lespedeza

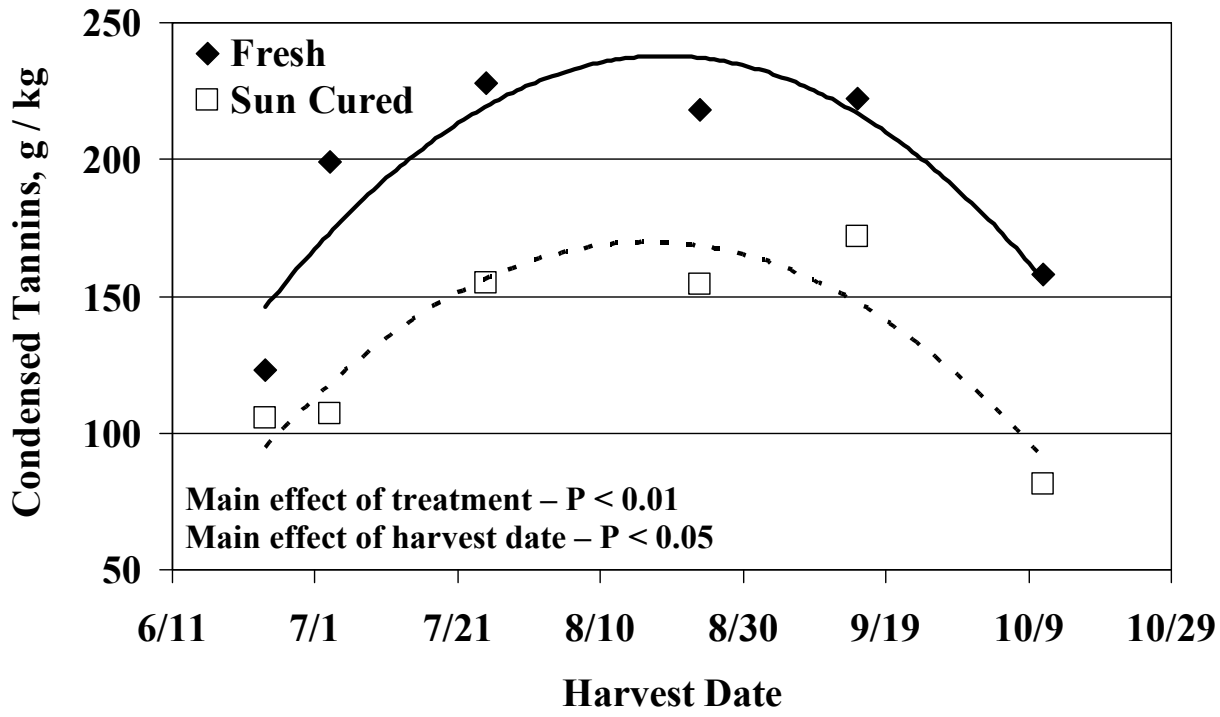
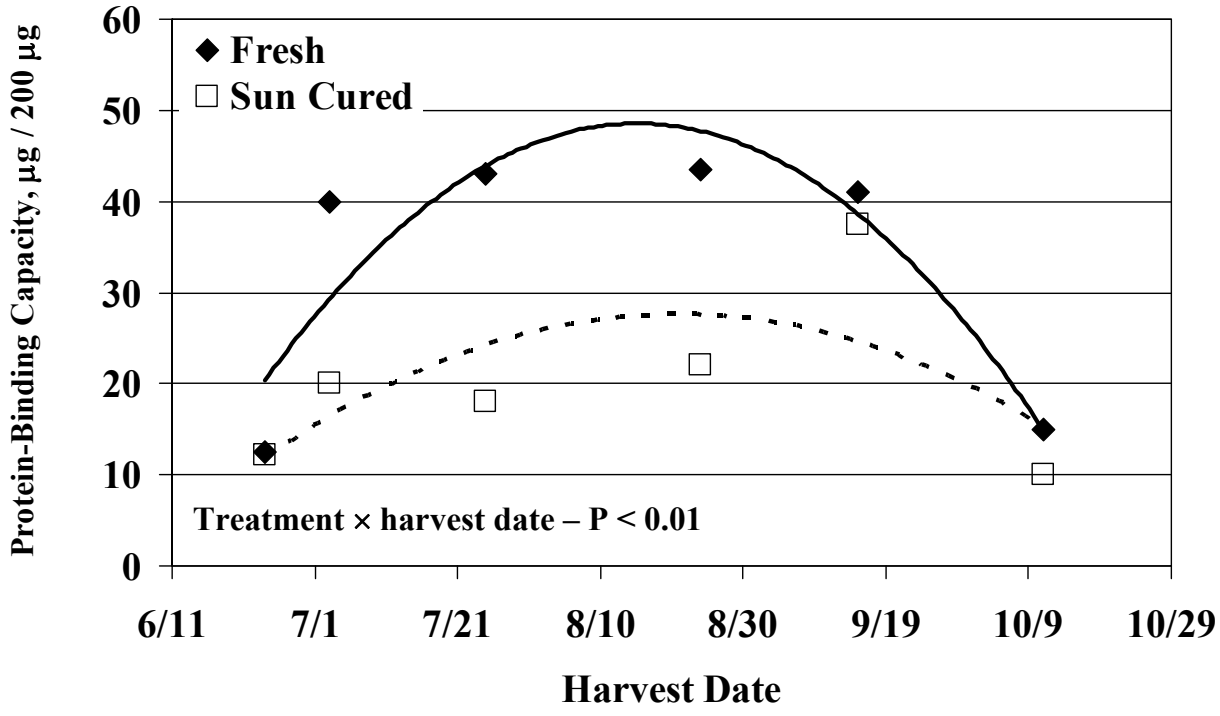


Figure 2. Effects of sun-curing and harvest date on the protein-binding capacity of condensed tannins in sericea lespedeza



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EFFECTS OF GESTATIONAL DIETARY METABOLIZABLE PROTEIN LEVEL AND DRY MATTER INTAKE ON SUBSEQUENT PRODUCTION TRAITS IN PRIMIPAROUS HEIFERS

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ABSTRACT: The objective of this experiment was to determine if feeding two levels of dietary metabolizable protein (102% vs. 119% of NRC requirements) and biological variation in feed intake during the second and third trimesters of gestation influenced subsequent production traits in primiparous heifers. Two-yr-old Angus and Simmental x Angus heifers (n = 120, initial BW = 448 ± 36 kg) had individual DMI determined using a GrowSafe feeding system. Dietary treatments were based on approximately 85% grass hay and 15% supplement. Supplements contained whole soybeans plus corn (102%) or dried distillers grains plus soybean meal (119%) and each supplement was assigned to two pens. Heifers were randomly assigned to one of three periods (P; 40/P) followed by random assignment to one of four pens (10/pen). Diets were fed at approximately 10.3 kg DM·heifer^{-1}·d^{-1}. After 35 d of intake measurement, heifers were placed into adjacent pens and fed their diets for an additional 50 (P1 and 2) or 82 d (P3). The next 40 heifers (P2) were placed in the facility and DMI was again determined over 35 d. Upon completion of the feeding trial, heifers were transported back to the ranch, managed as a single group, and production data were measured. Level of dietary MP had no effect ($P > 0.17$) on calf birthweight, adjusted 205 d weight, ADG, age at weaning, cow BW at calving, proportion of cows cycling at bull turnout, or proportion of cows to conceive. Dry matter intake per unit of BW$^{0.75}$ (range = 0.057 – 0.187 kg/kg) also had no effect ($P > 0.17$) on any of the variables measured. Under the conditions of this study, feeding MP in excess of NRC recommendations during mid- to late-gestation did not enhance heifer productivity. Heifers that consumed less DM/kg BW$^{0.75}$ produced similarly to heifers that consumed more DM/kg BW$^{0.75}$.

Key Words: metabolizable protein, dry matter intake

Introduction

Protein supplementation of spring-calving beef cows is a necessary practice in many places due to the winter forage not fulfilling rumen microbial and animal nutritional requirements. Metabolizable protein is defined as the true protein absorbed by the intestine, supplied by microbial protein and undegraded intake protein (UIP). Lardy (1997) found the MP value of grazed winter forage to be low, resulting in an MP deficiency. Patterson et al., (2003b) demonstrated that supplementation of UIP to meet MP requirements vs. conventional CP supplementation improved pregnancy rates in 2-yr-old heifers, but did not increase calf weaning weight.

An alternate way to decrease breakeven cost is by decreasing cow feed intake (input) without sacrificing weaning weights or reproductive efficiency (output). Jenkins and Ferrell (2004) reported a positive linear relationship between calf weaning weight adjusted to 200 d and cow DMI. Earlier, Jenkins et al. (2000) reported a quadratic relationship between calf BW at 140 d and daily cow ME intake when pooled over sire breed groups. However, neither of these studies examined intake per unit of BW and its effects on production traits. A protein deficiency can decrease feed intake. Nitrogen deficiency is common when feeding low-nitrogen, high-fiber forage, and supplemental nitrogen often increases DMI (Galyean and Goetch, 1993).

The objectives of this study were to: 1) determine if feeding gestating 2-yr-old heifers MP in excess of NRC requirements would impact heifer BW at calving, weaning weight, calf age at weaning, proportion of heifers cycling at bull turnout, and proportion of cows to conceive the following year; and 2) determine if heifer DMI per unit of BW$^{0.75}$ during the second and third trimesters of gestation influenced the same production variables.

Materials and Methods

Animals. The research protocols in this study were approved by the Montana State University Animal Care and Use Committee (AA-301). In September 2009, one hundred twenty primiparous Angus and Simmental x Angus heifers (average initial BW = 448 ± 36 kg) in the second trimester of pregnancy were transported from the Bair Ranch Foundation, Martinsdale, MT, to Bozeman Agricultural Research and Teaching Farm (BART) (latitude 45˚ 39’ N, longitude 110˚ 04’ W, altitude 1495 m), Montana State University, Bozeman, MT. Heifers used were purebred Angus (n = 26), 50% Simmental x 50% Angus (n = 60), or 25% Simmental x 75% Angus (n = 27). All animals were individually identified by an electronic identification transponder button in the middle of the left ear allowing for measurement of individual feed intake in a GrowSafe feed intake system (GrowSafe Systems Ltd., Airdrie, Alberta, Canada).

Design and Treatments. Upon arrival, heifers were randomly assigned to one of three periods (**P1, P2,** and **P3**; 40 heifers/period). Heifers were then randomly assigned to one of four pens (10 head/pen). Pens with GrowSafe feeders measured 7.3 m x 11.0 m. The

GrowSafe feeders were covered by an open sided metal barn that prevented precipitation from entering the feeding stations. Pens used while not on the intake trial were covered by a sloped shed which protected the feed bunks from precipitation. Wood chips were used as bedding and placed in the pens biweekly.

Dietary treatments were based on approximately 85% grass hay and 15% supplement. Supplements contained whole soybeans plus corn (**102% MP**) or dried distillers grains plus soybean meal (**119% MP**) and each supplement was assigned to two pens; Table 1. Diets were fed at approximately 10.3 kg DM/d. Diets were fed in this manner so that ADG did not exceed 0.63 kg/d.

Data Collection. Individual DM intakes were recorded using the GrowSafe system (two feeders/pen). After 35 d of intake measurement, heifers were placed into adjacent pens and fed their treatment for an additional 50 (P1 and P2) or 82 d (P3). The next 40 heifers (P2) were placed in the facility and DMI was again determined over 35 d. Weights were taken on 2 consecutive days upon arrival and the average was used as the initial weight. Single weights were then taken on heifers every two weeks. After intake data had been collected, heifers were returned to the ranch.

Rump fat was measured ultrasonographically using a PIE scanner-200 (PIE Medical Equipment Co., Maastrict, The Netherlands) equipped with an 18-cm, 3.5-MHz linear array transducer. Measurements were taken on d 16 and 83 to calculate rate of fat deposition, with d 0 being the day of arrival to Bozeman. Images were obtained at the juncture of the gluteus medius and biceps femoris muscles between the hook and pin bones, parallel to the backbone. Upon completion of the trial, heifers were returned to the ranch, managed as a single group, and production data were measured.

Calving began on January 31, 2009 and ended on March 22, 2009. Upon calving, male calves were castrated by the elastic band method, vaccinated for clostridial diseases; and birthweights, calving scores, and cow weights were collected. Calving ease scores were recorded as follows: 1 = calved with little or no assistance; or 2 = difficult assisted delivery, caesarean delivery, or abnormal presentation. Calf vigor scores were recorded as: 1 = nursed on its own; or 2 = required assistance to suckle, dead on arrival, or dead shortly after birth. Calves were vaccinated for IBR, PI3, BVD, BRSV, *haemophilus somnus*, *pasteurella multocida* and clostridial diseases, and treated with a pour-on parasiticide at weaning, then given their booster vaccinations two weeks after weaning. At weaning, all calves were weighed and tagged with a half-duplex radio frequency transponder button in the left ear.

Blood Collection and Radioimmunoassay. Blood samples were collected from the heifers via coccygeal venipuncture on May 28 and June 11, 2009. Samples were immediately placed on ice and centrifuged within 2 h. Serum was decanted and stored until assays were performed to determine concentrations of progesterone. Concentrations of progesterone were determined directly without extraction by solid-phase RIA (Coat-a-Count kit; Diagnostic Products Corp., Los Angeles, CA) as described by Bellows et al. (1991). All samples were analyzed in one assay. The interassay CV was 6.68% and assay sensitivity was 0.08 ng/mL.

Determination of Estrual Status and Pregnancy. Concentrations of progesterone were used to determine estrual status (estrual or anestrual) of the heifers before exposure to bulls. Females with concentrations of progesterone > 1 ng/ml of serum on either date were considered to have luteal function and categorized as estrual. Heifers were evaluated for pregnancy status via rectal palpation on September 15, 2009 by an experienced technician.

Statistical Analysis. Seven heifers were removed from the study due to late term abortions or abnormally low intakes. A total of 113 animals were included in the analysis. Gain was determined in two ways: 1) initial and final weights for the 35-d intake test with measures of BW obtained within 6 d after entering and within 6 d before leaving the GrowSafe pens to calculate ADG; and 2) multiple weights taken (P1 = 5, P2 = 6, P3 = 7) that coincided best with the intake test and spanning 70 (P1) or 84 d (P2 and P3). The multiple weights of individual heifers were then modeled by linear regression of BW against time using the regression procedure of SAS (SAS Inst., Inc., Cary, NC). This is referenced as Modeled ADG. To examine the relationships among DMI, and performance and production traits, partial correlation coefficients were determined using the MANOVA function of Proc GLM of SAS with treatment, breed, period, and pen included in the model as class variables. Cow production traits, excluding percent cycling at bull turnout, pregnancy rate, calving ease, and calf vigor were subjected to an analysis of variance using PROC MIXED of SAS. Treatment and breed were fit as fixed effects with period and pen fit as random effects. Treatment was tested by the error term pen (period x treatment). Breed was tested using the residual error term. Dry matter intake per unit of $BW^{0.75}$ was fit as a continuous variable in the same model and tested by the residual. All interactions of $DMI/BW^{0.75}$, treatment, and breed were tested by the residual error term. Differences due to treatment in percent cycling at bull exposure and percent conceiving were tested by Chi Square analysis using PROC FREQ of SAS. Calving ease and calf vigor scores were analyzed by Chi Square. Differences in percent cycling, pregnancy rate, and calving scores due to DMI and $DMI/BW^{0.75}$ were examined by separating feed intake into low, medium, and high groups that were < 0.5SD, ± 0.5 SD, and > 0.5 SD from the mean and analyzing by Chi Square.

Results

Cow BW at calving was greater (P = 0.05) for breeds with greater Simmental influence. Angus, 25% Simmental x 75% Angus, and 50% Simmental x 50% Angus heifers weighed 464, 479, and 489 kg, respectively, at calving.

Feeding MP in excess of NRC (1996) recommendations to heifers in mid- to late-gestation did not affect (P > 0.17) any of the performance or production variables measured (Table 2). Waterman et al. (2006) reported that BCS at nadir was slightly improved by supplementing 2-yr-old primiparous cows with 31 g of

excess MP. Conversely, Patterson et al. (2003a) found supplementing prepartum cows to meet MP requirements exhibited a greater ADG compared to cows supplemented to meet CP requirements. In the present study, ADG was not changed by feeding additional MP. Waterman et al. (2006) reported increased weaning weights as well as a decrease in postpartum interval, but found no difference in pregnancy rates due to additional amounts of dietary MP; while Anderson et al. (2001) also found no difference in pregnancy rates when supplements met either MP or CP requirements postpartum. Richards et al. (1986) suggested that the BCS of cows entering the calving season influenced whether or not a supplementation response was measured. Cows with a BCS $\geq$ 5 and consuming a high-quality postpartum diet showed no improvements in return to estrus at the beginning of the breeding season or subsequent pregnancy rates compared to cows with lower BCS. Postpartum supplementation of excess MP has shown increased milk production (Waterman et al., 2006). Likewise, results from other studies have also shown cows supplemented with UIP had increased milk production (Appeddu et al., 1997; Sawyer, 2000). However, in those experiments cows were supplemented postpartum rather than during gestation as in the current study.

The mechanisms of postpartum supplementation and its effects on production are different than prepartum supplementation. Prepartum supplementation of pregnant heifers to meet MP vs. CP requirements has increased pregnancy rates in 2-yr-old cows without affecting calf weaning weight, which does not support a hypothesis of increased milk production (Patterson et al., 2003b). The exact mechanism of increased pregnancy rate due to prepartum MP supplementation is not fully understood. However, Patterson et al. (2003b) hypothesized the mechanism may be similar to the response measured after fat supplementation during gestation (Bellows, 1997), and may be associated with changes in hormonal status of the postpartum cow. The response measured by Patterson et al. (2003b), but not in this study, may be a result of an MP deficiency. However, in the current study, both treatment groups were fed to meet MP requirements.

Dry matter intake was not different between treatments (P = 0.65). Dry matter intake ranged from 5.86 to 20.46 kg/d and averaged 12.05 ± 2.76 kg/d. The range of DMI/BW$^{0.75}$ was 0.057 to 0.187 kg/kg and averaged 0.114 ± 0.024 kg/kg. Dry matter intake (P > 0.20) and DMI/BW$^{0.75}$ (P > 0.17) were not significant sources of variation in the model for any production variables measured, even though weaning weight has been shown to increase with increased DMI (Jenkins and Ferrell, 2004).

Positive correlations were measured (P < 0.05) between DMI and initial BW, ADG, modeled ADG, and cow BW at calving; whereas, DMI/BW$^{0.75}$ was only correlated (P < 0.05) with modeled ADG (Table 3). We believe the modeled ADG presents a better fit because the measurement of gain was longer and therefore more accurate. No interactions (P > 0.05) were found for any of the variables measured. No differences in calving scores, percent cycling at bull turnout, or pregnancy rate were measured due to differences in DMI (P > 0.35) or DMI/BW$^{0.75}$ (P > 0.17; Table 4).

Implications

Feeding gestating heifers excess amounts of metabolizable protein above the recommendation made by the NRC (1996) provided no improvement in reproductive efficiency. Differences in gestational DMI did not alter subsequent calf productivity.

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Table 1. Composition and analysis of experimental diets (DM basis) formulated to provide 102 or 119% of MP requirements for mid- to late-gestation heifers

Item	102 % MP	119% MP
Ingredient, %		
Grass hay	84.5	82.5
Whole soybeans	10.2	
Dried distillers grains		12.8
Soybean meal		2.0
Corn grain, cracked	3.8	
Calcium carbonate	0.6	0.6
Mineral supplement[a]	0.9	0.8
Nutrients		
CP, %	10.7	12.6
CP intake, g/d	1112	1273
DIP, % of requirements[b]	100.0	100.0
MP, % of requirements[b]	102.0	119.0
NE_m	0.68	0.69
NE_g	0.41	0.41
Ca	0.79	0.78
P	0.38	0.44

[a]Contained 12.10% Ca, 4.00% P, 20.00% NaCl, 1.00% Mg, 2500 ppm Cu, 35.20 ppm Se, 5000 ppm Zn.
[b]Calculated as requirements for 409 kg gestating heifers gaining 0.63 kg/d according to NRC (1996).

Table 2. Performance and production characteristics of 2-yr-old heifers when fed 102 vs. 119% of dietary metabolizable protein (MP) requirements in mid- to late-gestation

	MP, % of NRC requirement			
Trait	102%	119%	SEM[a]	*P* – value[b]
Heifers				
Initial BW, kg	447.6	445.9	9.1	0.62
ADG, kg/d[c]	.61	.53	.07	0.32
Modeled ADG, kg/d[d]	.57	.59	.16	0.52
FCR[c]	18.77	21.25	7.44	0.74
Modeled FCR[d]	27.80	22.61	8.41	0.22
Rate of fat deposition, cm/d[e]	.0012	.0020	.00034	0.31
Cow BW @ calving, kg	478.0	476.0	9.5	0.65
Cycling at bull turnout, %	95.9	98.0		0.53
Pregnancy rate, %	84.3	89.6		0.44
Calves				
Birth weight, kg	37.0	38.8	.64	0.94
Calving ease[f], %	77.8	72.6		0.54
Calf vigor[g], %	90.7	88.2		0.68
ADG, kg/d[h]	.94	.96	.03	0.23
205 d weaning weight, kg	235.5	242.6	6.4	0.17
Weaning age, d	199.8	199.8	3.6	0.35

[a]For n = 6.
[b]*P*-value for Type 3 test of fixed effects except for traits expressed in percent which is the probability from analysis by Chi Square.
[c]FCR = feed conversion ratio; ADG and FCR were calculated using initial and final weights on 35-d intake test.
[d]Modeled ADG and FCR were calculated using linear regression of BW measured over 70 or 84 d.
[e]Calculated from two ultrasound measurements taken 67 d apart during feeding trial.
[f]Determined as the percentage of calves that calved with little or no assistance.
[g]Determined as the percentage of calves that suckled with no assistance.
[h]From birth to weaning.

Table 3. Calving and reproduction characteristics of heifers classified as having low, medium, or high DMI per metabolic bodyweight[a] and low, medium, or high DMI[b]

	$DMI/BW^{0.75}$ level			DMI level			Contrast[c]	
Trait	Low	Medium	High	Low	Medium	High	$DMI/BW^{0.75}$	DMI
Calving ease[d], %	79.4	78.1	66.7	74.2	80.0	69.0	0.43	0.55
	(34)[f]	(41)	(30)	(31)	(45)	(29)		
Calf vigor[e], %	91.2	90.2	86.7	93.6	91.1	82.8	0.83	0.36
	(34)	(41)	(30)	(31)	(45)	(29)		
Cycling at bull exposure, %	97.1	97.5	96.0	93.9	100.0	95.8	0.94	0.29
	(35)	(40)	(25)	(33)	(43)	(24)		
Pregnancy rate, %	78.1	93.0	87.5	86.7	86.4	88.0	0.17	0.98
	(32)	(43)	(24)	(30)	(44)	(25)		

[a]Low, medium, and high $DMI/BW^{0.75}$ heifers were < 0.5 SD, ± 0.5 SD, and > 0.5 SD from the mean $DMI/BW^{0.75}$ of 0.114 ± 0.024 kg/kg, respectively.
[b]Low, medium, and high DMI heifers were < 0.5 SD, ± 0.5 SD, and > 0.5 SD from the mean DMI of 12.05 ± 2.76 kg/d, respectively.
[c]Probability of a Chi Square test.
[d]Determined as the percentage of calves that calved with little or no assistance.
[e]Determined as the percentage of calves that suckled with no assistance.
[f]Number of observations per treatment.

Table 4. Partial correlations of gestational DMI and DMI/BW$^{0.75}$ with performance and production measures in 2-yr-old heifers and calves

Trait	No.	DMI, kg/d	DMI/BW$^{0.75}$
Heifers			
Initial BW	113	.33**	.03
ADG[a]	113	.21*	.17†
Modeled ADG[b]	113	.40**	.30**
FCR[a]	113	.10	.14
Modeled FCR[b]	113	.18†	.14
Rate of fat deposition[c]	113	.04	.04
Cow BW @ calving	110	.26**	.06
Calves			
Birth weight	112	.12	.02
ADG[d]	83	.12	.01
Adjusted 205 d weaning weight	83	.10	-.01
Weaning age	83	.08	.09

*$P < 0.05$; **$P < 0.01$; †$P < 0.10$

[a]FCR = feed conversion ratio; ADG and FCR were calculated using initial and final weights on 35 d intake test.

[b]Modeled ADG and FCR were calculated using linear regression of BW measured over 70 or 84 d.

[c]Calculated from two ultrasound measurements taken 67 d apart during trial.

[d]From birth to weaning.

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SAMPLING BIAS WHEN ESTIMATING ADIPOCYTE CELLULARITY

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ABSTRACT: The objectives of this study were to determine if one random adipose sample would represent the overall adipose cellularity mean within a muscle and to analyze the applicability of the smooth fractionator sampling technique when estimating intramuscular fat cellularity. Marbling is a major factor in the determination of beef quality grades and is evaluated by appraisal of the *Longissimus dorsi* at the 12-13th rib interface in the United States. Thus, a goal is to increase marbling without negatively affecting carcass characteristics. A common measurement of the development and distribution of adipocytes is through cellularity, which involves measurements of size and number of adipocytes. Current estimates rely on one sample obtained from the muscle. To evaluate sampling bias, one muscle (2.54cm thick) was divided horizontally into halves of 1.22cm and each half was vertically divided into approximately 10 strips of various lengths for a total of 20 strips. The 20 strips were placed next to each other and ten were selected by choosing every other one. These strips were divided horizontally into a total of 89 samples. Twenty-five milligrams of marbling fat were dissected from each sample and osmium tetroxide technique was applied to estimate adipocyte cellularity. A random number generator was used to choose five samples to represent the muscle. The mean diameters of the samples were 72.4, 90.7, 77.0, 93.4, and 94.2 μm and the overall mean diameter was 81.6 μm. The mean diameter of each of the five samples was different ($p<0.01$).

In conclusion, there is sampling bias up to 14 samples is the major source of variation. The adoption of a systematic sampling technique will minimize sampling bias and allow experiment treatment effects to be tested.

Keywords: adipocyte, sampling method, beef cattle

Introduction

Numerous variables of adipose tissue development and marbling are related to economic traits of food-producing animals. Marbling is a major factor in the determination of beef quality grades in the United States and is evaluated by appraisal of the *Longissimus dorsi* muscle at the 12-13th rib interface.

The most common measurement to access the development and distribution of adipose cells is through cellularity, which involves measurements of size and number of adipocytes in the muscle. Typically, one single adipose sample is obtained and its measurement is applied to the entire muscle mainly due to cost.

Moody and Cassens (1968) noticed an association of marbling cells with vascular network; they concluded that there is a higher concentration of larger intramuscular fat cells surrounding arterioles.

Yang et al. (2006) showed that within the same muscle cross-section, the intramuscular fat cell size change among marbling flecks, which have different size and are located at different positions; adipocytes of marbling flecks located ventrally were not only larger but more abundant than adipocytes located dorsally.

In stereology the most efficient method to mitigate sampling bias is the smooth fractionator (Gundersen, 2002), which is reordering of samples according to an arbitrary associated variable, such as, size. Smooth fractionator is a systematic-random-uniform sampling technique.

The most used technique to estimate cellularity was developed by Etherton, 1977, which is done by fixation of adipose cells through osmium tetroxide. This method is unsafe and expensive due to a large amount of biohazard disposal; the overall cost per sample is US$15.00.

The objectives of this study were to analyze cellularity variability within the *L. dorsi* muscle at the 12th rib and present the use of the smooth fractionator to reduce overall research cost and increase the precision when estimating adipose tissue cellularity.

Implications

The adoption of the smooth fractionator sampling technique could reduce work when counting and sizing adipocytes and the decrease sampling bias, therefore this method might bring new insights on adipose tissue cellularity.

In addition, there will be a reduction in research cost and hazardous waste, which could stimulate more scientists to investigate biological mechanisms in the adipose tissue.

Material and Methods

Longissimus dorsi at the 12th rib was removed from the carcass after slaughter and store in vacuum sealed bags for further analysis. One *L. dorsi* muscle was completely dissected following the smooth fractionator protocol.

Smooth Fractionator Procedure

Longissimus dorsi muscle of approximately 2.54cm thick was divided horizontally into halves of 1.22cm and each half was vertically divided into approximately 10 strips of various lengths for a total of 20 strips. The 20 strips were placed next to each other and ten were selected by choosing every other one. These strips were divided horizontally into a total of 89 samples (Gundersen, 2002). Twenty-five milligrams of marbling fat were dissected from each sample and osmium tetroxide technique (Etherton, 1977) was applied to estimate adipocyte cellularity.

Osmium Tetroxide Procedure

To determine adipocyte size and number through the osmium tetroxide technique adipose tissue samples were sliced into 1-mm thick sections while still frozen, transferred to 25-mL scintillation vials, and fixed with 3% osmium tetroxide. Fixed adipose tissue samples were filtered through 250- and 10-µm screens using 0.01% Triton x-100 buffer in double-distilled water. Tissues collected on the 250-µm screen were discarded, and tissues collected on the 10-µm screen were resuspended in 10 mL of 55.5% glycerol for determination of cell number and diameter by a Coulter Counter (Coulter Electronics, Hialeah, FL) (Etherton, 1977).

Random Sampling Procedure

Random samples were chosen using a random number generator from 1 to 89.

Smooth Fractionator Sampling Simulation

In order to test the minimum number of samples necessary to represent the overall muscle simulations were done with the 89 samples following the smooth fractionator sampling schematic. For example, for a total of 5 samples; the simulation was done 17 times, due to a no sample replacement, yet for a total of 20 samples; the simulation was done only 4 times.

The sampling starting point is determined by a random number generator from 1 to the maximum number of replication, which represents the spacing between each sample. For the 5 smooth fractionator samples, the starting point was any number from 1 to 17, after this number is randomly chosen the following sample will be 17 units after that, for example, if the starting point was 10 then the 10th, 27th, 44th, 61th and 78th samples were chosen.

Statistical Analyses

All data simulations and statistical analyses were done using R software (R Development Core Team, 2008).

- *Random Sample Test*

To test if one sample would represent the overall muscle; a paired t-test was performed, considering unequal variance and unequal sample sizes. Cell count and diameter were tested.

- *Normality Test on the Smooth Fractionator Simulations*

A normality test was performed on the log transformed data to study the effect of the smooth fractionator on accuracy of the measurement. Logarithmic mean diameter was used to test normality between sample and overall mean diameter.

The Kolmogorov-Smirnov test (ks.test) was used to determine if sample mean diameter differs significantly from the overall mean diameter. The ks.test has the advantage of making no assumption about the distribution of data. A p-value <0.05 represents a significant difference between the two datasets; which implies that the sample does not represent the overall muscle.

Results and Discussion

Random Sample

Five samples were chosen randomly (not using the smooth fractionator) and their mean diameters were 72.4, 90.7, 77.0, 93.4, and 94.2 µm and the overall mean diameter was 81.6 µm. The mean diameter of each of the five samples was different ($p<0.01$) from the overall mean.

The mean number of cells for each sample was 2.73, 6.36, 1.38, 5.41, and 1.40 cells/g x 10^{-5} and the overall mean number was 2.59 cells/g x 10^{-5}. Three of the five samples were different ($p<0.01$) from the overall mean number of cells.

The results support previous findings in the literature. Blumer et al. (1962) reported high range in marbling scores among slices within one *Longissimus* muscle. Zembayashi and Lunt (1995) studied the influence of breed on marbling distribution along the *Longissimus dorsi* (6-12th rib) and they noticed

greater magnitude difference of marbling distribution in Japanese Black cattle; the authors associated the high capacity of fat accumulation with the breed effect.

The difference in quantity and pattern of distribution of adipose tissue observed in these studies could be explained by the association of marbling cells with vascular network within a muscle (Moody and Cassens, 1968).

Smooth Fractionator Sampling Simulation

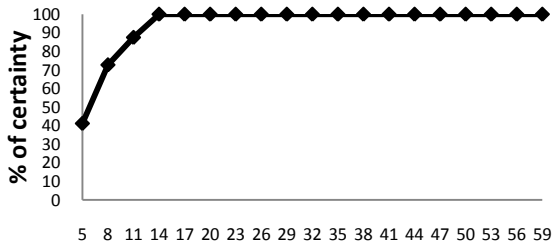
Figure 1 illustrates the effect of increasing number of samples on increasing the percentage of certainty (probability that sample represents the entire muscle) which was calculated as follows:

$$(1- \alpha/\beta)*100,$$

where α is the number of replicates within a group of sample ($P<0.05$) and β is the number of replicates within a group of that are not significantly different from the overall ($P>0.05$).

It is important to remember that from sample 47 to sample 59 there were only one P-value this is due to the replication process, 47 samples can only be replicated once in a total of 89 samples.

Figure 1. Effect of sample size on certainty



The percentage of certainty increases from 40% to 100% when numbers of samples go from 5 to 14, after that there is no improvement on the estimation.

As suggested by Gundersen, 2002 and by Gardi, 2006, smooth fractionator is the most efficient sampling technique and it can be applied regardless the cell spatial distribution and the homogeneity of the tissue.

Conclusion

This preliminary study shows that obtaining one sample from the *Longissimus dorsi* and extrapolate the result to the entire muscle is not accurate.

This study suggests that one random sample is not sufficient to estimate the mean adipocyte cellularity and a better sampling technique is needed, such as, the smooth fractionator.

Even though the study supports shows that by increasing number of samples from 5 to 14 increase certainty; more study should be done to determine a the real benefit of increasing sample size.

The applicability of stereological techniques should be considered with more attention in field of animal science, some of the techniques can increase the efficiency of the research and increase the accuracy of the results.

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EFFECT OF FORAGE ENERGY INTAKE AND SUPPLEMENTATION ON MARBLING DEPOSITION IN GROWING BEEF CATTLE

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ABSTRACT: Glucose is the primary carbon source for fatty acid synthesis in intramuscular fat, whereas, acetate is primarily utilized by subcutaneous fat. Our objective was to examine the effect of forage energy intake and type of fermentation on marbling deposition by stocker cattle grazing dormant native range (DNR) or winter wheat pasture (WP). Angus steer calves (n = 68; 258 ± 29 kg) were used in a completely randomized design comparing 4 winter grazing treatments: (1) control, 1.02 $kg \cdot hd^{-1} \cdot d^{-1}$ of a 40% CP supplement to meet their DIP requirement while grazing DNR; (2) control plus corn-based supplement at 1% BW while grazing DNR; (3) WP at a high stocking rate (3.2 steers/ha) to achieve a low rate of BW gain; and (4) WP at a low stocking rate (2.2 steers/ha) to achieve a high rate of BW gain. Supplements were fed individually 5 d/wk during the 138-d winter grazing phase. Following winter grazing, 3 steers per treatment were randomly selected for intermediate harvest. The remaining wheat pasture steers were transitioned to the finishing phase, while the DNR treatments remained on summer native range for 115 d prior to finishing. Steers were fed to a predicted backfat end point of 1.27 cm. During winter grazing, ADG was 0.19, 0.52, 0.68, and 1.37 ± 0.03 $kg \cdot d^{-1}$ ($P < 0.01$) for treatments 1-4, respectively. Steers that grazed WP had heavier HCW and larger REA ($P < 0.01$) at intermediate harvest than steers supplemented on DNR. Backfat was 0.03, 0.10, 0.17, and 0.85 ± 0.07 cm ($P < 0.01$) and marbling scores were 180, 217, 280, and 340 ± 11.67 ($P < 0.01$) for treatments 1-4, respectively. After finishing, treatment 3 had thicker backfat and smaller LM area resulting in higher YG ($P < 0.02$) compared with the other treatments. There were no differences in final marbling scores (423, 428, 427, and 425 ± 14.92; $P = 0.99$, respectively). These data indicate that growing programs differing in forage energy intake and type of fermentation can influence marbling deposition at the end of winter grazing; however, final marbling scores may not be affected when cattle are fed to a common fat end point.

Key Words: growing beef cattle, forage energy intake, marbling deposition

Introduction

The beef industry currently produces 2 billion kg of excess fat in an attempt to achieve improved quality grades (Smith et al., 2000). Thus, management practices that improve intramuscular fat deposition relative to other depots could enhance the efficiency of beef production. Intramuscular fat deposition develops early during growth (Bruns et al., 2004), and can be influenced by pre-feedyard management practices (Owens and Gardner, 2000; Anderson and Gleghorn, 2007).

Smith and Crouse (1984) found that intramuscular adipocytes preferentially utilize glucose as the primary substrate for fatty acid synthesis; whereas subcutaneous fat utilizes acetate. Faulkner et al. (1994) reported that suckling calves provided a corn-based creep feed had increased marbling scores at the end of the finishing phase compared to calves provided a soyhull-based creep feed indicating that increased glucose supply from corn supplementation influenced marbling deposition. In the Southern Great Plains, many fall-weaned calves are wintered on dormant native grass or winter wheat pasture each year. Cattle from these production systems differ considerably in fat deposition (Hersom et al., 2004). Moreover, cattle grazing winter wheat pasture have 40% lower acetate:propionate ratio compared to cattle grazing dormant native range (Choat et al., 2003). We hypothesized that growing cattle grazing winter wheat pasture would have increased intramuscular fat deposition resulting in greater final marbling scores. Therefore, our objective was to examine the effect of forage energy intake and type of fermentation on performance, fat deposition, and carcass merit of stocker cattle grazing dormant tallgrass native range or winter wheat pasture.

Materials and Methods

Prior to the initiation of this experiment, care, handling, and sampling of the animals used in this experiment were approved by the Oklahoma State University Institutional Animal Care and Use Committee.

Study Site and Vegetation. Fall-weaned Angus-crossbred steer calves grazed either 130 ha of dormant tallgrass native range (**DNR**; 94% DM, 74% NDF, and 5.5% CP) that was deferred from grazing during the previous growing season at the Bluestem Stocker Range or 35 ha of winter wheat pasture (**WP**; 32% DM, 49% NDF, and 22% CP). The dominant forage grass species in DNR pastures were big bluestem (*Andropogon gerardii* Vitman), little bluestem (*Schizachyrium scoparium* [Michx.] Nash), and indiangrass (*Sorghastrum nutans* [L.] Nash). The WP consisted of hard red winter wheat (*Triticum aestivum* L.; variety = Endurance). The steers had ad-libitum access to drinking water from seasonal streams and ponds, and improved water sources.

Fall/Winter Grazing Phase. Seventy-two Angus-cross steers (257 ± 29 kg) were utilized in this experiment and originated from the Range Cow Research Center-South

LCB Range near Stillwater, OK. The average age of the steers at the initiation of the winter grazing period was 276 ± 18 d. Initial BW was measured on December 2, 2008 and 4 steers were randomly selected and harvested for initial body composition at the Food Agricultural Products Center (FAPC) at Oklahoma State University. Standard carcass data (LM area, 12th rib fat thickness, marbling score, and yield grade) were collected. Equations used to calculate % carcass fat were reported by Sainz et al. (1995). The remaining 68 steers (258 ± 29 kg) were allotted randomly by BW to one of the following production programs during the fall/winter grazing phase: (1) control, 1.02 kg·hd^{-1}·d^{-1} of a 40% CP supplement to meet their DIP requirement while grazing DNR (**CON**); (2) CON plus corn-based supplement at 1% BW while grazing DNR (**CORN**); (3) grazing WP at a high stocking rate (3.2 steers/ha) to achieve a low rate of BW gain (**LGWP**); and (4) grazing WP at a low stocking rate (2.2 steers/ha) to achieve a high rate of BW gain (**HGWP**). Supplements were fed individually 5 d/wk during the 138 d winter grazing phase. Steers were not implanted during the winter grazing phase. Five-hour shrunk BW were collected every two weeks throughout winter grazing to adjust CORN supplement consumption to 1% of BW and to adjust the stocking rate of LGWP steers to achieve desired rate of BW gain.

At the conclusion of winter grazing, 3 steers per treatment were randomly selected for intermediate harvest. Carcass characteristics and specific gravity was collected as previously described for the initial harvest. The remainder of the steers grazing WP were transported 154 km to the USDA-ARS Grazinglands Research Laboratory in El Reno, OK for finishing. The remainder of the steers grazing DNR, were placed on a summer grazing program on native grass pastures and grazed summer grass for 115 d. Steers were fed a 40% CP supplement three d/wk at 0.5 kg·hd^{-1}·d^{-1} starting on July 15 (d 92 of summer grazing). At the conclusion of summer grazing, 3 steers from the CON and CORN treatments were randomly selected for a second intermediate harvest prior to finishing. Carcass characteristics were measured as previously described for the initial harvest. The remainder of the steers grazing summer native grass were transported 8 km to the Willard Sparks Beef Research Center in Stillwater, OK for finishing.

Cannulated Steers. An additional 8 ruminally cannulated steers (250 ± 14 kg; same age and source as experimental steers) were used to measure treatment effects on ruminal VFA and ammonia concentrations. There were 6 collection periods during winter grazing that consisted of a 13 d adaptation period and 1 d of sample collection. After each collection period, cannulated steers were rotated between treatments within DNR (CON and CORN) and WP (LGWP and HGWP). However, after the second sampling period, one cannulated steer grazing DNR would not consume the CORN supplement and was permanently adapted to the CON supplement for the remainder of the collection periods. Another steer was randomly selected and permanently adapted to the CORN supplement. Rumen fluid samples were collected on each sampling day at 0700, 1100, and 1600 h. Only DNR treatments were collected at 0700 h prior to morning supplementation. Immediately after collection, 1000 ml of rumen fluid was strained through two layers of cheese cloth and pH was measured. After pH was measured, two 40 ml subsamples were strained through two additional layers of cheesecloth collected into 50 ml conical tubes containing 2.0 mL of 6 *N* HCl. Samples were placed on ice and subsequently stored at -20°C until analyzed for ammonia N and VFA concentrations. Ruminal ammonia N and VFA concentrations were analyzed using procedures described by Broderick and Kang (1980) and Goetsch and Galyean (1983), respectively. Cannulated steers were included when calculating stocking rate.

Finishing Phase. Wheat pasture treatments were allotted to one of 3 pens per treatment (4 to 5 steers/pen) and were fed twice daily. Steers were implanted with Revalor-S (24 mg of estradiol and 120 mg trenbolone acetate; Intervet Inc., Millsboro, DE), vaccinated with Titanium®-5 (Bovine Rhinotracheitis-Virus Diarrhea-Parainfluenza$_3$-Respiratory Syncytial Virus Vaccine; Diamond Animal Health, Inc., Des Moines, IA), and given a pour-on dewormer (Ivomec® Eprinex® **[**5 mg eprinomectin/mL]; Merial, Duluth, GA). Unshrunk individual BW was measured every 21 d during the finishing phase. The finishing ration consisted of a cracked corn-based diet with a calculated composition of 89.02% DM, 14.0% CP, and 1.33 Mcal NEg/kg. The HGWP and LGWP steers were fed 83 and 138 days, respectively, to reach a predicted common fat endpoint of 1.27 cm of rib fat thickness. All steers were harvested at a commercial abattoir (Creekstone Farms, Arkansas City, KS) and carcass data (LM area, marbling score, 12th rib fat thickness, and yield grade) were collected by trained Oklahoma State University personnel.

Native range treatments were allotted to one of 3 pens per treatment (3 to 4 steers/pen) and were fed twice daily. Steers were implanted with Revalor-S, vaccinated with Titanium®-5, and given a pour-on dewormer (Cydectin® **[**5 mg moxidectin/mL]; Fort Dodge Animal Health, Fort Dodge, IA). Unshrunk individual BW was measured every 21 d during the finishing phase. The finishing ration consisted of a cracked corn-based diet with a calculated composition of 86.18% DM, 13.4% CP, and 1.39 Mcal NEg/kg. Steers were fed 112 days to achieve predicted 1.27 cm of rib fat thickness prior to harvest at a commercial abattoir (Creekstone Farms, Arkansas City, KS).

Individual steer ADG during the winter grazing phase was computed by linear regression (Proc GLM; SAS Inst., Inc., Cary, NC). Winter grazing performance and intermediate carcass data were analyzed as a completely randomized design with steer as the experimental unit (Proc MIXED of SAS). Finishing performance and final carcass data were analyzed using a model (Proc MIXED of SAS) to account for heterogeneous variance among treatments due to different feeding locations and finishing diets. Pen and steer were the experimental units for finishing performance and final carcass data, respectively. Hot carcass weight was used as a covariate when analyzing carcass data and was removed from the model when not significant ($P > 0.05$). Ammonia and VFA data were analyzed using a mixed model with repeated measures analysis (Proc MIXED).

Results and Discussion

Fall/winter grazing performance data are presented in Table 1. At the end of the winter grazing phase, HGWP steers had the heaviest BW followed by LGWP and CORN with the CON steers having the lowest BW ($P < 0.001$). Average daily gain followed a similar trend with 1.37, 0.68, 0.52, and 0.19 kg/d for HGWP, LGWP, CORN, and CON, respectively. Hersom et al. (2004) found similar results; HGWP, LGWP, and CON steers gained 1.21, 0.61, and 0.16 kg/d, respectively. Bodine and Purvis (2003) reported steers supplemented with a corn-based energy supplement with adequate degradable protein had increased ADG while grazing low quality forage compared with steers provided a soybean meal-based supplement.

At the first intermediate harvest, HGWP steers had heavier HCW and greater dressing percent ($P < 0.05$) compared to steers grazing DNR; LGWP steers were intermediate (Table 2). The HGWP, LGWP, and CORN steers had similar LM area, but larger ($P < 0.01$) LM area compared to the CON steers. In contrast, Hersom et al. (2004) reported that HGWP steers had greater HCW, dressing percent and LM area compared with LGWP steers. Henrickson et al. (1965) found that dressing percentage and LM area were similar when cattle were grown to similar final BW independent of growth rate. Thus, the differences in dressing percentage and LM area may be attributable to the differences in HCW at intermediate harvest more than differences in growth rates of the treatments.

Backfat and KPH were greater ($P < 0.009$) for HGWP than the other treatments and the CON, CORN, and LGWP were all similar. Marbling score was greater ($P < 0.001$) for HGWP than LGWP, and LGWP was greater than both the CORN and CON steers. There were no differences between the CORN and CON steers for marbling score. Carcass fat was greater for HGWP ($P < 0.001$) compared to the other treatments; LGWP and CORN steers were similar but greater than CON steers. Similar to our study, Hersom et al. (2004) found that HGWP had greater backfat than LGWP and CON, which were similar; however, HGWP had greater marbling scores than LGWP, and LGWP had greater marbling score than CON. These differences may be due to differences in HCW at harvest, rate of gain, or type of fermentation. The HGWP steers had the greatest rumen propionate concentration ($P < 0.03$), a lower acetate:propionate ratio ($P < 0.001$; Table 3), and greater marbling scores than the other treatments; however, the HGWP steers also had greater backfat than the other treatments. The LGWP had similar rumen propionate concentration, acetate:propionate ratio, and backfat, but greater marbling score than CORN steers. Several studies have found conflicting results when attempting to alter VFA patterns to increase marbling development. Bumpus (2006) found that steers fed a corn-based supplement had similar ultrasound IMF compared to steers fed a soyhull-based supplement. McCurdy et al. (2010) reported that steers limit-fed a corn-based diet had similar marbling scores compared to those fed a corn-silage based diet. In contrast, Faulkner et al. (1994) found that a corn-based creep feed increased quality grade compared to a soyhull-based creep feed. Sainz et al. (1995) reported that steers limit-fed a corn-based diet had greater marbling scores than those fed an alfalfa hay-based diet. However, in these studies, any improvement in marbling score coincided with an increase in backfat indicating that the change in VFA pattern did not increase intramuscular fat deposition relative to subcutaneous fat deposition. In the current study, LGWP had greater intramuscular fat deposition but similar backfat compared to CORN even though propionate concentrations were similar.

In addition to type of fermentation, differences in marbling score and back fat among treatments could be due to differences in HCW or rate of gain. Bruns et al. (2004) reported that marbling score and backfat increased as HCW increased during the feeding period. Furthermore, Guenther et al. (1965) found that differences in marbling scores between cattle fed at different planes of nutrition were greater when harvested at similar age than when harvested at similar carcass weights; similar results were found for backfat. Henrickson et al. (1965) reported that steers fed a moderate level of nutrition had greater marbling scores when harvested at a similar carcass weight compared to steers fed a high level of nutrition; backfat was similar between treatments. Moreover, Smith and Crouse (1984) found that cattle fed a more energy dense diet had greater *in vitro* fatty acid synthesis rates in subcutaneous fat, but not intramuscular fat compared with cattle fed a lower energy dense diet. These data suggest that carcass weight may influence marbling score, but that energy density of the diet and rate of gain has a stronger influence on back fat.

The CON steers at the second intermediate harvest, at the end of summer grazing, had similar HCW, LM area, back fat, KPH, and marbling score compared with CORN steers at the first intermediate harvest. Similar results were found when comparing CORN steers at the second intermediate harvest with LGWP steers at the first intermediate harvest. These data indicate that when harvested at similar HCW differences in carcass characteristics were minimal. However, CORN steers at the second intermediate harvest had similar HCW compared with HGWP steers, but lower backfat, KPH and marbling score. The CON and CORN steers entered the feedyard at similar backfat thickness and marbling scores as LGWP steers.

Feedlot performance data are presented in Table 4. Previous production program did not influence ADG, DMI, or G:F when steers were fed to a common fat endpoint. Hersom et al. (2004) found similar results between HGWP, LGWP and CON steers. In contrast, Choat et al. (2003) found that steers previously grazing DNR had greater ADG and G:F, but similar DMI compared with steers previously grazing WP. Sainz et al. (1995) found that steers fed a high-energy diet during the backgrounding phase and were of greater body condition at the start of the finishing phase had lower DMI, ADG, and G:F compared with steers limit-fed a high-energy diet or fed an alfalfa hay-based diet.

There were no differences in HCW or dressing percentage at final harvest (Table 5). Unexpectedly, the LGWP steers had thicker backfat and smaller LM area than the other treatments ($P < 0.02$). Steers previously grazing DNR had greater KPH ($P < 0.02$) than LGWP steers with

HGWP being intermediate. The LGWP steers had greater yield grade than CON and CORN steers, which had greater yield grade ($P < 0.002$) than HGWP steers. There were no differences in final marbling scores ($P = 0.99$). Previous studies (Sainz et al., 1995; Hersom et al., 2004; McCurdy et al., 2010) have reported that nutrition and management practices prior to finishing had minimal effects on final marbling score when harvested at similar backfat thickness.

Implications

Studies have shown cattle entering the feedyard with greater body fat from previous management practices had lower feedlot performance, but final marbling scores were not different. However, Hersom et al. (2004) reported that differences in ADG during winter grazing and initial body fat content did not influence rate of live or empty body weight gain or gain efficiency during finishing. The current steers entered the feedyard at different body composition and no differences in feedlot performance were found. Even though the HGWP steers had a higher propionate concentration and increased marbling scores at intermediate harvest, final carcass characteristics were similar to other treatments. Mean marbling score of steers at the end of grazing in this study ranged from 180 to 340; however, there were no differences in marbling score at the end of finishing when the steers were fed to a similar backfat end point.

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Table 1. Performance of steers during the winter grazing phase

	Treatment[1]					
Item	CON	CORN	LGWP	HGWP	SEM	*P*-value
Steers, No.	17	17	18	16	-	-
Supp. Intake, kg/hd/d	1.01	2.74	-	-	-	-
Initial BW, kg	258	262	261	249	7.18	0.52
Final BW[2], kg	281[a]	322[b]	341[c]	430[d]	3.45	0.001
ADG, kg/d	0.19[a]	0.52[b]	0.68[c]	1.37[d]	0.03	0.001

[1]CON = 40% CP supplement; CORN = corn-based supplement; LGWP = low rate of gain on wheat pasture; HGWP = high rate of gain on wheat pasture
[2]Initial BW was used as a covariate
[a,b,c,d] Means within a row lacking a common superscript letter differ ($P < 0.05$)

Table 2. Intermediate carcass characteristics of steers following the winter and summer grazing phase

	Treatment[1]							
	First Intermediate				Second Intermediate			
Item	CON	CORN	LGWP	HGWP	CON	CORN	SEM	*P*-value
Steers, No.	3	3	3	3	3	3	-	-
HCW, kg	150[a]	180[ab]	210[bc]	238[c]	188[b]	208[c]	11.64	0.05
Dressing Percent	52.68[a]	55.59[b]	59.25[c]	59.45[c]	51.86[a]	51.38[a]	0.67	0.001
Backfat, cm	0.03[a]	0.10[ab]	0.17[ab]	0.85[c]	0.17[ab]	0.27[b]	0.06	0.001
KPH, %	0.50[a]	0.50[a]	0.67[a]	1.33[b]	0.67[a]	0.83[a]	0.14	0.009
LM area, cm[2]	37.20[a]	50.96[b]	58.27[b]	60.64[b]	55.69[b]	55.48[b]	3.23	0.003
Yield Grade	2.07[ab]	1.67[a]	1.70[a]	2.57[b]	1.60[a]	1.93[a]	0.18	0.02
Marbling Score[2]	180[a]	217[a]	280[b]	340[c]	233[ab]	240[b]	18.36	0.001
Carcass Fat, g/kg HCW	104.7[a]	114.2[ab]	133.6[bc]	209.7[d]	131.6[bc]	146.2[c]	6.50	0.001

[1]CON = 40% CP supplement; CORN = corn-based supplement; LGWP = low rate of gain on wheat pasture; HGWP = high rate of gain on wheat pasture
[2]Marbling grid: 100 = Practically Devoid00; 200 = Traces00; 300 = Slight00; 400 = Small00
[a,b,c,d] Means within a row lacking a common superscript letter differ ($P < 0.05$)

Table 3. Ruminal volatile fatty acid and ammonia concentrations of cannulated steers grazing dormant native range or winter wheat pasture.

	Treatment[1]					*P*-value	
Item	CON	CORN	LGWP	HGWP	SEM	Trt[2]	Trt*Time
Ruminal pH	6.54[a]	6.18[ab]	6.32[ab]	6.06[b]	0.14	0.09	0.001
Ruminal Ammonia, mM	6.70[a]	3.29[b]	16.79[c]	12.36[d]	1.39	0.001	0.001
Total VFA, mM	94.63[a]	99.07[a]	99.38[a]	118.14[b]	3.17	0.002	0.08
Acetate:propionate	3.80[a]	3.24[b]	3.10[b]	2.61[c]	0.15	0.001	0.001
Acetate, mM/100mM	60.61[a]	57.72[b]	55.20[bc]	52.97[c]	1.07	0.001	0.001
Propionate, mM/100mM	16.24[a]	18.13[b]	17.90[b]	20.23[c]	0.57	0.001	0.03

[1]CON = 40% CP supplement; CORN = corn-based supplement; LGWP = low rate of gain on wheat pasture; HGWP = high rate of gain on wheat pasture
[2]Trt = Treatment
[a,b,c] Means within a row lacking a common superscript letter differ ($P < 0.05$)

Table 4. Finishing performance of steers previously grazing native range or winter wheat pasture

	Treatment[1]					
Item	CON	CORN	LGWP	HGWP	SEM	*P*-value
Steers, No.	11	11	13	15	-	-
Initial BW, kg	360[a]	403[b]	352[a]	432[c]	3.12	0.002
Final BW, kg	597	632	610	588	7.65	0.14
ADG, kg/d	2.12	2.04	1.87	1.87	0.07	0.31
DMI, kg/d	12.14	12.53	11.84	11.17	0.41	0.17
Gain:Feed, kg/kg	0.17	0.16	0.16	0.17	0.004	0.10

[1]CON = 40% CP supplement; CORN = corn-based supplement; LGWP = low rate of gain on wheat pasture; HGWP = high rate of gain on wheat pasture.
[a,b,c] Means within a row lacking a common superscript letter differ ($P < 0.05$)

Table 5. Final carcass characteristics of steers previously grazing native range or winter wheat pasture

	Treatment[1]					
Item	CON	CORN	LGWP	HGWP	SEM	*P*-value
Steers, No.	11	11	13	15	-	-
HCW, kg	375	397	383	375	9.13	0.29
Dressing Percent	62.70	63.07	62.84	63.13	0.41	0.81
Backfat, cm	1.59[a]	1.55[a]	1.94[b]	1.37[a]	0.10	0.02
KPH, %	2.18[a]	2.09[ab]	1.73[c]	1.97[bc]	0.07	0.02
LM area, cm^2	91.81[a]	91.97[a]	83.76[b]	96.57[a]	1.90	0.001
Yield Grade	3.15[a]	3.13[a]	3.81[b]	2.74[c]	0.15	0.002
Marbling Score[2]	423	428	427	425	14.92	0.99

[1]CON = 40% CP supplement; CORN = corn-based supplement; LGWP = low rate of gain on wheat pasture; HGWP = high rate of gain on wheat pasture
[2]Marbling grid: 400 = Small00; 500 = Modest00
[a,b,c] Means within a row lacking a common superscript letter differ ($P < 0.05$)

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GRAZING PATTERNS OF ANGUS, BRANGUS, AND BRAHMAN COWS IN THE CHIHUAHUAN DESERT

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ABSTRACT: In extensive pastures, forage utilization may decrease due to limited water sources. However, adapted breeds of cattle may facilitate an improvement in grazing distribution by utilizing distant portions of extensive pastures. A 2-yr study was conducted to evaluate grazing distribution and quality of diet for Angus, Brangus and Brahman cows in the Chihuahuan Desert during 3 seasons (winter, early summer and late summer) using 3 pastures varying in terrain. Cows were tracked with GPS technologies every 10 minutes for 10 to 14 d periods in each pasture (3 periods per season). Pooled data from 7 cows of each breed were evaluated in 2008 utilizing a Latin square design with breed as the treatment and period and pasture as blocking factors (n = 9). Breeds were kept together during 2009 and evaluated for 10 to 14 d in each of 3 pastures during each season using breed and pasture as fixed effects. When cows were rotated among pastures, fecal samples were collected and analyzed using near infrared spectroscopy **(NIRS)** to estimate diet quality. In 2008, crude protein content of diets was similar ($P > 0.31$) among breeds during all seasons. Brahman cows regularly traveled greater distances per day than Angus or Brangus cows during early and late summer seasons in 2008 and 2009 ($P < 0.05$). Brahman cows traveled 12.4 ± 0.6 km/d while Angus and Brangus traveled 7.2 ± 0.6 and 8.3 ± 0.6 km/d, respectively, during late summer 2009. In contrast, average distance from water was similar ($P \geq 0.59$) among breeds during both 2008 and 2009, which suggest that distribution patters were similar. Diurnal movement patterns sometimes differed among breeds. In late summer 2009, Brahman cows (1.81 ± 0.11) made more ($P = 0.03$) trips to water each day than Angus (1.15 ± 0.11) or Brangus (1.36 ± 0.11); however, during the winter and early summer in 2008 and 2009, trips to water each day were similar ($P \geq 0.48$) among breeds. Spatial movement patterns of Brahmans appeared to differ from Angus and Brangus, however, no clear advantage in grazing distribution was observed for any breed.

Key Words: Behavior, Breed, Distribution, Telemetry

Introduction

Achieving an even distribution of livestock use among areas and plant communities within a pasture is a major objective of grazing management (Holechek, 1988). In extensive rangeland pastures, many range management issues can be attributed to grazing distribution and associated spatial movement patterns of livestock grazing at patch to landscape scales (Coughenour, 1991; Bailey, 2004). Poor grazing distribution may contribute to resource deterioration when livestock over-use preferred areas that offer key resources while other areas receive little use even though there is ample forage available (Bailey, 2004). Selecting livestock based on their grazing patterns and terrain use has the potential for improving grazing distribution (Roath and Kruegar, 1982; Howery et al., 1996). Herbal and Nelson (1966) found breed differences between Santa Gertrudis and Hereford cows in the Chihuahuan desert, where Santa Gertudis cows walked farther each day than Hereford cows in large, extensive rangeland pastures. Winder et al., (1992) analyzed heterotic effects on annual cow productivity for Hereford and Brangus cows and reciprocal crossbred cows under semidesert conditions. They found an adaptive advantage for cows with Brangus sires and (or) dams that expressed high levels of maternal heterosis under stressful environments when genetically diverse breeds were crossed (Winder et al., 1992). The objectives of this study were to compare grazing distribution and diet selection of Angus, Brangus, and Brahman cows in extensive pastures in the Chihuahuan Desert. We hypothesized that Brangus cows would walk farther and correspondingly use areas farther from water than Angus and Brangus cows.

Materials and Methods

Study Site and Animals. All animal handling and experimental procedures were in accordance with guidelines set by the New Mexico State University's Institutional Animal Care and Use Committee. All Brahman and Brangus cows were born and raised at the Chihuahuan Desert Rangeland Research Center **(CDRRC)**, and all Angus cows were developed on extensive rangelands for one year at Corona Range and Livestock Research Center **(CRLRC)** in Corona, NM and then brought to the CDRRC one year before the study. This study was conducted at the CDRRC located 37 km north of Las Cruces in south-central New Mexico. Elevation of the study pastures range from 1,200 to 1,800 m. Average rainfall is 234mm occurring during the primary growing season of July - September. Temperatures in the summer are high, with a mean maximum temperature 36ºC during June, and the mean maximum temperature in January is 13ºC. Mean minimum temperature for January is -3ºC and 16ºC for June. Monthly precipitation during study years is shown in Figure 1. From January of 2008 to June of 2008, conditions were dry with only 3.3 mm of precipitation;

whereas, precipitation during July through September of 2008 was relatively wet with 232.16 mm of precipitation. In 2009, precipitation was near normal with 190 mm of annual precipitation.

Dominant grasses in the study pastures were dropseeds (*Sporobolus* spp.), threeawns (*Aristida* spp.), and black grama (*Bouteloua eripoda* [Torr.] Torr.). Common shrubs are honey mesquite (*Prosopis glanulosa* Torr.), broom snakeweed (*Guiterrezia sarothrae* [Pursh] Britton & Rusby), and creosote bush (*Larrea tridentata* [Sesse' & Moc. Ex DC.] Coville).

In 2008 and during the winter of 2009, 3 pastures (12, 13, and 19) were used. Pasture 19 was the most rough and rugged pasture of the three pastures. Study pastures contained only one water source. Pasture 16 was utilized in 2009 due to inadequate water in pasture 19. Forage production was not limiting in any of the study pastures. Pasture sizes were approximately 1,960-ha, 3,700-ha, 1,450-ha, 1,490-ha for pastures 12, 13, 19, and 16, respectively. Pasture 12 had a maximum distance from water of 7.9 km. Terrain was generally gentle with some alluvial outflow areas (bajada) with slopes varying from 1% to 16%. Pasture 13 contained variable topography with a maximum distance from water of 10.2 km. Terrain in pasture 13 consisted of rolling hills, with a series of small ridges and arroyos with slopes usually varying from 1% to 20%. Pasture 19 had a maximum distance to water of 8.9 km. Pasture 19 was the most rough and rugged pasture with slopes up to 28% and elevation up to 1,530 m. Pasture 16 was 1,409 ha with a maximum distance to water 9.2 km. Terrain in pasture 16 is variable, but the areas used by cattle in 2009 were relatively gentle with slopes varying from 1%- 21%.

Design and Protocol. Angus, Brangus and Brahman cows were compared and evaluated during three different seasons (28-30 d). The first season (winter) began 4 January 2008, prior to calving. The second season (early summer) began 2 May 2008, during early lactation. The third season (late summer) began 1 August 2008, during late lactation. In 2008, each group of cows (n = 6 or 7) grazed in each of the three study pastures (12, 13, and 19) for 10- to 14-d periods during a season (3 periods per season) in a Latin square design. In 2009, we combined all Angus, Brangus, and Brahman cows and evaluated them at the same time in the same pasture.

Cows were mature (4 to 10 years) in age. Sixty percent of the cows of each breed were used throughout the study. The other 40% of the cows were changed during the interim between seasons. During a season, the same 6 to 7 cows in each breed type were evaluated and compared.

GPS Tracking. Two randomly selected cows from each breed were tracked with global positioning system **(GPS)** collars. Cows were tracked with Lotek GPS 3300 collars (Lotek Wireless, Newmarket Ontario) at 10-min intervals. Distance from water was calculated for each recorded position and averaged together for each cow during each period. Distance traveled each day was determined by summing the successive distance between recorded positions of each collared cow and dividing by the number days cows were tracked in a pasture.

Diet Quality Sampling. Fecal samples were collected from each cow at the end of each period during 2008. Fecal samples were frozen, dried, and ground in a Wiley mill to pass a 1 mm screen. Fecal samples were dried in a forced-air oven (50ºC for 24 h). Fecal samples were scanned using a scanning reflectance monochromator (model 6500, NIR Systmes Inc., Silver Springs, MD). Reflected energy (log [1/R], where R = reflectance) was measured and averaged over the 32 scans and recorded at 2-nm intervals from 1100 to 2500nm. Diet DOM and CP of cows during a period were determined using the equations originally developed by Lyons and Stuth (1992).

Statistical Analyses. A 3 × 3 Latin square design (n = 9) used in 2008 required a statistical model that included breed (Angus, Brangus, and Brahman), pastures (12, 13 and 19) and period (first, second and third periods within a season). Each season (winter, early summer and late summer) was analyzed separately. In 2008, data was pooled data from 3 seasons and analyzed it using a repeated measures model where breed × pasture was the subject and season, breed, pasture, period and their interactions were fixed effects. Covariance between repeated records was modeled using compound symmetry, which had the lowest Akaike's Information Criterion (**AIC**) value (Littell et al. 1996). For data collected in 2009, breed groups grazed together and evaluated at the same time within the same pasture. Each season was analyzed separately in 2009. Fixed effects of the model were breed and pasture (n = 9). Mean separation among breeds was completed using the pdiff option of PROC MIXED (SAS, Institute, Cary, NC).

Results and Discussion

Diet Selection. In 2008, CP content of diets was similar ($P > 0.31$) among Angus, Brangus, and Brahman cows across seasons. Herbal and Nelson (1966b) found similar results yielding no difference in diet selection between Hereford and Santa Gertrudis cows. Scimone et al. (2007) and Wallis De Vries et al. (2007) reported that breed effects on diet preference were generally small, and possible breed differences could be related to differences to live weight (Dumont et al., 2007).

CP increased ($P < 0.01$; Table 1) in late summer compared to early summer and winter most likely due to the monsoon season precipitation (Figure 1). Average precipitation from July through September 2008 was 232.16 mm compared to 3.3 mm from January through June 2008 (Figure 1).

2008 Distribution Patterns. During the winter, early summer, and late summer of 2008, there were no differences among breeds in average distance to water, time spent at water, slope, or elevation ($P > 0.43$; Table 2). However, Brahman cows walked farther ($P < 0.01$) each day than Angus or Brangus cows in early and late summer. This is similar to the findings of Herbal and Nelson (1966) that found breed differences in Hereford and Santa

Gertrudis cattle. They found Santa Gertrudis cattle walked farther each day than Hereford cattle during the spring and summer in southern New Mexico. Although, Brahmans walked farther distances each day in this study, they did not use areas farther from water than Angus or Brangus cows. Although the number of trips to water of each breed was similar ($P = 0.62$), Brahmans grazing movements appeared to differ in the 3 study pastures. In the pasture (19) with the most rugged topography, Brahmans walked over 5 km from water to the gate they entered almost on a daily basis. This gate was also nearest to the pastures that Brahman cattle at the CDRRC usually grazed. In contrast, in pasture 12, a pasture adjacent to their normal grazing area, Brahmans rarely walked over 3 km from water.

We suspected that Brahmans may have in 2008 been attempting to return to their Brahman herd mates that remained in the traditional Brahman pasture. We examined this further in 2009 to help explain differences in distance traveled. All Brahmans (study cows and herdmates from the traditional pasture for this breed) were tracked in pastures 13 and 19 during December 2008 without other breeds. Brahmans continued to walk the 5 km from water to the exit gate of pasture 19. The increase in mean distance traveled resulting from their travels from water to the exit gate in pasture 19 was not simply an attempt to return to their herdmates. Instead, this continued pattern of Brahman cows attempting to leave pasture 19 each day suggested that either Brahmans are uncomfortable with rugged terrain and attempting to avoid it, or they were attempting to return to an area in which they are more familiar.

2009 Distribution Patterns. During the winter, early summer, and late summer of 2009, there were no differences among breeds for average distance to water, time spent at water, slope, or elevation ($P \geq 0.55$; Table 3). Brahmans walked farther each day than Angus during the early summer of 2009 ($P < 0.01$). However, Brahmans were similar to Angus and Brangus in trips to water ($P = 0.51$). During the late summer of 2009, Brahmans walked farther each day than Angus ($P < 0.01$). Unlike the early summer season, Brahmans made more trips to water than Angus ($P < 0.01$). During the winter, all breeds traveled similar ($P = 0.12$) distances each day, and made a similar number of trips to water ($P = 0.81$).

Implications

Results found in this study reject the hypothesis that Brangus cows would walk farther and correspondingly use areas farther from water than Angus and Brangus cows. Instead, Brahman cattle walk farther each day than Angus or Brangus during the early and late summer seasons, but grazing areas far from water did not vary among breeds. The overall distribution patterns are relatively similar for the 3 breeds. Brahman cows may walk farther than Angus or Brangus cows during the summer, because they may sometimes return to water more frequently than the other breeds. In addition, Brahman cows may also have a tendency to prefer more gentle terrain or prefer areas that they are more familiar with based on the movement patterns of Brahman cows observed in this study.

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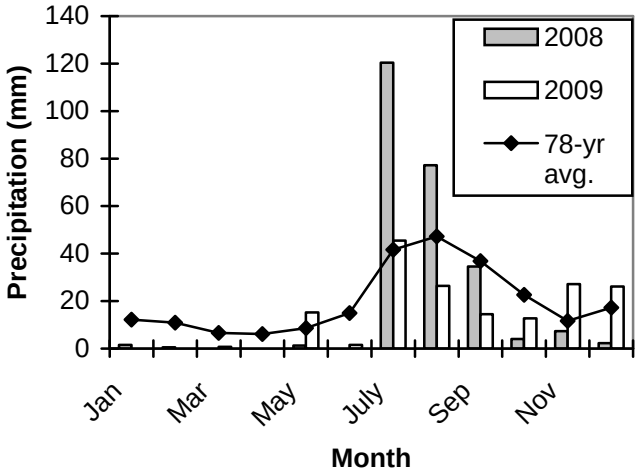

Figure 1. Bars show annual precipitation by month for 2008 and 2009 (years of study). Line shows 78-yr avg. precipitation

Table 1. Dietary CP selected by Angus, Brangus and Brahman cows[1].

Season	Angus	Brangus	Brahman	SE	*P*-value
Winter ,	7.9	6.4	7.9	0.6	0.31
Early Summer	7.6	7.6	7.5	0.5	0.98
Late Summer	10.5	12.2	11.6	0.6	0.38

[1] CP concentrations are expressed on a DM basis.

Table 2. Mean terrain use and behavior of Angus, Brangus, and Brahman cows pooled across the winter, early summer and late summer season of GPS tracking during 2008.

	Breed				
Measurement	Angus	Brangus	Brahman	SE	*P*-value
Average distance to water, km/day	1294	1147	1569	283.4	0.59
Distance traveled, km/day	5.9	6.6	9.6	0.4	< 0.01
Time spent at water, %	24.5	17.1	24.7	6.5	0.65
Elevation, m	1311	1307	1326	9.5	0.44
Slope, ˚	3.2	3.3	2.8	0.3	0.46
Trips to water	48.2	62.3	42.3	3.4	0.62

Table 3. Mean terrain use and behavior of Angus, Brangus, and Brahman cows by season during 2009.

	Breed				
Measurement	Angus	Brangus	Brahman	SE	*P*-value
Winter Season					
Average distance to water, km/day	698	1090	1257	282.6	0.44
Distance traveled, km/day	3.3	3.6	4.9	0.4	0.12
Time spent at water, %	20.4	20.2	17.7	3.9	0.86
Elevation, m	1299	1314	1321	10.4	0.41
Slope, ˚	4.9	3.5	3.8	0.8	0.50
Trips to water	1.0	0.9	1.1	0.1	0.67
Early Summer Season					
Average distance to water, km/day	1185	1029	964	69.3	0.13
Distance traveled, km/day	5.7	7.9	8.6	0.5	< 0.01
Time spent at water, %	24.9	26.6	29.3	2.8	0.55
Elevation, m	1322	1323	1322	0.6	0.55
Slope, ˚	1.4	1.4	1.4	0.1	0.70
Trips to water	1.9	1.3	2.1	0.5	0.61
Late Summer Season					
Average distance to water, km/day	1276	1364	1337	163.6	0.92
Distance traveled, km/day	7.2	8.3	12.4	0.6	< 0.01
Time spent at water, %	15.9	23.1	18.4	3.8	0.47
Elevation, m	1324	1320	1321	0.8	0.06
Slope, ˚	1.4	1.4	1.4	0.1	0.84
Trips to water	1.2	1.4	1.8	0.1	< 0.01

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ARGININE SUPPLEMENTATION DOES NOT ALTER NITROGEN METABOLISM OF BEEF STEERS DURING A LIPOPOLYSACCHARIDE CHALLENGE

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ABSTRACT: Demand for Arg is reported to increase during immune challenges. This study evaluated effects of lipopolysaccharide (LPS) and abomasal Arg infusion on N metabolism and immune response of 20 ruminally cannulated steers (369 ± 46 kg BW) in a randomized block design. Each block consisted of a 14-d adaptation, 1-d blood collection, and 5-d fecal and urine collection. Steers were fed a diet (12.9% CP, 0.99 Mcal/kg NE_g) at 1.5% BW. Treatments (2 × 2 factorial) were AA solutions with no Arg (-ARG) or 10 g/d Arg (+ARG), and sterile saline with no LPS (-LPS) or 1 µg LPS (+LPS; E. coli 055:B5) per kg BW. The AA solutions were abomasally infused (720 mL/d) from d 7 to 20; LPS solutions (100 mL) were intravenously infused (1 mL/min) on d 15. Rectal temperature (RT) and blood samples were collected 0, 2, 4, 8, 12, and 24 h after LPS infusion on d 15. No LPS × ARG × h or LPS × ARG interactions occurred ($P > 0.18$). Cortisol, IL-6, and RT were greater (LPS × h, $P < 0.01$) for +LPS vs -LPS at 2, 4 (peak), 8 and 12 h (cortisol, IL-6). Tumor necrosis factor-α was greater at 2 h, and haptoglobin was greater at 24 h in +LPS vs -LPS steers (LPS × h, $P < 0.01$). Plasma Met, Leu, Val, Gln, and Orn of +LPS vs -LPS steers were greater (Met, Leu) or not different (Val, Gln, Orn) at 0 h, not different at 2 and 4 h, lower at 8 (all) and 12 h (Met, Val, Gln, Orn), and either not different (Met, Val, Orn) or greater (Leu, Gln) at 24 h (LPS × h, $P < 0.01$). Plasma Thr, Ser, Asp, Asn, and Glu were lower (LPS × h, $P \leq 0.02$) for +LPS vs -LPS at 2 (Asn), 4, 8, 12, and 24 h (Thr, Ser, Asp, Glu). Plasma Ile and Pro were lower (LPS × h, $P < 0.01$) for +LPS vs -LPS at 4, 8, and 12 h (Ile). Plasma Ala was greater (LPS × h, $P = 0.04$) for +LPS vs -LPS at 2, 12, and 24 h. Plasma Lys, Tyr, and Trp were lower ($P < 0.05$) for +LPS vs -LPS, and plasma Ala, Pro, and Orn were greater ($P \leq 0.05$) for +ARG vs -ARG. The +LPS vs -LPS steers tended to have greater ($P = 0.13$) urinary N excretion and lower ($P = 0.11$) N retention, and steers infused with Arg had greater ($P < 0.01$) digested N and tended to have greater ($P = 0.09$) N retention. Abomasal infusion of Arg does not alter the effects of LPS on N metabolism.

Key words: arginine, lipopolysaccharide, steer

INTRODUCTION

Immune challenge and stress shifts nutrient partitioning away from growth and concomitantly toward the immune response (Calder, 2006). Among the major products of the innate immune response are acute-phase proteins and pro-inflammatory cytokines. These products are responsible for a febrile response, tissue inflammation, proteolysis, lipolysis, and anorexia (Melchior et al., 2004). According to Reeds et al. (1994), the AA profiles needed for synthesis of these immune cells and products are different from the AA profiles of muscle tissues, and thus excessive proteolysis is necessary to provide AA for the immune system.

Waggoner et al. (2009a) demonstrated that decreases observed in N retention of steers challenged with lipopolysaccharide (**LPS**) can be alleviated by increasing dietary CP concentrations, possibly because of a reduced need to catabolize muscle tissue to meet the AA demands of immune cells. Supplementing a specific limiting AA for the immune response may result in similar improvement in N retention by reducing tissue proteolysis. Arginine is a substrate for the production of several immune modulators, including nitrous oxide and polyamine growth factors (Wu and Morris, 1998). In mice and chickens, Arg supplementation increased lymphoid hyperplasia, lymphocyte proliferation and BW gain during pathogen challenges (Kwak et al., 1999; Lewis and Langkamp-Henken, 2000). Also, Arg has been supplemented in humans before surgery to promote N retention during post-operative stress (Daly et al., 1988).

We hypothesized that Arg supplementation will increase the supply of a potentially limiting AA for the immune response, and thus alleviate decreases in N retention associated with excess body protein catabolism in LPS-challenged steers. Therefore, the objective of this study was to determine the effects of post-ruminal Arg supplementation on N retention and plasma AA concentration in beef steers stressed with LPS.

MATERIALS AND METHODS

Animals, Design, and Treatments

Procedures were approved by the New Mexico State University Institutional Animal Care and Use Committee. Twenty ruminally cannulated Angus-cross steers (369 ± 46 kg initial BW) were housed in individual tie stalls within a continuously lit and temperature controlled (22 ± 1.7°C) environment. Each stall was padded with 2.54 cm thick rubber floor mats and equipped with automatic watering troughs (Nelson Manufacturing, Cedar Rapids, IA). Steers were fed a diet (Table 1) at 1.5% of BW (DM basis), which was provided in 2 equal portions at 0700 and 1800.

The experiment was a randomized block design. Each block consisted of a 20-d experimental period, which

included a 14-d adaptation period followed by a 1-d blood and 5-d total fecal and urine collection period. Treatments, in a 2 × 2 factorial arrangement, were abomasal infusion of an essential AA solution containing either no Arg (**-ARG**) or 10 g Arg (**+ARG**), and jugular infusion of sterile saline containing either no LPS (**-LPS**) or 1 µg LPS (**+LPS**; *E. coli* 055:B5; Sigma Chem. Co., St. Louis, MO) per kg of BW. The AA solutions (720 mL/d) were infused in 3 equal portions at 1000, 1400, and 1800 beginning on d 7 of the adaptation period and continuing throughout the collection period. Disposable syringes (60 mL) were used to infuse the AA solutions into the abomasum via indwelling flexible tubing (3.2 mm i.d.) inserted through each animal's ruminal cannula and reticulo-omasal orifice. The +ARG solution contained 10 g Arg, 5 g His, 10 g Lys, 5 g Met, 5 g Phe, 5 g Thr, 2.5 g Trp, 5 g Ile, 5 g Leu and 5 g Val, whereas -ARG was the same solution with Arg omitted. The sterile saline solutions (100 mL) with or without LPS were infused on d 15 at 3 h after the 0700 feeding. An electronic syringe pump (Model 230, KD Scientific, Holliston, MA) was used to infuse the LPS solutions via jugular catheters (J457A; Jorgenson Laboratories, Loveland, CO) at 1 mL/min. The +LPS infusion in 1 steer (block 1) was stopped at 70 mL because of a severe reaction to LPS.

Table 1. Diet composition (DM basis)

Item	Amount
Ingredient, %	
Wheat grain, ground	30.0
Corn silage	21.3
Alfalfa hay	20.0
Soybean hulls	20.0
Molasses	4.0
Tallow	2.5
Supplement premix[1]	1.9
Urea	0.3
Nutrient	
NDF, %	37.3
CP, %	12.9
Ca, %	0.87
NE_g, Mcal/kg	0.99

[1]Supplied (per kg diet DM): 5 g limestone, 5 g dicalcium phosphate, 5 g sodium bicarbonate, 3 g salt, 90 mg zinc sulfate, 40 g copper sulfate, 0.09 mg sodium selenite, 33 mg monensin (Rumensin; Elanco Animal Health, Indianapolis, IN), 1,500 IU vitamin A, and 150 IU vitamin E.

Collections

On d 15, rectal temperature and blood samples were collected immediately before LPS infusion (0 h) and at 2, 4, 8, 12, and 24 h thereafter. Rectal temperatures were measured with a digital thermometer (Cooper Atkins Corp., Middlefield, CT). Blood samples were collected through jugular catheters into 10 mL vacuum tubes (Corvac serum separator and Monoject Sodium Heparin, Kendall, Ontario, CA). Blood samples were centrifuged (Sorvall RT600B, Thermo Electron Corp., Asheville, NC) at 1,500 × *g* for 15 min at 10°C. Serum and plasma were immediately decanted into 7-mL vials and frozen at -70°C for later analysis.

Diet samples were collected on d 15 through 19; feed refusal and total feces and urine were collected on d 16 through 20. Feces were collected using fecal bags fitted to steers with harnesses. Urine was collected using vacuum pouches that drained into 20-L canisters (Nasco, Modesto, CA) which contained 600 mL of 3 *M* HCL (to minimize NH_3 loss). Total daily fecal and urinary output was weighed and representative samples of feces (10%) and urine (1%) were frozen at -20°C for later analysis.

Sample Analysis

Diet, feed refusals, and fecal samples were dried at 55°C in a forced-air oven (Blue M Electric Company, Blue Island, IL) for 48 h, allowed to air-equilibrate for 24 h, weighed to determine moisture loss, and ground to pass a 2-mm screen in a Wiley mill (Thomas scientific, Swedesboro, NJ). Ground samples were dried in a convection oven (Precision Scientific Group, Chicago, IL) at 105°C for 24 h to determine DM. Concentrations of N in the diet, feed refusals, feces, and urine were assayed by total combustion (Leco FP-528, Leco Corp., St. Joseph, MI).

Serum concentrations of cortisol were determined by solid-phase RIA using components of commercial kits (Siemens Diagnostic, Los Angeles, CA) and antibody-coated tubes as described by Kiyma et al. (2004). Serum samples were analyzed for haptoglobin by the Kansas State University Veterinary Diagnostic Lab (Manhatten, KS) as described by Smith et al. (1998). The cytokines, IL-6 and tumor necrosis factor-α (**TNF-α**), were measured in serum samples according to the manufacturer's protocol using a bovine specific ELISA kit for pro-inflammatory cytokines (SearchLight Bovine Inflammatory Cytokine Array #84664; Pierce, Rockford, IL) as described by Carroll et al. (2009). Plasma samples were analyzed for AA using GLC (CP-3800, Varian, Walnut Creek, CA) and a commercially available kit (EZ:FAAST No. KGO-7165, Phenomenex, Torrance, CA) as described by Waggoner et al. (2009b).

Statistical Analysis

Data were analyzed as a randomized block design with the MIXED procedure (SAS Inst. Inc., Cary, NC). The animal facility had only 12 tie stalls, and therefore data was blocked by collection period (12 steers in period 1, 8 steers in period 2). Steer was the experimental unit.

The statistical model included LPS, ARG, and LPS × ARG interaction for all dietary measures; block and steer were random effects. Rectal temperature and blood metabolites were analyzed as repeated measures with compound symmetry covariance structure. The statistical model included LPS, ARG, hour and the interactions; block and steer within treatment were random effects. Means were least squares, and differences were considered significant at $P \leq 0.05$.

RESULTS

No LPS × ARG × hour ($P > 0.18$) or LPS × ARG ($P > 0.24$) interactions were observed. Therefore, means for the effects of LPS and ARG are presented separately. Rectal

temperature increased and was greater for +LPS than -LPS steers at 2, 4 (peak), and 8 h, and was not different at 12 and 24 h after LPS infusion (LPS × h, $P < 0.01$; Figure 1). Serum concentrations of cortisol and IL-6 increased in +LPS steers and were greater than -LPS steers at 2, 4 (peak), 8, and 12 h, but were not different at 24 h after LPS infusion (LPS × h, $P < 0.01$). Serum TNF-α increased and was greater in +LPS than -LPS steers at 2 h after LPS infusion, then decreased and was not different at 4, 8, 12, and 24 h after infusion (LPS × h, $P < 0.01$). Serum haptoglobin was not different at 0, 2, 4, 8, and 12 h, but was greater in +LPS vs. -LPS steers at 24 h after infusion (LPS × h, $P < 0.01$).

Plasma concentrations of Ile and Pro decreased in +LPS steers and were lower than -LPS steers at 4, 8, and 12 h for Ile, and at 4 and 8 h for Pro (LPS × h, $P < 0.01$; Figure 2). Similarly, plasma Val and Orn decreased and were lower in +LPS than -LPS steers at 8 and 12 h after LPS infusion (LPS × h, $P \leq 0.01$). Plasma Met and Leu of +LPS compared to -LPS steers were greater at 0 h, then decreased and were not different at 2 and 4 h, lower at 8 h, either lower (Met) or not different (Leu) at 12 h, and either not different (Met) or greater (Leu) at 24 h after LPS infusion (LPS × h, $P < 0.01$). Plasma concentrations of Thr, Ser, Asp, and Glu decreased and were lower among +LPS than -LPS steers at 4, 8, 12, and 24 h after LPS infusion (LPS × h, $P \leq 0.02$). Plasma Asn decreased and was lower among +LPS than -LPS steers at 2, 4, 8, and 12 h after LPS infusion (LPS × h, $P < 0.01$). Plasma Gln decreased and was lower among +LPS than -LPS steers at 8 and 12 h, but was greater in +LPS vs. -LPS steers at 24 h after LPS infusion (LPS × h, $P < 0.01$). Plasma Ala was not different among LPS treatments at 0, 4, and 8 h, but was greater in +LPS than -LPS steers at 2, 12, and 24 h (LPS × h, $P = 0.04$; data not shown). Plasma Lys, Tyr, and Trp were lower ($P < 0.05$) for +LPS vs. -LPS (Table 2), and plasma Ala, Pro, and Orn were greater ($P \leq 0.05$) for +ARG vs. -ARG (Table 3). Plasma Gly and His were not affected ($P \geq 0.10$) by LPS challenge or Arg supplementation.

Steers challenged with LPS tended to have greater ($P = 0.13$) urinary N excretion and lower ($P = 0.11$) N retention (Table 2). Steers supplemented with Arg had greater ($P < 0.01$) N digested and tended to have greater ($P = 0.09$) N retention (Table 3).

DISCUSSION

Effects of LPS on N Metabolism

Lipopolysaccharide has been used as an immune challenge model because it initiates an acute innate immune response characterized by production of pro-inflammatory cytokines and acute-phase proteins (Carroll et al., 2009). In the current study, increases in rectal temperature, cortisol, TNF-α, IL-6, and haptoglobin indicated that steers infused with LPS exhibited an acute-phase response. Additionally, decreases in plasma concentrations of Ile, Leu, Val, Met, Thr, Ser, Orn, Pro, Gln, Glu, Asn, and Asp of LPS-challenged steers indicated a transient shift in AA metabolism. Waggoner et al. (2009a; 2009b) similarly reported decreases in plasma AA concentration in steers exposed to LPS, and concluded that an activated immune system may have increased the demand for these AA. A tendency for greater urinary N excretion and lower N retention in LPS-challenged steers is indicative of a shift in N metabolism, possibly because of increased tissue protein catabolism to support an increased AA demand for the synthesis of immune cells or glucose precursors. A lower amount of LPS was used in the current study, and therefore the LPS-induced decrease in N retention was less than that reported previously (Waggoner et al., 2009a; 2009b).

Effects of Arg on N Metabolism

Arginine is a substrate for the production of several immune modulators, including nitrous oxide and polyamines (Wu and Morris, 1998). Nitrous oxide acts as a growth factor and cytotoxic immune effector in macrophages (Grimm and Kraus, 2001), and polyamines are regulators under conditions of increased protein proliferation, such as when rapid proliferation of immune tissues occur (Tabor and Tabor, 1976). Supplemental Arg has increased lymphoid hyperplasia, lymphocyte proliferation and BW gain during pathogen challenges in mice and chickens (Kwak et al., 1999; Lewis and Langkamo-Henken, 2000), and Arg has been supplemented in humans before surgery to promote N retention during post-operative stress (Daly et al., 1988). Our hypothesis was that Arg supplementation will increase the supply of a potentially limiting AA for the immune response, and thus alleviate decreases in N retention associated with excess body protein catabolism in LPS-challenged steers.

Although our plasma AA analysis technique did not allow for direct measurement of Arg, increased plasma concentration of the Arg metabolites, Orn and Pro, in response to Arg supplementation indicated that this abomasally infused treatment was effective at supplying metabolizable Arg. Also, an increase in plasma Ala concentrations in response to Arg supplementation represents a shift in AA metabolism. However, the additional supply of metabolizable Arg did not alter other plasma AA concentrations, nor did it decrease urinary N excretion. This indicates that Arg had little effect on the utilization of absorbed AA for tissue protein accretion. The tendency for Arg supplementation to increase the amount of N retained was due to its effect on N digested, which appeared to be a function of the additional N infused via the Arg treatment. Nolte et al. (2008) similarly reported an increase in N digestibility when sheep received abomasal infusions of Arg. In summary, Arg supplementation did not appear to increase tissue protein accretion or decreased tissue protein catabolism.

Implications

Decreases in both plasma AA and N retention in response to LPS imply that steers with an activated immune system have a greater metabolic demand for AA. However, the lack of interactions between LPS and Arg infusion imply that supplemental Arg does not aid in preventing the negative effects of an immune response on AA metabolism and N balance.

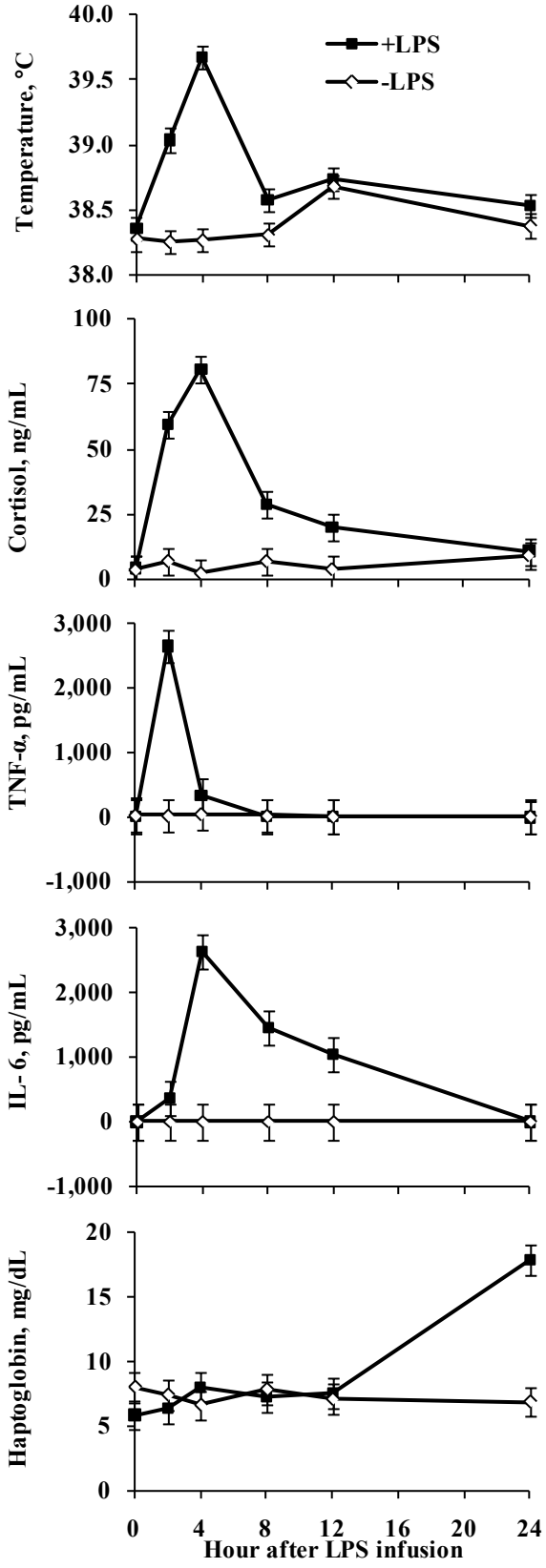

Figure 1. Rectal temperature and serum concentrations of cortisol, tumor necrosis factor-α (TNF-α), IL-6, and haptoglobin in growing beef steers in response to intravenous infusion (1 mL/min) of 100 mL sterile saline containing either 0 or 1.0 μg lipopolysaccharide (-LPS vs. +LPS) per kg BW. Effect of LPS × h ($P < 0.01$).

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Table 2. Plasma Lys, Tyr, Trp, and N balance of growing beef steers in response to lipopolysaccharide (LPS)

	Treatment[1]			P-
Item	-LPS	+LPS	SEM	value[2]
N	10	10		
Plasma AA, μM				
Lys	84.88	67.14	5.4	0.03
Tyr	37.20	28.60	2.1	0.01
Trp	55.30	37.87	5.4	0.03
Nitrogen, g/d				
Intake	104.9	103.3	5.18	0.18
Infused	7.95	7.95	-	-
Fecal	33.46	33.05	1.63	0.73
Digested	79.45	78.28	3.66	0.31
Urinary	35.46	44.40	3.96	0.13
Retained	44.38	34.27	4.89	0.11

[1]Treatments were a 2 × 2 factorial of intravenous infusion (1 mL/min) of 100 mL sterile saline containing either 0 or 1.0 μg LPS (-LPS vs. +LPS) per kg BW, and abomasal infusion of 720 mL AA solution to supply either 0 or 10 g/d Arg (-ARG vs. +ARG).

[2]Observed significance level for the effects of LPS; no LPS × ARG interactions were observed ($P > 0.18$).

Table 3. Plasma Ala, Pro, Orn, and N balance of growing beef steers in response to Arg supplementation

	Treatment[1]			P-
Item	-ARG	+ARG	SEM	value[2]
N	10	10		
Plasma AA, μM				
Ala	190.3	215.2	17.1	0.05
Pro	60.72	67.96	3.2	0.02
Orn	38.76	49.95	2.4	<0.01
Nitrogen, g/d				
Intake	103.5	104.8	5.18	0.29
Infused	6.34	9.55	-	-
Fecal	33.23	33.27	1.63	0.98
Digested	76.65	81.07	3.66	<0.01
Urinary	43.07	36.79	3.96	0.27
Retained	33.97	44.68	4.89	0.09

[1]Treatments were a 2 × 2 factorial of intravenous infusion (1 mL/min) of 100 mL sterile saline containing either 0 or 1.0 μg LPS (-LPS vs. +LPS) per kg BW, and abomasal infusion of 720 mL AA solution to supply either 0 or 10 g/d Arg (-ARG vs. +ARG).

[2]Observed significance level for the effects of ARG; no LPS × ARG interactions were observed ($P > 0.18$).

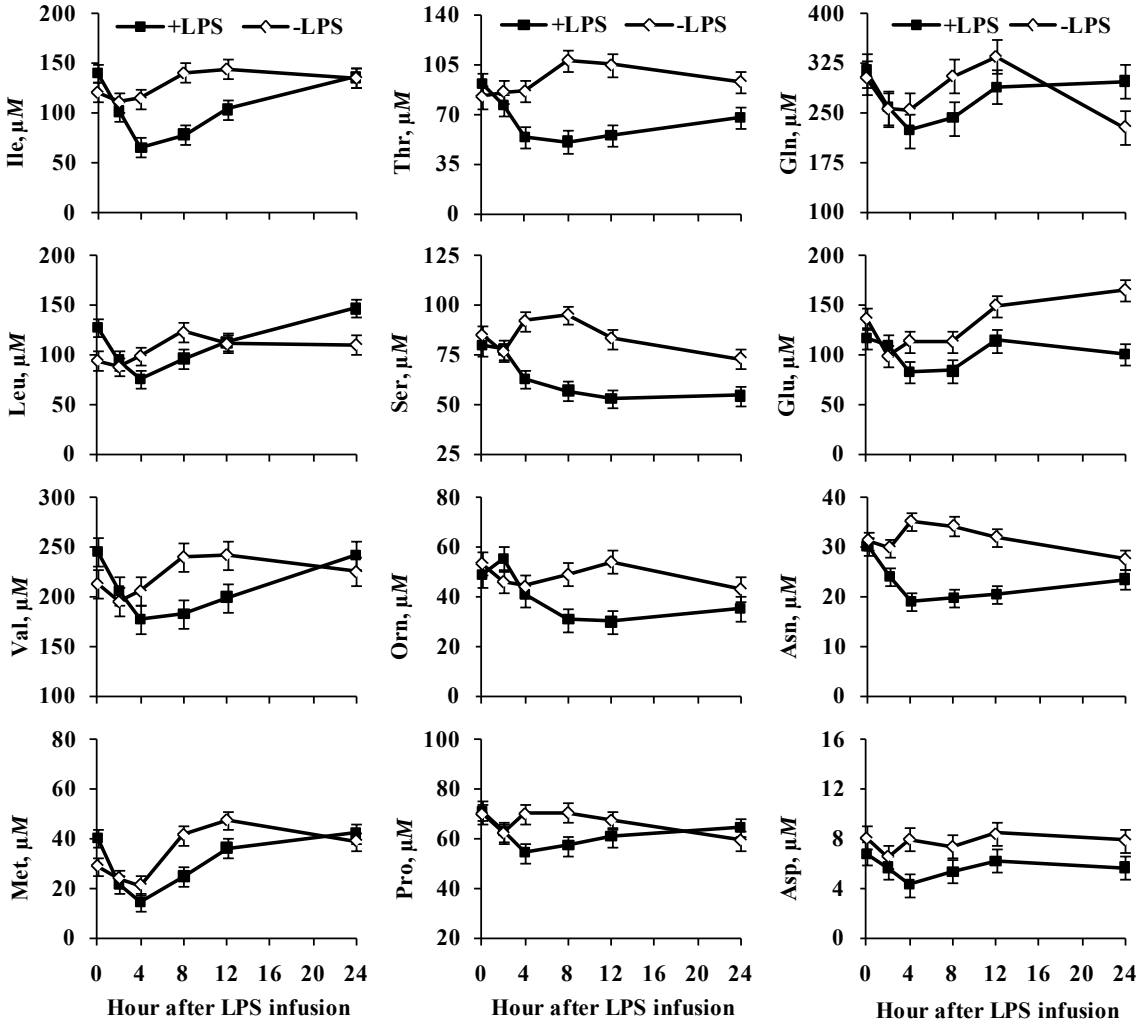

Figure 2. Plasma concentrations of Ile, Leu, Val, Met, Thr, Ser, Orn, Pro, Gln, Glu, Asn, and Asp in growing beef steers in response to intravenous infusion (1 mL/min) of 100 mL sterile saline containing either 0 or 1.0 μg lipopolysaccharide (-LPS vs. +LPS) per kg BW. Effect of LPS × h ($P \leq 0.02$).

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CALCIUM AND PHOSPHORUS METABOLISM IN FINISHING STEERS SUPPLEMENTED WITH VITAMIN D_3

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ABSTRACT: Twelve Angus steers (453 ± 5.01 kg) were used to determine the effect of high dietary vitamin D_3 (**Vit D_3**) on calcium (**Ca**) and phosphorus (**P**) metabolism in feedlot cattle. Steers were randomly assigned to one of two treatments: (1) 0.5 x 10^6 IU of Vit D_3•hd^{-1}•d^{-1} (**0.5 Vit D_3**) or (2) 5.0 x 10^6 IU of Vit D_3•hd^{-1}•d^{-1} (**5.0 Vit D_3**) for eight consecutive days. Steers were maintained on a basal ration for 7 d, followed by 8 d of Vit D_3 supplementation and then 5 d of basal ration. Vitamin D_3 was administered orally via a premix carrier immediately prior to feeding the basal diet to assure complete consumption of Vit D_3. Individual daily DMI, 24-h urine volume, and fecal excretion were recorded and sub-sampled daily for subsequent Ca and P apparent absorption and retention determination. Jugular blood samples were obtained prior to initiation of Vit D_3 supplementation, at the end of Vit D_3 supplementation, and 5 d following Vit D_3 supplementation. Vitamin D_3 supplementation increased ($P < 0.05$) serum concentrations of 25-OH_2-Vit D_3 in both treatments. Steers supplemented with 5.0 Vit D_3 had greater ($P < 0.05$) serum concentrations of 25-OH_2-Vit D_3 than 0.5 Vit D_3 supplemented steers. Serum Ca concentrations were higher in steers supplemented with 5.0 Vit D_3 compared to 0.5 Vit D_3 supplemented steers. Relative to baseline measurements for each treatment, apparent absorption and retention of Ca were reduced ($P < 0.05$) in steers supplemented with 5.0 Vit D_3 but not altered in steers supplemented with 0.5 Vit D_3. Apparent absorption of dietary P was similar for both treatments. Daily urine excretion increased ($P < 0.05$) in 5.0 Vit D_3 supplemented steers from the pre-supplementation period to the end of the Vit D_3 supplementation period and remained greater ($P < 0.05$) throughout the subsequent 5 d non-Vit D_3 supplementation period relative to baseline excretion volumes. Supplementation of feedlot steers with 5.0 million IU of Vit D_3•hd^{-1}•d^{-1} increased serum Ca concentrations, and decreased Ca absorption, and retention levels.

Key Words: calcium, phosphorus, steer, vitamin D

Introduction

Supplementation of feedlot cattle with supranutritional concentrations of vitamin D_3 (**Vit D_3**) has been identified and studied as a tenderness improving feed-additive. In theory, supplementing high dietary Vit D_3 to finishing beef cattle increases blood calcium (**Ca**) concentrations and possibly skeletal muscle cytosolic Ca concentrations. As muscle cytosolic Ca concentrations increase, Ca activated protease activity is increased postmortem which enhances beef tenderness (Montgomery et al., 2000; Koohmaraie et al., 1989; Swanek et al., 1999). Development of a consensus regarding any effect of Vit D_3 has not yet been generated. Areas of inconsistency surrounding Vit D_3 supplementation are three fold: (1) when an effect of Vit D_3 supplementation is found, dose and time of administration have varied between 0.5 x 10^6 IU/hd for 8 d (Montgomery et al., 2000) to 7.5 x 10^6 IU/hd for 10 d (Swanek et al., 1998), (2) the effect of hypervitaminosis D on the apparent absorption and retention of Ca and phosphorus (**P**) in beef cattle has not been thoroughly studied. Blood Ca concentrations have been reported to be increased by supplementing dietary vitamin D_3 (Hibbs and Pounden, 1955), and (3) concern exists regarding Vit D toxicity due to the association of signs of hypervitaminosis D in young children with given therapeutic doses of irradiated ergosterol (Reed and Thacker, 1931). In earlier studies, hypercalcaemia or hyperphosphataemia was shown to exist in infants receiving excessive doses of Vit D (Harris, L J. and J. R. Maitland Innes. 1930). Therefore, the objective of this experiment was to evaluate the effect of Vit D_3 (0.5 x 10^6 or 5.0 x 10^6 IU/hd for 8 d) supplementation on Vit D_3, Ca and P metabolism in finishing steers.

Materials and Methods

All animals and procedures described herein were approved by the Colorado State University Animal Care and Use Committee.

Twelve Angus steers (453 ± 5.01 kg mean initial BW) were randomly assigned to one of two treatments (1) 0.5 x 10^6 IU of Vit D_3•hd^{-1}•d^{-1} (**0.5 Vit D_3**) or (2) 5.0 x 10^6 IU of Vit D_3•hd^{-1}•d^{-1} (**5.0 Vi t D_3**) for eight consecutive days. Seven days prior to Vit D_3 supplementation (d 0), each steer was individually weighed, bled from the jugular, and equipped with a urine collection harness. Steers were then randomly assigned to indoor individual metabolism crates (150 x 225 cm) and had ad libitum access to water and a finishing ration consisting of 85.6% whole corn, 7.1% alfalfa hay, 6.3% protein pellet, and 1.0% trace mineral supplement balanced to NRC (2000) guidelines. Steers were maintained on the basal ration for 7 consecutive days (beginning d 0), followed by 8 consecutive days of Vit D_3 supplementation , and then 5 additional days on the basal ration. Vitamin D_3 was administered orally via a premix

carrier consisting of rice hulls, calcium carbonate, and mineral oil at a rate of 0.5 x 10^6 IU Vit D_3/10g premix. Each predetermined premix portion was hand mixed with 227 g dry molasses, 18 g trace mineral supplement and 1.36 kg of ration and presented to each steer immediately prior to feeding to assure complete consumption of the appropriate dose of Vit D_3.

Prior to collections, all pens were thoroughly scrubbed and washed. Total urine volume, total fecal weight, and individual steer DMI were monitored and sampled daily during the trial for subsequent analysis. Three venous blood samples were collected from each steer on d 11, 16, and 20 to monitor changes in serum Ca, P, and Vit D_3 concentrations.

Chemical Analysis. All feed and fecal samples were ground in a Thomas-Wiley laboratory Mill (Arthur H Thomas Company, Philadelphia, PA) to pass through a 2 mm screen and stored at -20°C in sealed bags until analysis.

Fecal samples were collected daily as the greater of 453.6 g or 10% of the total feces collected. Samples were bagged in a 3.8 L plastic bag and immediately frozen at –20°C until all samples had been collected. Ensuing collection and freezing, samples were tempered at approximately 25°C for 24h. Samples were weighed wet, dehydrated in an oven at 100°C for approximately 48h and reweighed dry. Dry samples were then ground and sorted into three time periods (1, 2, and 3). Period 1 corresponded to the five days preceding vitamin D_3 supplementation (d 2 to 6), period 2 corresponded to the eight days of vitamin D_3 supplementation (d 7 to 14), and period 3 corresponded to the five days succeeding vitamin D_3 supplementation (d 15 to 19). Ground samples from each period were combined to form three 120 g composite samples per animal.

Urine samples were obtained from the total daily collection and placed in a 10 L polyethylene bottle and immediately frozen at –20°C until analyzed. Following collection samples were tempered at approximately 25°C for 24h. Thawed samples from each animal were divided into the three periods (1, 2, and 3) and were then combined into three composite samples according to period assignment in 50 mL polyethylene vials and frozen at –20°C until subsequent analysis. Duplicate samples of feed and feces were analyzed for DM, ash, and N using AOAC (1984, 1999) procedures.

Venous blood samples were collected using 10 mL Vacutainer® (Becton Dickinson and Company, Franklin Lakes, NJ) tubes and immediately refrigerated for 24 h. Following refrigeration, samples were centrifuged at 1200 x g for 25 min at room temperature. Serum was then removed, transferred to a polyethylene tube, capped, and stored at –80°C.

Plasma Ca concentrations were determined by atomic absorption spectrometry as described by Montgomery et al. (2000). Serum inorganic P concentrations were determined via a colorimetric method (Sigma, 1984). Serum Vit D_3 concentrations were determined via chromatography as described by Imawari et al. (1982).

Calculations. Apparent absorption of Ca and P were calculated by taking the total amount of Ca or P consumed in the diet (total amount fed – total amount refused) minus the total amount of Ca or P in the feces. Apparent retentions were calculated by taking the total amount of Ca or P consumed in the diet (total amount fed – total amount refused) minus (the total amount of Ca or P in the feces + the total amount of Ca or P in the urine).

Statistical Analysis. Data were analyzed as a completely randomized design with individual steer serving as the experimental unit. Statistical analyses of data were performed using the mixed model procedure of SAS (SAS Inst. Inc., Cary, NC). The model included steer, period, steer x period, and treatment. A probability of $P < 0.05$ was considered significant.

Results

Performance Data. All steers had similar initial and final BW. Steers receiving 0.5 Vit D_3 had a higher ($P < 0.02$) ADG compared to 5.0 Vit D_3 supplemented steers (Table 1).

Vitamin D_3 supplementation had an impact ($P < 0.001$) on DMI as steers supplemented with 5.0 Vit D_3 had lower DMI's than 0.5 Vit D_3 supplemented steers (Table 1). There were no treatment differences in feed refusal during the 20 d experiment.

Fecal and Urine Excretion. Although there were no treatment effects, urine excretion did increase ($P < 0.03$) linearly over time (Period 1 average = 6.51 mL, Period 2 average = 10.51 mL, and Period 3 average = 12.60 mL; Table 2). There was a decrease ($P < 0.002$) in the daily amount of fecal excretion in the 5.0 Vit D_3 supplemented steers. Furthermore, urine and fecal Ca and P were greater ($P < 0.05$) in 0.5 Vit D_3 supplemented steers when compared to 5.0 Vit D_3 supplemented steers. Additionally there was a tendency ($P < 0.08$) for Ca concentrations within the urine to increase linearly over time regardless of treatment (Table 2).

Plasma Ca, P, and Vit D_3 Concentrations. The main objective of this study was to determine whether blood Ca concentrations would be altered at varying concentrations of Vit D_3 supplementation. Calcium, Vit D_3, and P all had linear increases ($P < 0.05$) in blood serum concentrations throughout the 8 d supplementation period of Vit D_3 and by d 19 of the study (5 d post supplementation) concentrations of Ca, Vit D_3, and P had begun to decline to initial concentrations (Table 3). There was a treatment by period interaction ($P < 0.01$) for serum Ca and Vit D_3 concentrations. Calcium and Vit D_3 increased linearly from period 2 (d 7, initiation of Vit D_3 supplementation) until the end of supplementation (d 15). Steers receiving 5.0 Vit D_3 had greater serum concentrations of Ca and Vit D_3 when compared to steers supplemented with 0.5 Vit D_3 (Table 3).

Calcium and Phosphorus Retention and Absorption. Apparent absorption of Ca was higher ($P < 0.002$) in the 0.5 Vit D_3 supplemented steers compared to steers supplemented with 5.0 Vit D_3 (Table 4). There were no treatment effects for P apparent absorption.

Additionally, apparent retention of Ca and P were higher ($P < 0.01$) in the 0.5 Vit D_3 supplemented steers compared to steers supplemented with 0.5 Vit D_3 (Table 4).

Discussion

Several studies have indicated that there is a direct relationship between supplementing supranutritional concentrations of Vit D and decreased performance. In two research projects conducted at Oklahoma State University (Karges et al., 1999), researchers reported intakes were directly associated with the levels of Vit D supplied in the basal ration. In the first study, steers were supplemented with 0, 5.0, 7.5, 15.0 or 75.0 million IU of Vit D daily. A significant decline ($P < 0.05$) in DMI was observed in the 75.0 Vit D supplemented group after 2 d of supplementation and within 6 d the 5.0 Vit D supplement group had declined intakes. In the second study, DMI was numerically lower for steers within 4 d for cattle receiving 6 IU of Vit D_3 which resulted in an 11.7% decrease in intake.

In a study conducted by Hove et al., (1983) using non-lactating, non-pregnant Jersey cows supplemented with Vit D_3, a linear effect between the increased amount of serum Ca and the increased amount of urinary Ca excretion was observed. Additionally, hypervitaminosis of Vit D in rats resulted in greater ($P < 0.01$) urinary concentrations of Ca 24 h after supplementation versus control rats which were given no supplemental Vit D (Clark I. and M. R. Smith, 1964).

One of the first uses of Vit D administration in regards to enhancing Ca status was to prevent milk fever. Hibbs and Pounden (1955) found that by supplementing Vit D orally at doses of 5, 10, 20, and 30 x 10^6 IU to dairy cattle for a short duration of time prior to calving increased serum Ca concentrations which helped prevent milk fever.

Increases in serum P have been associated with elevated parathyroid hormone and compromised renal function (Chi-yuan and Glenn, 2002). Thus, it can be hypothesized that Vit D_3 causes a direct effect on the metabolic system at multiple levels.

In summary, giving supranutritional concentrations s of 0.5 Vit D_3 to feedlot steers increased serum Ca ($P < 0.001$) and altered Ca and P metabolism, Therefore, feeding Vit D_3 would be an effective way to increase serum Ca concentrations

Implications

Supplementing steers with Vit D_3 may alter the metabolic efficiency of feedlot animals. Supplementation of 0.5 Vit D_3 to finishing steers effectively increased serum Ca concentrations. Future experiments are warranted to determine if increased serum Ca concentrations translates to increased muscle Ca concentrations and potentially increased tenderness.

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Table 1. Least squares means for performance traits of cattle given two supplemental doses of vitamin D_3

	Treatment [a]			*P*-value [b]	
Item	0.5 % Vit D_3	5.0% Vit D_3	SEM	Trt	Period
ADG, kg/d	0.91	(0.18)	0.27	0.02	-
Total Feed Fed, kg/d	8.77	6.88	0.17	0.001	0.001
Feed Consumption, kg/d	7.68	5.57	0.19	0.001	0.09
Feed Refusal, kg/d	1.09	1.31	0.12	0.19	0.04

[a]Steers fed vitamin D were supplemented with 0.5 x 10^6 IU of Vit D_3 or 5.0 x 10^6 IU of Vit D_3 for 8 d.
[b]Initial BW was used as a covariate in the analysis

Table 2. Ca and P concentrations least squares means in the urine and feces of cattle given two supplemental doses of vitamin D_3

	Treatment [a]			*P*-value	
Item	0.5 % Vit D_3	5.0% Vit D_3	SEM	Trt	Period
Total Output					
Urine, mL	8.23	9.54	0.86	0.29	0.03
Feces, kg	5.00	3.07	0.33	0.002	0.47
Fecal Mineral Output, mg					
Ca	26960	18769	1908.19	0.005	0.66
P	17224	8260	1460.76	0.001	0.99
Urine Mineral Output, mg					
Ca	1164.30	2182.10	343.35	0.04	0.08
P	4342.50	7275.22	932.24	0.03	0.98

[a]Steers fed vitamin D were supplemented with 0.5 x 10^6 IU of Vit D_3 or 5.0 x 10^6 IU of Vit D_3 for 8 d.

Table 3. Serum vitamin and mineral concentrations least squares means of cattle given two supplemental doses of vitamin D_3

	Treatment[a]			*P*-value
Item[b]	0.5 % Vit D	5.0% Vit D	SEM	Trt
Vitamin D, mg/dl	124.26	353.71	29.75	0.001
Ca, mg/dl	100.49	112.39	1.95	0.001
P, mg/dl	82.99	75.31	2.70	0.05
Ca:P	1.23	1.53	0.05	0.001

[a]Steers fed vitamin D were supplemented with 0.5 x 10^6 IU of Vit D_3 or 5.0 x 10^6 IU of Vit D_3 for 8 d.
[b]Blood plasma samples were collected from each steer once per period.

Table 4. Ca and P retention and absorption least squares means of cattle given two supplemental doses of vitamin D_3

	Treatment[a]			*P*-value	
Item[b]	0.5 % Vit D_3	5.0% Vit D_3	SEM	Trt	Period
Mineral Absorption, mg					
Ca	23830	15872	1645.60	0.002	0.26
P	21017	18681	1551.46	0.30	0.67
Mineral Retention, mg					
Ca	22665	13690	1626.52	0.001	0.15
P	16675	11406	1344.46	0.01	0.50

[a]Steers fed vitamin D were supplemented with 0.5 x 10^6 IU of Vit D_3 or 5.0 x 10^6 IU of Vit D_3 for 8 d.
[b]Absorption and Retention values calculated each day and were then averaged over period

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GENETIC AND ENVIRONMENTAL INFLUENCES ON DISTRIBUTION PATTERNS OF BEEF CATTLE GRAZING FOOTHILL RANGELAND

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ABSTRACT: A study was conducted in foothill rangelands of northern Montana to determine the relative effects of genotype and environment (or early learning) on grazing distribution. Based on 5 years of observations, 5 of 180 Hereford and Tarentaise crossed cows that used the highest and steepest terrain (hill climbers) and 5 cows that used the most gentle terrain near water (bottom dwellers) were used as donors for embryo transfer. A single AI sire was used in these matings. Crossbred recipient cows were classified as hill climbers (HC) and bottom dwellers (BD) based on 4 years of observation from a separate herd of 98 cows. This resulted in 2x2 factorial study with donor and recipient as the two factors and HC and BD as the two levels within each factor. A total of 28 of these cows were observed in late summer of 2009 when they were mature (4 to 6 years of age). Horseback riders recorded positions of cows during the early morning when they were gazing for 10 days during the 6 weeks cows were in the 336 ha study pasture. Elevation in the pasture ranged from 1184 to 1398 m and the average slope was 34%. Horizontal distance to water, elevation, and slope of the recorded positions of each cow were averaged together resulting in one value for each trait for each cow. Donor (genotype), recipient (environment) and the donor x recipient interaction were used as fixed effects in statistical analyses. Distances from water and slope use were not affected by donors, recipients or the donor x recipient interaction ($P > 0.20$). Daughters of HC donors (1314 ± 7 m) used higher elevations ($P = 0.04$) than those from BD (1290 ± 8 m), and cows raised by HC recipients (1315 ± 7 m) also used higher elevations ($P = 0.04$) than cows from BD recipients (1290 ± 8 m). Cattle use of higher elevations in foothill rangeland appears to be influenced to at least some degree by both genetic (donor dam to daughter relationships) and environmental factors such as early learning (recipient dam to daughter relationships).

Key Words: Genotype, Early Learning, Behavior

Introduction

Many of the challenges associated with cattle grazing in the Western US are due to uneven grazing on expansive and mountainous rangelands. Production systems are often faced with natural resource issues that result from poor distribution in rugged topography and over-utilization in the gentle terrain closer to water. If cattle spend more time grazing upland slopes farther from water, condition and function of riparian areas can be improved and wildlife habitat can be managed more effectively (Bailey., 2005).

Selection of cattle that use higher and steeper terrain (hill climbers) and culling of animals that prefer gentle terrain near water (bottom dwellers) has been shown to have potential for increasing uniformity of grazing in mountainous terrain (Bailey et al., 2006). However we do not know the extent that grazing distribution is inherited, which could be critical for a successful genetic selection program. Therefore, the objective of this study was to determine the extent that grazing distribution of beef cows in mountainous terrain was affected by genotype and environmental factors such as early learning.

Materials and Methods

All animal handing and experimental procedures were in accordance with guidelines set by the Montana State University's Agricultural Animal Care and Use Committee.

Study Site. Research was conducted at the Thackeray Ranch located in the Bear's Paw Mountains approximately 25 km south of Havre, Montana. Lower elevations with gentle slopes were dominated by Kentucky bluegrass (Poa pratensis L.), and steep slopes (> 20º) were dominated by rough fescue (Festuca scabrella Torr.). Kentucky blue grass, rough fescue, bluebunch wheatgrass (Pseudoregnaria spicata [Pursh] A Love), and Idaho fescue (Festuca idahoensis Elmer) were dominant in the majority of the study site. The study was conducted in the Back pasture (336 ha). Slopes ranged from 0 to 107%) with an average slope of 33.8%. Vertical relief was 215 m and the average distance to water was 504 m.

Cattle. For 5 years prior to the study, a herd of 180 Hereford-Tarentaise cross cows were visually observed and their locations recorded 2 to 3 times per week during the early morning in a total of 5 pastures for 12 weeks during each summer (Bailey et al., 2001; Bailey et al., 2006). Cows were ranked based on their use of higher elevations and steep slopes. The 5 cows that used the steepest slopes and highest elevations (hill climbers) and the 5 cows that used the gentlest slopes and areas closest to water (bottom dwellers) were used as donors for superovulation and embryo transfer. A single Simmental sire was used for these AI matings. Recipient cows ($n = 98$) were sired by Angus, Charolais, Piedmontese and Salers bulls and their dams were Hereford and Tarentaise crosses (Van Wagoner et al., 2006). Recipient cows were observed for 4 years by

horseback observers in the same pastures as the donors. Locations of recipient cows were recorded during the early morning when most of the animals were grazing. Recipients were ranked based on use of steep slopes and higher elevations. Half of the recipient cows that used steeper slopes and higher elevations were classified as the hill climbers (HC) and the other half of the recipients that used gentler slopes near water were classified as bottom dwellers (BD).

As a result of these matings, a total of 39 heifer calves were born during 2003 (n = 7), 2004 (n = 18) and 2005 (n = 14). These heifers grazed the study pastures with their recipient dams as calves and grazed study pastures and adjacent pastures as yearlings. During the study in 2009, only 28 of the 39 heifers were available for observation. All cows were mature (4 to 6 years of age) and had calves.

Study Design. The matings described above allowed a 2 x2 factorial design. Genotype (donors) and environment (recipients) were the two factors, and HC or BD were the two levels within each factor.

Observations. Cow locations were recorded by horseback observers during the early morning (0630 to 0930) for 10 days during August and early September 2009. Topographic maps of the Back pasture were subdivided into 200 x 200 m grid cells. Trained observers that were familiar with the pasture recorded the cell in which cows were located. The mean of distance to water, elevation, and slope for each cell was assigned to that cow for each day it was observed. Values for each cow were then averaged and used in the analyses. Cows that were only observed once during the 10 days of observation were removed from the analyses.

Statistical Analysis. Average terrain use (distance to water, elevation and slope) based on locations recorded by horseback observers were evaluated using a model that included donor, recipient and the donor x recipient interaction using PROC MIXED of SAS (SAS, 2005). Age was not included in the model because previous research at the Thackeray Ranch showed that mature cows 4 to 10 years of age had similar grazing patterns (Bailey et al., 2001; Van Wagoner et al., 2006). Preliminary analyses showed that age was not an important factor for explaining variation in terrain use ($P > 0.15$).The Kenwood-Rogers method was used for calculating degrees of freedom (SAS, 2005).

Results and Discussion

Donor Effects. Average distance traveled from water and slope use of daughters of HC and BD donors was similar (Table 1). However, daughters of HC used higher ($P = 0.04$) elevations than BD. The least squares means for elevation from daughters of hill climber donors was 1314.6 ±7.4 m, while mean elevation use for bottom dwellers was 1290.4 ± 7.6. Bailey et al. (2004) reported that hill climbers used higher elevations than bottom dwellers using GPS tracking data. Similarly, Bailey et al. (2006) found that the hill climber cows traveled farther vertically from water than bottom dwellers using location data recorded by horseback observers during the early morning. Differences between daughters of HC and BD donors suggest that elevation use in this pasture may be inherited.

Recipient Effects. Average distance to water and slope use of cows raised by hill climber recipients was similar to bottom dwellers (Table 1). Daughters from HC recipients (1314.7 ± 7.1 m) used higher elevations ($P = 0.04$) than those from BD (1290.3 ± 7.9 m). Results from this study support the Howery et al. (1998) study. These researchers found that daughters used areas similar to both their biologic and foster mother in a study examining both cross-fostered calves and controls that were not cross fostered. Results from Bailey et al. (2010) also show that early experience can play an important role in grazing distribution. Cows that were raised and remained in the Chihuahuan Desert used areas farther from water than naïve cows raised in subtropical conditions in eastern Texas.

Genotypic and Environmental Interactions. Although there was no interaction between donor and recipient for average distance to water or slope use, there was a tendency ($P = 0.08$) for an interaction with elevation use (Table 1). Daughters from BD donors and BD recipients tended to use lower elevations than the other cows.

Terrain Use Considerations. Although water is usually the most crucial component of livestock habitat (Bailey, 2005) distance to water may not have been a critical factor in this study because distance to water in the pasture averaged only 504 m. Holechek (1988) recommended adjusting stocking rates for areas greater than 1.6 km from water. In this study, maximum distance to water in any given part of the pasture was 1275 m.

Slope is another important abiotic factor affecting grazing distribution in rough terrain. Gillen et al. (1984) reported that cattle avoid slopes in excess of 20%. Furthermore, cows grazing steep slopes greatly reduce their estimated grazing capacities by 30% for areas with slopes between 11% and 30% and reducing capacity by 60% for areas with slopes between 31% and 60% (Holechek, 1988). In this study, areas near water often had steep slopes as water sources were typically in valley bottoms. In contrast, slopes at high elevations were not always steep because slopes on ridge tops were only slightly or moderately steep. Previous research in the study pasture (Bailey et al. 2004; Bailey et al. 2006) has shown that cattle varied greatly in their use of higher elevations, but variation in slope use was relatively small.

Implications

Both genetic and environmental factors, such as early learning, appear to affect grazing patterns of beef cattle grazing foothill rangeland. Differences observed between HC and BD donors suggests that use of higher elevations may be inherited, while difference observed between HC and BD recipients demonstrate that environmental factors may also be important. Although more research is needed to confirm the findings observed in this study, results strongly suggest that additional research in the genetic and environmental factors affecting cattle grazing distribution is warranted.

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Table 1. Least squares means of distance to water, elevation and slope of corresponding bottom dweller (BD) and hill climber (HC), donor and recipient cows.

Donor	**Recipient**	**Distance to Water, m**		**Elevation, m**		**Slope. °**	
		Mean	SE	Mean	SE	Mean	SE
BD	BD	671.3	93.1	1268.3	11.7	14.29	2.68
HC	BD	613.1	76.0	1312.5	9.6	13.54	2.19
BD	HC	631.8	83.3	1312.3	10.5	13.05	2.39
HC	HC	674.3	83.3	1316.9	10.5	13.12	2.39

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PROPIONIBACTERIUM ACIDIPROPIONICI P169 AND GLUCOGENIC PRECURSORS TO IMPROVE RUMEN PARAMETERS ASSOCIATED WITH LOW QUALITY FORAGE

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ABSTRACT: Cattle grazing dormant western rangelands tend to have a high ruminal acetate to propionate ratio (A:P) and may have low tissue clearance of acetate. Two studies were conducted to evaluate the effects of *P. acidipropionici*, P169 (P169) on VFA production, forage digestibility, and rumen bacterial ecology. In Exp. 1, in vitro effect of P169 on IVDMD and VFA production was evaluated in a 2 x 2 factorial arrangement of treatments. Factors were substrate (dormant warm-season grass extrusa or 50:50 Sudan:corn, DM basis) and P169 (with or without). In Exp. 2, twelve 2-yr old, pregnant Brangus heifers (BW = 416 ± 85 kg) were assigned to 1 of 3 treatments (n = 4). All cattle were fed a basal ration consisting of Old World Blue stem hay at 1.5% BW 10 d prior to initiation of treatment and for the duration of the experiment. Treatments were 1) protein supplement (36% CP, 35% UIP of CP, DM basis, fed at 454 g/hd per d; CON), 2) CON plus P169 (6×10^{10} cfu/hd, twice per d; P169), 3) calcium-propionate supplement fed at 454 g/hd per d (36% CP, 53 % UIP of CP + 80 g calcium propionate; PROP). Ruminal fluid was collected and analyzed for VFA, ammonia, pH and community DNA was extracted for denaturing gradient gel electrophoresis (DGGE). Glucogenic potential of treatment was evaluated with an acetate tolerance test on d 49. In Exp. 1, IVDMD, total VFA, acetate, propionate, and A:P increased ($P < 0.001$) in both extrusa and 50:50 with P169 addition. In Exp. 2, the only effect of P169 on rumen parameters was a 4.3% increase in propionate ($P < 0.02$) over CON. Calcium-propionate supplement increased propionate and decreased A:P by 7.8% and 5.9% respectively ($P < 0.004$) over CON. Similarity of bacterial populations between treatments was evaluated with construction of a DGGE dendrogram using the Dice coefficient and samples were 73.9 ± 6.38% similar. Acetate half-life did not differ by treatment ($P = 0.49$). These data indicate that addition of propionate-producing bacteria to low quality forage diets could be as beneficial as supplementing with a propionic salt.

Key words: cattle, propionate, *Propionibacterium acidipropionici*

Introduction

Range forage diets generally promote high ruminal production of acetate relative to propionate (Cronjé et al., 1991) when vegetation is dormant. Low quality forage can cause metabolic imbalances because they contain a higher proportion of slowly fermentable carbohydrate and low crude protein (Van Soest, 1994). Propionic acid serves as the primary precursor of glucose in the liver of ruminants, which must be synthesized de novo, because little glucose is absorbed into the hepatic portal vasculature (Peters et al., 1990). Providing glucogenic precursors, such as propionic salts, can influence metabolic limitations changing the balance of intermediates required in oxidative metabolism, influencing overall energy utilization and improving overall energy balance during the dormant season (Mulliniks et al., 2008).

Research efforts to increase the amount of propionate produced in the rumen have focused on feed supplementation and addition of propionic salts (Mulliniks et al., 2008). Specific strains of the genus *Propionibacterium* are known to produces high levels of propionate and are used in several industrial processes because of their ability to convert lactate and carbohydrates to propionic acid (Woskow and Glatz, 2001). Specifically, *Propionibacterium acidipropionici* is naturally found in the rumen of animals fed mixed forage and concentrate diets and strain P169 was isolated from rumen fluid collected from dairy cows (Stein et al. 2006; Davidson, 1998). We hypothesized the adding P169 to diets fed to cattle high in structural carbohydrates may increase hepatic glucose production via increased production of ruminal propionate. Also by increasing the amount of ruminal propionate production, acetate will be used more efficiently utilized. Two experiments were conducted to evaluate the effect of *Propionibacterium acidipropionici* P169 on VFA production, forage digestibility and rumen bacterial ecology *in vitro* and *in vivo*.

Materials and Methods

All animal care and handling procedures were approved by the NMSU IACUC.

Exp. 1

***Growth of Propionibacterium acidipropionici* P169.** *Propionibacterium acidipropionici* P169 (**P169**) was obtained from the culture collection of American Type Culture Collection. Sodium lactate broth (Østlie, 1995) was used as the growth medium for P169 containing 1% tryptone (Difco Laboratory, Detroit, MI), 1% yeast extract (Difco Lab), 1.5% of 50% sodium lactate (Fisher Scientific, Fair Lawn, NJ), 0.25% K_2HPO_4 (Fisher Scientific), 0.02% $MgSO_4$ (Sigma-Aldrich Inc., St. Louis,

MO), and $MnSO_4 \cdot H_20$ (Sigma). Medium was prepared anaerobically and aliquoted (9.70 mL) to 25-mL (18 x 150 mm) balch tubes, capped with butyl rubber stoppers and sterilized by autoclaving. *Propionibacterium acidipropionici* P169 was added aseptically using a needle and syringe through the stopper and cultures were incubated at 37°C. Growth of P169 was verified by culture turbidity (at 600 nm) over a 24 h period. Growth curves and doubling times were calculated using standard microbiology techniques to determine when a cell density of 6×10^{10} colony forming units (cfu) was obtained (approximately 8 h).

In Vitro Substrates. Fermentation substrates were: 100% dormant warm season grass extrusa (4.6% CP, 56.1% NDF, OM basis; **Corona**) and 50% Sudan hay: 50% corn (8% CP, 31.6% NDF, OM basis; **50:50**). Extrusa samples were collected at the Corona Range Livestock Research Center (CRLRC) from two ruminally cannulated cows that had been held off of feed overnight and were allowed ad libitum access to water. Cows were rumen evacuated and allowed to graze for a period of 1 h. Following the 1 h grazing period animals were gathered and extrusa was collected from the rumen. Corona and 50:50 were dried in a forced-air oven (50°C) and then ground in a Wiley Mill to pass a 2mm screen. Resulting substrates were analyzed for DM, ash (Galyean, 1997), NDF (ANKOM Technology Corp.; Fairport, NY), and CP (LECO Corp. St. Joseph, MO). Each substrate was weighed (0.5g) and placed in 50 mL in vitro tubes.

In Vitro Incubations. The effects of adding P169 on rumen microbial fermentation and diet digestibility was evaluated using IVDMD procedures (Tilley and Terry, 1963) and subsequent VFA production was analyzed by gas chromatography (Goestch and Galyean, 1983). Treatments for this study were arranged as a 2 X 2 factorial with two different fermentation substrates and addition or no addition of P169. Rumen fluid was obtained from 2 ruminally cannulated cows, which were allowed ad libitum access to sudan hay (8% CP and 57% NDF, OM basis). Ruminal fluid was obtained from the ventral and anterior sections of the rumen via plastic tubing connected to a metal suction strainer (approximately 7.3 cm length × 0.7 cm width; Precision Machine Co. Inc., Hasting, NE) into a collection thermos previously heated to 37°C and transported immediately to the laboratory. Ruminal fluid was mixed (50:50) with McDougall's buffer (Tilley and Terry, 1963) and bubbled with CO_2. In vitro tubes with substrate were filled with 20 mL of the ruminal fluid McDougall buffer mixture, gassed with CO_2 and capped. Cultures of P169 ($6x10^{10}$ cfu; 500 µL of pure P169 incubated for 8 h at 37°C) were added using a needle and syringe. In vitro tubes incubated in an anaerobic chamber (10% H, 90% $C0_2$ atmosphere) and were manually agitated 10 times at the beginning of experiment and then every 12 h for the remainder of the experiment. Tubes were incubated at 37° C for 48 h. After 48 h of incubation, the tubes were removed and immediately centrifuged using (Sorvall, Du Pont Instruments) at 5,500 x g for 15 minutes at 4° C. Samples of the supernatant collected, stored at -20°C and later utilized for VFA analyses.

Statistical Analysis. In vitro data were analyzed as a completely random design using MIXED procedures of SAS (Version 9.2, SAS Inst., Inc., Cary, NC). The influence of P169 was analyzed by substrate with the model including fixed effects of P169 on VFA and IVDMD. Significance was determined at $P \leq 0.05$. Means were calculated using LSMEANS and means were separated using PDIFF.

Exp 2.

Animals and Experimental Design. Twelve 2-yr old pregnant Brangus heifers (416 ± 85 kg BW) from the Chihuahuan Desert Rangeland Research Center were used in a completely randomized design with three treatments (n=4). Cattle were individually penned and were hand fed daily with offered feed being divided into two equal parts. Cattle received a basal ration of chopped Old World Blue Stem hay (5.8% CP, 76.5% NDF; DM basis) at 1.5% body weight for 10 d prior to the initation of treatments and for the duration of the experiment (45 d).

Diets. Treatments consisted of 1) 36 % protein supplement (**CON**), 2) CON plus $6x10^{10}$ cfu/cow of *Propionibacterium acidipropionici* strain P169 (**P169**), 3) calcium propionate protein supplement (**PROP**). The CON supplement was a 36% CP range cube (35% UIP; 57% CSM, 21% wheat midds, 10% soybean meal, 9% molasses, 1.2% urea and fortified with trace vitamins and minerals DM basis; with 44 g of glucogenic precursor). The CON supplement was fed at a rate of 454 g/hd per d divided into two equal parts delivered twice daily. The P169 group received CON plus P169 manufactured by Danisco Animal Nut. (Waukesha, WI) as a viable freeze-dried cell. The P169 (60g) was dissolved in 1000 mL of dH_2O and 250 mL of solution was sprinkled over the basal diet twice daily. The PROP supplement was a 36% range cube (53% UIP; 61% CSM, 11% DDG, 9% fish meal, 3% molasses and fortified with trace vitamins and minerals; plus 80 g calcium propionate salt (NutroCal™, Kemin Industries, Inc.) providing 124 g of glucogenic potential. The PROP supplement was fed at a rate of 454 g/hd per d divided into two equal parts delivered twice daily.

Sampling and Measures. Ruminal fluid was collected every third day upon initiation of treatments. Fluid was collected via oral lavage with metal suction strainer 4 h post morning feeding (Lodge-Ivey et al., 2009). Ruminal pH was measured upon collection. Samples were kept on ice and transported to the laboratory for storage at -20°C until analyzed for VFA and ammonia as well as extraction of community DNA. Ruminal fluid was centrifuged and prepared for VFA analysis using high performance liquid chromatography (**HPLC**). Total community DNA was extracted from ruminal fluid using the repeated bead beating and column method described by Yu and Morrison (2004). Body weights were collected on a weekly basis. Ammonia nitrogen in rumen fluid was

analyzed using the procedures of Broderick and Kang (1980) adapted to a microtiter plate (BioTek Instruments, Winooski, VT).

Titanium dioxide (TiO_2; Sigma-Aldrich, Inc., St. Louis, MO) was utilized as an external marker to determine diet OM digestibility (Myers et al., 2004). Titanium dioxide was weighed out (5 g) into Lock Ring Capsules (# 11, Torpac Inc., Fairfield, NJ). Capsules were administered via metal balling gun (Torpac Inc., Fairfield, NJ) twice daily (600 h and 1700 h) for 10 d. Fecal grab samples were collected on 10 different occasions over 5 d to represent a 24 h time period starting on d 39. Fecal samples were pooled and analyzed using procedures of Myers et al., 2004 adapted to a microtiter plate (BioTek Insterments, Winooski, VT) where absorbances were measured at 410 nm.

Acetate tolerance test (**ATT**) was conducted on d 49 to evaluate acetate half-life. The methods described by Mulliniks et al., (2008) were utilized to conduct the ATT. A 20% acetic acid solution (pH approximately 7.40) was filter sterilized using Steritop Filter Unit (Millipore, Billerica, MA). Prior to infusion of acetic acid heifers were fitted with an indwelling jugular catheter. The acetic acid solution was infused over a 20 min period at a rate of 1.25 mL/kg of BW into each animal. Blood samples were collected at -1, 0, 1, 3, 5, 7, 10, 15, 30, 60, and 90 min following the administration of 20% acetic acid. Blood was collected into serum separator tubes (Corvac, Mansfield, MA) and was allowed to clot at room temperature for 45 min. Blood serum was collected via centrifugation (Sorvall, Du Pont Instruments) at 2000 x g for 25 min at 4°C. Serum (2mL) was then filtered through a centrifugal filter (Millipore Amicon Ultra, Ultracel-10K, Billeria,MA) at 7,000 x g for 80min at 4°C. Filtered serum was analyzed for serum acetate concentrations using HPLC. Acetate half-life was calculated as the time requires for a 50% decrease in peak serum acetate concentration.

Statistical Analysis. Data were analyzed as a completely randomized design using the MIXED procedures of SAS. The influence of supplement was analyzed by animal with the model including fixed effects of animal, day and treatment and their interactions. Means were calculated using LSMEANS and PDIFF was used to separate means. Mean comparisons with *P*-values less than or equal to 0.05 were declared significant, and values less than or equal to 0.10 were considered tendencies.

Results and Discussion

Influence of P169 on IVDMD and VFA concentration in vitro. Data for IVDMD and VFA are in Table 1. Addition of P169 to Corona increased ($P < 0.001$) IVDMD by 36% and total VFA concentration by 22% Addition of P169 to Corona ($P < 0.001$) decreased acetate by 3% and increased propionate by 7% resulting in a lower acetate to propionate ratio for P169 (3.56 vs 3.10; no P169 vs P169, respectively). The use of P169 had no effect ($P \geq 0.86$) on IVDMD and total VFA when added to 50:50. However individual VFAs showed a trend similar to Corona with P169 addition increasing propionate and acetate and acetate to propionate ratio decreased ($P < 0.004$). Akay and Dado (1999) reported that total IVDMD were decreased while total VFA, acetate and propionate concentrations were increased by (9.0%, 6.3%, 16.6% and 13.9% respectfully) with the use of Propionibacterium. However, in the present study use of Propionibacterium improved both IVDMD and VFA concentrations with poor quality diets, suggesting that this particular strain of Propionibacterium has the capability of enhancing VFA production while improving fiber digestion of low quality forages.

Effect of P169 on forage digestibility, VFA production and acetate clearance in vivo. Data for Experiment 2 are in Table 2. Volatile fatty acids that originate from carbohydrate fermentation by rumen microflora are absorbed through the rumen wall and serve as the primary source of metabolizable energy for ruminate animals (Erwin et al., 1961). Propionate being most important glucogenic precursor was increased ($P = 0.001$) in both P169 and PROP vs. CON, resulting in a reduction in acetate to propionate ratio ($P > 0.001$). Leehloenya et al., (2008) found similar results which were attributed to greater proportions of propionate therefore altering the acetate production. Providing the animal with more propionate and lower acetate to propionate ratio allows for more hepatic glucose production. Stein et al., (2006) reported an 18% increase propionate and an 14% decrease acetate to propionate ratio when P169 was added to a dairy diet when compared to no P169. However, total VFA and acetate concentrations remained unchanged ($P > 0.68$) among treatments. These data indicate that adding P169 to a variety of ruminant production diets increases propionate and is a useful tool to increase the glucogenic potential of a diet. Also interesting to note was during the 10 week study, change in BW did not differ ($P = 0.69$) between treatments. However, numerically heifers receiving P169 gained 46% more weight than heifers receiving CON or PROP similar to that found by Francisco et al., (2002).

Titanium dioxide has been reported to be a viable marker for total-tract digestibility in studies with beef steers (Titgemeyer et al., 2001) and beef cows (Myers et al., 2004). Total tract digestibility of OM and NDF did not differ ($P > 0.42$) between treatments and averaged 66% for OM and 78% for NDF. Our values were higher than Köster et al., (1996) that investigated the addition of DIP to Prairie hay that had 76.6% NDF and 1.94% CP. When 720 g/d DIP was added total tract OM digestibility was 53.8% and NDF digestibility was 55.6%.

Supplementation tended to affect ($P = 0.13$) ruminal pH (7.23, 7.44, 7.27 for CON, P169, and PROP, respectively) with P169 resulting in the highest observed pH value. All pH measurements were found to be within an acceptable range for adequate fiber digestion (Russell et al., 1996). Ruminal ammonia concentrations tended ($P = 0.09$) to be influenced by treatment (1.91, 1.70, 1.42 m*M* for CON, P169, and PROP, respectively). Treatment P169 and CON had greater ammonia concentrations than PROP. The PROP supplement contained 36% CP which was the same

as the CON supplement however a larger proportion of the CP was in the form of UIP. The higher UIP content is most likely the cause for the lower ruminal ammonia concentrations. Overall our diets did not supply the 3 mM ammonia proposed by Satter and Slyter (1974) for maximal microbial growth however our OM and NDF digestibility were greater than Köster et al., (1996) who reported ammonia value of 6.87 m*M* when 720 g/d DIP was added to a Prairie hay diet. Our treatments resulted in 295 g/d DIP for CON and P196 and 213 g/d DIP for PROP. The DIP of the forage was estimated to be 50% of the CP and supplied 413 g/d.

Acetate clearance can be used as an indicator of glucogenic potential of the diet Mulliniks et al., (2008). If glucose output from the hepatic system is improved, potentially accumulated acetate generated by low quality forages (Cronjé et al., 1991) maybe cleared at an accelerated rate. In the present study acetate half-life were not affected ($P = 0.48$) by treatment. Mulliniks et al., (2008) reported a linear decrease in acetate half-life with increasing amounts of glucogenic precursors, whereas in this study the level of clearance was not significant. This could be attributed to the brevity of the experiment and the reduced maintenance requirements of the heifers due to being fed in a pen.

The supplementation of glucogenic precursors in the form of calcium propionic salts and *Propionibacterium acidipropionici* P169 increased propionate concentrations and decreased acetate to propionate ratios within the rumen. These data indicate that addition of propionate-producing bacteria to low quality forage diets could be as beneficial as supplementing with a calcium propionic salt.

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Table 1. Effects of *Propionibacterium acidipropionici* P169 on in vitro fermentation of low quality extrusa samples and Sudan: corn mixture.

	Treatments							
	Extrusa[1]				50% Sudan: 50 % Corn[2]			
Item	No P169	P169	SE	*P*	No P169	P169	SE[3]	P-value[4]
IVDMD	20.45	32.03	0.85	<0.001	46.92	46.77	0.61	0.86
VFA, mM								
Total	92.81	119.06	2.91	<0.001	144.74	150.07	3.44	0.28
Acetate mol/ 100mol	70.33	68.47	0.28	<0.001	59.47	56.71	0.52	0.0004
Propionate mol/ 100mol	20.39	22.01	0.27	<0.001	23.01	27.98	0.63	0.0001
Acetate:Propionate	3.56	3.10	0.09	<0.001	2.60	2.10	0.06	0.0001

[1]Dormant warm season grass collected from cannulated cows; No P169 = extrusa; P169 = extrusa plus *Propionibacterium acidipropionici* P169 (6×10^{10} cfu).
[2]50% Sudan hay: 50% corn; No P169 = 50% Sudan hay: 50% corn; P169 = 50% Sudan hay: 50% corn plus *Propionibacterium acidipropionici* P169 (6×10^{10} cfu).
[3]SE = standard error (n = 6)
[4]Protected F-statistic for the effect of treatment.

Table 2. Effects of glucogenic precursors on VFA production, change in BW, pH, ammonia concentrations, total tract digestibility and acetate half-life in heifers consuming poor quality forage.

	Treatment[1]				
Item	CON	P169	PROP	SE[2]	P-value[3]
Total VFA, mM	62.17	54.87	58.13	2.58	0.19
Acetate mol/100mol	73.02	72.74	73.09	0.29	0.68
Propionate mol/100mol	16.15	16.88	15.52	0.18	0.001
Acetate: Propionate	4.56	4.35	4.19	0.04	<0.004
Change in BW, kg	37.06	40.11	28.51	9.64	0.69
pH	7.23	7.44	7.27	0.07	0.13
Ammonia, mM	1.91	1.70	1.42	0.14	0.09
Total-tract OM digestibility, %	65.70	68.61	64.40	2.18	0.42
NDF digestibility, %	77.84	79.45	76.49	1.67	0.49
Acetate half-life, min	37.24	46.56	39.55	4.89	0.48

[1] All treatments were fed at 454 g/hd each day. CON = 36 % protein supplement (35% UIP; 57% CSM, 21% wheat midds, 10% soybean meal, 9% molasses, 1.2% urea and fortified with trace vitamins and minerals DM basis; with 44 g of glucogenic precursor); P169 = CON plus *Propionibacterium acidipropionici* P169 (6×10^{10} cfu/hd, twice per d); PROP = 36% range cube (53% UIP; 61% CSM, 11% DDG, 9% fish meal, 3% molasses and fortified with trace vitamins and minerals; plus 80 g calcium propionate salt (NutroCal™, Kemin Industries, Inc.) providing 124 g of glucogenic potential.
[2]SE = standard error (n = 4)
[3]Protected F-statistic for the effect of treatment.

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THERMOGENESIS, SERUM METABOLITES, AND GROWTH IN LAMBS BORN TO EWES SUPPLEMENTED WITH DOCOSAHEXAENOIC ACID[1]

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ABSTRACT: Eighty twin-bearing Targhee ewes (ages 2 to 5 yr; 68.5 ± 3 kg) were stratified by age and assigned randomly to 1 of 2 supplemental treatments to determine the effects of feeding algae containing docosahexaenoic acid (DHA) to ewes during late gestation and early lactation on lamb thermogenesis, serum metabolites, and growth. Treatments within supplements were: 1) 12 g/ewe daily of the product DHA Gold (Advanced Bionutrition Corporation, Columbia, MD), in the form of algal biomass (ALGAE), and 2) no DHA (CONTROL). Supplements were formulated to be isocaloric and isonitrogenous, and when fed at the rate of 0.9 kg daily with a 10% CP and 58.1% TDN hay met the CP and TDN requirements of a 70-kg twin-bearing ewe during late gestation. Treatments were individually fed (40 ewes/treatment) daily during the last 30 ± 7 d of gestation and pen fed (6 pens/treatment, and 6 or 7 ewes/pen) during the first 38 ± 7 d of lactation. One h after lambing and before nursing, twin-born lambs were weighed, bled via jugular puncture, and placed in a dry cold chamber for 30 min (0°C). Lamb rectal temperatures were recorded every 1 min. After 30 min, lambs were removed from the cold chamber, bled again via jugular puncture, warmed for 15 min and returned to their dam. Lamb sera were assayed for glucose, cortisol and NEFA. Although lambs born to ALGAE supplemented ewes had a consistently higher rectal temperature over the 30 min cold exposure, lamb rectal temperature did not differ between ALGAE and CONTROL lambs. When evaluated within time, lambs born to ALGAE ewes had higher rectal temperatures at 0 min (P = 0.07) and at 1 min (P = 0.08); However, rectal temperatures did not differ at any other time during cold exposure. Glucose, cortisol, NEFA, and birth weights did not differ between treatments. Thirty-eight-day BW was greater (P = 0.03) in lambs born to CONTROL ewes than in lambs born to ALGAE ewes. Supplementation of DHA during late gestation and early lactation did not appear to benefit lamb production.

Key words: docosahexaenoic acid, lamb growth, thermogenesis

INTRODUCTION

Nearly 50% of pre-weaning lamb mortalities occur during the first 24 h of life (Dwyer, 2007), with lamb mortality rates of 10 to 35% occurring between birth and weaning in typical western range sheep operations (Rowland et al., 1992). Hypothermia and starvation were major causes of lamb mortality in a study by Rook et al. (1997). In lambs, the active processes involved in generating heat include shivering and non-shivering thermogenesis (Alexander, 1979). Shivering is replaced by non-shivering thermogenesis with energy derived from brown adipose tissue (**BAT**; Symonds and Lomax, 1992). In cold environments and before nursing, newborn lambs rely on BAT to produce heat in order to prevent hypothermia (Alexander and Williams, 1968).

Altering maternal nutrition during late gestation may be a management practice to enhance lamb thermogenic potential (Encinias et al., 2004). A majority of the growth of BAT in bovine fetuses occurred during the last 28 d of gestation (Casteilla et al., 1987). Linoleic acid, a poly-unsaturated fatty acid (**PUFA**) is the major energy source used for fueling heat production in BAT of lambs. Docosahexaenoic acid (**DHA**) is also a PUFA, but its effects on BAT have not been studied. Pickard et al. (2008) reported that lamb vigor was improved when ewes were fed 12 g/ewe DHA daily for 6 or 9 wk during late gestation, compared to lambs born to ewes fed no DHA. However, Pickard et al. (2008) did not measure any indices of lamb thermogenesis. The objective of the present study was to determine the effects of feeding DHA to ewes during late gestation and early lactation on lamb thermogenesis, serum metabolites, and growth. The null hypothesis was that supplementing ewes during late gestation and early lactation with or without algae-derived DHA in the diet will not alter lamb birth weight, growth from birth to 38 d, serum metabolites, or body temperature when exposed to 0°C for 30 min.

MATERIALS AND METHODS

General

All animal procedures were approved by the Montana State University Institutional Animal Care and Use Committee. Eighty twin-bearing Targhee ewes (ages 2 to 5; 68.5 ± 3 kg) were stratified by age and assigned randomly to 1 of 2 supplement treatments. Twin-bearing ewes, determined by ultrasonography (Acuson, Siemens Medical Solutions USA, Inc., Malvern, PA) were randomly selected from a band of approximately 2,000 ewes from the Bair Ranch near Martinsdale, MT. Ewes were transported from the Bair Ranch to Montana State University's Fort Ellis facilities near Bozeman on February 2, 2009 where they were confined in a dry lot with access to shelter. Ewes had ad libitum access to water and grass hay (Table 1), trace mineral (Westfeeds, Inc., Billings, MT) and salt (mixed with the trace mineral) during late

[1] We would like to thank the Bair Ranch Foundation for funding this research project.

gestation. Beginning on February 7, ewes were fed an 80% alfalfa/20% barley pellet and whole barley (~ 454 g of each/ewe daily) to supplement the grass hay and adapt the ewes to the area in which they were to be individually fed the experimental diets.

Diets

Treatment diets were: 1) 12 g/ewe daily DHA Gold (Advanced Bionutrition Corporation, Columbia, MD) containing 2.2 g of DHA, in the form of algal biomass (ALGAE; n = 40**)**, and 2) no DHA **(**CONTROL; n = 40**)**. Supplements (Westfeeds, Billings, MT) were formulated to be isocaloric and isonitrogenous, and when fed at the rate of 0.9 kg daily with a 10% CP and 58.1% TDN hay met the CP and TDN requirements of a 70 kg twin-bearing ewe during late gestation. The amount of DHA (2.2 g/daily) fed contained 10 times more than the recommended level of DHA for pregnant women, which is 0.22 g daily (Simopoulos et al., 1999). Diets were individually fed daily during the last 30 ± 7 d of gestation, beginning March 6. Ewes were placed in individual pens (0.75 m^2**)** once daily and fed the appropriate supplement. Ewes remained in individual pens until all supplement had been consumed. During late gestation, ewe was the experimental unit. After lambing, pen (65 m^2, 6 pens/treatment, and 6 or 7 ewes/pen) was the experimental unit.

Thermogenesis

At 1 h after birth and before nursing, lambs were bled via jugular puncture (10 mL) using non-hepranized Vacutainers® (Becton, Dickinson and Company, Franklin Lakes, NJ), and lamb thermogenesis was measured in the manner described by Dafoe et al. (2008). Lambs were fitted with a rectal temperature sensor connected to a data-logger (Omega Engineering, Inc., HH506RA, Stamford, CT). After an initial temperature reading, both twin lambs were placed in crates (183 cm^2) in a dry-cold environmental chamber for 30 min (0°C). Rectal temperature of each lamb was recorded automatically every 1 min. Lambs were removed from the cold chamber, bled again via jugular puncture (10 mL), warmed for 15 min, and returned to their dam.

Blood Processing and Assays

Blood samples were centrifuged for 30 min at 1,000 x *g*. Sera was decanted into plastic tubes and stored at -20°C. Lamb sera were assayed for glucose, cortisol, and NEFA. Glucose assays were performed in duplicate using a spectrophotometric method using glucose hexokinase reagent (Infinity, Glucose kit; Sigma Diagnostics, St. Louis, MO). This assay was validated for sheep serum and intra- and inter-assay CVs for pooled serum that contained 26.8 and 101.4 mg/dL glucose were < 10%, respectively.

Cortisol concentrations were assayed using solid-phase RIA kits (Siemens Medical Diagnostic, Los Angeles, CA) described by Berardinelli et al. (1992). Intra- and inter-assay CVs for pooled serum at 12.95 ng/ml were 8.49 and 11.7%, respectively. Intra- and inter-assay CVs for pooled serum that contained 45.5 ng/mL were 5.7 and 10.4%, respectively. Glucose and Cortisol were assayed at the Montana State University Reproductive Physiology lab.

Non-esterified fatty acids were assayed by the Diagnostic Center for Population and Animal Health at Michigan State University (Lansing, MI) on an Olympus chemical analyzer (Olympus America, Inc., Melville, NY) using NEFA-C kits (Wako Chemicals USA, Inc., Richmond, VA) described by Carr et al. (1995). Intra- and inter- assay CVs for pooled serum at 0.08 and 0.80 mEq/L NEFA< 10%, respectively.

Growth and Survival

At birth, lambs were weighed with a spring balance hand scale and sling. Lambs were weighed again (un-shrunk, live weight) on the last day of diet supplementation (38 ± 7 d postpartum) with a digital livestock scale, and growth was determined by kg gained from birth to 38 d.

Statistical Analyses

Data were analyzed by ANOVA as a completely randomized design using the Proc GLM and Proc Mixed procedures of SAS (SAS Inst., Inc., Cary, NC). Temperature data were analyzed using the Proc Mixed repeated measures procedure of SAS. Metabolite data included concentrations for 0 min, 30 min, and numeric change from 0 to 30 min. The models included treatment diet, lambing date, lamb gender, and birth weight. Ewe was the experimental unit for blood metabolite concentrations and birth weights. Lamb birth weights, temperatures, and metabolite data were averaged to calculate lamb values per ewe. Pen was the experimental unit for lamb growth data using the same model. Means were separated using the LSD procedure. Values < 0.10 were considered significant.

RESULTS AND DISCUSSION

Although lambs born to ALGAE supplemented ewes had a consistently higher rectal temperature over the 30 min cold exposure period, lamb rectal temperature did not differ between ALGAE and CONTROL lambs (Figure 1). When evaluated within time, lambs born to ALGAE ewes had higher rectal temperatures at 0 min (P = 0.07) and at 1 min (P = 0.08); However, rectal temperatures did not differ at any other time during cold exposure. Glucose, cortisol, and NEFA concentrations of lambs did not differ between treatments before (0 min), after (30 min), or when comparing the change in metabolite concentrations over

the 30 min-cold exposure period (Table 2). Body weight of lambs 38 ± 7 d after birth was greater (P = 0.03) in lambs born to CONTROL-supplemented ewes than in lambs born to ALGAE-supplemented ewes (Table 3).

Polyunsaturated fatty acids (PUFA), such as linoleic acid, have been shown to be major contributors to the energy fueling heat production in the BAT of the lamb (Lammoglia et al., 1999). Pups born to rats consuming high-fat diets rich in linoleic acid during pregnancy had increased BAT activity, as indicated by the amount of adenyl cyclase activity (Cresteil et al., 1977). Docosahexaenoic acid is a PUFA found in algae and fish oils. Pickard et al. (2008) studied the effects of DHA supplementation to ewes during the last 63 d of gestation on lamb vigor. In this study control ewes received no DHA, while treated ewes received 12 g DHA/ewe daily. They found that concentrations of eicosapentaenoic acid and DHA (both omega-3 fatty acids) in ewes throughout gestation and at lambing were elevated in proportion to the length of time that the DHA diet had been fed. In the present study, NEFA was measured but concentrations in ewes did not differ between treatments.

Birth weight of lambs did not differ between treatments in the study by Pickard et al. (2008) which agrees with the results of the present study. However, lamb BW at 5 wk of age did not differ between treatments in the study of Pickard et al. (2008) which was in contrast with the results of the present study, in which CONTROL lambs were heavier than lambs of ALGAE-supplemented ewes at 38 ± 7 d. The effects of PUFAs on lamb BW were studied by Dafoe et al. (2009). Late gestating ewes were assigned one of four supplemental diets that included: whole safflower seed (high in linoleic acid) with and without supplemental vitamin E or an isocaloric barley-based supplement with our without supplemental vitamin E. At 32 d of age, lamb born to ewes fed the barley-based supplement had higher BW than lambs born to ewes fed the linoleic acid-rich safflower seed supplement. These results agree with those of the present study; however, in both studies, supplemental PUFA did not affect lamb birth weight.

Lamb thermogenesis was also evaluated by Dafoe et al. (2009). Lambs born to ewes supplemented with safflower but no supplemental vitamin E had lower rectal temperatures than all other treatment groups. In the present study, rectal temperature did not differ between treatments but was consistently greater in ALGAE than CONTROL lambs. One possible explanation for the difference between these two studies is the level of PUFA in the treatment diets. In the present study the treatment diet was 2% ether extract. In the study by Dafoe et al., (2009) ether extract was 49% in the treatment diet.

Glucose, cortisol and NEFA concentrations at time 0 and 30 min, and numeric change from 0 to 30 min were not affected by supplementation with DHA. It may be that DHA supplementation does not influence energy homeostasis in lambs.

In conclusion, the results of this experiment indicate that supplementing ewes during late gestation and early lactation with algae-derived DHA in the diet does not affect birth weight, serum metabolites, or body temperature of lambs, and may reduce BW early in lactation.

IMPLICATIONS

Supplemental DHA to ewes during late gestation and early lactation did not improve indices of lamb thermogenesis and may result in decreased lamb weight gain.

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Table 1. Chemical analysis (DM basis) of trace mineral, treatment supplements (Algae and Control), grass hay, and alfalfa/barley pellets[3], fed to ewes during late gestation and early lactation

Item	Trace Mineral[1]	Algae[2,4] Supplement	Control[2,5] Supplement	Grass Hay[3]	Alfalfa/Barley Pellet[6]
CP, %		27.2	27.2	10.0	16.8
TDN, %		70.0	70.0	58.1	68.3
Ether Extract, %		2.0	2.0	1.0	1.3
ADF, %		8.2	8.3	40.5	37.6
NDF, %		21.7	21.8	58.8	48.2
Calcium, %	12.0	1.1	1.1		
Phosphorus, %	8.0	0.8	0.8		
Salt, %	10.0	1.6	1.6		
Potassium, %	1.0	1.4	1.4		
Magnesium, %	2.0	0.3	0.3		
Sulfur, %	1.0	0.3	0.3		
Zinc, ppm	3800	176.0	176.4		
Manganese, ppm	3200	155.62	156.0		
Selenium, ppm	36	0.60	0.6		
Vitamin A, IU/kg	200,000	22,000	22,000		
Vitamin D, IU/kg	20,000	2,200	2,200		
Vitamin E, IU/kg	500	330	330		
DHA, g		2.2			
Decoquinate, g/kg	1.2				

[1] Chemical analysis provided by Westfeeds, Inc., Billings, MT.
[2] Chemical analysis provided by CHS Nutrition, Great Falls, MT.
[3] Chemical analysis conducted at the Oscar Thomas Nutrition Center, Montana State University, Bozeman, MT.
[4] Algae = 0.9 kg/(ewe·d) supplement containing 12 g of the product DHA Gold (Advanced Bionutrition Corporation, Columbia, MD). Each 12 g of DHA Gold contains 2.2 g of actual DHA.
[5] Control = 0.9 kg/(ewe·d) isocaloric and isonitrogenous control supplement containing no DHA .
[6] 80% alfalfa, 20% barley pellet.

Table 2. Least squares means for initial (0 min) and final (30 min) serum metabolites for cold-stressed lambs[1] (0ºC) born to ewes individually fed 0.9 kg of Algae or Control supplement daily during the last 30 d gestation

	Treatment[1]			
Variable	Algae	Control	SEM[2]	*P*-Value
Glucose, mg/dl				
0 min	90.30	87.69	5.45	0.74
30 min	73.44	79.61	5.25	0.41
Change	-16.86	-8.08	5.12	0.23
Cortisol, ng/ml				
0 min	126.90	131.48	11.11	0.77
30 min	80.79	83.01	7.97	0.84
Change	-46.11	-48.47	7.80	0.83
NEFA, mEq/L				
0 min	0.86	0.87	0.10	0.95
30 min	1.27	1.12	0.08	0.19
Change	0.41	0.27	0.10	0.33

[1] Treatments within isocaloric and isonitrogenous supplements were: 1) 12 g/ewe daily DHA Gold (Advanced Bionutrition Corporation, Columbia, MD) containing 2.2 g of DHA, in the form of algal biomass (ALGAE**)**, and 2) no DHA **(**CONTROL).
[2] n = 22 observations/treatment (blood metabolites); ewe was the experimental unit (values from twin lambs were averaged per ewe).

Table 3. Least squares means of lamb birth weight and lamb BW (38 ± 7 d of age) from ewes individually supplemented during the last 30 d gestation and group-supplemented during the first 38 d lactation with 0.9 kg of Algae or Control diets

	Treatment[1]			
Variable	Algae	Control	SEM	*P*-value
Lamb birth BW, kg[2]	5.4	5.2	0.11	0.26
Lamb 38 d BW, kg[3]	30.4	32.3	0.53	0.03

[1] Treatments within isocaloric and isonitrogenous supplements were: 1) 12 g/ewe daily DHA Gold (Advanced Bionutrition Corporation, Columbia, MD) containing 2.2 g of DHA, in the form of algal biomass (ALGAE), and 2) no DHA **(**CONTROL).
[2] n = 40 observations/treatment; ewe was the experimental unit (values from twin lambs were averaged per ewe).
[3] n = 6 observations/treatment; experimental unit for all items was pen (5 to 7 ewes/pen; 6 pens/treatment); values for lambs were averaged within pen.

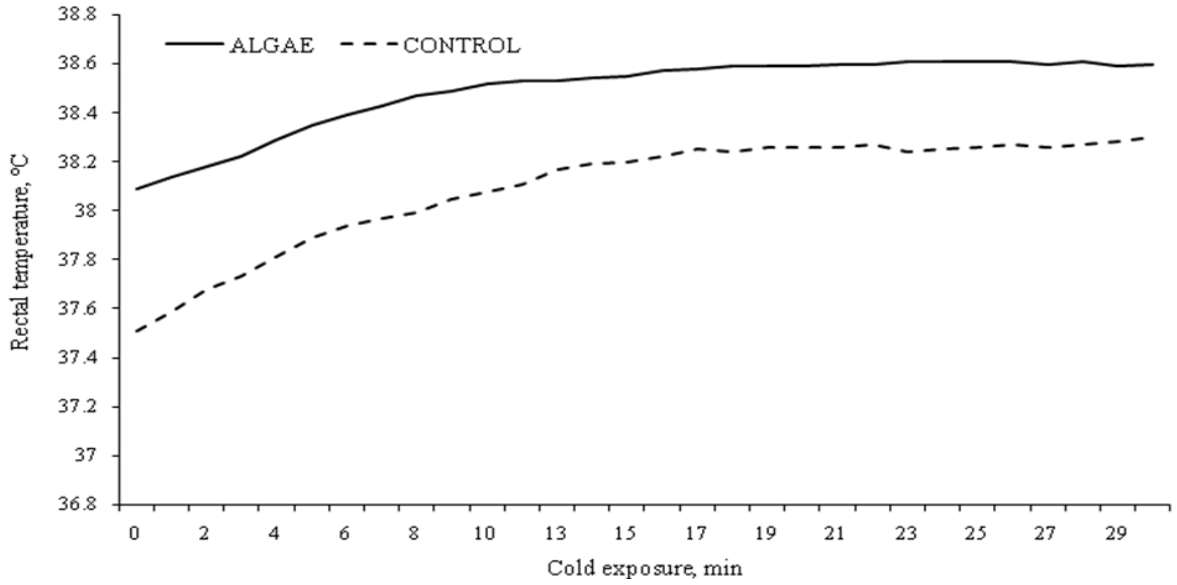

Figure 1: Least squares means of rectal temperature for 44 twin lamb pairs exposed to 0°C for 30 min 1 h after birth. Treatments within isocaloric and isonitrogenous supplements were: 1) 12 g/ewe daily DHA Gold (Advanced Bionutrition Corporation, Columbia, MD) containing 2.2 g of DHA, in the form of algal biomass (ALGAE**)**, and 2) no DHA (CONTROL). The SEM for differences = 0.22°C. Rectal temperatures of lambs from ewes supplemented with ALGAE were greater at time 0 ($P = 0.07$) and time 1 ($P = 0.08$), but did not differ at any other time ($P \geq 0.11$). Proc Mixed repeated measures evaluated the effects of time, treatment (trt), trt x time interaction. None of these factors differed ($P \geq 0.11$), with the exception of time ($P < 0.0001$).

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SUSTAINABILITY IMPLICATIONS OF FEEDLOT MANAGEMENT PRACTICES

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ABSTRACT: There is an increased consumer demand for animal products that have been raised sustainably. This term has many definitions, but generally refers to some balance of environmental, social, and economic goals. The use of biotechnologies that increase units of output (e.g. pounds of meat) with the same or fewer inputs should be included in sustainability assessments. The objective of this project was to quantify the inputs (days on feed, kg feed fed and refused, ADG, health treatments) and outputs (carcass measurements, greenhouse gas emissions) associated with two feedlot cattle management regimes: Never Ever 3 (NE3) and conventional cattle (CON). The former treatment group received no feed additives or implants, whereas the latter were implanted with Synovex® Choice (Fort Dodge) on day 1 and day 70, and were additionally fed Elanco′s Rumensin® (330 mg/animal/day), Tylan® (90 mg/animal/day), and for the 29 days prior to shipping Optaflexx™ β-agonist (254 mg/animal/day). Angus-cross steers were stratified by BW (n=104; 337 kg ± 17) and randomly assigned to four pens per treatment group. Amount of feed fed per pen and refusals were recorded daily. Animals were shipped on a constant average pen weight basis (Target 590 kg; actual 596 kg ± 32 BW). The CON cattle had higher ADG (1.81 vs. 1.35 kg, $P < 0.01$), and were on feed fewer days (146 vs. 188 d, $P < 0.01$) than NE3. No significant differences were observed in HCW or dressing percentage between groups ($P > 0.05$), however CON carcasses had larger ribeyes (87 vs. 80 cm^2, $P < 0.01$), lower USDA marbling score (5.4 vs. 6.2, $P < 0.01$), backfat thickness (1.64 vs. 1.84 cm, $P < 0.05$) and yield grade (3.38 vs. 3.95, $P < 0.01$) as compared to NE3. Overall, CON cattle consumed 393 kg less feed in the feedlot (1250 vs. 1643 kg; $P < 0.05$). Although additives resulted in an additional CON feed cost, the cost of feed per kg of gain was significantly lower ($1.12/kg vs. $1.35/kg; $P < 0.05$) relative to NE3. The use of implants and feed additives reduced the feed inputs and production resources required to produce a fixed amount of output, with resultant environmental and economic sustainability advantages.

Key Words: feedlot, sustainability, biotechnology

Introduction

A succinct definition of sustainability as it relates to agricultural systems remains somewhat elusive. Some key concepts include the need to develop technologies and practices that do not have adverse effects on environmental goods and services, are accessible to and effective for farmers, and lead to improvements in food productivity (Pretty, 2008). The term sustainability has become a desirable selling point, and the marketplace has responded by developing a range of value-added "sustainable" products. One area that has received considerable attention is feedlot management practices, and there now exists a market for "natural" beef products. Although no formal standards exist for "natural" beef, the USDA Agricultural Marketing Service (**AMS**) has developed a set of requirements for a marketing claim for a product called "Never Ever 3" (**NE3**). This is defined as cattle that from birth to death do not receive antibiotics, growth promotants, or animal byproducts (AMS, 2009). This management regime is quite distinct from the feedlot management practices that are employed by the majority of the U.S. feedlots where cattle are typically implanted with anabolic steroids, fed ionophores (e.g. Rumensin®) and antimicrobial drugs (e.g. Tylan®), and may also receive β-agonists in the final finishing phase. These biotechnologies which are specifically excluded by NE3 are used because they have been shown to improve production efficiency. Data is needed to quantify the effects of altering production practices to achieve sustainability goals. The Intergovernmental Panel on Climate Change (**IPCC**, 2006, Tier 2) estimates that cattle lose 6.5% of GE intake as methane, except for feedlot cattle for which 3% of GE intake is lost as methane. Improving production efficiency would be predicted to decrease methane loss per unit of beef production. The objective of this study was to compare animal feedlot performance, carcass attributes, costs of production, and greenhouse gas emissions implications associated with two feedlot management regimes, one being NE3 and the other being a 'biotechnology' input regime. While it is understood that there are sustainability implications associated with the production of the feeder steers that were used in this trial prior to their arrival at the feedlot (i.e. at the cow-calf operation), the role of feedlot management practices was the sole focus of this study.

Materials &Methods

This experiment was conducted at the University of California, Davis Feedlot facility. Animal care, handling, and protocols were followed according to the approved by the UC Davis Institutional Animal Care and Use Committee.

Animals and Treatments. One hundred and four Angus crossbred steers from the same calf crop and source were stratified by weight and randomly assigned to one of the two treatment groups in a matched pair design. The two

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treatment groups were Never Ever 3 and conventional (**CON**). The NE3 group received no growth promotants or feed additives. Conversely, the CON cattle were implanted with a growth promotant (Synovex® Choice, Fort Dodge Animal Health, Overland Park, KS; 100 mg trenbolone acetate and 14 mg estradiol benzoate) at day 1 and day 70. Throughout the study CON cattle received monensin (Rumensin®, Elanco, Greenfield, IN) at 330 mg/animal/day and tylosin phosphate (Tylan®, Elanco) at 90 mg/animal/day in their ration. Additionally, for the 29 days prior to shipping, the CON cattle were fed the β-agonist ractopamine hydrochloride (Optaflexx™, Elanco) at 254 mg/animal/day. There were four pens of 13 steers per treatment. Pens were given ad libitum access to a corn-based finisher ration (89% DM, 12.8% CP). The trial began when the average weight of matched-pair pens was 337 kg ± 17, therefore the starting date for each set of matched-pairs varied. Cattle were shipped on a constant end weight basis when the average pen weight reached a target of 590 kg (actual 596 kg ± 32) BW. For the last 7 days on feed, the CON cattle and their respective contemporary NE3 pen were moved to a cattle pen enclosure (**CPE**) facility where pen methane emissions were continuously recorded using a TEI 55C analyzer. Each CPE is comprised of a dome-like structure measuring 22 x 11 m with dirt floors, pipe fencing, feed bunks, and a water trough. Inflow (through a cooling pad) and outflow (through fans with ventilation openings) methane concentrations and air turnover were measured to calculate emissions. Airflow was determined by the RPM of the fans and the static differential pressure from inside and outside the CPE by using data loggers on 10 minute intervals.

Data collection. The amount of feed given to each pen was recorded, and refusals were weighed daily. Feed samples were taken on a monthly basis for proximate analysis. The cattle were fed 30% of daily intake at 7 AM and 70% at 2 PM. Cattle were weighed every 28 days and upon removal. At the processing plant, HCW, ribeye area (**REA**), marbling score, back fat, yield grade, and KPH data were collection. Methane (**CH_4**) emissions were captured hourly for five days for only two of the four matched-pairs due to equipment malfunction.

Data and statistical analysis. The ADG and DOF were calculated. Methane emissions were calculated on a g per kg of live animal. Data were analyzed as a randomized pair design using the PROC MIXED procedure of SAS (SAS Inst. Inc, Cary, NC) with treatment and match pair as fixed effects and Sire as a random effect. Traits that were collected only on a per pen basis (e.g. amount of feed given) were analyzed using PROC MIXED with treatment and period as fixed effects. The methane data from the CPE were corrected to a constant dry matter feed intake (**DMI**) basis and analyzed by calculating the area under the curve and using the generalized least squares fit by REML in R (The R Foundation for Statistical Computing, Vienna, Austria). The model included treatment, day, period, and treatment by day interactions.

Results & Discussion

This experiment was designed to compare the inputs and outputs associated with different feedlot management options to produce the same end product i.e. a constant liveweight finished steer. Feedlot performance and carcass attributes of the two treatment groups are shown in Table 1.

Table 1. Pen and individual carcass averages for (SEM) for CON and NE3 treatment groups.

	NE3[1]	CON[2]	P-value
Item			
Pens, n	4	4	-
In weight, kg	337 (7.91)	337 (7.53)	.77
Out weight, kg	591 (5.82)	600 (5.74)	.09
ADG, kg/d	1.35 (0.03)	1.81 (0.05)	< 0.0001
DOF	188 (7.38)	146 (8.51)	< 0.01
Feed data			
Total kg feed (as fed)/steer	1643 (96)	1250 (119)	0.041
kg feed (DM)/steer	1462 (86)	1112 (106)	0.041
kg feed (DM)/steer/day	7.8 (0.3)	7.6 (0.3)	0.22
Implant cost	-	$4.50/steer	-
Optaflexx™ cost	-	$8.70/steer	-
Cost of feed+technology/ kg gain	$1.35 (0.05)	$1.13 (0.07)	0.011
Carcass Data			
Carcasses, n	52	50	-
Average HCW, kg	362 (3.06)	368 (3.47)	0.072
Average Ribeye area, cm2	79.9 (0.09)	87.1 (0.20)	< 0.0001
Average Yield grade	3.95 (0.09)	3.38 (0.12)	< 0.0001
Average KPH, %	2.83 (0.21)	2.51 (0.13)	0.005
Average Fat thickness, cm	1.84 (0.02)	1.64 (0.02)	0.008
Average Marbling Score	6.2 (0.21)	5.4 (0.05)	0.0002
Average Dressing %	61.3 (0.3)	61.3 (0.3)	0.62

[1] Never Ever 3 (no implants or feed additives)

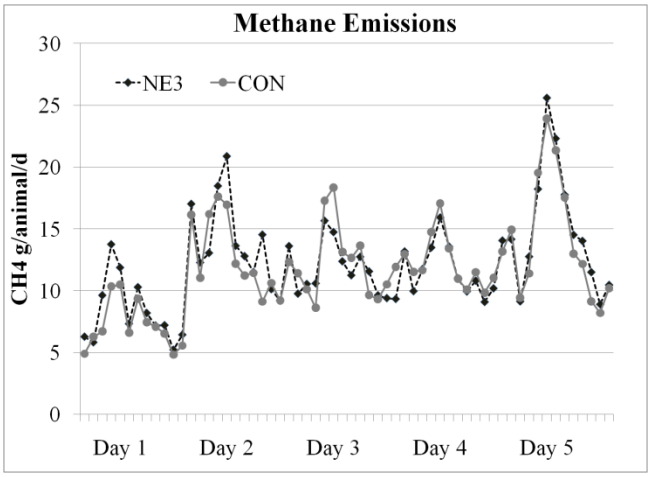
[2] Conventional cattle (implants, feed additives)

The CON cattle had higher ADG ($P < .0001$) and less DOF ($P < .01$, Table 1). The CON cattle had lower

yield grades ($P < 0.0001$) and marbling scores ($P < 0.0001$), larger ribeyes ($P < .0001$), and less backfat ($P = 0.009$). The technologies used in the CON treatment group decreased the cost per kg liveweight gain ($P = 0.011$). The CON cattle consumed 393 kg less feed to achieve finish and were on feed an average of 44 fewer days than the NE3. This resulted in a lower feed cost of gain for the CON cattle even though there were additional costs attributable to technology inputs. The CON cattle grew 34% more rapidly than the NE3 cattle. The different number of carcasses between treatments was due to death loss. It should also be noted that there was a therapeutic need to treat some cattle in each treatment group for an infection caused by *Histophilus somni* using tulathromycin (DRAXXIN®, Pfizer Animal Health, New York, NY) or ceftiofur crystalline free acid (EXCEDE® Sterile Suspension, Pharmacia & Upjohn Company, Division of Pfizer, New York, NY). In commercial settings, such treatments would disqualify NE3 cattle from that value-added market. This cost was not accounted for in the current study, but would be associated with an opportunity cost in commercial feedlots. Sire did not have an effect for any trait evaluated. There was a match pair effect for YG, with a significant difference in match pair 1 and 2 and 1 and 3 ($P < 0.05$). There was also a trend towards significance for match pair to have an effect on ADG.

Anabolic steroids have been shown to improve growth rates by as much as 30% and feed efficiency by as much as 15% when animals are slaughtered at the same liveweight (Preston, 1999). Other studies with beef steers and heifers implanted with Synovex®-SP, have shown improved ADG, larger LM area and HCW (Smith et al., 2007). However unlike the current study, no significant treatment effects were observed on yield grade, fat thickness, or marbling score possibly because cattle were harvested at a constant time endpoint (steers were finished for 133 d). β-agonists increase muscle accretion and decrease fat deposition. Vogel et al. (2009) examined the effects of ractopamine hydrochloride (**RAC**) in Holstein steers and reported cattle fed 200 mg or 300 mg increased ADG (.24 - .28 kg/d) and feed efficiency (14.4%) compared to the control cattle (0 mg RAC). They also found heavier carcasses and increased LM area in the RAC fed groups, although they did not find significant treatment effect on other carcass measurement traits. Gruber et al. (2007) found similar results when they compared beef steers of different biological type (British, Continental, Brahman) fed 0 mg versus 200 mg/animal/d RAC, however they did find a trend for lower marbling scores in cattle fed 200 mg/animal/d RAC consistent with the decrease in marbling scores observed in this study.

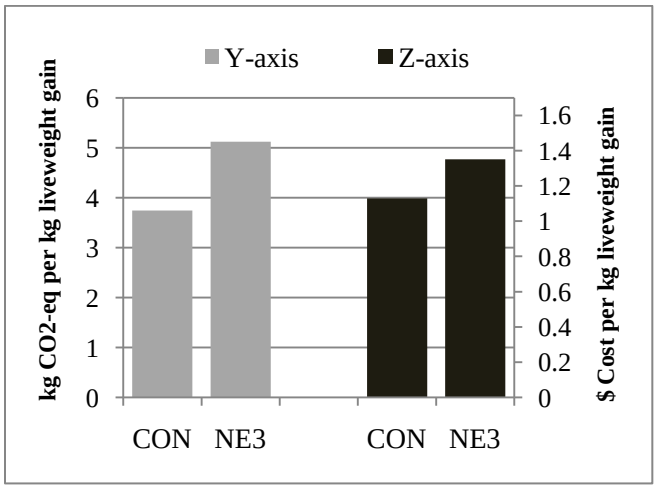
Figure 1. Methane emission results from conventional (CON) and Never Ever 3 (NE3) treatment groups for the 5 day period in the CPE.



There was an effect of day and time of day on methane production. The distinct diurnal pattern of CH_4 emissions is the result of decreased activity and rumination during the night, and has been observed in other studies (Hamilton et al., 2010). The increase in methane production over time was likely the result of methane derived from the accumulating manure in the CPE. It has been estimated that gas emissions from manure deposited in an environmental chamber contribute 5.8 % to measured CH_4 output (Kinsman et al., 1995). There was no treatment effect on daily CH_4 emissions/steer (301 g CH_4 for NE3 versus 293 g CH_4 for CON (corrected to 9.32 kg DMI)/day, $P = .729$) during the period in the CPE. The rationale for correcting the emissions to DMI was that there is a high correlation between DMI and methane emissions (Mc Court et al., 2006). This daily methane production per animal was in approximate agreement with other studies (Beauchemin and McGinn, 2005). If the emission rates that were observed in this experiment are assumed to be approximately constant on the basis of the DMI of the feedlot ration, then overall CH_4 produced during the feedlot period would be 32% less (43 vs. 57 kg CH_4/steer) for the CON vs. NE3 cattle because of their improved CON production efficiency. Global Warming Potentials (**GWP**) can be used to compare the abilities of different greenhouse gases to trap heat in the atmosphere. Non-CO_2 emission reductions can be converted to a CO_2-equivalent (**CO_2-eq**) basis using a GWP of 23 for CH_4 (IPCC, 2006). Expressing methane on a CO_2-eq basis using this GWP results in a difference of 1.37 kg CO_2-eq per kg liveweight gain (5.12 NE3 vs. 3.74 CON) in the feedlot. The current study does not account for the emissions associated with the production of the extra feed consumed by the NE3 cattle during feedlot finishing period,

or for those associated with the waste generated during the extra 44 days on feed.

Figure 2. The conventional (CON) versus Never Ever 3 (NE3) treatment comparison of kg of methane produced per kg of liveweight gain and cost per kg of liveweight gain.



The expanding world population, increased demand for meat products, and decreasing amount of land available for agriculture necessitate data-driven evaluation of the sustainability of alternative production systems. Agricultural production systems invariably present trade-offs among environmental, social, and economic goals (Stern el al., 2005), and no single production system is likely to satisfy all aspects of sustainability concurrently. Although some biotechnological approaches are prohibited by agricultural production systems that are purported to be sustainable, technologies that work to improve efficiencies, and do not deleteriously affect the environment, are likely to have some sustainability benefits. The technological inputs used in the CON treatment to produce a finished steer resulted in positive economic (decreased cost of gain) and environmental (decreased feed use, fewer days on feed, reduced CH_4 emissions) outcomes.

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EFFECT OF RAM EXPOSURE ON TEMPORAL PATTERNS OF PROGESTERONE AND METABOLIC HORMONES CONCENTRATIONS IN 18-MO-OLD VIRGIN TARGHEE EWES DURING THE TRANSITION INTO THE BREEDING SEASON[1]

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ABSTRACT: The objective was to determine if ram exposure during the transition into the breeding season altered progesterone (P4), cortisol, triiodothyronine (T3), thyroxine (T4), T3:T4 ratios, prolactin (PRL) or IGF-1 concentrations in 18-mo-old Targhee ewes. Anestrous ewes were stratified by residual feed intake (RFI) score (efficient; n = 12); middle; n = 12; inefficient; n = 12) and assigned randomly to be exposed to rams (RE; n = 18) or wethers (NE; n = 18). Ewes within exposure type were assigned to one of two pens (1 male/9 ewes/pen); with 30 m separation between RE and NE pens. Blood samples were collected from each ewe by jugular venipuncture every other day for 22 d, beginning on the first d of exposure. Samples were assayed for P4, cortisol, T3, T4, PRL, and IGF-1. Resumption of luteal activity began earlier ($P < 0$ .05) in RE than in NE ewes. There were no differences in patterns of cortisol, T3 or IGF-1 concentrations, or T3:T4 ratios between RE and NE ewes or among ewes with efficient, middle, or inefficient RFI scores. There was a treatment by day interaction ($P < 0.05$) for T4 and PRL concentrations. Concentrations of T4 in RE ewes decreased less rapidly and over a longer interval before increasing by the end of the sampling period than those in NE ewes. Concentrations of PRL were greater in RE than in NE ewes 4 d after exposure but decreased over the next 12 d; whereas, PRL decreased in NE ewes during the first 6 d then increased over the next 14 d. There was an exposure type by RFI score interaction ($P < 0.05$) for BW change. Change in BW did not differ among NE and RE ewes with medium or inefficient RFI scores. However, RE ewes with efficient RFI scores showed a greater increase in BW over the 22-d experiment than NE ewes with efficient RFI scores. Exposing 18-mo-old ewes to rams accelerated resumption of luteal activity and altered T4 and PRL concentrations during the transition into the breeding season. Furthermore, the ram effect appears to alter BW change in ewes with efficient RFI scores differently than in ewes of lower RFI scores.

Key words: ram biostimulation, seasonal anestrus, metabolic hormones

INTRODUCTION

The biostimulatory effect of rams is the phenomena whereby the physical presence of rams stimulates the resumption of ovarian activity in seasonally anovular ewes (Schinckel, 1954). This effect can be used as a management strategy to accelerate and synchronize estrus and ovulation in sheep. Furthermore, 'flushing' is a nutritional management practice wherein increasing levels of energy are fed during the transition into the breeding season which increases ovulation rate in ewes.

Feed is a major cost in sheep production and improved conversion of feed to product is one approach for increasing profitability. A measure of feed efficiency is residual feed intake (**RFI**), defined as the difference between actual feed intake of an animal and its predicted intake based on body size and level of performance (Koch et al., 1963). However, there is little or no knowledge of the underlying biological mechanisms controlling RFI in sheep.

Metabolic hormones could be useful to evaluate the overall metabolic status of sheep that diverge in RFI. Changes in metabolic hormones have been identified in cows exposed to bulls (Olsen et al., 2009). However, it is not known whether RFI and exposure of ewes to rams affects resumption of ovulatory activity or metabolic status of ewes during the transition into the breeding season. There the possibility that efficient RFI class ewes are more sensitive to the 'ram effect' than ewes of other RFI classes.

The objective of this study was to determine if ewes, of varied RFI score, exposed to rams during the transition into the breeding season alters resumption of ovulatory activity and temporal patterns of metabolic hormone concentrations. The null hypotheses were that resumption of luteal activity and temporal patterns of cortisol, leptin, prolactin (**PRL**), IGF-1 T3 and T4 do not differ among virgin ewes that were classified by RFI as efficient, middle, or inefficient and exposed to rams.

MATERIALS AND METHODS

Animals and RFI

Thirty-six 18-mo-old virgin Targhee ewes were selected from the Montana State University, Red Bluff Research Ranch for use in determining RFI. All experimental procedures were approved by the Montana

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State University Agricultural Animal Care and Use Committee.

Residual feed intake for ewes in this study was determined in a 57-d trial that concluded 15 d before exposure to males. Details of the feeding trial and method for determining RFI were given in Redden et al. (2009). Based on calculations for RFI, ewes were classified into efficient (**E**), middle (**M**) and inefficient (**I**) RFI classes that were less than 0.5, $\pm$ 0.5, and greater than 0.5 SD, respectively, from the mean RFI.

Blood samples were collected from each ewe 10 to 15 d before exposure to males and assayed for progesterone concentrations. All of these ewes had concentrations of progesterone that were less than 1.0 ng/mL and considered to be anovular. Body weight of each ewe was obtained before exposure to males and at the end of the 22-d exposure period. Four 4-yr-old Rambouillet wethers and four 3-yr-old, sexually-experienced, epididymectomzed Rambouillet rams were used in this experiment.

Treatments

Ewes were stratified by RFI class and assigned randomly to be exposed to rams (**RE**; n = 18) or exposed to wethers (**NE**; n = 18). Each ewe was then assigned within exposure type to be housed in either an east or west pen. Pens were considered replicates within exposure type: NE-east (n = 9), NE-west (n = 9), RE-east (n = 9), and RE-west (n = 9). Each pen was approximately 10 x 30 m. Visual and olfactory contact between exposure types was limited by distance (~30m) and by fences draped with black plastic tarpaulins.

Rams and wethers were introduced to ewes within pens on d 0. The male to female ratio in each pen was 1:9. The experiment began on August 20 and the exposure period ended on September 11.

All animals had free access to water, good quality sanfoin hay (~12.5% protein), any pasture grasses within the pens, and salt blocks during exposure to males.

Blood Sampling and Processing

Blood samples were collected from each ewe every other day for 22 d by jugular venepuncture into 7 mL vacutainers (Becton-Dickinson, Franklin Lakes, NJ). Samples were stored on ice, allowed to clot over night and centrifuged at 1,850 x *g* for 30 min. Serum was decanted into 12 mm x 75 mm plastic culture tubes, capped and stored at -25^{o} C, until assayed for each hormone.

Assay Procedures

Progesterone and cortisol concentrations were assayed in every sample; whereas, T3, T4, PRL IGF-1 and leptin were assayed in samples collected at 4 d- intervals.

Progesterone was assayed in duplicate using solid phase RIA kits (Siemens Medical Diagnostics Los Angeles, CA, USA) validated for sheep serum in our laboratory. Intra- and inter-assay CVs were less than 5% for a ewe serum pool that contained 2.4 ng/mL.

Cortisol was assayed in duplicate using solid-phase RIA kits (Siemens Medical Diagnostics Los Angeles, CA, USA) validated for sheep serum in our laboratory. Intra- and inter-assay CVs were less than 10% for ewe serum pools that contained 91.0 ng/mL and 21.5 ng/mL respectively.

Triiodothyronine and T4 were assayed in duplicate using solid phase RIA kits (Siemens Medical Diagnostics Los Angeles, CA, USA) validated for sheep serum (Wells et al., 2003). Intra- and inter-assay CVs for T3 were 9.3 and 12.6%, respectively. Intra- and inter-assay CVs for T4 were 7.5 and 13.3%, respectively.

Prolactin and IGF-1 were assayed in duplicate using a double antibody RIA validated for sheep serum (Kiyma et al., 2004, and Spoon and Hallford, 1989, respectively). Intra- and inter-assay CVs for PRL were less than 10%, respectively; and Intra- and inter-assay CVs for IGF-1 were less than 10%, respectively.

Leptin was assayed in triplicate using a competitive liquid-liquid phase, double-antibody RIA procedure by Dr. Duane Kiesler described previously (Delavaud et al., 2000). The intra- and inter- assay coefficients of variation were less than 5.0%.

Statistical Analyses

Initial analyses indicated that pen or interactions of pen with independent variable did not affect any dependent variable and pen data were pooled for further analyses. Progesterone concentrations patterns were used to assess the resumption of luteal activity. A rise in progesterone concentration of > 1.0 ng/mL in two consecutive samples after exposure provided evidence that ewes resumed luteal activity during the experimental period. The d before the rise was considered the d of resumption of luteal activity.

Interval to luteal activity was analyzed by two-way ANOVA. The model included exposure type, RFI class and their interaction using PROC GLM of SAS (SAS, Cary, NC). Means were separated using Bonferroni Multiple Comparison tests. Proportions of ewes that resumed luteal activity at 8 d after exposure and by the end of the exposure period were analyzed by chi-square analyses using PROC FREQ of SAS.

Cortisol, PRL, IGF-1, T3, T4 and leptin concentrations were analyzed using the PROC MIXED for repeated measures analysis of SAS. The model included exposure type, RFI class, day, and the interactions between these variables. Animal was the experimental unit with day after exposure as the repeated measure. Means were separated using Bonferroni Multiple Comparison tests.

RESULTS

Based on progesterone concentrations on d 0, it was determined that 5 RE and 6 NE ewes had resumed luteal activity and were excluded from analyses related to resumption of luteal activity. Ewes exposed to rams resumed luteal activity sooner (P = 0.04) than ewes exposed to wethers (Table 1). More (P = 0.02) RE ewes resumed luteal activity by 8 d after exposure than NE ewes. However, by the end of the exposure period there

was no difference between the proportion of RE and NE ewes that resumed luteal activity.

There was no difference in the interval from exposure to resumption of luteal activity or proportions of ewes that resumed luteal activity by d 8 or the end of the exposure period among ewes of RFI classes.

Table 1. Resumption of luteal activity in anovular, virgin Targhee ewes exposed to rams (RE) or wethers (NE)[1]

Variable	NE	RE	SEM	X^2	*P*-value
n	12	13			
Interval from exposure, d	7.5[a]	3.5[b]	4.4		0.04
% resuming luteal activity by d 8 of exposure	62[a]	100[b]		5.76	0.02
% resuming luteal activity by end of exposure	92[a]	100[b]		0.96	0.32

[1] Day 0 = introduction of males.
[a,b] Values within rows with different superscripts differ.

There were no differences between RE and NE ewes or among ewes of RFI classes for temporal concentrations patterns of cortisol, T3, IGF-1, leptin or T3:T4 ratios. There was no difference among ewes of RFI classes for concentrations of T4; however, there was an exposure type by day interaction ($P = 0.05$) for T4 concentrations (Figure 1). Concentrations of T4 decreased in NE ewes between d 1.5 and 9.5; whereas, T4 in RE ewes decreased between d 1.5 and 5.5 with no further decrease until d 17.5. Concentrations of T4 did not differ between RE and NE ewes after d 9.5.

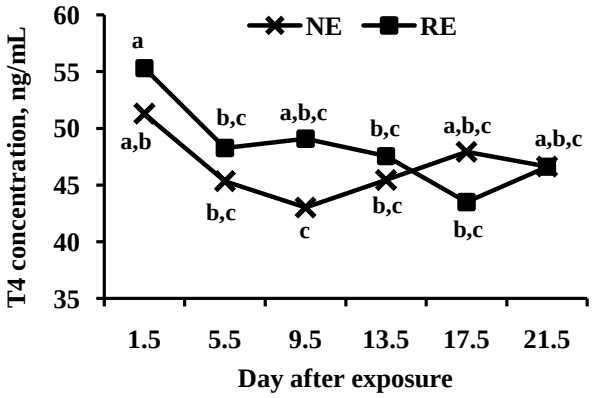

Figure 1. Least squares means for T4 concentrations of ewes after exposure to rams (RE; n = 18) and wethers (NE; n = 18). Exposure type by d interaction, $P = 0.05$. Means that have different letters differ ($P < 0.05$). SEM = 5.7 ng/mL.

There was no difference among ewes of RFI classes for concentrations of PRL. However, there was significant individual animal variation in temporal concentrations of PRL. Nevertheless, there was an exposure type by day interaction ($P = 0.01$) for PRL concentrations. This interaction appeared to be due to a decrease in PRL concentration in RE ewes between d 5.5 and 17.5; whereas, there was no change in PRL concentrations in NE ewes (Figure 2).

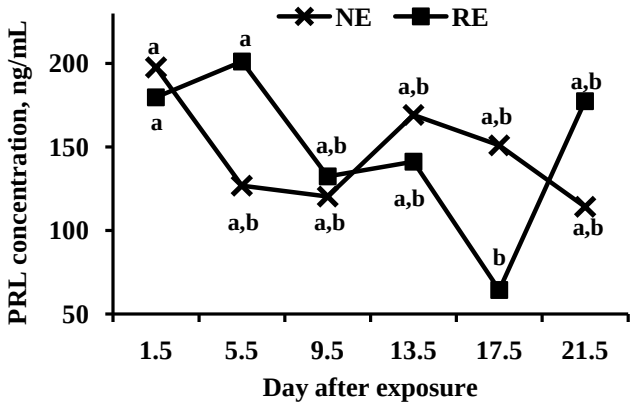

Figure 2. Least squares means for prolactin (PRL) concentrations of ewes after exposure to rams (RE; n = 18) and wethers (NE; n = 18). Exposure type by d interaction, $P = 0.01$. Means that have different letters differ ($P < 0.05$). SEM = 111.5 ng/mL.

There was no difference among ewes of RFI classes for change in BW. However, there was an interaction ($P = 0.03$) between exposure type and RFI class for change in body weight. Change in BW during the exposure period did not differ among middle and inefficient RFI class ewes exposed to males (Figure 3). However, efficient RFI class ewes exposed to rams gained more ($P = 0.002$) weight than efficient RFI class ewes exposed to wethers (Figure 3).

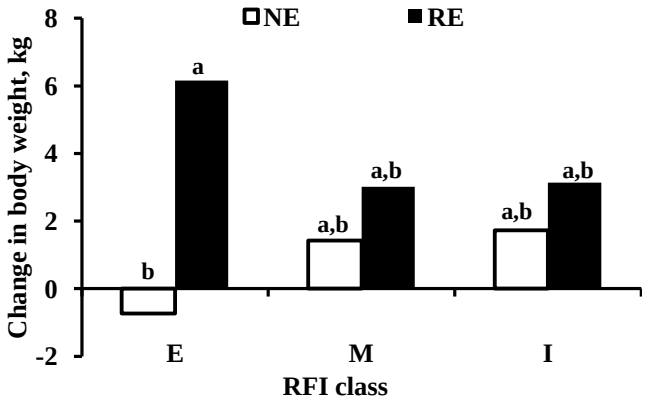

Figure 3. Least squares means for changes in body weight of ewes of efficient (E; n = 12), middle (M; n = 12) and inefficient (I; n = 12) RFI classes exposed to rams (RE; n = 18) and wethers (NE; n = 18) during the experiment. Bars that have different letters differ ($P < 0.05$).

DISSCUSION

The rationale for this experiment was that exposing ewes to rams at the beginning of the breeding season accelerates resumption and synchronizes estrus and

ovulation in sheep. Furthermore, 'flushing' increases ovulation rate in ewes during the transition into the breeding season. Flushing increases feed costs and potentially reduces profitability. Residual feed intake is a measure of feed efficiency and there is the possibility that selection for RFI could reduce feeding cost in sheep. It is not known if the response of ewes to rams during the transition into the breeding season is influenced by feed efficiency as measured by RFI. The metabolic hormone profiles of ewes of varied RFI exposed to rams is not known. However, an understanding of changes in metabolic hormone profiles associated with RFI and ram exposure may allow a means for selecting ewes that respond to rams without increasing feed costs. Thus, objective of this study was to determine if ewes, of varied RFI score, exposed to rams during the transition into the breeding season alters resumption of ovulatory activity and temporal patterns of metabolic hormone concentrations.

Exposing virgin ewes to rams during the transition into the breeding season accelerated resumption of ovulatory activity; consistent with numerous reports (for review, see Senger, 2005). However, RFI class did not influence resumption of ovulatory activity in theses ewes. This is the first report that the authors are aware of that evaluated the effect of RFI on resumption of ovulatory activity and response to a ram during the transition into the breeding season.

Metabolic hormones may be important indicators of RFI, especially IGF-1 (Kelly et al., 2010). Residual feed intake class did not affect temporal patterns of cortisol, T3, T4, PRL, IGF-1, or leptin. This indicates that these hormones may not be appropriate, long-term metabolic markers for RFI in ewes. On the other hand, exposing ewes to rams altered temporal patterns of T4 and PRL. The general decrease in T4 in response to rams indicates that metabolic rate may have decreased in ewes exposed to rams. This is interesting in light of the fact that we found that RE ewes gained more weight during the exposure period than the NE ewes. Theoretically a reduction in metabolic rate at the same feed intake would promote an increase in BW gain. There was no significant change in temporal patterns of T3; nevertheless, the trend in T3 concentrations followed those of T4, and the T3:T4 ratio was numerically lower in RE ewes than in NE ewes. Lack of statistical significance for T3 and T3:T4 ratio was due primarily to the large individual animal variation.

Recently, PRL has been shown to have a positive influence on gonadal function during the transition into the breeding season of sheep (Sanford and Baker, 2010). Concentrations of PRL in ewes exposed to rams differed from those exposed to wethers. We found that PRL in RE ewes decreased later after exposure than in NE ewes, which is reflected in the decrease in the interval from exposure to resumption of ovulatory activity.

In conclusion, the biostimulatory effect of rams on ewes during the transition into the breeding season also appears to include changes in certain metabolic hormones. However, RFI class does not appear to alter either resumption of ovulatory activity or metabolic hormone profiles during the transition into the breeding season. Furthermore, it appears that the ram effect may induce a flushing-like effect through its influence on thyroid function.

IMPLICATIONS

These results indicate that RFI may not influence the resumption of ovulatory activity during the transition into the breeding season in sheep. This means that an efficient ewe is no more likely to resume ovulatory activity earlier than an inefficient ewe. The results of this study indicate that the mechanism whereby the ram accelerates resumption of ovulatory activity involves a metabolic component associated with thyroid and prolactin activity.

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CONJUGATED LINOLEIC ACID DECREASES PROSTAGLANDIN SYNTHESIS IN BOVINE LUTEAL CELLS

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ABSTRACT: Feeding conjugated linoleic acids (CLA) improves reproductive performance in dairy cows; however, the molecular mechanisms by which CLA improves reproduction are not well understood. Therefore, we evaluated whether the CLA isomers *trans*-10, *cis*-12 CLA and *cis*-9, *trans*-11 CLA altered synthesis of steroidogenic hormones in bovine luteal cells by measuring concentrations of progesterone, prostaglandin E_2, and prostaglandin $F_{2\alpha}$ in conditioned medium and expression of genes involved in their synthesis. Confluent luteal cells from each of 4 cows were cultured in 0 μM (control) or 0.1 μM solutions of *trans*-10, *cis*-12 CLA and *cis*-9, *trans*-11 CLA in varying ratios (1:0, 0:1, 1:1, 2:1, 1:2, 5:1, 1:5, 9:1, or 1:9) for 48 h in the presence and absence of 1 μM of the adenylate cyclase activator forskolin. Independent of CLA isomer and ratio, CLA decreased, compared to control, concentrations of prostaglandin $F_{2\alpha}$ (62.6 ± 10.5 vs. 50.4 ± 9.9 pg/mL; $P = 0.003$) and, in the absence of forskolin, prostaglandin E_2 (61.2 ± 11.3 vs. 36.1 ± 10.1 pg/mL; $P < 0.001$), while no effect was observed for progesterone ($P = 0.94$). Compared to control, CLA decreased relative levels of COX-2 mRNA, a rate limiting enzyme in prostaglandin synthesis, by 1.7 fold ($P < 0.001$) and 3 β-hydroxysteroid dehydrogenase mRNA, a rate limiting enzyme in progesterone synthesis, by 1.4 fold ($P = 0.008$). Relative levels of PGE synthase and PGE_2 9-keto-reductase mRNA, both involved in prostaglandin synthesis, and steroid acute regulatory protein and cytochrome P450 side chain cleavage mRNA, both involved in progesterone synthesis, were not significantly altered by CLA. In conclusion, a potential mechanism by which *trans*-10, *cis*-12 CLA and *cis*-9, *trans*-11 CLA may improve reproductive performance in dairy cows, is by suppressing $PGF_{2\alpha}$ synthesis in luteal cells through attenuating COX-2 gene expression.

Keywords: cattle, conjugated linoleic acid, corpus luteum, progesterone, prostaglandin

Introduction

The decline in reproductive performance over the last 50 years in dairy cows is an important concern for the dairy industry (Butler, 2003). A recent study suggested that feeding CLA, a group of positional and geometric isomers of linoleic acid with conjugated double bonds, increases pregnancy rates and decreases days to first ovulation and days open (de Veth et al., 2009); however, the underlying molecular mechanism is unknown. We hypothesized that CLA may prevent early embryo mortality, in part, by preventing luteal regression through increasing progesterone and PGE_2 secretion and inhibiting $PGF_{2\alpha}$ secretion of the corpus luteum (CL). Little is known how CLA affects the synthesis of steroidogenic hormones in reproductive tissues; except for that CLA decreased $PGF_{2\alpha}$ secretion in cultured bovine endometrial cells (Rodriguez-Sallaberry et al., 2006) and in late gestation ewe endometrium (Cheng et al., 2003).

Therefore, the objective of this study was to examine the effects of two of the most common CLA isomers *trans*-10, *cis*-12 CLA and *cis*-9, *trans*-11 CLA on production of steroidogenic hormones (PGE_2, $PGF_{2\alpha}$, and progesterone) and relative mRNA concentrations of proteins involved in their synthesis in the bovine CL.

Materials and Methods

Animal care and experimental procedures were conducted with approval of the Oregon State University Institutional Animal Care and Use Committee. One primiparous Holstein cow (29 mo of age, 165 DIM), two primiparous Jersey cows (24 and 39 mo of age, 198 and 205 DIM), and one multiparous Jersey cow (third lactation, 53 mo of age, 77 DIM) were estrous synchronized with two 25-mg injections of $PGF_{2\alpha}$ (Lutalyse; Pfizer Animal Health, New York, NY) administered intramuscularly 12 d apart. On day 11 of the estrous cycle (day 0 = onset of estrus), corpora lutea were collected and stored in ice-cold modified F-10 medium. Modified F-10 medium was prepared by adding 0.32 mg putrescine dihydrochloride (MP Biomedical, Solon, OH) and 160 mg D-(+)-Glucose (Sigma, St. Louis, MO) to 1 L of Ham's F-10 medium with L-glutamine (Hyclone Thermo Fisher Scientific, Logan, UT) and adjusting the pH to 7.4 by adding 5.72 g HEPES (EMD Chemical, Gibbstown, NJ).

To examine the effect of supplemental CLA on luteal progesterone and prostaglandin synthesis (**Figure 1**), luteal cells were cultured as described by Pate and Condon (1982) with minor modifications. Luteal cell culture medium was prepared by adding 5 μg/mL insulin, 5 μg/mL transferrin, 5 ng/mL sodium selenite (ITS premix; Sigma, St. Louis, MO) and 20 μg/mL gentamicin sulfate (Cellgro, Manassas, MA) to the modified F-10 medium. We decided to use a serum- and cholesterol-free medium because serum or cholesterol may have confounded the potential effect of CLA on gene expression. Culture flasks were conditioned for cell attachment by incubation with 5 mL of PBS containing 10% bovine calf serum (Hyclone, Logan, UT) for 1 h, after which the serum-containing PBS was aspirated and the flasks were rinsed three times with PBS only. Luteal cells were suspended at density of 5.0×10^6 cells/mL in 5 mL of luteal cell culture medium into 25 cm^2 flasks (Grenier Bio-one, Monroe, NC) and incubated at 37 ºC in a humidified atmosphere of 5% CO_2 in air.

After 24 h, cell culture medium was changed and 0 μM or 1 μM forskolin (Sigma, St. Louis, MO) and 0 μM or 0.1 μM *cis*-9, *trans*-11 CLA and *trans*-10, *cis*-12 CLA at

varying ratios (0:1, 1:0, 1:1, 2:1, 1:2, 1:5, 5:1, 9:1, and 1:9) (Matreya, Pleasant Gap, PA) in 100% ethanol (EMD Chemical Gibbstown, NJ) were added to the fresh medium. After 48 h, cell-conditioned medium was collected for subsequent hormone analysis and stored at -20 ºC. Luteal cells were removed from the culture flasks, lysed in 1 mL TRIzol® reagent (Invitrogen, Carlsbad, CA), and stored at -80 ºC until subsequent mRNA analysis.

Concentrations of PGE_2, $PGF_{2\alpha}$, and progesterone were measured in conditioned medium using commercially available enzyme-linked immunoabsorbent assays (Cayman Chemical, Ann Arbor, MI). Hormone concentrations were expressed as pg/mL of medium assuming an equal cell number among flasks. Hormone concentrations were measured from two identically treated flasks and averaged for further analysis. The CV of duplicate samples for PGE_2, $PGF_{2\alpha}$, and progesterone concentrations were 19.1, 15.0, and 13.5%, respectively.

To examine the effect of CLA on gene expression, we measured the relative mRNA levels of proteins known to be rate limiting for synthesis of prostaglandin (cyclooxygenase [COX] 2, prostaglandin E synthase [PGES], prostaglandin E_2-9-ketoreductase [9KR]) and progesterone (steroid acute regulatory protein [StAR], cytochrome P450 side chain cleavage [P450scc] enzyme, 3β-hydroxysteroid dehydrogenase [3βHSD]). Total cellular RNA was isolated from luteal cell cultures using chloroform/isopropanol precipitation according to the manufacturer's instructions (Invitrogen, Carlsbad, CA). Two µg of total RNA from each sample was utilized to synthesize cDNA using the High Capacity cDNA RT Kit according to the manufacturer's instructions (Applied Biosystems, Foster City, CA).

Relative mRNA levels were determined by quantitative real-time PCR using the 7300 Real-Time PCR System (Applied Biosystems, Foster City, CA). Commercially available gene primers (**Table 1**) from Applied Biosystems were used according to the manufacturer's instructions (TaqMan® Gene Expression Assays) to amplify cDNA with the following two-step cycling program: cycle 1 (2 min at 50 ° C followed by 10 min at 95 °C) and cycle 2 (40 cycles at 15 s at 95°C followed by 1 min at 60°C with data collection occurring during the last 30 sec). Cycle threshold (Ct) values were measured for individual genes of interest using the same amplification cut-off value within genes. Data were normalized by subtracting the Ct for glyceraldehyde 3-phosphate dehydrogenase (GAPDH) from the Ct value of the gene of interest (i.e., calculating a ΔΔCt). The average of the triplicate ΔΔCt was used for statistical analysis.

Hormone and mRNA levels were analyzed as a 2 x 2 factorial experiment within a split-plot design using the mixed models procedure (PROC MIXED) of SAS Version 9.1.3 (SAS, 2004). The fixed effects in the mixed model were CLA (no CLA, *cis*-9, *trans*-11 CLA and *trans*-10, *cis*-12 CLA in varying ratios: 0:1, 1:0, 1:1, 2:1, 1:2, 1:5, 5:1, 9:1, and 1:9) and forskolin (0, 1) and their interaction. To account for multiple measures within the same cow, a compound symmetry structure was used in PROC MIXED that assumes equal correlations for observations of the same cow. Because CLA ratios did not differ in their hormone and mRNA levels (results not shown), the average of CLA-treated samples within cows was computed and further statistical analysis was done using a simplified model with the fixed effects CLA (0, 1), forskolin (0, 1), and their interaction term. Denominator degrees of freedom were adjusted for multiple measures within the same cow using the KENWARDROGER option. Significance was declared at $P \leq 0.05$. Means presented in figures and tables are multivariate-adjusted means.

Results and Discussion

The objective of our study was to evaluate whether *trans*-10, *cis*-12 CLA and *cis*-9, *trans*-11 CLA alter the synthesis of steroidogenic hormones in luteal cells. Furthermore, we examined whether changes in expression of genes involved in the synthesis of steroidogenic hormones is one potential mechanism by which CLA alters concentrations of steroidogenic hormones. Our results suggest that CLA, independent of isomer and ratio, may decrease PGE_2 and $PGF_{2\alpha}$ synthesis, which may be, in part, by down-regulation of COX-2 gene expression. We did not observe an effect of CLA on progesterone synthesis. To our knowledge, this is the first study to report on the effect of CLA on prostaglandin and progesterone synthesis in luteal cells.

CLA decreased hormone concentrations of prostaglandin $F_{2\alpha}$ (62.6 ± 10.5 vs. 50.4 ± 9.9 pg/mL; $P = 0.003$) and in the absence of forskolin prostaglandin E_2 (61.2 ± 11.3 vs. 36.1 ± 10.1 pg/mL; $P < 0.001$) in conditioned medium recovered from cultured luteal cells (**Figure 2A, 2B**). Similar to our results, both CLA isomers suppressed PGE_2 synthesis in endothelial cells (Eder et al., 2003) and macrophages (Stachowska et al., 2009). In cultured bovine endometrial cells, CLA isomers decreased $PGF_{2\alpha}$ secretion in the presence and absence of the protein kinase C activator phorbol 12, 13-dibutyrate (Kendall et al., 2006; Moussavi et al., 2006; Rodriguez-Sallaberry et al., 2006) and $PGF_{2\alpha}$ secretion in late gestation ewe endometrium (Cheng et al., 2003), while no effect of CLA feeding was observed on oxytocin-induced secretion of $PGF_{2\alpha}$ metabolites in dairy cows (Castañeda-Guitiérrez et al., 2007).

CLA may decrease prostaglandin synthesis in bovine luteal cells through a variety of processes. We focused on the effect of *trans*-10, *cis*-12 and *cis*-9, *trans*-11 CLA on the gene expression of enzymes essential for PGE_2 and $PGF_{2\alpha}$ synthesis and observed that CLA decreased mRNA levels of COX-2 ($P = 0.001$) with the greatest decrease observed when forskolin was added (2.4-fold; $P < 0.001$; $P_{Interaction} = 0.064$; **Figure 3A**). Similar to our results, both CLA isomers decreased COX-2 mRNA levels in aortic endothelial cells (Eder et al., 2003) and macrophages (Iwakiri et al., 2002). In cultured bovine endometrial cells, however, CLA increased COX-2 gene expression (Rodriguez-Sallaberry et al., 2006). The CLA-induced increase in COX-2 is surprising given that $PGF_{2\alpha}$ synthesis was concomitantly decreased (Rodriguez-Sallaberry et al., 2006) and COX-2 catabolizes a rate-limiting step of prostaglandin synthesis (Dubois et al., 1998).

The adenylate cyclase activator forskolin increased, as expected (Pate and Condon, 1984), progesterone synthesis in the luteal cells of the three Jersey cows (**Figure 4A)**. In contrast, forskolin decreased progesterone synthesis in luteal cells of the Holstein cow (**Figure 4B**). This unexpected decrease in progesterone synthesis may be due to differences in hormone responsiveness as a result of differences in proportions of small and large luteal cells (Mamluk et al., 1999), differences in substrate availability, or both.

Addition of CLA did not affect progesterone level in conditioned medium (P = 0.94; results not shown), however, CLA decreased mRNA levels of 3βHSD by 1.4-fold (P = 0.008; **Figure 5C**). The lack of progesterone response to CLA in our experiment may be caused, in part, by the surprising absence of a CLA effect on STAR and P450scc mRNA concentrations (**Figures 5A, 5C**). We examined mRNA levels of STAR, P450scc, and 3βHSD because previous studies had shown that the promoter region of their genes have response elements that can interact with CLA and its ligands (LaVoie and King, 2009; Ringseis et al., 2008). The absence of progesterone substrates in our cell culture medium, such as serum or cholesterol, may have inhibited a potential effect of CLA on progesterone synthesis.

Implications

Our results suggest that one potential molecular mechanism whereby *trans*-10, *cis*-12 CLA and *cis*-9, *trans*-11 CLA may improve reproductive performance in dairy cows is by decreasing $PGF_{2\alpha}$ secretion of luteal cells through down-regulation of COX-2 gene expression. Decreasing luteal $PGF_{2\alpha}$ secretion in the mid to late CL may increase the chance for luteal rescue of the developing embryo and decreased embryo mortality. The observed decrease in PGE_2 concentrations cannot be considered beneficial because PGE_2 promotes progesterone synthesis (Rekawiecki et al., 2005). Further studies are warranted to examine the effect of CLA on prostaglandin and progesterone synthesis in the presence and absence of various prostaglandin and progesterone substrates in the culture medium.

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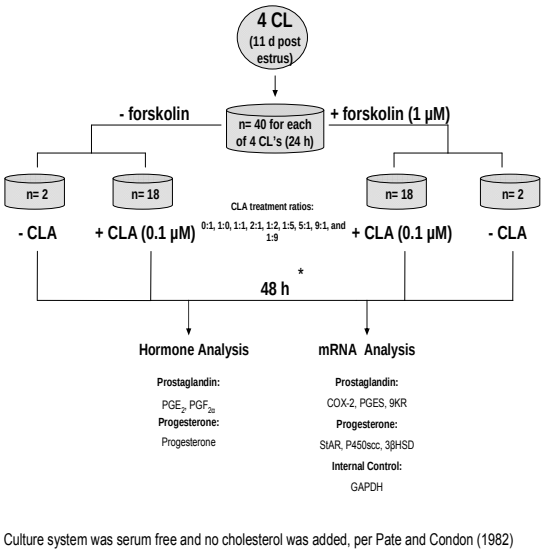

* Culture system was serum free and no cholesterol was added, per Pate and Condon (1982)

Figure 1. Experimental Design. One corpus luteum from each of four cows was collected at 11 d post estrus. Luteal cells were grown to confluency for 24 h (40 plates per cow for a total of 160 plates). Luteal cells were cultured for 48 h with 0 µM or 1 µM forskolin and 0.1 µM *cis*-9, *trans*-11 CLA and *trans*-10, *cis*-12 CLA at varying ratios (0:0, 0:1, 1:0, 1:1, 2:1, 1:2, 1:5, 5:1, 9:1, and 1:9).

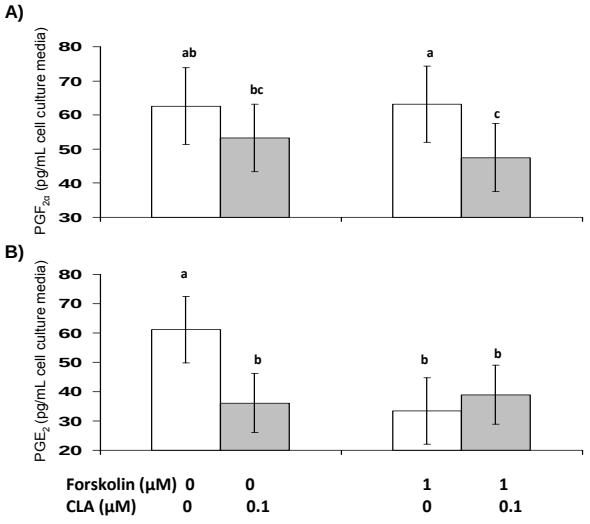

Figure 2. Effect of CLA and forskolin on $PGF_{2\alpha}$ and PGE_2 concentrations in cultured bovine luteal cells. A) Average prostaglandin concentrations (± standard errors) with the same letter did not differ at $P \leq 0.05$. CLA *(*$P = 0.003$*)* but not forskolin ($P = 0.57$) decreased $PGF_{2\alpha}$ concentrations ($P = 0.39$). **B)** CLA decreased PGE_2 concentrations in the absence of forskolin *(*$P < 0.001$*)* but not in its presence ($P_{CLA} = 0.02$; $P_{Forskolin} = 0.003$; $P_{Interaction} < 0.001$).

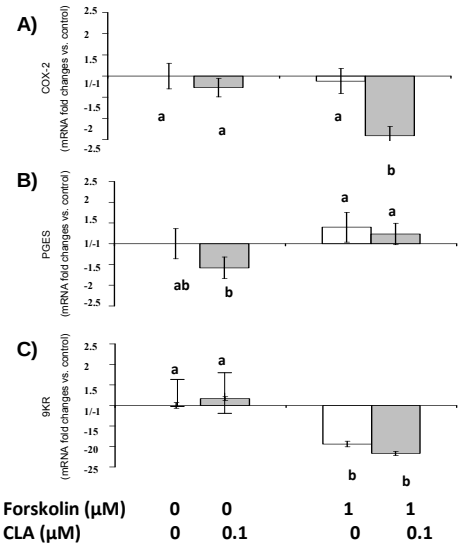

Figure 3. Effect of CLA and forskolin on relative mRNA concentrations of COX-2, PGES, 9KR in cultured bovine luteal cells. Average relative mRNA levels versus no CLA and no forskolin (± standard errors) with the same letter did not differ at $P \leq 0.05$ (SE for fold changes: 0.20 – 0.36). **A)** CLA *(*$P < 0.001$*)* and forskolin ($P = 0.008$) decreased relative COX-2 levels ($P_{Interaction} = 0.06$). **B)** Forskolin *(*$P = 0.003$*)* but not CLA ($P = 0.08$) increased relative PGES levels ($P_{Interaction} = 0.32$. **C)** Forskolin *(*$P < 0.001$*)* but not CLA ($P = 0.94$) decreased relative 9KR levels ($P_{Interaction} = 0.63$).

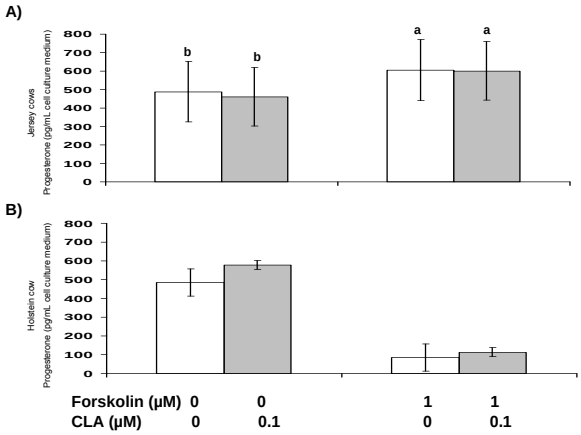

Figure 4. Effect of CLA and forskolin on progesterone concentrations in cultured bovine luteal cells. Average progesterone concentrations (± standard errors) with the same letter did not differ at $P \leq 0.05$. **A)** Forskolin *(*$P < 0.001$*)* but not CLA ($P = 0.63$) increased progesterone concentrations in three Jersey cows ($P_{Interaction} = 0.73$). **B)** Forskolin but not CLA decreased progesterone concentrations in one Holstein cow.

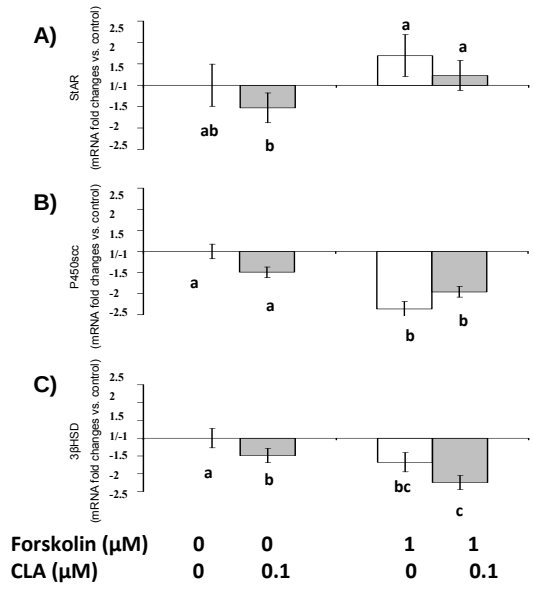

Figure 5. Effect of CLA and forskolin on relative mRNA concentrations of StAR, P450scc, and 3βHSD in cultured bovine luteal cells. Average relative mRNA levels versus no CLA and no forskolin (± standard errors) with the same letter did not differ at $P \leq 0.05$. **A)** Forskolin *(*$P = 0.008$*)* but not CLA ($P = 0.08$) increased relative StAR levels ($P_{Interaction} = 0.81$). **B)** Forskolin *(*$P < 0.001$*)* but not CLA ($P = 0.91$) decreased relative P450scc levels ($P_{Interaction} = 0.10$). **C)** Forskolin *(*$P < 0.001$*)* and CLA ($P = 0.008$) decreased relative 3βHSD levels ($P_{Interaction} = 0.70$).

Table 1. Forward and reverse primers used for qRT-PCR. Primers listed (5' → 3'). All concentrations used were 75 nM.

Gene	EMBL/GenBank accession number	Forward primer	Reverse primer
COX-2[1]	AF004944	TCTTTGACTGTGGGAGGATAC	TCCAGATCACATTTGATTGAC
9-keto-reductase[2]	XM_001253824	CCAAGTCCATCGGGGTGT	GCTGCCGTTTTCTTGTGC
PGES[3]	NM_174443	GTACGTGGTGGCCGTCATC	GGGTTGGCAAAAGCCTTCTT
StAR[4]	Y17260	CATGGTGCTCCGCCCCTTGGCT	CATTGCCCACAGACCTCTTGA
P450scc[5]	U18447	CATCATGCTGGACACCTCTAAC	ATGTCTCTTTCACCAACAACAGTC
3βHSD[6]	X17614	TACCCAGCTGCTGTTGGAG	ATGCCGTTGTTATTCAAGGC
GAPDH[7]	AB098979	GCATCGTGGAGGGACTTATGA	GGGCCATCCACAGTCTTCTG

[1] Cyclooxygenase-2
[2] Prostaglandin E2-9-keto-reductase
[3] Prostaglandin E2 synthase
[4] Steroid acute regulatory protein
[5] Cytochrome P450 side cleavage enzyme
[6] 3β-hydroxysteroid dehydrogenase-isomerase
[7] Glyceraldehyde 3-phosphate dehydrogenase

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CAMELINA MEAL AND CRUDE GLYCERIN AS FEED SUPPLEMENTS FOR DEVELOPING REPLACEMENT BEEF HEIFERS*

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ABSTRACT: Two hundred and four (n = 99, yr 1; n = 105, yr 2) Angus × Gelbvieh rotationally crossbred heifers were used in a 2-yr randomized complete block designed (RCBD) experiment to determine the effect of feeding camelina biodiesel co-products (meal and crude glycerin) on serum concentrations of thyroid hormones and glucose, as well as on growth and reproductive performance. Heifers were stratified by BW (297 ± 5.8 kg) and randomly allocated to a pen that received bromegrass hay plus 1 of 3 supplements (12.6% CP): control (50% ground corn and 50% soybean meal, as-fed); camelina meal (mechanically extracted); glycerin (50% soybean meal, 33% ground corn, 15% crude glycerin, 2% corn gluten meal; as-fed) for a 60 d period. Preprandial blood samples were collected via the jugular at d 0, 30 and 60 of the experimental feeding period. On d 60, heifers were synchronized for estrus using a 2-shot $PGF_{2\alpha}$ protocol; any heifer exhibiting estrus was bred via AI 12 h after standing heat. Heifers not exhibiting estrus were given GnRH and bred by AI on d 74. Data were analyzed as a RCBD using the MIXED procedure of SAS with pen as a random effect for BW and reproduction traits; serum parameters were analyzed as repeated measures. Dietary treatment × sampling period interactions were not detected (P = 0.17 to 0.87). Dietary treatment did not affect serum T_4 (P = 0.96), glucose (P = 0.59) or BW at d 30 or 60 ($P \geq 0.40$), but increased (P = 0.05) T_3 in heifers fed camelina meal. Additionally, dietary treatment did not affect the percentage of heifers detected in estrus before timed AI (P = 0.82), first service conception rates of those heifers detected in estrus (P = 0.87), conception rates to timed AI (P = 0.19), or overall first conception rates (P = 0.65). Heifers fed camelina co-products maintained growth and reproductive performance comparable to heifers fed the control supplement. Therefore, camelina co-products can replace conventional corn-soybean meal supplements.

Key Words: beef heifers, supplementation, biodiesel co-products

Introduction

Two co-products are generated when camelina seeds are processed for biodiesel production. Camelina meal is produced from pressing the seeds for oil extraction. The meal is a good source of CP (Bonjean and Le Goffic, 1999) and has 10% oil with 73% unsaturated fatty acids (Hurtaud and Peyraud, 2007). Although camelina contains glucosinolates, its concentration (22 µmol/g) of glucosinolates is relatively low (Lange et al., 1995) compared with that of rapeseed meal (90 to 140 µmol/g; Lardy and Kerley, 1994). Crude glycerin is a co-product remaining after the oil processed into biodiesel. Glycerol, the main compound in crude glycerin, has an energy value similar to cornstarch (1.9 vs. 2.12 Mcal of NE_L/kg; De Frain et al., 2004). Glycerol is extensively fermented in the rumen (Kijora et al., 1998), increases molar proportions of propionate and butyrate (Khalili et al., 1997), and regardless of purity, could replace up to 30% of dietary forage with minimal effects on ruminal digestibility and fermentation (Nayigihugu et al., 2008).

It was hypothesized that biodiesel co-products could be used as substitutes for a traditional corn-soybean meal supplement without affecting growth or reproductive performance of developing replacement heifers. Our primary objective was to determine the effects of replacing supplemental corn and soybean meal with camelina meal or crude glycerin on growth and reproductive performance of peripuberal beef heifers. Secondary objectives were to determine the effects of dietary supplements on serum concentrations of glucose and thyroid hormones.

Materials and Methods

General. All procedures for the following 2-yr study were approved by the University of Wyoming Animal Care and Use Committee. Angus × Gelbvieh rotationally crossed heifers (yr 1, n = 99; 300 ± 8.9 kg initial BW; yr 2, n = 105; 294 ± 7.6 kg initial BW) were stratified by initial BW within each BW block and then allotted randomly to 1 of 15 pens (6 to 7 heifers/pen). Heifer BW was recorded as the average pre-feeding live weights taken on 2 consecutive d at the beginning (d 0 and 1), middle (d 30 and 31), and end (d 60 and 61) of the experimental feeding period.

Diets. Diets were formulated to be isonitrogenous and to provide 12.6% CP of dietary DM. Heifers had limited access to bromegrass hay (Table 1), offered (as-fed) at 7.03 and 7.34 $kg \cdot heifer^{-1} \cdot d^{-1}$ from d 0 through 30 and d 31 through 60, respectively. Diets were formulated for heifers to gain 1.0 kg/d in order to achieve 60 to 65% of mature BW at the end of feeding period. Within respective BW blocks, heifers were offered 1 of 3 experimental supplements (Table 1): a control supplement consisting of 50% finely ground corn and 50% soybean meal (as-fed); mechanically extracted camelina meal; and a glycerin supplement consisting of 50% soybean meal, 33% finely ground corn, 15% crude glycerin, and 2% corn gluten meal (as-fed). Supplements were offered (as-fed) daily at 0.95 and 0.99 $kg \cdot heifer^{-1} \cdot d^{-1}$ during d 0 through 30 and d 31 through 60, respectively. No feed remained in the bunks after each 24-h ration was delivered. In yr 1, heifers had free access to water and trace mineralized salt [Ultra

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Balance Spring & Summer Mineral, Hergert Milling Inc., Scottsbluff, NE; guaranteed analysis (percentage of DM): NaCl, 14 to 16; Ca, 18 to 20; P, 8; Mg, 2.5; K, Co, Cu, I, Mn, Zn and Se, less than 1) throughout the experiment, whereas in yr 2, the same trace mineralized salt was included at 6% (as-fed) of the dietary supplements (based on average consumption by heifers in yr 1).

Blood Sampling. Pre-prandial blood samples were taken from jugular vein at d 0, 30 and 60 of the experimental period. Blood samples were collected into commercial blood collection tubes (Vacutainer, 10 mL; Becton Dickinson and Co., Franklin Lakes, NJ). Blood samples were placed on ice immediately after collection and then were stored at 4º C for 12 h. Samples were centrifuged at 2500 x *g* for 20 min, the resulting serum was decanted and stored at -20ºC until laboratory analysis.

Synchronization. On d 60, a 5 mL (25 mg) i.m. dose of $PGF_{2\alpha}$ (Lutalyse®, Pfizer Animal Health, US) was administered to all heifers. Heifers were combined into 1 large group where they had free access to water, trace mineralized salt (described previously), and bromegrass hay. A second i.m. injection of $PGF_{2\alpha}$ (5 mL; 25 mg) was administered to all heifers 10 d after the first shot (d 70). Estrous activity was evaluated twice daily, and any heifer showing estrus was artificially inseminated 12 h after standing heat. Heifers that did not exhibit estrus were given a 2 mL i.m. injection of GnRH (100 µg; Fertagyl®, Intervet, Inc., Millsboro, DE) and bred via AI on d 74. Any heifer showing estrus up through 10:00 a.m. on d 75 was again bred via AI 12 h after standing heat. Conception was determined by heifers not showing estrus after d 75 (yr 1) and by transrectal ultrasonography (variable MHz linear array transducer, MicroMaxx, Sonosite, Bothell, WA) at d 104 (yr 2).

Laboratory Analysis. Preprandial serum samples were analyzed for glucose (Liquid Glucose Hexokinase kit; Pointe Scientific Inc., Canton, MI; inter- and intraassay CV of 4.6 and 4.1%, respectively), and total T_3 and T_4 (solid-phase ^{125}I RIA; Coat-A-Count kits, DPC Diagnostic Products Inc., Los Angeles, CA; inter- and intraassay CV of 5.8 and 5.9% for T_3, and 7.3 and 5.5% for T_4, respectively).

Statistical Analysis. Data were analyzed as a randomized complete block design using the PROC MIXED procedure of SAS (SAS Institue Inc., Cary, NC, USA, version 9.2). Body weight at d 0, 30 and 60, ADG (d 0 to 30 and d 31 to 60), percentage of heifers detected in estrus, conception rate of heifer bred by heat, conception rate to timed-AI, and overall conception rates to AI were tested with the random effect of pen as the experimental unit. Serum concentrations of glucose, T_3, and T_4, were analyzed as repeated measures with pen(block) as the subject. The UNIVARIATE covariate structure was used for all serum variables. Means were separated using the Tukey multiple comparison test following a significant preliminary F-test.

Results and Discussion

Growth Performance. Dietary treatments did not affect BW ($P \geq 0.44$) or ADG during the first ($P = 0.59$) or second ($P = 0.63$) 30 d period (Table 2). The lack of differences in growth performance among heifers fed control, camelina, and glycerin supplements suggests that, in addition to being formulated to be isonitrogenous, the supplements provided the same amount of energy. In agreement with our results, Price et al. (2009) reported similar growth performance of lambs fed when whole camelina seeds replaced soybean meal in a corn-based diet. Likewise, including up to 12% DM as crude glycerin in a dietary concentrate did not affect growth performance of Holstein bulls (Mach et al., 2009).

Serum Glucose Concentrations. Ruminants consuming high-forage diets rely on liver gluconeogenesis to meet their daily requirements of glucose (Huntington, 1997). Propionate is the major substrate for hepatic gluconeogenesis (Reynolds et al., 1994). Although fermentation of glycerol by ruminal bacteria may increase propionate (Rémond et al., 1993), no dietary treatment x sampling period ($P = 0.61$) or dietary treatment effects ($P = 0.59$) were detected for average serum concentrations of glucose among dietary treatments (Table 3). In agreement with our results, Mach et al. (2009) observed no differences in plasma concentrations of glucose in Holstein bulls fed increasing concentrations of glycerin (0, 4, 8, and 12% of concentrate DM). DeFrain et al. (2004) also observed that the inclusion of glycerol at approximately 2.5 to 7.2% of dietary DM did not affect plasma glucose concentrations of dairy cows transitioning into copious milk production. Crude glycerin accounted for 1.78% of the treatment's dietary DM in the present study. Whitney et al. (2000) reported greater concentrations of glucose in serum of heifers fed forage-based diets with soybean oil added at 3% of DMI. Heifers fed camelina diets consumed 1.24% dietary fatty acids (DM basis), which may have not been sufficient to increase serum glucose concentrations.

Serum Thyroid Hormone Concentrations. Dietary treatment x sampling period interactions were not detected for serum concentrations of T_4 ($P = 0.87$) or T_3 ($P = 0.17$). Serum concentrations of T_3 ($P < 0.0001$) increased 30 d after feeding (0.86, 0.98, and 0.92 ng/mL for d 0, 30 and 60 respectively; SEM = 0.02), whereas T_4 only increased ($P = 0.0001$) at d 60 (38.9, 39.0, and 43.8 ng/mL for d 0, 30 and 60, respectively; SEM = 1.1). Thyroxine (T_4), the less active yet predominant thyroid hormone in circulation, is the precursor to the more biologically active thyroid hormone T_3 (Leonard and Visser, 1986). Cassar-Malek et al. (2001) attributed greater T_3 concentrations to the greater conversion of T_4 to T_3 by the hepatic 5'D-deiodinase. Energy availability affects bovine thyroidal status, with plasma concentrations of thyroid hormones reflecting feed intake and growth rate in growing steers (Blum et al., 1985). Concentrations of T_3 were more highly correlated with shifts in energy metabolism than T_4 (Blum et al., 1985). The changes in thyroid hormones between sampling periods in the present experiment seem to be reflective of the magnitude of change observed for ADG between the first (1.12 kg/d) and second (0.87 kg/d) 30-d feeding periods.

Glucosinolates are polar compounds present in camelina (Schuster and Friedt, 1998). It has been demonstrated that the derivative products of glucosinolates

(thiocyanate and isothiocyantes) are released after breakdown by ruminal microflora activity (Duncan and Milne, 1992). Guyton (1986) demonstrated that thiocyanate ions prevented the iodination of thyroid hormones resulting in inactive hormones when released into the blood stream. Lardy and Kerley (1994) observed a linear decrease in DM and CP intake with a concomitant decrease in serum concentrations of T_4, but no effect on T_3 concentrations after 28 d of feeding steers increasing amounts of rapeseed meal. In the present study, dietary treatment did not affect (P = 0.96; Table 3) serum concentrations of T_4. The discrepancy between the present study and results of Lardy and Kerley (1994) can be explained by the lower concentrations of glucosinolates in camelina (22 µmol/g; Lange et al., 1995) compared with rapeseed meal (90 to 140 µmol/g; Lardy and Kerley, 1994). Heifers fed camelina had greater (P = 0.05) average concentrations of T_3 in serum compared with heifers fed either the control or glycerin supplement; serum concentrations of T_3 did not differ (P = 0.99) between the control and glycerin treatments. Moriel et al. (2009) reported greater plasma concentrations of total fatty acids in heifers fed camelina meal compared with heifers fed either the control or glycerin supplement. It has been demonstrated that fat supplementation increases T_3 concentration (Bunting et al., 1996) by decreasing the binding of T_3 to its nuclear receptor (Wiersinga et al., 1988).

Reproductive Performance. Data presented in Table 4 illustrate that dietary treatment did not affect heifers detected in estrus before timed AI (P = 0.82), first conception rate of those bred by heat (P = 0.87), timed AI first conception rates (P = 0.19), and overall first conception rate to AI (P = 0.65). In an extensive review of the literature, Hess et al. (2008) concluded that overall pregnancy rates for heifers fed supplemental fat increased by 15% compared with heifers fed supplements without fat. Although not statistically significant, the magnitude of difference in overall first service conception rate observed for heifers fed camelina meal versus heifers fed the control supplement was consistent with literature results summarized by Hess et al. (2008). However, unlike the literature reviewed by Hess et al. (2008), the previously noted increase in plasma fatty acids for heifers fed camelina meal (Moriel et al., 2009) may not have been sufficient to impact reproductive performance. In agreement with our results, Funston et al. (2002) reported no improvement in estrous response or pregnancy rates of beef heifers supplemented with sunflower seeds at 0.91kg/d for 30 or 60 d before breeding.

Implications

Feeding camelina meal or crude glycerin did not affect growth and reproductive performance of peripuberal beef heifers. Therefore, camelina co-products (meal and crude glycerin) are suitable replacements for conventional corn-soybean meal supplements when offered to replacement beef heifers for 60 days before estrous synchronization.

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Table 1. Chemical composition of supplements[1] and the hay fed to developing replacement heifers.

Ingredients	Control	Camelina	Glycerin	Hay
DM, %	90.20	91.15	86.73	93.17
IVDMD, %	92.55	70.57	93.78	61.21
		% of DM		
OM	93.11	94.74	94.59	91.64
NDF	10.75	34.75	8.95	66.62
ADF	5.85	15.95	5.22	39.30
CP	27.83	23.46	24.54	8.21
		Mcal/kg of DM[2]		
DE	4.07	3.10	4.12	2.69
ME	3.33	2.54	3.38	2.20
NE_m	2.30	1.64	2.34	1.34
NE_g	1.60	1.03	1.63	0.76

[1]Supplements (as-fed) consisted of 50% finely ground corn and 50% soybean meal (Control), mechanically extracted camelina meal (Camelina), and 50% soybean meal, 33% finely ground corn, 15% crude glycerin, and 2% corn gluten meal (Glycerin).
[2]Calculated based on equations from NRC (1996) using IVDMD percentage as an estimate of TDN.

Table 2. Growth performance of developing replacement beef heifers fed supplements[1] for 60 d before estrous synchronization.

	Control	Camelina	Glycerin	SE	*P* value
BW at d 30, kg	330.51	328.22	328.95	1.26	0.44
BW at d 60, kg	356.24	354.61	356.31	1.12	0.50
Total gain, kg	59.34	57.28	58.87	1.11	0.22
ADG 1st 30 d, kg	1.14	1.09	1.12	0.04	0.59
ADG 2nd 30 d, kg	0.85	0.87	0.88	0.04	0.63

[1]Supplements (as-fed) consisted of 50% finely ground corn and 50% soybean meal (Control), mechanically extracted camelina meal (Camelina), and 50% soybean meal, 33% finely ground corn, 15% crude glycerin, and 2% corn gluten meal (Glycerin).

Table 3. Mean concentrations of glucose, T_4, and T_3 in serum of developing replacement beef heifers fed supplements[1] for 60 d before estrous synchronization.

	Control	Camelina	Glycerin	SE	*P* value
Glucose, mg/dL	66.64	67.03	65.97	0.72	0.59
T_4, ng/mL	40.41	40.36	40.92	1.46	0.96
T_3, ng/mL	0.89[a]	0.97[b]	0.90[a]	0.02	0.05

[a–b] Means within a row and main effect lacking a common superscript letter differ ($P \leq 0.05$).
[1]Supplements (as-fed) consisted of 50% finely ground corn and 50% soybean meal (Control), mechanically extracted camelina meal (Camelina), and 50% soybean meal, 33% finely ground corn, 15% crude glycerin, and 2% corn gluten meal (Glycerin).

Table 4. Reproductive performance of developing replacement beef heifers fed supplements[1] for 60 d before being synchronized for estrus[2].

	Control	Camelina	Glycerin	SE	*P* value
Heifers detected in estrus, %	42.7	41.5	48.2	8.3	0.82
First conception rates to AI, %					
by heat	50.0	55.8	58.5	11.9	0.87
timed-AI	26.6	44.3	25.6	7.4	0.19
Overall	40.0	48.8	41.2	7.1	0.65

[1]Supplements (as-fed) consisted of 50% finely ground corn and 50% soybean meal (Control), mechanically extracted camelina meal (Camelina), and 50% soybean meal, 33% finely ground corn, 15% crude glycerin, and 2% corn gluten meal (Glycerin).
[2]On d 60 and 70, a 5 mL shot of $PGF_{2\alpha}$ was administered to all heifers. Estrous activity was evaluated twice daily, and any heifer showing estrus after d 70 was artificially inseminated 12 h after standing heat. Heifers that did not exhibit estrus were given a 2 mL injection of GnRH and bred via AI on d 74. Any heifer showing estrus up through 10:00 a.m. on d 75 was again bred via AI 12 h after standing heat.

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USE OF A PORTABLE NEAR-INFRARED SPECTROPHOTOMETER TO PREDICT NUTRIENT COMPOSITION OF FECES FROM HOLSTEIN CATTLE FED HIGH-CONCENTRATE DIETS

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ABSTRACT: Our objective was to evaluate a chute-side infrared spectrophotometer (NIRS) analysis to predict nutrient composition of feces from Holstein cattle. Growing Holstein cattle (42 steers and 2 freemartin heifers; average initial BW = 220 kg) were fed either 86 or 90% steam-flaked corn-based concentrate diets (3 pens/treatment w 7 to 8 animals/pen). Fecal samples were collected in plastic bags and scanned within 2 h after collection using an ASD Field Spec NIRS unit (Boulder, CO). Spectra were collected under ambient conditions using a contact probe. Samples were then dried at 60°C, ground in a Wiley mill to pass a 1 mm screen and analyzed for DM, CP, NDF and ADF. Calibrations were developed using samples collected on d 0 and 28 with log 1/R spectra in the 1,100 to 2,400 nm range. Partial least squares (PLS) regression in SAS was used to develop calibrations. Cross validation was employed to determine the number of PLS factors to use. Simple regression was used to evaluate the relationship between observed and predicted constituent values. Although regression values were moderate for predicting CP (R^2 = 0.88) and fair for DM (R^2 = 0.68) and NDF (R^2 = 0.62), prediction regression values for ADF were statistically significant ($P < 0.01$) but not predictive (R2 = 0.34). Our data indicate that while our calibrations were variably successful, validations were mostly unsuccessful ($R^2 < 0.4$). Lack of validation success is most likely due to small sample number and limited range of values. However, this project has illustrated a relationship between NIR spectra and the observed laboratory values for these constituents, and that the use of a portable NIRS on-site may improve the nutritional management of a commercial feedlot.

Key Words: Holstein, NIRS, nutrient composition.

Introduction

Feedlot nutritionists routinely analyze diet samples for nutrient composition including DM, CP, NDF, ADF as well as estimates of starch availability. Besides nutrient composition of diets, fecal analyses can provide indices for nutrient utilization (Hussein and Berger, 1995; Bradshaw et al., 1996). Samples are often analyzed at commercial laboratories using wet chemistry procedures. However, commercial analyses may be expensive and time consuming. The time period between sampling and notification of results may extend beyond the time period in which results would be most beneficial for decisions involving nutrient management. Aside from the continuous cost and time spent waiting for results, fecal samples are susceptible to continued degradation if not properly stored. Therefore, quick analysis of fecal components is important for the nutritional management of cattle.

The use of near infrared spectroscopy in animal agriculture has been used for over 20 years (Marten et al., 1985), but research has recently studied its possible application in on-site testing of animal feedstuffs (Perez-Marin et al., 2004; Berzaghi et al., 2005). However, the use of a bulky and heavy near infrared spectrophotometer (NIRS) on-site at a commercial feedlot would require accommodations such as laboratory space and labor spent transporting samples to the laboratory. Portable NIRS technology is currently available that can perform analyses without these accommodations (Berzaghi et al., 2005).

Currently, there has been no report using NIRS analysis of unprocessed cattle feces in real-time. We hypothesize that accurate fecal analyses can be obtained with a portable NIRS. Therefore, the objective of this experiment was to evaluate a chute-side portable NIRS analysis of nutrients from fecal samples from Holstein cattle in a feedlot setting.

Materials and Methods

Animals, Facilities, and Diet. Procedures were approved by the University of Arizona Institutional Animal and Care Use Committee. Forty-four growing Holstein cattle (42 steers and 2 freemartin heifers; 219 ± 37.2 kg) housed at the University of Arizona feedlot were randomly allotted into 6 pens (8 to 9 cattle/pen). Pens were assigned 1 of 2 diets: 86% or 90% concentrate (DM basis; Table 1; 3 pens/diet). Animals were provided free access to water and adequate shade. Cattle were previously on a growing diet, so diet acclimation was not necessary. Cattle were fed respective diets for 91 days. Initial and final unshrunk BW were collected, with respective ADG calculated.

Collections. On d 0, 28, 56, and 91, fecal samples were collected. Diet samples were obtained on the last 3 collection dates. Feces were collected by running cattle through a squeeze chute and either collecting identified piles on the ground or by rectal retrieval. Feces contaminated with dirt were not sampled. All samples were placed in 13 x 19 cm plastic bags (Nasco; Whirl-Pak; Modesto, CA). After all samples were collected for that day, the outside of the bags were cleaned with running water at ambient temperature to avoid contamination of the NIRS probe.

Sample Analysis. Samples were scanned within 2 h after collection using an ASD Field Spec NIRS unit (Boulder, CO). Spectra were collected under ambient conditions using a contact probe upon each sample bag. Samples containing small amounts of feces (< 13 g wet basis) were rejected due to the inability of the NIRS to read samples that could not produce a scanning area of 25 cm^2 with a depth of 0.67 cm.

Table 1. Dietary ingredient and chemical composition of experimental diets (DM basis)

	Diet	
Item	86%	90%
Ingredient, %		
Corn	72.5	76.5
Alfalfa hay	13.5	9.5
Molasses	5.2	5.2
Fat	4.4	4.4
Mineral mix[1]	2.2	2.2
Urea	1.2	1.2
Rumensin premix[2]	1.0	1.0
Chemical composition, %		
DM	83.7	83.9
CP	16.7	15.6
NDF	13.6	14.2
ADF	8.5	8.7
Starch	36.0	36.5

[1]Composition (% mix DM): Limestone (46), Ground corn (20), Salt (20.2), Potassium Cl(7.8), Ammonium sulfate (6.5), Magnesium oxide (3.4), Dicalcium P (1), Zinc sulfate (0.83), Vitamin E (0.54), Manganese sulfate (0.45), Vitamin A (0.27), Copper sulfate (0.15), Iron sulfate (0.13), Selenium (0.12), Calcium iodate (0.003) and Cobalt carbonate (0.002).
[2]Mixed to provide 300 $mg \cdot animal^{-1} \cdot d^{-1}$ of Rumensin 90 and 100 $mg \cdot animal^{-1} \cdot d^{-1}$ of Tylan 40 (Elanco Animal Health, Greenfield, IN).

For wet laboratory analysis, samples were dried at 60° C and ground in a Wiley mill to pass through a 1 mm screen. Ground samples were analyzed for all or part of the following: ADF and NDF using an Ankom system (Macedon, NY) and CP using a nitrogen analyzer (TC400; Leco Corp.; St. Joseph, MO). Briefly, starch was analyzed by gelatinization, followed by amyloglucosidase digestion, and finished with measurement of glucose concentration (Zinn, 1990, with modifications per R.A. Zinn, personal communication).

Statistics. Growth performance and diet and fecal data from wet chemistry were analyzed as a completely random design using the Proc Mixed procedure in SAS (Cary, NC). Pen was considered the experimental unit.

Spectrophotometer calibrations were developed using samples collected on d 0 and 28 with log 1/R spectra in the 1,100 to 2,400 nm range. Partial least squares (PLS) regression in SAS was used to develop calibrations. Cross validation was employed to avoid over-fitting. Simple regression was used to evaluate the relationship between observed and predicted constituent values. Samples from d 56 and 91 were not used for calibration.

Results

Sample number, mean, SD, and data ranges of the calibration set (d 0 and 28) are shown in Table 2. The range and SD for starch concentrations were numerically highest (31.9 and 8.86% respectively) with NDF having the second highest parameters. Not all calibration samples yielded enough DM for all constituent analysis.

Table 2. Chemical composition of fecal samples from Holstein cattle used as the initial calibration set.[1]

Item	Sample #	Mean, %	SD, %	Range, %
DM	57	22.1	2.77	15.6 – 27.4
CP[2]	56	20.7	3.34	15.1 – 30.2
NDF	56	33.5	6.64	21.5 – 48.1
ADF	56	20.9	4.82	10.7 – 34.3
Starch	56	15.5	8.86	1.2 – 33.1

[1]Samples are from d 0 of trial when animals (n = 44) were receiving same diet and d 28 when animals were receiving either an 86 or 90% concentrate diet. Calibration set used for prediction of fecal composition by a portable NIRS.
[2]CP, ADF, NDF and starch reported on a DM basis.

Although not pertinent to the objective of this project, growth performance of the cattle and statistical analysis of wet chemistry is provided (Table 3) to verify differences between the 86 and 90% concentrate diets. Growth performance characteristics were statistically equivalent ($P > 0.10$) between the 2 diets. However, chemical analysis of feces collected on all 4 dates reveal differences between the diets. Dry matter and CP were not different ($P > 0.10$), but starch tended ($P < 0.10$) to be higher in feces sampled from cattle receiving the 86% concentrate diet. In contrast, NDF tended ($P < 0.10$) to be higher and ADF was higher ($P < 0.05$) in feces from cattle receiving the 90% concentrate diet.

Calibration values for the NIRS were statistically significant ($P < 0.01$; Table 4) for all components. Calibration regression values were fair to good for fecal CP ($R^2 = 0.89$), DM ($R^2 = 0.69$) and NDF ($R^2 = 0.62$) but not predictive for ADF ($R^2 = 0.34$) and starch ($R^2 = 0.31$). Regression values for validation of the calibration set were lower. All regression validation values were both not predictive ($R^2 < 0.35$; Table 4) and statistically invalid ($P > 0.07$).

Discussion

Recent research has reported the use of NIRS technology in determination of unprocessed samples (i.e. "as is" vs. dried and ground), including dairy silage (Berzaghi et al., 2005). Perez-Marin et al. (2004) reported

workable predictive regressions (R^2 > 0.84) on various feedstuffs, including ruminant pellets and companion animal feedstuffs. To further justify calibrating to unprocessed samples, these various feedstuffs were also dried and ground to 2 different particle sizes and reanalyzed by the NIRS. The authors reported some constituents to have higher predictive regression values when left unprocessed when compared to the further processed counterparts. Altogether, it was reported that regardless of processing, predictive analyses of all 3 sample forms were accurate (Perez-Marin et al., 2004). This suggests that processing samples prior to NIRS analysis is not necessary, saving cost and time that would be spent to have samples processed. In a feedlot setting, this would result in quicker analysis of fecal and diet components and improved nutritional management.

Research involving NIRS analysis of feces of feedlot cattle is minimal or focused on manure management involving processed samples contaminated with soil and bedding (Malley et al., 2005). However, calibration of any spectrophotometer, regardless of organic material involved, is based upon 4 major factors: the number of samples in the calibration set, the range within specific component values, the range of the constituent SD, and the accuracy and precision of the wet chemistry. Sample numbers used in calibration of past research that analyzed feedstuffs have varied from over 600 to less than 200 (Perez-Marin et al., 2004). The current study had only 58 samples used for calibration, which may have played part in the failed validation regression values. Calibration sets can be strengthened as wet chemistry results for validation and future samples are included. Adding more samples has the potential to create more robust regression values for calibration and validation, making NIRS predictive values more accurate (Reich, 2005).

Although calibration number is important, the other factors should also be evaluated. After a calibration set consisting of 111 feedstuff samples, Xiccato et al. (2003) considered their validation regression values for some of the constituents to be low (R^2 < 0.70). While disregarding the importance of calibration sample numbers, Perez-Marin et al. (2004) attributed the low values of Xiccato et al. (2003) to the limited range and narrow SD of the individual constituents. Range and SD values for fecal components in the current study could also be considered limiting, especially when compared to the diverse calibration samples used by others (Perez-Marin et al., 2004). Reich (2005) further expressed the importance for any calibration set to contain samples that expressed the wide range and variability that was to be expected in further samples. The use of only 2 diets in calibrating the NIRS in the current study may have led to the limited range and SD of fecal constituents.

Based on the previous discussion, it is counter-intuitive to see a lower R^2 value for starch, which is the component with the widest range and SD as compared to the other fecal constituents. This may be explained by the nature of NIRS calibration. Predictive values from NIRS analysis are derived from sample spectra calibrated to wet chemistry analysis of the same sample (Reich, 2005). Essentially, the NIRS predictive capability is only as accurate as the chemistry that the calibration is based. In the current study, starch assay values were allowed with minimal variation (sample CV values were < 0.10), but a more confident regression value may have been obtained if sample CV values were kept to less than 0.05 (R.A. Zinn, personal communication). Researchers have reported accurate results with this particular starch assay (Zinn, 1990; Zinn et al. 2007), suggesting our NIRS-predicted starch variability may be overcome with a greater number of calibration samples and a lower CV value tolerance for sample wet chemistry.

Although validation of predicted NIRS values in the current study is not as accurate as has been reported by others (Xiccato et al., 2003; Perez-Marin et al., 2004), it should be noted that the potential for NIRS analysis on fresh cattle feces is still viable. Calibration regressions in the current study were statistically significant, suggesting that NIRS analysis of constituents of unprocessed bovine feces is possible, and calculated regression formulas can be strengthened. The failed validation regressions merely reinforce the need for calibrating NIRS spectra according to the 4 factors described above. Samples for all collection dates in the current study were analyzed with wet chemistry, allowing for inclusion into the calibration set and creating a more robust regression potential in predicting fecal constituents.

Implications

The results from the current study imply that on-site NIRS-predicted values of fecal constituents from Holstein cattle are possible. Furthermore, a portable NIRS may be used for quick on-site feedlot fecal analysis without sample processing. Faster determination of these parameters from a portable NIRS may help improve the nutritional and health management of cattle in commercial feedlots by decreasing time spent in performing wet chemistry analysis and quickly and accurately predicting digestibility of feedlot diets. Although NIRS prediction of fecal composition is possible, future research utilizing a larger calibration data set is needed to verify the predictive accuracy of on-site NIRS analysis of fecal composition.

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Table 3. Growth performance of Holstein cattle and wet chemistry of fecal samples for 2 diets.[1]

	Diet			
Item	86	90	SEM	*P* value
Growth Performance				
Initial BW, kg	223.2	215.5	19.92	0.80
Final BW, kg	335.8	328.0	17.43	0.77
ADG, kg/d	1.78	1.79	0.084	0.98
Fecal Composition, %[2]				
DM	23.1	21.9	0.54	0.18
CP	17.6	19.1	0.53	0.12
NDF	31.9	36.0	1.13	0.06
ADF	21.3	25.2	0.73	0.02
Starch	16.8	13.5	1.08	0.09

[1]Diets consisted of either 86 or 90 % concentrate, DM basis. Pen (n = 6) was the experimental unit.

[2]Components other than DM expressed on DM basis. Fecal samples (n = 116) from d 28, 56, and 91 were analyzed.

Table 4. Predictive NIRS regression values of fecal constituents from Holstein cattle.[1]

	Calibration Set		Validation set	
Item:	R^2	*P* value	R^2	*P* value
DM	0.69	0.0001	0.31	NS[2]
CP	0.89	0.0001	0.15	NS
NDF	0.62	0.0001	0.13	NS
ADF	0.33	0.0002	0.004	NS
Starch	0.31	0.003	0.21	NS

[1]Cattle (n = 44) fed either an 86 or 90% concentrate diet. Fecal samples for calibration (n = 58) and validation (n = 7) sets collected on d 0 and 28 after incorporation of diets.

[2]NS = Not statistically relevant.

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EFFECTS OF IMPLANT TYPE AND PROTEIN SOURCE ON GROWTH OF STEERS GRAZING SUMMER PASTURE

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ABSTRACT: Implants consistently increase performance 10 to 15% in grazing cattle and supplemental protein is necessary in late summer when rumen ammonia-N is first limiting. Therefore a split-plot design was used to investigate the effects of implant type and protein source on performance of steers grazing summer pasture. Crossbred steers (n = 392; BW = 212 ± 24 kg) were ranked by weight and randomly assigned to 1 of 15 pastures and then randomly allotted to implant treatment, within pasture. Supplement treatments were control (no supplement), cottonseed meal based supplement (CSM; 33% CP), and dried distillers grains based supplement (DDGS; 33% CP). Implant treatments were control (no implant), Ralgro® and Component TE-G®. The grazing season was 126 d with supplementation beginning in late July. Steers were group fed, within pasture, each wk on Monday, Wednesday and Friday at a rate of 0.95 kg·steer^{-1}·feeding^{-1}. Data were analyzed using PROC MIXED procedure of SAS where supplement treatment served as whole-plot and implant treatment served as sub-plot. The interactions of implant by supplement and treatment by year were tested ($P > 0.05$), as well as orthoganol contrasts. Protein supplementation increased BW and ADG by 12 and 0.16 kg, respectively ($P < 0.05$). Rate of BW gain was also improved by DDGS (0.05 kg; $P < 0.05$) as compared with CSM. This difference indicates that steers were able to utilize increased energy from DDGS, resulting in 2.39 vs. 3.49 kg of supplement per kg of additional ADG for DDGS and CSM, respectively. Implantation increased final BW ($P = 0.02$) and improved ADG 8.1% ($P < 0.05$) during the first ~95 d, but implant type had no influence on rate of BW gain during this period. However, Component TE-G® increased ADG (0.08 kg; $P < 0.05$) during the final ~31 d of the grazing season as compared with control and Ralgro®. Supplementation efficiency can be improved when including DDGS in protein supplements for steers grazing summer pasture. Additionally, Component TE-G® implants have a slower payout rate than Ralgro®, continuing to increase ADG over non implanted steers for at least 126 d.

Key W ords: implants, protein supplementation, grazing steers

Introduction

Stocker cattle are a major component of the beef industry in the southern Great Plains. Within this industry, there are several technologies available to operators to improve efficiency and increase profits. Some of these management strategies include, but are not limited to, implants, protein supplementation, and the inclusion of ionophores in mineral or feed supplements. Implants are one of the most profitable technologies available. Ralgro®, an estrogenic implant (zeranol), is frequently used in the stocker industry. Kuhl (1997) reported that body weight gains of 12 kg were seen when Ralgro® was used, but that it is only efficacious for approximately 100 d. Combination implants have been more highly promoted in recent years because of a potentially longer payout period. One of these implants is Component TE-G®, a trenbolone acetate/estradiol implant for grazing cattle. In addition to implants, another commonly used management tool is protein supplementation during late summer, when forage maturity is increasing and quality is decreasing. During this period of time rumen ammonia-N is first-limiting, hindering forage intake and digestibility (McCollum and Horn, 1990). The "Oklahoma Gold" program developed at Oklahoma State University was established on the basis that providing 0.454 kg of a high protein supplement (38-40% CP) 3 d/wk will improve performance of grazing steers by 0.20 kg/d. This program was established using oilseed meals as a base commodity. In recent years these oilseed meals have increased in price relative to alternative protein sources. The hypothesis is that Component TE-G® will have a longer payout period and that dried distillers grains with solubles can be an effective replacement for cottonseed meal as a protein source for summer stocker steers grazing warm season grasses. Therefore, the objectives of this study were to evaluate the effects of implant type and protein source on performance of steers grazing summer pasture.

Materials and Methods

Study site, Vegetation and Stocking Rate. This study was conducted during 2 consecutive yr at the Oklahoma State University Crosstimbers-Bluestem Stocker Range, 11 km southwest of Stillwater from late Spring until early Fall. Each year, 12 pastures (106 ha) consisting primarily of introduced Old World Bluestem (**OWB;** *Bothriochloa ischaemum*) and 3 tallgrass native range pastures (**NR**; 97 ha) consisting primarily of big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*) and Indiangrass (*Sorghastrum nutans*) were used to evaluate steer performance. In May of each year Nitrogen fertilizer was applied at a rate of 90 kg ha^{-1} to the OWB pastures.

Introduced OWB pastures represented a more homogeneous grazing site in contrast to the NR pastures. Accordingly, it has been suggested that an improvement in forage available for use is increased by 25% for pastures containing introduced forages as opposed to NR pastures

(Redfearn et al., 2008). Therefore, stocking rates were adjusted accordingly. Each year, OWB pastures (8.80 ± 2.22 ha) were grazed at a stocking density of 311 kg·ha^{-1} resulting in 0.25 ± 0.02 steers·ha^{-1} (165 steers). This stocking rate was a conservative estimate to ensure forage availability was not limiting during the grazing period based from previous research at the Crosstimbers-Bluestem Stocker Range (Ackerman et al., 2001). Native pastures (32 ± 14 ha) were also lightly stocked at a rate of 0.15 ± 0.02 steers·ha^{-1} for yr 1 (35 steers) and 0.18 ± 0.04 steers·ha^{-1} for yr 2 (42 steers). Prior to green-up in yr 2, previous yr litter was removed by an unintentional range fire, so stocking density was increased in an effort to try and control yr to yr variation in forage availability and quality. Multiple sources of water were present, including free flowing streams, ponds and improved water sources so that livestock had ad libitum access to water.

Hand plucked forage samples, from each pasture, were collected in triplicate, every other week throughout the supplementation phase of the study to determine forage quality (Table 1). Dry matter (oven drying at 55°C) was determined immediately following collection and after drying, samples were ground through a Wiley Mill grinder using a 2 mm screen and stored for future proximate analysis.

Animals. All experimental protocols were approved by the Oklahoma State University Animal Care and Use Committee. In both yrs steers arrived in late spring. In yr 1, crossbred stocker steers (n = 200) consisting of primarily Bos-Indicus breeds arrived from Arizona and in yr 2, crossbred stocker steers (n = 207), consisting of primarily British breeds with modest Bos-Indicus influence, arrived from Hawaii, via California, on two separate shipment dates. Upon arrival, cattle were dewormed with Ivermax® according to label directions (5 mg ivermectin/ml; American Livestock Supply, Inc.), individually weighed and identified with a treatment tag. Steers were provided a brief acclimation period at which time therapeutic treatments were administered whenever necessary for morbidity. In yr 2, due to a late arrival, load 2 was metaphylactically treated with Micotil® (7 ml/hd; Elanco Animal Health). In two yrs, only 2 steers were excluded due to mortality.

Steers were stratified by arrival weight and randomly allotted to one of three implant treatments. Treatment groups were then randomly assigned to 1 of 15 pastures. Steers were assigned to treatments so that initial weight was uniform across all three implant treatments and across all 15 pastures. Each yr, 196 steers were used to evaluate performance while the extra steers were equally dispersed across NR pastures and included in stocking rate calculations. On d 0, steers were removed from access to feed and water overnight (14 h) and on d 1 (May 29, 2008 and June 6, 2009) steers were weighed, palpated for implant presence, tagged by treatment and implanted according to treatment. Average initial BW remained uniform across treatments and was similar across years (212 ± 24 kg; P = 0.97).

Pastures were randomly assigned to one of three supplement treatments (Table 2): 1) control (no supplement); 2) cottonseed meal based supplement (**CSM**; 33% CP); and 3) dried distillers grains with solubles based supplement (**DDGS**; 33% CP). Supplements were formulated to provide 125 mg·steer^{-1}·d^{-1} of monensin. Supplements were were group fed 3 d/wk and delivered as 0.48 cm pellets in bunks at a rate of 0.95 kg·steer^{-1}·feeding^{-1} (DM basis). Beginning in late July, supplements were fed for 70 and 84 d for yr 1 and 2, respectively. Implant treatments consisted of: 1) Control (no implant); 2) Ralgro® (**R**; 36 mg zeranol; Schering-Plough Animal Health Corp., Union, NJ 07083); and 3) Component TE-G®, with Tylan (**TEG**; 40 mg trenbolone acetate (**TBA**), 8 mg estradiol USP, 29 mg tylosin tartrate; Ivy Animal Health, Overaland Park, KS 66214). All implants were administered on d 1 (same technician each year), in the middle third of the ear using the standard implanting device for the respective product. Prior to implantation, the ear and the implant-gun needle were disinfected and after implantation, each ear was palpated to verify proper implant placement. Implant sites were evaluated via palpation of the ears at ~d 95 and d 126 and scored as follows: 1 = implant present, normal; 2 = implant present, abnormal; 3 = no implant present, normal; 4 = no implant present, abnormal.

Cattle were maintained in treatment groups for a grazing period of 126 d and individual shrunk BW were obtained at the beginning of the supplementation period (~d 49), the mid-point (~d 95), and the conclusion of the experiment (d 126). Cattle were observed regularly throughout the study for morbidity.

Lab Analysis. Forage and supplement samples were analyzed for lab DM (oven drying at 105°C), NDF and ADF (Ankom Tech Corp, Fairport, NY), Ash (combusted 6-h in a muffle furnace at 500°C), CP (% N x 6.25; Truspec-CN LECO Corporation, St. Joseph, MI 49085). Supplement samples were also sent to an independent laboratory (Dairy One; Ithica, NY) and subjected to analysis of NDIN, ADIN, ether extract (**EE**), and lignin. Additionally, in vitro true digestibility (**IVTD$_{DM}$**) was determined using the DAISY^{II} incubator (Ankom Tech Corp, Fairport, NY). These data were used to calculate TDN according to Weiss et al. (1992).

Statistical Analysis. Effects of type of implant and protein source on growth performance of steers were analyzed as a split-plot design using MIXED procedures of SAS (SAS Inc., Cary, NC) with $\alpha = 0.05$. Whole-plot was supplement treatment (pasture = experimental unit) and sub-plot was implant treatment (steer = experimental unit). Random variables included source, pasture and source*pasture type*supplement within pasture. Source of cattle was used to control year and multiple shipment dates in year 2. While pasture type was used to manage influences of forage type and quality. Orthogonal contrasts were used to determine implant, implant type, supplement and supplement type effects on performance. Effects of implant, supplement, and the interaction on ear score were analyzed using GENMOD. Finding no effects on ear score due to supplement or its interaction with implant, differences due to implant were determined using FREQ procedures in SAS (SAS Inc., Cary, NC) and Chi Square calculations to separate mean percent differences. The tables included implant by ear score at ~d 91 and d 126.

Results and Discussion

The implant by supplement interaction for BW or ADG was not significant ($P > 0.05$), nor was protein source by forage type ($P > 0.05$) and therefore main effect means are presented (Table 3 and 4).

Supplementation. Protein supplementation increased BW and ADG by 12 and 0.16 kg, respectively ($P < 0.05$). This increase in BW gain from small amounts of a monensin containing protein supplement during summer grazing is consistent with summarized data (Lalman, 2008). This summary reports a rate of BW gain of 0.17 ± 0.04 kg/d (7 studies). This additional gain validates the adequacy of forage available for animal growth and that rumen ammonia-N is a limiting factor affecting energy intake and its utilization (McCollum and Horn, 1990).

When comparing sources of protein, rate of BW gain was improved by DDGS (0.05 kg; $P < 0.05$) as compared with CSM. This resulted in a supplement conversion of 2.39 vs. 3.49 kg of supplement per kg of additional ADG for DDGS and CSM, respectively. When compared with summarized data (Lalman, 2008), observed supplement conversion for CSM is below average (2.8 ± 0.08), but within one standard deviation of the mean, whereas supplement conversion for DDGS is above average. This amount of protein (0.14 $kg \cdot steer^{-1} \cdot d^{-1}$) is the minimum allowance suggested by Lalman (2008) for an expected increase in growth performance and could explain the decrease in supplement conversion of CSM. Another potential reason may be the inadequacy of digestible energy from CSM (69.2 vs. 86.3% TDN) to support equivalent microbial growth and protein utilization as DDGS. However, energy provided by forage may actually be less for DDGS supplemented steers than steers provided CSM due to differences in forage DMI. It has been shown that supplementing DDGS to weaned calves consuming low quality forage has a negative influence on hay DMI of 0.32 kg for every 1 kg of DDGS supplemented (Winterholler et al., 2009a). In the current study, DDGS were supplied at 0.64 kg 3 d/wk resulting in an estimated decrease in forage DMI of 0.20 kg each time supplemented. Moreover, Morris et al. (2006) showed that when supplementing DDGS to summer stocker steers, forage DMI decreased linearly with increasing levels of DDGS, but ADG also increased linearly. This suggests that the energy provided by DDGS can overcome the loss of energy intake from a small decrease in forage intake.

The energy supplied by DDGS is in the form of fat (9.95%) and MacDonald et al. (2006) demonstrated that the inclusion of oil at the same ether extract concentration as DDGS did not increase ADG similarly. Therefore, it was suggested that DDGS may potentially fulfill a deficiency of metabolizable protein (MP; MacDonald et al., 2006). It has been suggested by McCollum and Horn (1990) that providing escape protein to cattle consuming low quality forages may potentially reduce the amount of protein needed. Winterholler et al. (2009b) demonstrated that CP of CSM is 73.5% ruminally degradable in cattle consuming low quality roughage, resulting in minimal escape protein. Whereas, tabular values from NRC (2000) show that DDGS is only 45.1% ruminally degradable. However, when urea was added to DDGS in supplements deficient in rumen degradable protein there was no increase in performance of heifers consuming grass hay (Stalker et al., 2004). Therefore, this study may provide evidence that combining a protein source high in rumen undegradable protein with a highly rumen degradable plant protein source can improve ADG in summer stocker steers.

Implantation. Final BW was increased when steers were implanted with TEG as compared with control ($P < 0.05$). Change in BW was increased due to implantation by 5 and 11 kg for R and TEG, respectively ($P < 0.05$). This gain in BW from R is less than the average improvement of 12 kg reported by Kuhl (1997). However, there is no published data reporting an average increase in BW gain from TEG during the stocker phase on growing steers. Implantation increased ADG 7.0% (0.86 vs. 0.92 kg/d; $P < 0.05$) during the entire grazing period (126 d). This improvement is slightly lower than the range suggested by Reuter et al. (2008) of 0.08 to 0.12 kg ADG. Differences in type of cattle and year of forage production may cause these differences. Furthermore, type of implant influenced ADG ($P < 0.05$). When compared to R, TEG positively influenced rate of BW gain by 0.04 kg for the entire grazing period. But more importantly, ADG was increased by 0.08 kg during the final ~31 d, while R was similar to control (0.66 and 0.67 kg/d, respectively). This may be due to a slower payout rate of TEG as suggested by ear palpation results presented in Table 5. There was an increased presence of implants in cattle administered TEG at ~95 and 126 d ($\chi^2 < 0.01$) as compared with R implanted steers. There was a lower presence of implants at d 126 than at d ~95 for TEG (76 vs 34% present) suggesting that the payout period may continue past d 126 for some steers. In contrast, the lack of R implants, upon palpation, at d ~95 explains why there was a difference in ADG between implant type during the final ~31 d of the grazing season. This decrease in payout rate is potentially due to the implant carrier. The carrier utilized in TEG is cholesterol as compared with the carrier lactose for R (personal communication with Dr. Robert Botts, Elanco Animal Health). Implants with a lactose matrix (carrier) have been deemed "short-acting" vs "long-acting" implants with a cholesterol carrier (Istasse et al., 1988).

Implanting site defects occurred at a rate of 5.3 and 10% at d ~95 for R and TEG, respectively. However, the final palpation data demonstrates a very low detection rate of defects which is not different than non-implanted steers ($P > 0.05$). Anderson and Botts (2002) reported that implant site defects in feedlot cattle range from 6 to 10%.

Implications

Utilizing dried distillers grains with solubles as the primary ingredient of a monensin containing protein supplement in combination with a highly degradable plant protein source can increase growth and improve supplement conversion of steers grazing summer warm-season grasses. In addition, Ralgro® and Component TE-G® implants cost $1.12 and $1.34, respectively (Valley Vet Supply) and return 5 and 11 kg to calves grazing summer warm-season grasses for 126 days. This results in a cost of gain of $0.22

and $0.12 per kilogram of body weight gain for Ralgro® and Component TE-G®, respectively. These low costs for improvements in rate of body weight gain are complimentary to those captured by providing small amounts of a monensin containing protein supplement.

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Table 1. Composition of old world bluestem (OWB) and tallgrass native range (NR) forages during summer supplementation from late July until early October during 2008 and 2009

							P-Value[3]		
	Wk2	Wk4	Wk6	Wk8	Wk10	Wk12	Ptype[4]	Wk	Ptype* Wk
Chemical Component, %DM									
DM									
OWB	42.6^{a1}	38.9^{b}	39.2^{b}	41.7^{a}	48.3^{c}	46.0^{c}	0.02	0.01	0.09
NR	48.4^{a2}	43.3^{b}	40.0^{c}	43.0^{bc}	47.9^{a}	47.8^{ab}			
OM									
OWB	94.5^{a}	94.5^{a}	94.5^{a}	94.3^{ab1}	94.5^{a1}	93.7^{c}	0.01	0.01	0.01
NR	94.1^{a}	94.6^{ab}	94.7^{b2}	94.9^{b2}	95.4^{c2}	94.1^{a}			
CP									
OWB	8.2^{b1}	10.1^{c1}	8.7^{bc1}	9.2^{bc1}	7.7^{ab1}	6.8^{a1}	0.01	0.01	0.70
NR	5.2^{2}	6.3^{2}	5.4^{2}	5.5^{2}	5.0^{2}	4.5^{2}			
NDF									
OWB	73.2^{a1}	73.3^{a}	74.3^{b}	74.4^{b}	75.2^{c}	77.7^{d1}	0.32	0.01	0.01
NR	71.5^{a2}	72.2^{a}	74.9^{b}	75.2^{b}	76.5^{c}	75.2^{bc2}			
ADF									
OWB	38.4^{a}	38.9^{a}	40.0^{b1}	40.5^{b}	40.8^{b1}	44.7^{c}	0.03	0.01	0.10
NR	39.4^{a}	39.6^{a}	42.6^{b2}	42.3^{b}	43.9^{b2}	46.4^{c}			

[a,b,c,d] Means within a row lacking a common superscript differ ($P < 0.05$)
[1,2]Means within a column lacking a common superscript differ ($P < 0.05$)
[3]Probability of a greater F-statistic
[4]Ptype = forage type of pastures (OWB or NR)

Table 2. Ingredients and chemical composition of cottonseed meal (CSM) and dried distillers grains with solubles (DDGS) supplements

	Supplement	
Ingredients, %DM	CSM	DDGS
Cottonseed Meal (44% CP)	55.7	31.49
Dried Distillers Grains w/ Solubles	-	61.11
Wheat Middlings	37.74	-
Cane Molasses (pellet binder)	4.18	4.23
Limestone	2.22	1.86
Dical	-	1.15
Rumensin 80	0.16	0.16

	Year		Year	
Chemical Composition, %DM	2008	2009	2008	2009
CP	31.8	33.90	34.30	34.60
Fat	3.20	3.90	9.90	10.00
TDN[a]	69.40	69.00	87.00	85.60
Ca	1.08	1.44	0.94	1.04
P	1.04	1.16	1.12	1.25
S	0.34	0.45	0.62	0.76

[a]Calculated using a multiple-component model including CP, lignin, ash, ether extract, ADIN, NDIN, NDF, IVNDFD (Weiss, 1992)

Table 3. Effects of protein source, cottonseed meal (CSM) or dried distillers grains with solubles (DDGS) on performance of steers grazing summer warm-season grass pastures during 2008 and 2009

	Treatments				*P*-value[1]	Contrasts[2]	
Item	Control	CSM	DDGS	SEM	Trt[3]	C_1	C_2
Steers, No.	131	130	131				
BW, kg							
Initial	252	252	254	4.59	0.83	0.85	0.56
Final	317[a]	325[b]	331[b]	2.61	0.01	0.01	0.12
BW Gain, kg	64[a]	74[b]	78[c]	3.61	0.01	0.01	0.02
ADG, kg							
D ~49 to ~95	0.95[a]	1.10[b]	1.14[b]	0.08	0.01	0.01	0.25
D ~95 to 126	0.61[a]	0.72[b]	0.73[b]	0.11	0.04	0.01	0.83
Overall	0.81[a]	0.93[b]	0.98[c]	0.01	0.01	0.01	0.02

[1] Probability of a greater F-statistic
[2] Orthoganol contrasts: C_1 = no supplement vs Supplementation; C_2 = Cottonseed meal (CSM) vs Dried distillers grains with solubles (DDGS)
[3]Trt = Treatment
[a,b,c] Means within a row lacking a common superscript differ ($P < 0.05$)

Table 4. Effects of the type of single dose, moderate term implant, Ralgro® (R) or Component TE-G® (TEG), on performance of steers grazing summer warm-season grass pastures during 2008 and 2009

	Treatments				*P*-value[1]	Contrasts[2]	
Item	Control	R	TEG	SEM	Trt[3]	C_1	C_2
Steers, No.	130	132	130				
BW, kg							
Initial	211	211	210	3.14	0.97	0.98	0.81
Final	319[a]	325[ab]	329[b]	2.62	0.02	0.01	0.17
BW Gain, kg	108[a]	113[b]	119[c]	3.01	0.01	0.01	0.01
ADG, kg							
D 0 to ~95	0.93[a]	0.99[b]	1.02[b]	0.07	0.01	0.01	0.13
D ~95 to 126	0.67[a]	0.66[a]	0.74[b]	0.12	0.02	0.34	0.01
Overall	0.86[a]	0.90[b]	0.94[c]	0.02	0.01	0.01	0.01

[1] Probability of a greater F-statistic
[2] Orthogonal contrasts: C_1 = Control (no implant) vs Implant; C_2 = Ralgro® vs Component TE-G®
[3]Trt = Treatment
[a,b,c] Means within a row lacking a common superscript differ ($P < 0.05$)

Table 5.Ear palpation score ~95 d and 126 d post implantation with Ralgro® (R) or Component TE-G® (TEG)

	Treatments			*P*-value[1]	$P>\chi^2$
Item	Control	R	TEG	Implant	Trt[2]
Steers, No.	130	132	130		
Ear Score[3]					
D ~95, % (No.)					
Abnormal	0.00[a]	5.30 (7)[b]	10.00 (13)[c]	0.01	0.01
Implant present	0.00[a]	3.79 (5)[b]	76.15 (99)[c]	0.01	0.01
D 126, % (No.)					
Abnormal	0.00[a]	3.85 (5)	3.13 (4)	0.53	0.10
Implant present	0.00[a]	0.77 (1)[b]	34.38 (44)[c]	0.03	0.01

[a,b]Means in the same row without a common superscript are different ($P < 0.05$)
[1] Probability of a greater F-statistic
[2]Trt = Implant treatment
[3]1 = implant present, normal; 2 = implant present, abnormal; 3 = no implant present, normal; 4 = no implant present, abnormal

BEHAVIOR

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RELATIONSHIP OF TEMPERAMENT AT CALVING AND DISTRIBUTION OF BEEF COWS GRAZING FOOTHILL RANGELAND

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ABSTRACT: Objective of this study was to determine if docility score measured at calving was related to measures of cattle grazing distribution in foothill rangeland of northern Montana. We hypothesized that cows with aggressive temperaments would travel farther horizontally and vertically from water and use steeper slopes than docile cows. A herd of Hereford and Tarentaise crossed cows (n = 186) and a herd of Angus, Charolais, Hereford, Piedmontese, Salers, and Tarentaise crossed cows (n = 191) were observed at calving and assigned a temperament score (1 = calm and 6 = dangerous and extremely aggressive) for 5 years. Both herds were also visually observed during grazing and their locations were recorded in multiple pastures with rugged topography for 5 years. Only cows that had 2 or more calves in their lifetime were included in the analyses. Mean temperament, number of calves and breed were used to explain differences in the average recorded terrain use with a mixed model analysis. Temperament at calving was not related to horizontal or vertical distance traveled to water and slope use in either herd. For the Hereford and Tarentaise crossed cows, breed and number of calves affected both horizontal and vertical distance traveled to water ($P < 0.05$). Cows with more Tarentaise breeding traveled farther than cows with predominantly Hereford breeding. Tarentaise cows traveled 58 ± 2 m vertically from water while Hereford cows traveled 50 ±2 m. Cows with 3 or more calves during their lifetime (56 ± 2 m) traveled farther ($P < 0.01$) vertically from water than cows with only 2 calves (48 ± 2 m). For the other herd, vertical distance traveled to water was affected by the number calves ($P = 0.01$) with cows with 4 or more calves traveling farther than cows with 2 or 3 calves. We rejected our hypothesis and concluded that docility at calving was not related to terrain use during grazing.

Key Words: Behavior, Breed, Docility

Introduction

Livestock distribution is a critical issue for grazing management, especially in mountainous rangelands and in production systems involving areas with extensive pastures. Concentrated grazing near riparian areas and other critical habitat can result in resource degradation (DelCurto et al. 2005). Bailey et al. (2008) found that selection has the potential to modify cattle grazing patterns. However, consequences of selection for grazing patterns on other traits must be considered. Cow weights, body conditions scores, and calf weaning weights were not related to terrain use in studies of Bailey et al. (2001) and VanWagoner et al. (2006). Performance of cows that use high and steep terrain (hill climbers) is similar to cows that use gentle slopes near water (bottom dwellers). Effects of selection for terrain use on other behavioral traits such as temperament are also a concern. The objective of this study was to determine if docility score measured at calving was related to measures of cattle grazing distribution in foothill rangeland. We hypothesized that hill climbers would have a more aggressive temperament than bottom dwellers.

Materials and Methods

All animal handing and experimental procedures were in accordance with guidelines set by the Montana State University's Agricultural Animal Care and Use Committee.

Study Site. Two locations were used, the Northern Agricultural Research Center **(NARC)** located 10 km south west of Havre, Montana and the Thackeray Ranch located in the Bear's Paw Mountains approximately 25km south of Havre. During the winter and spring, cows were kept at NARC and fed hay. Cows calved during March and April at NARC. In mid-May, cows were moved to the Thackeray Ranch where they grazed from May to December.

Thackeray Ranch is composed of foothill rangeland. Slopes within 4 study pastures vary from 0 to 107%. Average slope in the study pastures vary from 28 to 34%. Vertical relief in study pastures vary from 107 to 214 m. Average distance to water in study pastures vary from 429 to 504 m.

Lower elevations of study pastures were dominated by Kentucky bluegrass (Poa pratensis L.), and steep slopes (> 20º) were dominated by rough fescue (Festuca scabrella Torr.). Kentucky blue grass, rough fescue, bluebunch wheatgrass (Pseudoregnaria spicata [Pursh] A Love), and Idaho fescue (Festuca idahoensis Elmer) were dominant in the majority of areas in each pasture.

Animals. Two herds of cattle were used in the study. One herd was composed of cows with Hereford and Tarentaise breeding (n = 186). Cows were either Hereford or Tarentaise or contained 25, 50, 75% Tarentaise breeding with the remainder being Hereford (Bailey et al., 2001). Cows were 3 to 9 years of age. A second herd (n = 191) were daughters from the first herd (Hereford and Tarentaise

breeding) and were sired by Angus, Charolais, Hereford, Piedmontese, Salers or Tarentaise bulls (**ACHPST herd**).

Measurements. Temperament of cows was categorized at calving on a 1 to 6 scale. Cows that were gentle and calm received a 1, while cows that were extremely aggressive and very dangerous received a 6. Temperament scores (**score**) were assigned by trained observers while calves were weighed and tagged the day after calving. All scores assigned for a cow during the period between 1997 and 2003 were averaged together to provide a representation for an individual cow's temperament at calving.

At the Thackeray Ranch, locations of cows were recorded during the summers from 1997 to 2001 by horseback observers (Bailey et al. 2001). Cows were observed 2 to 4 times per week in 2 pastures during the summer grazing season. Topographic maps of each pasture were subdivided into 1 to 7 ha units based on slope, elevation, aspect and distance to water. Observers were trained to recognize the boundaries of all subunits within each pasture. Two to 4 observers on horseback rode pastures during the early morning (0600 to 0900 hours) and recorded the location of every cow in the pasture. Observers rode close enough to each cow to observe the identification number from a plastic ear tag or a brand on the animal's hip (Thackeray Ranch) or shoulder (Ross Ranch). Observers recorded the pasture unit in which the animal was located. Ideally, scan samples should be instantaneous (Lehner 1979). However, individually identifying and observing 27 to 119 animals instantaneously on extensive foothill rangeland pastures was not feasible. Observers recorded about 87% of the animals in the herd during an observation period.

To describe the terrain use in a pasture, average slope and distance to water (horizontal and vertical) were calculated for each pasture subunit. For each cow, location data collected in a pasture during a grazing season were pooled and used to determine the average slope, horizontal distance to water (HDW) and vertical distance to water (VDW) of observed cow locations in a pasture (Bailey et al. 2001). Least squares means were calculated for each cow for all terrain use data collected from 1997 to 2001.

Statistical Analysis. We used mean temperament, number of calves in a cow's lifetime and breed to explain difference in mean terrain use (HDW, VDW, and slope). Mean temperament score was evaluated as a continuous variable and as a categorical variable with 5 classes (1 to 2, 2 to 3, 3 to 4, 4 to 5, and > 5). For the Hereford and Tarentaise crossed herd, breed was modeled with 5 classes (Hereford, ¼ Hereford ¾ Tarentaise, ½ Hereford ½ Tarentaise, ¼ Hereford ¾ Tarentaise and Tarentaise). For the other herd, breed of dam was included using the 5 classes described above and breed of sire included (Angus, Charolais, Hereford, Piedmontese, Salers, and Tarentaise). Individual cows were the experimental unit, and only cows that had two or more calves during their lifetime were included in the analyses. Analyses were completed using SAS PROC MIXED (ver 9.1.3). The Kenward-Roger degrees of freedom method was used to adjust standard errors and calculate denominator degrees of freedom. Differences among breeds for temperament score were evaluate using the Kruskis Wallis non-parametric one-way of analysis of variance test as mean temperament scores were not distributed normally.

Results and Discussion

In the Hereford and Tarentaise cross herd, terrain use was not related to temperament score when evaluated as a categorical variable (Table 1) or when evaluated as a continuous variable. Breed affected ($P < 0.05$) both horizontal and vertical distance traveled to water, but not slope. Bailey et al. (2001) evaluated terrain use with data from this herd and reported similar results. Number of calves a cow in their life time affected all measures of terrain use. Cows with more calves during their lifetime used steeper slope and traveled farther vertically from water than cows with fewer calves (Table 1). Bailey et al. (2006) reported that older cows used higher terrain than younger cows. In this study, cows with more calves in their lifetime were comparable to older cows.

For the ACHPST herd, measures of terrain use were not related to temperament evaluated as a continuous variable or as a categorical score (Table 2). Dam breed tended to be related to vertical distance to water ($P = 0.08$), and breed of sire tended ($P = 0.07$) to be related to horizontal distance to water. Van Wagoner et al. (2006) in their analyses of this herd found that Charolais and Piedmontese sired cows traveled farther horizontally from water than cows sired by Angus bulls. However in their repeated measures analyses, terrain use was evaluated by pasture rather than by an overall average. Slope use and horizontal distance to water was not related to the number of calves a cow had during their life time. However, cows with 4 or more calves (56.1 ± 1.5 m) traveled farther vertically from water than ($P < 0.05$) than cows with 2 (53.6 ± 1.8 m) or 3 calves (52.5 ± 1.6 m) in their lifetimes.

In the Hereford and Tarentaise cross herd, temperament scores at calving varied among breeds. Hereford cows had the lowest mean temperament score, while Tarentaise cows had the highest scores (Table 3). However, in the second herd, breed of sire and breed of dam did not affect temperament score.

We rejected our hypothesis that temperament at calving was related to terrain use. Mean temperament score was not a useful predictor of terrain use when evaluated as a continuous or categorical variable in either herd.

Implications

Selecting cows that use more rugged terrain or culling cows that graze gentle slopes and lower elevations to improve uniformity of grazing distribution should not result in more aggressive cows at calving.

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Table 1. Least squares means of terrain use for mean temperament at calving, number of calves during a cow's lifetime and breed for Hereford and Tarentaise crossed cows.

	Horizontal Distance to Water, m			Vertical Distance to Water, m			Slope, %		
Measurement	Mean	SE	P-value	Mean	SE	*P*-value	Mean	SE	*P*-value
Mean									0.78
Temperament			0.82			0.94			
1 – 2	635	7		53.4	0.9		21.36	0.22	
2 – 3	646	18		52.4	2.1		20.92	0.53	
3 – 4	612	43		55.4	5.0		22.15	1.26	
4 - 5	661	58		53.7	6.9		21.07	1.72	
>5				-	-				
Number of calves in a cow's lifetime			0.01			0.001			0.01
2	669 [a]	24		48.0[a]	2.8		20.40[a]	0.71	
3	612 [b]	21		56.3[b]	2.5		21.96[b]	0.62	
4 or more	635 [ab]	19		56.9[b]	2.3		21.77[b]	0.57	
Breed			0.04			0.004			0.13
Hereford	609a	25		50.3[a]	2.9		20.82	0.72	
¼ Hereford ¾ Tarentaise	621[ab]	24		52.9[ab]	2.8		21.08	0.69	
½ Hereford ½ Tarentaise	659[b]	22		50.5[a]	2.6		20.89	0.65	
¼ Hereford ¾ Tarentaise	640[ab]	25		56.5[b]	2.9		22.13	0.73	
Tarentaise	663[b]	21		58.5[b]	2.5		21.95	0.63	

[a,,b,] Means with in column with different superscript differ ($P < 0.05$).

Table 2. Least squares means of terrain use for mean temperament at calving, number of calves during a cow's lifetime and breed for Angus-, Charolais-, Hereford-, Piedmontese-, and Salers-sired cows.

	Horizontal Distance to Water, m			Vertical Distance to Water, m			Slope		
Measurement	Mean	SE	P-value	Mean	SE	*P*-value	Mean	SE	*P*-value
Mean Temperament			0.37			0.96			0.50
1 – 2	644	7		53.7	0.7		20.22	0.19	
2 – 3	655	17		54.5	1.8		20.91	0.45	
3 – 4	634	24		52.4	2.5		20.97	0.63	
4 - 5	650	31		54.1	3.2		20.55	0.82	
>5	740	50		55.6	5.3		20.52	1.33	
Number of calves in a cow's lifetime			0.61			0.01			0.37
2	664	17		53.6[ab]	1.8		20.66	0.44	
3	659	15		52.5[a]	1.6		20.40	0.41	
4 or more	671	14		56.1[b]	1.5		20.85	0.39	
Breed of Dam			0.10			0.07			0.72
Hereford	658	17		53.6	1.8		20.82	0.50	
¼ Hereford ¾ Tarentaise	654	17		51.8	1.8		20.34	0.45	
½ Hereford ½ Tarentaise	659	17		53.5	1.8		20.74	0.46	
¼ Hereford ¾ Tarentaise	655	19		54.3	2.0		20.83	0.50	
Tarentaise	698	18		57.1	1.9		20.79	0.48	
Breed of Sire			0.07			0.18			0.81
Angus	649	16		53.6	1.7		20.85	0.43	
Charolais	680	16		54.3	1.7		20.42	0.42	
Hereford	642	26		51.5	2.8		20.53	0.70	
Piedmontese	688	15		57.0	1.6		20.95	0.40	
Salers	673	17		54.7	1.8		20.72	0.45	
Tarentaise	656	27		53.2	2.9		20.34	0.73	

[a,b] Means with in column with different superscript differ ($P < 0.05$).

Table 3. Average temperament scores at calving for breeds for the Herford and Tarentaise crossed cows.

Breed	Temperament Score
Hereford	1.12
¼ Herford ¾ Tarentiase	1.48
½ Hereford ½ Tarentaise	1.42
¼ Hereford ¾ Tarentaise	1.68
Tarentaise	2.03

BREEDING AND GENETICS

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GENETIC PARAMETERS FOR GROWTH TRAITS IN THE PROGENY OF NUBIAN, FRENCH ALPINE, SANNEN, TOGGENBURGH, AND SPANISH GOATS MATED NATURALLY TO BOER SIRES

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ABSTRACT. Data came from a commercial goat farm at Imperial Valley California. The objectives were to compare the performance of the progeny of goats involving inheritance of Nubian(N), French Alpine (A), Saanen (S) Toggenburgh (T), and Spanish (SP), (n=160), and to estimate genetic parameters for growth traits. Traits analyzed were weight at birth BWT and weaning WWT, and average daily gain (ADG) from birth to weaning. Separate analysis for each trait used least squares mixed model SAS (1999). The analytical model included: breed of dam, age of dam, sex of the kid, season of parturition as fixed effects; sire x breed of dam interaction and the residual as random. The overall mean values for weight at birth, weaning, and average daily gain were (2.06±.06,13.34±.36,and.175±.30 kg), respectively. The average values (2.12±.07, 2.11±.06, 2.10 ±.05, 2.04±.05, 1.95±.06; 1.93±.06, 1.98±.07, 1.97±.06, 1.96±.06, 1.93±.05, and 1.83±.05**;** 13.99±.37, 13.29±.33, 13.51±.43, 13.25±.34, and 12.67±.31, and 12.50±.29, 12.48 ±.30, 12.60±.41, 11.98±0.29, and 12.03± .29**;** .197±.33, .186±.31, .197±.29, .187±.34, .178±.27, and .175±.31, .175±.31, .177±.30, .175±.32, and .174±.35 kg**)** for BWT, WWT, and ADG for male and female kids, respectively. Estimates of heritability direct values were (h^2=0.20±.67, h^2=0.15±.68, and h^2=0.25±0.64) to BWT, WWT, and ADG, respectively.

Key Words: Genetic parameters, Crossbreeding, Growth traits, Boer goat,

Introduction

The Boer goat was developed in South Africa in the early 1900s for meat production. Their name is derived from the Dutch word Boer meaning farmer. The Boer goat was probably bred from the indigenous goats of the Namaqua Bushmen and the Fooku tribes, with some crossing of Indian and European bloodlines being possible (Van Niekrik et al. 1993). The Boer goat has a fast growth rate and excellent carcass qualities, making it one of the most popular breeds of meat goat in the world. Boer goats have a adapt well to hot, dry semi-deserts. The original US breeding stock came from herds in New Zealand. Mature Boer goat weigh between 110–135 kg, and between 90–100 kg for bucks and does, respectively. Efficiency of various methods for utilizing genetic diversity among breeds (Dickerson, 1969) is determined mainly by such factors as (i) reproductive rate of the species, i.e., in commercial matings, (ii) magnitude of crossbreeding heterosis for individual maternal and paternal performance (h^I, h^M, and h^P) and of loss in epistatic superiority of pure breeds due to recombination in gametes produced by crossbred parents (r^I, r^M, and r^P) (iii) size of breeds differences in individual and paternal vs. maternal performance of purebreds (g^I and g^P vs. g^M) and (iv) importance of interactions of genetic components with management or marketing systems.

Materials and Methods

This experiment used data from a commercial goat farm at Imperial Valley California. There was used the progeny of goats involving inheritance of Nubian N (n=52), French Alpine A (n=52), Saanen S (n=52) Toggenburgh T (n=52), and Spanish SP (n=52), Traits analyzed were weight at birth BWT and weaning WWT, and average daily gain ADG from birth to weaning. Goats were mated naturally to Boer sires. Goats were maintained in a legume pasture during winter, and grazing in a sudan grass during summer.

*Statistical analysis.*Separate analysis for each trait used least squares mixed model SAS (1999). The analytical model included: breed of dam, age of dam, sex of the kid, season of parturition as fixed effects; sire x breed of dam interaction and the residual as random.

Results and Discussion

Growth traits. Overall mean values and their standard errors for growth traits BWT, WWT, and ADG of male and female kids from dams involving inheritance of N, A, S, T, and SP in different proportion and different ages mated naturally to Boer sires are presented in Table 1. As shown highest values in BWT, WWT, and ADG corresponded to the progeny of N, A, SP, S and T, respectively. Lowest values on BWT, WWT, and ADG corresponded to the progeny of T goats mated naturally to Boer sires.

Genetic parameters. Estimates of heritability direct (h^2= 0.20 ±.42, h^2=0.15±.44, and h^2=0.25± .39) for BWT, WWT, and ADG are presented in Table 2. The estimates (h^2= 0.20 ± .42) of BWT at this study suggest a moderate value for this trait. Handford et al. (2003), and Van Wyk et al. (1993) found heritability (direct) values (h^2=0.27± 0.02 and h^2=0.16) for BWT and WWT, respectively. Van Wyk et al. (1993) reported estimates of heritability (maternal) values (h^2=0.43 and h^2=0.13) for BWT and WWT, respectively. Mousa et al. (1999)

estimated variances due to direct genetic effects of heritability (h^2=0.09 and h^2=0.17) for BWT and WWT, respectively. Notter (1998) found a value (h^2=0.19) for WWT at 60 d. Van Wyk et al. (1993) estimated heritability values (h^2=0.13 and h^2=0.18) direct and maternal, respectively for ADG. The estimated direct value (h^2=0.13) by Van Wyk et al. (1993) was quite half than the estimates (h^2=0.25±0.05) for ADG at this study. This maternal heritability estimates suggest that genetic maternal effects are not important for weights or gain at older ages. When the variances of maternal effects are near zero, the covariance between direct and maternal effects (r_{am}) has little meaning. It suggests, being an antagonism between direct genetic and maternal genetic effects (Robinsin, 1981) especially for WWT, in agreement with the direct-maternal correlation of -0.39 from the analysis of (Maria et al. 1993).

Efficiency of different methods for utilizing genetic diversity and heterosis of divergence in maternal versus individual performance and epistatic deviations from additive dominant gene effects (i) greater heterosis benefits of crossbreeding, (ii) lower reproductive rate benefits rotation crossbreeding rather than specific crossbreeding, (iii) larger breed differences in maternal versus individual performance increase advantage of crossing specific terminal sire with maternal crossbred dams, (iv) greater recombination loss of paternal epistatic superiority in progeny of crossbred parents means less potential for multibred synthetics versus rotation or specific crossbreeding. In meat sheep and goats, large breed differences in reproductive rate and growth and carcass traits benefits specific crossing of terminal sire on maternal crossbred sheep and goats. If epistatic recombination loss is negligible, there is potential advantage in using more heterotic synthetyc parental breeds or strains in crossbreeding, particularly in goats, sheep and cattle where low reproductive rate requires large number of pure breeds to supply replacements for commercial matings. The amount of heterosis expressed for a trait relates inversely to its heritability, which is the proportion of the measurable difference observed between animals that is due to additive differences and passes from one generation to the next.

Implications.

Genetic progress is possible through both selection and crossbreeding. Designing, long term mating plans to get benefits of both direct and maternal heterosis while capitalizing on maternal and terminal lines is an important step to in attemtping to maximize sustainted profit.

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Table 1.Mean values for birth weight, weaning weight, and average daily gain of kids of the progeny of dams involving inheritance of Nubian, French Alpine, Spanish, Saanen, and Toggenburgh from different ages, mated naturally to Boer sires.

Breed group	Birth weight (kg)		Weaning weight (kg)		Average daily weight (kg)	
	Males	Females	Males	Females	Males	Females
Overall mean	2.06 ± .05	1.93± .06	13.34±.36	12.44±.32	187±.30	.175±.31
Nubian	2.12 ± .07	1.98± .07	13.99±.37	12.50±.29	197±.33	.175±.31
Alpine	2.11 ±.06	1.97± .06	13.29±.33	12.48±.30	186±.31	.175±.31
Spanish	2.10± .05	1.96± .06	13.51±.43	12.60±.41	197±.29	.177±.30
Saanen	2.04± .05	1.93±.05	13.25±.34	11.98±.29	187±.34	.175±.32
Toggenburgh	1.95± .06	1.83± .05	12.67±.31	12.03±.41	178±.27	.174±.35

Table 2. Estimates of heritability (direct) values of kids for weights at birth at weaning, and average daily gain (grams) from birth to weaning.

Trait	h^2	SE
Birth weight	0.20	±.67
Weaning weight	0.15	±.68
Average daily gain	0.25	±.64

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IMPACT OF SIRE BIRTH WEIGHT POTENTIAL ON BIRTH AND WEANING TRAITS WHEN MATED TO VIRGIN HEIFERS

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ABSTRACT: The objective of this study was to examine the effect that mating virgin heifers to sires of varying birth weight potential (**BWP**) has on birth and weaning traits of offspring. In June, 2008, 98 virgin heifers 13 to15 mo of age were stratified by frame score and weight within frame score. Heifers were assigned randomly to two treatment groups. Treatments were based on sire BWP: 1) moderate BWP (**MBWP**) sires—Angus sires with birth weight (EPD between -1.6 and +0.4 kg, and 2) very low BWP (**VLBWP**) sires—Lowline sires. Pre-calving heifer weights were obtained 18 February 2009. Calves were born March through May of 2009. Birth weights and a calving difficulty (**CD**) score (1 = unassisted, 2 = hand pull, 3 = jack pull, 4 = Caesarean, 5 = abnormal presentation) were recorded within 24 h of calving. Calf weaning weights and post-calving dam weights were recorded in October of 2009. Weaning weights were adjusted to a constant 205-day weaning age. There was a calf sex by sire BWP interaction for birth weight (P = 0.01) and CD score (P = 0.03). Bull calves from MBWP sires were heavier at birth than bull calves from VLBWP sires (40vs. 34 kg; P = 0.0002) and had a greater CD score (1.7 vs. 1.1; P = 0.01). Birth weights did not differ (P = 0.92) between heifer calves sired by the MBWP sires (33 kg) and those sired by VLBWP sires (32 kg). All heifer calves from both sire groups were born unassisted (CD=1). Calf weaning weight was affected (P < 0.0001) by sire BWP, and calf sex (P = 0.01). Offspring of MBWP sires were heavier at weaning than those of VLBWP sires, 243 and 213 kg, respectively. Steer calves were heavier at weaning (235 kg) than heifer calves (220 kg). Dams nursing calves of VLBWP sires lost less weight than dams nursing calves of MBWP sires (28 vs. 43 kg; P = 0.04). In summary, using VLBWP sires reduced birth weight and calving difficulty in bull calves and reduced dam weight loss. However, calves sired by VLBWP sires weighed less at weaning than calves sired by MBWP sires.

Key Words: birth weight, calving difficulty, heifers, weaning weight

Introduction

Dystocia (difficult calving) is a major problem in first-calf (primiparous) heifers. Records of the American Angus Association analyzed by Berger et al. (1992) indicate that first-calf heifers are nearly 12 times as likely to require calving assistance as mature cows. That study also found a trend of increasing incidence of dystocia in the Angus breed during the 1972 to 1985 time period when breeders were selecting for increased growth rate. Dystocia decreases the odds of a calf surviving to 24 h of age (Berger et al., 1992; Johanson and Berger, 2003). Calf birth weight is considered the primary determinant of calving ease (Basarab et al., 1993; Cook et al., 1993). However, calves of low birth weight potential sires often weight less at weaning (Cundiff et al., 1998). The objective of the present study was to examine the effect that mating virgin heifers to sires of varying birth weight potential (**BWP**) has on birth weight, calving difficulty, weaning weights, and pre-calving to post-weaning changes in dam weight.

Materials and Methods

This study utilized 98 crossbred virgin heifers born at the Central Grasslands Research Extension Center in 2007. The breed composition of the heifers was 50% or greater Angus with varying percentages of Simmental, Maine Anjou and Shorthorn.

In June 2008 the heifers, 13 to 15 mo of age, were weighed and frame scored according to Beef Improvement Federation Standards (BIF, 2002). Heifers were stratified by frame score and weight within frame score. Heifers were then randomly assigned to 2 treatment groups. The treatments were based sire BWP: 1) moderate BWP (**MBWP**) sires—Angus sires with birth weight EPD between -1.6 and +0.4 kg, and 2) very low BWP (**VLBWP**) sires—Lowline sires. Heifers were synchronized and artificially inseminated and then exposed to natural service sires of the respective BWP groups for 2 estrus cycles. Except for the time period they were exposed to natural service sires the heifers were managed as single herd in the same pasture or pen.

Pre-calving heifer (dam) weights were obtained 18 February 2009. Calves were born March through May of 2009. Heifers were calved in a corral to allow frequent monitoring. Heifers were observed at least once every 4 h during calving. Heifers not delivering a calf within 2 h of displaying placental membranes were assisted. Birth weights and a calving difficulty (**CD**) score (1= unassisted, 2 = hand pull, 3 = jack pull, 4 = Caesarean, 5 = abnormal presentation) were recorded within 24 h of birth. Bull calves were castrated and the calves branded and vaccinated in late May of 2009 when cow-calf pairs were moved from dry lot to native range pasture. Calf weaning weights and post-calving dam weights were obtained in October of 2009. Calf weaning weights were adjusted to common 205-day weaning age.

Data were analyzed in Proc GLM (SAS Institute, Cary, NC) as a two-way analysis of variance with sire BWP and calf sex as factors.

Results

A significant calf sex by sire BWP interaction was observed for birth weight ($P = 0.01$) and calving difficulty score ($P = 0.03$). Bull calves from MBWP sires were heavier at birth $P = 0.002$) than bull calves from VLBWP sires (Table 1.) and had greater CD scores ($P = 0.01$; Table 1). However, heifer calves from MBWP and VLBWP sires did not differ (Table 1) in birth weight ($P = 0.92$) or calving difficulty score ($P = 1.00$).

Calf weaning weights were affected by both sire BWP ($P = 0.001$) calf sex ($P = 0.01$) but there was no sire BWP by calf sex interaction for weaning weight ($P = 0.95$). Offspring of MBWP sires were heavier at weaning than offspring of VLBWP sires and steer calves were heavier at weaning than heifer calves (Table 2).

Dams nursing calves sired by VLBWP sires lost less weight pre-calving to weaning than those nursing calves sired by MBWP sires ($P = 0.04$; Table 3). However calf sex did not affect dam weight loss ($P = 0.46$) nor was the calf sex by sire BWP interaction significant for dam weight loss ($P = 0.70$).

Discussion

The calf sex by sire BWP interaction for birth weight and calving ease in our study is consistent with observations of other calving ease studies (Smith et al., 1976; Gregory et al. 1978). In sire groups with potential for higher birth weight and increased calving difficulty, the impact of calf sex on calving difficulty is more pronounced (Gregory et al., 1978). Previous work has found that the relationship between birth weight and calving ease is not a perfect linear relationship but involves threshold birth weights above which increases birth weight increase calving difficulty (Basarab et al., 1993). The threshold birth weight values they established were 36 kg for British first-calf heifers and 38 kg for British x Continental cross first-calf heifers. In our study the birth weight of the heifer calves of MBWP sires and the heifer and bull calves of VLBWP sires fell below those threshold values. However the bull calves sired by MBWP sires exceeded those threshold values.

We have not discovered any other reports in the literature of differences in pre-calving to post-weaning dam weight changes due to the effect of the growth potential of the calves they were nursing. Grings et al. (1996) found no difference in milk intake by calves with high and low growth potential because the calves with higher growth potential met their increased nutritional demands by increasing forage intake rather than milk intake. In our study the greater weight loss by dams nursing calves of MBWP sires was primarily due to greater weight loss in the immediate post-calving period when the cow-calf pairs were still in the dry lot and calves were just beginning to ingest forage. Thus the calves sired by MBWP sires may have met their requirements for added nutrients by increased suckling thereby stimulating more milk production. Increased milk production is associated with greater weight loss during lactation (Adams et al. 1993).

The differences in weaning weights by sire BWP with calves sired by VLBWP sires weaning lighter than calves sired by MBWP sires in our study agrees with Cundiff et al. (1998) who found sire groups which produced lower birth weights and less calving difficulty also produced lighter calves at weaning. The VLBWP sires used in our study were of the Lowline breed this may have impacted the degree of difference in calf weaning weights versus the MBWP sires. The Lowline breed was developed by selecting a herd of Angus cattle for minimum yearling weight (Oklahoma State University, 2008) and thus the lower BWP was an associated effect of selection for lower yearling weights. Although lower birth weights are associated with lower mature body weights (Brinks et al., 1964; MacNeil et al., 2000) differences in growth curves may dictate at what age the differences in body weights become manifest. Colburn et al. (1997) found calves that were lighter at birth had weaning weights equal to those with heavier birth weights, but the calves which were lighter at birth had reduced ADG in the finishing phase and lighter slaughter weights. A selection program which reduced birth weights by 55% reduced mature cow size by 25% but only resulted in a 10% reduction in birth weight (Dickerson et al., 1974).

Thus, by utilizing sires from lines of cattle specifically selected for low birth weight it may be possible to achieve the lower birth weights and lesser calving difficulty we found from using VLBP sires with yet smaller differences in weaning weight versus the MBWP sires reported here. Our research is continuing with the MBWP and VLBWP sires but a third sire group termed the low BWP sire group has been added. The Low birth weight potential sires will consist of Red Angus sires with a birth weight EPD of -2.7 to -3.6 kg which translate to a birth weight EPD of -1.4 to -2.3 kg on the Angus birth weight EPD scale.

Implications

Findings from the first year of this multi-year calving ease project indicate that mating virgin heifers to VLBWP sires results in bull calves with lower birth weights and lower calving difficulty scores, and first-calf heifer dams losing less weight pre-calving to weaning when compared to mating with MBWP sires. However, the calves sired by VLBWP sires are considerably lighter at weaning than those sired by MBWP sires. Going forward we hope to identify sire groups which equal the VLBWP sires in calving ease but compare more favorably to the MBWP sires in terms of weaning weight.

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Table 1. Birth weights and calving difficulty scores of calves born to first-calf heifers by sire birth weight potential and calf sex.

Sire Birth Weight Potential and Calf Sex		Birth Weight (kg)	Calving Difficulty (scale 1 to 5)
Moderate			
	Bull	40 [a]	1.7 [a]
	Heifer	33 [b]	1.0 [b]
Very Low			
	Bull	34 [b]	1.1 [b]
	Heifer	32 [b]	1.0 [b]

Values in the same column with different superscripts differ ($P < 0.05$).

Table 2. Weaning weights adjusted to a 205-day weaning age of calves born to first-calf heifers by sire birth weight potential (**BWP**) and calf sex.

Sire BWP	Weaning Weight (kg)	Calf Sex	Weaning Weight (kg)
Moderate	243 [a]	Steer	235 [a]
Very Low	213 [b]	Heifer	220 [b]

Values in the same column with different superscripts differ ($P < 0.05$)

Table 3. Dam weight loss pre-calving to weaning for 1st-calf heifer dams nursing calves sired by moderate andvery low birth weight potential sires.

Sire Birth Weight Potential	Dam Weight Loss (kg)
Moderate	43 [a]
Very Low	28 [b]

Values with different superscripts differ ($P < 0.05$).

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FACTORS AFFECTING SPERMATOZOA MORPHOLOGY IN BEEF BULLS[1]

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ABSTRACT: The objective of this study was to evaluate factors affecting sperm morphology of bulls (n=908) collected at 320 days of age. Bulls were a composite breed (50% Red Angus, 25% Charolais, and 25% Tarentaise) born from 2002 to 2008 to dams fed levels of feed during mid and late gestation that were expected to provide marginal or adequate nutrition while grazing dormant winter forage. After weaning, bulls were fed to appetite (**CON**) or restricted (**REST**) to 80% of that consumed by CON on BW basis. Semen samples were collected using an electroejaculator and evaluated using standard BSE procedures. Spermatozoa morphology was evaluated by classifying 100 spermatozoa per bull at 400 X magnification into the following categories: normal spermatozoa, knobbed acrosome, head defects, distal midpiece reflex, dag defect, bowed midpiece, proximal droplet, distal droplet, coiled principle piece, and bent principle piece. Each morphological trait, along with scrotal circumference (SC), gross motility, and percent progressive motility was analyzed using MTDFREML and pedigree information from 8163 relatives born from 1974 to 2008 to provide heritability estimates. Heritability estimates for these traits were: SC (h^2 = 0.67), normal sperm (h^2 = 0.18), dag defect (h^2 = 50), bowed midpiece (h^2 = 0.19), proximal droplets (h^2 = 0.37), bent principle piece (h^2 = 0.18), gross motility (h^2 = 0.20), and progressive motility (h^2 = 0.20). The moderate heritability of percent normal sperm and several of the other sperm defects suggest that selection for improved sperm morphology is possible. Further analysis with MTDFREML determined genetic correlations between the above traits and pre-weaning gain direct, pre-weaning gain maternal, post-weaning gain, and scrotal circumference. Maternal pre-weaning gain was highly correlated with scrotal circumference (r = 0.70 ± 0.24) but pre-weaning gain direct (r = 0.29 ± 0.20) and post-weaning gain (r = 0.01 ± 0.17) were not. Scrotal circumference and post-weaning gain were not highly correlated with morphology and therefore are not good indicators of spermatozoa morphology. Neither in utero nor postweaning diet affected any of the traits measured.

Key Words: bull, spermatozoa morphology, heritability

Introduction

Bull fertility is critical to the economic success of beef cattle operations. Spermatozoa morphology has been shown to be a fundamental element affecting spermatozoa's ability to reach the site of fertilization in the female tract, fertilize an ovum, and initiate embryogenesis (Saacke, 2008). Reproductive traits and seminal quality have not been traditionally subjected to intense selection pressure (Coulter, 1994). The ability to select and breed for a higher percentage of morphologically normal spermatozoa would improve the efficiency and cost effectiveness of beef operations by allowing producers to develop only those bulls with greater potential as successful breeders. The objective of this study was to examine the heritability of traits traditionally associated with bull fertility: scrotal circumference, gross motility, and percent progressive motility; as well as the following morphological characteristics: normal spermatozoa, knobbed acrosome, head defects, distal midpiece reflex, dag defect, bowed midpiece, proximal droplet, distal droplet, coiled principle piece, and bent principle piece. A further objective of this study was to examine the correlations, both phenotypic and genetic, between the following factors and spermatozoa morphology: in utero (dam) nutritional treatment, scrotal circumference, pre-weaning gain direct, pre-weaning gain maternal, and post weaning gain. Establishment of genetic and environmental correlations between traditional measures of bull fertility and spermatozoa morphology could improve interpretation of standard breeding soundness examinations and selection for improved bull fertility.

Materials and Methods

Animals, facilities, and diet. Procedures were approved by USDA-ARS Fort Keogh Livestock and Range Research Laboratory Animal Care and Use Committee. Bulls included in the study (n=908) were a stabilized composite including 50% Red Angus, 25% Charolais, and 25% Tarentaise germplasm. Bulls were evaluated at 320 ± days of age during a six year period from 2003 to 2009. Bulls were born to dams that were fed levels of harvested feed during mid and late gestation (Dec to March) that were expected to provide marginal (**MARG**) or adequate (**ADEQ**) nutrition while grazing dormant winter forage through this period. After weaning, bulls were fed to appetite (**CON**) or restricted (**REST**) to 80 % of that consumed by CON on common BW basis until time of evaluation.

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Collection and Sample Evaluation. Semen was collected from 908 bulls using an electroejaculator. Volume of the ejaculate was recorded. Gross motility (swirl) was evaluated on undiluted semen samples using a light microscope at 100 X magnification. Swirl was evaluated on a 0-5 scale with 0 indicating no movement present and 5 indicating many swirls with rapid and vigorous speed. Percent progressive motility was evaluated in semen samples diluted 1:4 with pre-warmed (37°) Dulbecco's Phosphate-Buffer Saline using 400 X magnification. Percent progressive motility was subjectively scored from 0% to 100% based upon a visual measurement of spermatozoa that exhibited straight-line movement. Concentration of spermatozoa was determined by hemocytometer from neat semen diluted 1:40 in eosin counting solution. Spermatozoa morphology was evaluated from a fixed slide prepared at time of collection using morphology stain. One hundred spermatozoa per bull were evaluated at 400 X magnification for the following morphological characteristics: normal, knobbed acrosome, head defects, distal midpiece reflex, dag defect, bowed midpiece, proximal droplet, distal droplet, coiled principle piece, and bent principle piece. Scrotal circumference was also recorded at time of collection using a scrotal tape.

Statistics. Data were initially analyzed using PROC MIXED (SAS Inst. Inc., Cary, NC). The model included fixed effects of year, dam treatment (either ADEQ or MARG) and postweaning treatment (either CON or REST) of the bulls, age-of-dam (2, 3, 4, ≥ 5 yr), and age of bull in days. Dependent variables were percentage of each morphological characteristic: normal, knobbed acrosome, head defects, distal midpiece reflex, dag defect, bowed midpiece, proximal droplet, distal droplet, coiled principle piece, and bent principle piece, gross motility (swirl), percent progressive motility, scrotal circumference, pre-weaning gain and post-weaning gain.

Subsequently, multiple-trait-derivative-free REML (Boldman et al. 1995) was used to estimate additive genetic and residual variance components in univariate analyses for each sperm morphology trait. The relationship matrix used was derived from 8,163 animals born between 1974 and 2008. Contemporary groups were defined by year and postweaning treatment. Fixed effects were contemporary group, dam treatment and age (linear). In addition to the univariate analysis of sperm morphology traits, additional bivariate analyses were conducted to estimate correlations of the sperm morphology traits with pre-and post-weaning gain and scrotal circumference.

Results and Discussion

In utero (dam) nutritional treatment (MARG or ADEQ) had no effect on traditional measures of bull fertility or spermatozoa morphology. Post weaning (REST or CON) nutritional treatment affected postweaning growth, scrotal circumference, and had significant, but biologically unimportant, effects on the frequencies of distal midpiece reflex, proximal droplets, and bent principle piece defects. Our data differs from that of Coulter et al., (1997) in that bulls in the current study were fed diets that were on full feed or 80% of full feed. Thus, our CON diet was more similar to their moderate-energy diet. New data presented here demonstrates that nutrient limitation did not have detrimental effects either.

Heritability estimates for the traits measured are shown in Table 1. The heritability estimate for scrotal circumference is lower than that of Bourdon et al. (1986). The heritability estimate for percent normal spermatozoa was low, but suggests progress could be made in selection for this trait. The major classification for spermatozoa morphology was percent normal. Heritability estimates for percent dag defect and proximal droplets were high, thus producers could apply selection pressure against these traits that, according to Barth and Oko (1989), are known to negatively affect fertility. Considerable debate has existed between the origin of primary verses secondary abnormalities and major and minor spermatozoa defects contributing to fertility and which traits were genetic abnormalities. The heritability estimates of dag defect, bowed midpiece, proximal droplet, and bent principle piece suggest these to be primarily of genetic origin and that bulls with these abnormalities might be expected to not recover from them. Table 1 also identifies percent bowed midpiece and percent bent principle piece as being lowly heritable, but the incidence of these traits is negligible.

Correlations between pre-weaning gain and each of the fertility and spermatozoa traits measured are listed in Table 2. Maternal pre-weaning gain was highly correlated with scrotal circumference ($r = 0.70 \pm 0.24$). Thus selection for increased milk production would be expected to increase scrotal size and selection for increased scrotal size would indirectly increase milk production in daughters. Bourdon and Brinks (1986) reported a similar direct genetic correlation between scrotal circumference and weaning weight ($r = 0.20 \pm 0.18$) as observed in the present study for pre-weaning gain ($r = 0.29 \pm 0.20$). Post-weaning feed levels and gain had no effect on scrotal circumference in the current data but Bourdon and Brinks (1986) demonstrated increased scrotal circumference for bulls receiving full feed compared to either limited or intermediate feed during the post-weaning period. While the genetic correlation between direct pre-weaning gain and bent principle pieces was high, the incidence of bent principle pieces was negligible. Also, Table 3 suggests that selection for increased post-weaning gain would decrease the percentage of bowed midpiece, but the incidence of this trait was also very small.

Implications

Scrotal circumference and post-weaning gain were not highly correlated with morphology and therefore are not good indicators of spermatozoa morphology. Neither in utero nor postweaning diet affected any of the traits measured. However, the heritability of percent normal sperm and several of the other sperm defects suggest that selection for improved sperm morphology is possible.

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Table 1. Summary of univariate analysis results

Trait	CON μ	RES μ	μ of CON and RES	Phenotypic variation	Standard Deviation	h^2	h^2 standard error	Additive Genetic Variance	Residual Variance
Scrotal circumference, cm	30.78	29.98	30.83	5.89	2.43	0.67	0.09	3.95	1.95
% normal	43.54	41.81	42.68	192.67	13.88	0.18	0.07	34.68	157.99
% knobbed acrosome	0.43	0.41	0.42	0.72	0.85	0.02	0.04	0.01	0.71
% head defects	1.65	1.73	1.68	2.75	1.66	0.00	0.05	0.00	2.75
% distal midpiece reflex	2.47	1.98	2.22	10.86	3.30	0.01	0.04	0.11	10.75
% dag defect	6.85	6.70	6.78	46.92	6.85	0.50	0.10	23.46	23.46
% bowed midpiece	14.96	15.90	15.43	127.37	11.29	0.19	0.07	24.20	103.17
% proximal droplet	23.12	20.13	21.62	306.29	17.50	0.37	0.08	113.33	192.96
% distal droplet	3.07	2.92	3.00	12.68	3.56	0.09	0.06	1.14	11.54
% coiled principle piece	0.88	0.77	0.83	2.31	1.52	0.07	0.05	0.16	2.15
% bent principle piece	0.81	0.49	0.65	2.54	1.59	0.18	0.08	0.46	2.08
Gross motility score	1.58	1.58	1.58	0.65	0.81	0.20	0.07	0.12	0.52
% progressive motility	25.21	24.39	24.80	201.35	14.19	0.20	0.08	40.27	161.08

Table 2. Estimates of correlation between components of pre-weaning gain and common measures of bull fertility

Trait	Direct genetic correlation to pre-weaning gain	Maternal genetic correlation to pre-weaning gain	Residual correlation to pre-weaning gain
Scrotal circumference, cm	0.29 ± 0.20	0.70 ± 0.24	0.41 ± 0.13
% normal	0.09 ± 0.29	0.24 ± 0.35	0.03 ± 0.08
% knobbed acrosome	-0.94 ± 1.04	0.37 ± 0.97	0.05 ± 0.07
% distal midpiece reflex	0.64 ± 1.44	-0.80 ± 1.87	-0.04 ± 0.07
% dag defect	0.05 ± 0.25	0.03 ± 0.27	0.03 ± 0.12
% bowed midpiece	0.06 ± 0.28	-0.12 ± 0.35	0 ± 0.08
% proximal droplet	-0.14 ± 0.23	-0.09 ± 0.29	0 ± 0.09
% distal droplet	-0.15 ± 0.35	-0.08 ± 0.46	-0.04 ± 0.07
% coiled principle piece	0.05 ± 0.39	-0.46 ± 0.52	0.01 ± 0.07
% bent principle piece	0.64 ± 0.26	-0.37 ± 0.39	-0.28 ± 0.09
Gross Motility score	-0.02 ± 0.29	0.20 ± 0.38	0.08 ± 0.09
% progressive motility	-0.29 ± 0.29	0.06 ± 0.38	0.09 ± 0.09

Table 3. Estimates of correlation between common measures of bull fertility and post-weaning gain and scrotal circumference

Trait	Genetic correlation to post-weaning gain	Residual correlation to post-weaning gain	Genetic correlation to scrotal circumference	Residual correlation to scrotal circumference
Scrotal circumference, cm	0.01 ± 0.17	0.35 ± 0.10	n/a	n/a
% normal	-0.24 ± 0.24	0.05 ± 0.06	0.06 ± 0.20	0.19 ± 0.10
% knobbed acrosome	0.1 ± 0.67	-0.05 ± 0.06	-0.18 ± 0.54	0.04 ± 0.09
% distal midpiece reflex	0.64 ± 1.44	-0.01 ± 0.05	1.00 ± 2.01	-0.13 ± 0.09
% dag defect	0.07 ± 0.19	-0.03 ± 0.09	0.02 ± 0.20	-0.01 ± 0.02
% bowed midpiece	-0.47 ± 0.22	0.06 ± 0.07	0.04 ± 0.20	0.09 ± 0.10
% proximal droplet	0.30 ± 0.19	-0.07 ± 0.08	-0.16 ± 0.15	-0.10 ± 0.12
% distal droplet	-0.18 ± 0.31	-0.02 ± 0.06	-0.02 ± 0.26	-0.03 ± 0.09
% coiled principle piece	-0.20 ± 0.34	0.02 ± 0.06	-0.40 ± 0.27	0.08 ± 0.09
% bent principle piece	-0.03 ± 0.28	0.01 ± 0.07	0.11 ± 0.22	-0.02 ± 0.11
Gross Motility score	-0.14 ± 0.26	0.01 ± 0.07	0.32 ± 1.36	0.17 ± 0.68
% progressive motility	-0.49 ± 0.25	0.05 ± 0.07	-0.14 ± 0.20	0.21 ± 0.12

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GENETIC CHARACTERIZATION OF FEED INTAKE AND UTILIZATION IN PERFORMANCE TESTED BEEF BULLS

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ABSTRACT: Feed intake, growth, and pedigree data from the Midland Bull Test database were used to estimate parameters required for genetic evaluation of feed utilization traits. Length of the feeding period was 70 d, and test ADG was estimated as the slope of the regression of BW on test d. Records on DMI, ADG, and estimated mid-test BW raised to the power of 0.75 (**MBW**) from bulls (n = 2,346) and heifers (n = 221) representing 11 breeds (1,819 Angus) were included in a multiple trait animal model to estimate variance components using average information REML. The model for all traits included the fixed effects of contemporary group (n = 99) and a linear covariate for age at the start of test, and random animal genetic effects (n = 10,327). Heritability estimates for DMI, ADG, and MBW were 0.54 ± 0.09, 0.31 ± 0.07, and 0.58 ± 0.09, respectively, and genetic correlation estimates (SE < 0.13) among the traits were positive, ranging from 0.37 to 0.60. Phenotypic residual feed intake (**RFI**; SD = 0.61 kg/d) was defined as the difference between DMI and expected DMI from regression on ADG and MBW, (h^2 = 0.30 ± 0.08). A four trait model including phenotypic RFI failed to converge because of the linear dependence with DMI, ADG, and MBW. Breeding values for genetic RFI were then estimated as the difference between EBV for DMI and expected DMI derived using genetic regression. Genetic RFI has the property of independence from EBV for ADG and MBW whereas traditional EBV for phenotypic RFI could have genetic correlations with ADG and MBW. Genetic RFI EBV ranged from -1.08 to 1.15 kg/d (SD = 0.09). Phenotypic or genetic RFI contain no more information than DMI, ADG, and MBW phenotypes or EBV, respectively. Therefore, genetic evaluation of RFI is equivalent to evaluation of a function of the component traits.

Key Words: Beef Cattle, Feed Intake, Genetic Evaluation

Introduction

Genetic evaluation of feed intake is of interest to beef producers whose breeding objective is to reduce input costs associated with feed and feed supplementation. At least two-thirds of non-fixed beef production costs in North America can be attributed to feeding, which mainly include the costs of forages and supplement for the cow herd, and high-grain diets in the feedlot sector. Implementation of national cattle evaluation programs that include feed intake has been limited due to the complexity and expense of collecting individual feed intake records. Unlike output or revenue traits such as reproductive rate, growth performance, and carcass merit, a sufficient national database of feed intake records does not exist such that entire breeds or populations could routinely publish genetic evaluations. An increasing number of central testing facilities are being equipped with technology to record individual feed intake on group-fed cattle according to standardized guidelines recommended by the Beef Improvement Federation (2010). Given this limitation, prototype genetic evaluation systems have been developed using data from individual commercial test and research facilities. Genetic evaluation of feed intake and utilization requires appropriate parameter estimates to predict breeding values which can then be incorporated into selection tools used for genetic improvement. The objectives of this study were to estimate genetic parameters among feed intake and growth traits measured on growing bulls, and to evaluate alternative measures of feed utilization.

Materials and Methods

Animals and Phenotypes. Daily dry matter intake (DMI) was measured on 2,346 bulls and 221 heifers between 2007 and 2009 at the Midland Bull Test (**MBT**) in southern Montana. Although 11 breeds were represented in the data, approximately 70% of the data were from Angus bulls. Up to three generations of ancestors of animals with records were used to construct a pedigree file using information from either MBT or the appropriate breed association database. During the 70-d tests, live weight was recorded serially at 14-d intervals, and average daily gain (ADG) equated to the slope from the within-animal regression of live weight on test day. The ADG of animals with live weight regression R^2 less than 0.90 were considered outliers and set to missing. Weight at mid-test was computed using the live weight regression estimates as β_0 + ADG × (length of test / 2), and metabolic body weight (MBW) was defined as mid-test weight raised to the power of 0.75. Phenotypic residual feed intake (RFIp) was computed as the residual term from the regression of DMI on ADG and MBW (Koch et al., 1963).

Analysis. Genetic (co)variances were estimated using a multiple trait animal model and average information REML. The model was equivalent for DMI, ADG, MBW, and RFIp which included fixed effects of feeding

contemporary group (test × breed × sex × pen, n = 99) and a linear covariate for age at the start of test (average 302 d). After standard data edits 2,567 records were retained for analysis and 10,327 animals were included in the pedigree file. Random animal (direct) genetic effects were included to predict breeding values.

Genetic Residual Feed Intake. Genetic regression was used to predict expected DMI EBV from EBV for ADG and MBW. Then genetic residual feed intake (RFIg) was defined as the difference between DMI and expected DMI EBV. The genetic regression approach requires estimates of genetic (co)variances between ADG and MBW, as well as genetic covariances of these with DMI. Similar to the phenotypic independence of RFIp from ADG and MBW, RFIg would be genetically independent of ADG and MBW.

Results and Discussion

Table 1 contains a summary of records and genetic parameter estimates for DMI, ADG, MBW, and RFIp. The multiple trait model including all four traits failed to converge, most likely because RFIp is a linear function of the three remaining traits in that model. The phenotypic correlation of DMI with RFIp was 0.43. Further investigation revealed that any model including both DMI and RFIp failed to converge, suggesting that in these data, the genetic correlation estimate was near the boundary of 1.0. Other researchers have not reported convergence failure with multiple trait models including RFIp (e.g., Arthur et al., 2001; Schenkel et al., 2004; Hoque et al., 2009). Reported genetic correlation estimates in 10 studies published since 2001 for DMI with RFIp were highly positive, ranging from 0.43 to 0.92, with a weighted average of 0.70 (Pendley et al., 2010).

Table 1. Descriptive statistics and genetic parameter[a] (± SE) estimates

Item	DMI, kg/d	ADG, kg	MBW, kg	RFIp, kg/d
Mean	9.74	1.43	93.28	0
SD	1.79	0.33	13.58	0.61
V(P)[b]	1.139	0.054	34.465	0.599
DMI	0.54 ± 0.09	0.0602	1.9059	--[c]
ADG	0.60 ± 0.11	0.31 ± 0.07	0.2107	0.0147
MBW	0.55 ± 0.08	0.37 ± 0.13	0.58 ± 0.09	-0.1506
RFIp	--[c]	0.27 ± 0.18	-0.08 ±0.16	0.30 ± 0.08

[a] In the lower table block, heritabilities (± SE) are on the diagonal, genetic correlations (± SE) are below the diagonal, and genetic covariances are above the diagonal.
[b] Phenotypic variance.
[c] Parameter not estimated due to model convergence failure.

Heritability estimates in Table 1 for DMI, ADG, and MBW are similar to or slightly higher than the average estimates included in Pendley et al. (2010). In particular, most heritability estimates recently reported for MBW range from 0.31 to 0.41. The heritability estimate for RFIp (0.30 ± 0.08) is within the range of those recently reported, although slightly lower than their weighted average of 0.38. Genetic correlations among growth traits (ADG, MBW) and DMI were moderate to high and positive, ranging from 0.37 to 0.60. These estimates are similar to those reported by Arthur et al. (2001), but higher than Schenkel et al. (2004). Most recent studies have reported genetic parameters for RFIp, specifically estimating near-zero genetic correlations of RFIp with ADG and MBW. The estimate in these data of 0.27 ± 0.18 for the genetic correlation between ADG and RFIp illustrates that although RFIp is independent from its components (including ADG and MBW), RFIp is not necessarily genetically independent from its components (Kennedy et al., 1993). Selection on RFIp breeding values, therefore, may result in correlated response in ADG.

Without assuming some genetic covariance estimate between RFIp and DMI, multivariate prediction of breeding values for all traits in this study would not be possible. Further, Kennedy et al. (1993) and van der Werf (2004) have shown that the genetic information in RFI is equivalent to a linear combination of breeding values for DMI, ADG, and MBW. Therefore, publication of expected progeny differences (EPD) for RFIp along with its components is simply repackaging genetic information, possibly leading to confusion among breeders and sub-optimal if not incorrect selection decisions.

Genetic regression can be represented in matrix notation as $\mathbf{u^*} = \mathbf{UG}^{-1}\mathbf{c}$, where breeding values for an unmeasured trait for n animals ($\mathbf{u^*}$) are predicted as the product of $\mathbf{U}$, an n × t matrix of breeding values on t measured traits, their t × t genetic (co)variance matrix $\mathbf{G}$, and the t × 1 vector $\mathbf{c}$ whose elements are the genetic covariances of the measured traits with the unmeasured trait. This approach is commonly used to predict breeding values for composite traits (e.g., retail product yield) which are linear combinations using estimated breeding values for their components (e.g., Crews et al., 2008). From Table 1,

$$\mathbf{G}^{-1} = \begin{bmatrix} 0.0167 & 0.2107 \\ 0.2107 & 19.990 \end{bmatrix}^{-1}$$

and

$$\mathbf{c} = \begin{bmatrix} 0.0602 \\ 1.9059 \end{bmatrix}.$$

The difference between DMI EBV (denoted by the vector $\mathbf{d}$) and expected DMI EBV (from $\mathbf{u^*}$ above) is defined as $\mathbf{f} = \mathbf{d} - \mathbf{u^*}$, then $\mathbf{f}$ is the vector of genetic residual feed intake (RFIg) EBV (Crews, 2005). Table 2 summarizes EBV for DMI, ADG, MBW, and RFIg.

Table 2. Summary statistics and simple correlations among EBV

Statistic/EBV	DMI	ADG	MBW	RFIg
Minimum	-1.182	-0.221	-10.51	-1.083
Maximum	1.259	0.242	13.34	1.152
SD	0.099	0.022	0.987	0.099
ADG	0.02			
MBW	0.02	0.30		
RFIg	0.37	0[a]	0[a]	

[a] r = 0 by definition.

Breeding value estimates for DMI and RFIg had similar range and SD, but did not rank animals equivalently (r = 0.37). The expected value of the simple correlation between breeding values for two traits is equal to their genetic correlation, but only under the assumption of perfect accuracy. Accuracy values were approximately 0.70 or less for animals with records, and averaged 0.14 to 0.22 for all animals in these data.

Results from this study provide parameter estimates required for implementation of a genetic evaluation system for a central beef cattle test database that includes individual feed intake and growth data. Genetic parameters for these traits were generally similar to those published recently. As a linear function of intake and growth, genetic evaluation of phenotypic residual feed intake may lead to less than optimal selection decisions. By comparison, reporting of genetic residual feed intake requires solving fewer equations in national cattle evaluation, and results in breeding values that are genetically uncorrelated to growth traits but that contain the same genetic information as feed intake and growth.

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FORAGES AND PASTURES

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EFFECT OF CORN HYBRID ON AMOUNT OF RESIDUE AVAILABLE FOR GRAZING RELATIVE TO GRAIN YEILD

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ABSTRACT: Utilization of corn crop residue by cattle to extend grazing can have positive economic impacts. Cattle primarily consume the leaf and husk portions of the corn residue. Amount of residue available to grazing cattle may be influenced by corn hybrid. Ten corn hybrids were evaluated to determine differences in corn grain yield and crop residue dry matter. Ten hybrids that best represented a wide range of production traits were selected from a total of 40 hybrids grown in a test plot located near Paxton, NE. The following hybrids were evaluated: Pioneer P0541XR, P1173HR, P1395XR, Dekalb 59-35, 61-04, NK N68B-GT, N74C-3000GT, Croplan Genetic 5757 VT3, Golden Harvest 8211 3000GT, and Midwest Genetics 76482R. Each sample consisted of the complete above ground portion of the corn plant and was collected randomly. Each sample was sorted into the following parts: stems, leaves (including leaf sheath), husks, cobs and corn grain. Plant parts were dried in a forced air oven at 60º C to determine dry matter yield. Data were analyzed as a completely randomized design. There was no difference in corn grain yield among hybrids (13,240 kg/ha ± 788, DMB; P = 0.23). Differences were present between hybrids in amount of stems (P < 0.001), leaves (P = 0.05), husks (P = 0.01), and cobs (P < 0.001). Considering these differences, it is not surprising that total residue production (sum of stems, leaves, husks and cobs) was different (P = 0.02) among hybrids. However, differences also existed in the ratio of corn grain to total residue production (P < 0.001) and corn grain to leaf and husk (P < 0.001), indicating potential differences in plant efficiency. Corn hybrids differ in the amount of residue produced independent of the amount of grain. Since corn hybrids differ in the amount of residue they produce, possible differences in amount of residue available for cattle to graze, also differs. Using these differences, economic estimates of the ranking identify potential value differences.

KEY WORDS: corn stalks, corn residue, grazing

Introduction

The largest cost to cow-calf and backgrounding operations is feeding harvested feedstuffs in winter months. To lower feed costs, many producers attempt to extend the grazing season by utilizing corn crop residues (Wilson, et. al. 2004). Many variables need to be considered in the effective management of corn residue as a source of grazed forage. Cattle will select the highest quality parts of the corn plant first. Wilson et. al. (2004) reported that husk (3.6% CP and 67% IVDMD) and leaf (7.8% CP and 47% IVDMD) were more palatable than stem (4.5% CP and 45% IVDMD) and cob (2.2% CP and 35% IVDMD). Fernandez-Rivera and Klopfenstein (1989) observed that 65 to 72% of DM utilized was represented by leaf plus husk. Therefore, relative amount of plant parts, as well as their quality, could affect performance by grazing animals. The objectives of this research were to determine whether differences exist among hybrids in the amount of residue available for grazing and in the ratio of corn grain to total residue produced.

Materials and Methods

Ten hybrids that best represented a wide range of production traits were selected from a total of 40 hybrids grown in a test plot near Paxton, NE. The following hybrids were evaluated: Pioneer P0541XR, P1173HR, P1395XR, Dekalb 59-35, 61-04, NK N68B-GT, N74C-3000GT, Croplan Genetic 5757 VT3, Golden Harvest 8211 3000GT, and Midwest Genetics 76482R. Plot received center pivot irrigation and had a silt loam soil type.

The plot contained four rows per hybrid and rows were 76.2 cm apart. Plants were selected randomly for each hybrid by measuring 30 meters then sampling the tenth plant down, alternating between the four rows for each sample. Each plant was cut at ground level. Plant density was measured by counting the number of plants present in a 4.6 m length of row.

Each plant was sorted into the following parts: stems, leaves (including leaf sheath), husks, cobs and corn grain. Plant parts were dried in a forced air oven at 60º C to determine dry matter yield per plant. Yield was then expressed on a kg/ha basis using the following equation: avg plant yield/hybrid (kg)*plant density (# plants present in a .762 X 4.572 m area)/0.000348 ha.

Data were analyzed as a completely randomized design using the mixed procedures of SAS (SAS Inst., Inc., Cary, N.C.). The model included the fixed effect of hybrid. Differences were considered significant when P values were <0.05.

Results

Residue (leaf and husk) yield has been shown to be related to grain yield (Wilson, et. al. 2004). There was no difference in corn grain yield among hybrids (13,240 kg/ha ± 788, DMB; $P = 0.23$). Differences were present between hybrids in amount of stems ($P < 0.001$), leaves ($P = 0.05$), husks ($P = 0.01$), and cobs ($P < 0.001$, Table 1). Considering these differences, it is not surprising that total residue production (sum of stems, leaves, husks and cobs) was different ($P = 0.02$) among hybrids. However, differences also existed in the ratio of corn grain to total residue production ($P < 0.001$) and corn grain to leaf and husk ($P < 0.001$), indicating potential differences in plant efficiency. Wilson, et al. (2004) reported an average of 7.26 kg leaf and husk produced per 25.4 kg grain yield for high producing corn. Leaf and husk produced per 25.4 kg grain in the current study ranged from 6.86 to 10.58 kg. Corn hybrids differ in the amount of residue produced independent of the amount of grain.

Since corn hybrids differ in the amount of residue they produce, possible differences in amount of residue available for cattle to graze, also differs. The production of leaf and husk ranged from 3662 to 4938 kg/ha. A 544 kg cow will consume about 356 kg/month in a corn residue grazing situation (DMB; NRC, 1996). Assuming a 50% utilization of the leaf and husk (Wilson, et. al., 2004), the high and low husk and leaf producing hybrids could support 6.9 and 5.1 cows/ha, respectively. If corn residue cost $14.83/ha, this would equate to $2.15 and $2.90/AUM for the high and low leaf and husk producing hybrids, respectively. The findings of this study indicate differences in total residue as well as the ratio of grain yield to total residue do exist among hybrids. These differences can equate to potential economic differences among hybrids in the grazing value of the corn residue.

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Table 1. Composition of corn residue components of ten corn hybrids.

Hybrid[1]	5	8	10	21	25	29	35	38	46	48	SE	P-value
Grain, kg/ha	13853	13534	13406	14364	13726	12896	13279	13343	11555	12449	702	0.23
Stem, kg/ha	5029	4585	4441	4498	4286	3786	5154	5380	6138	5157	227	<0.001
Husk, kg/ha	921	1132	944	925	1005	1122	1150	894	964	695	83	0.01
Leaf, kg/ha	2908	3617	3211	3572	3325	3431	3788	3410	3711	2967	210	0.05
Cob, kg/ha	1580	1856	1488	1591	1677	1581	1940	1610	1479	1280	90	<0.001
Total, kg/ha[2]	10438^{a}	11190^{ab}	10084^{a}	10586^{a}	10294^{a}	9920^{a}	12033^{b}	11292^{ab}	12291^{b}	10100^{a}	544	0.02
Grain:total, g/g[2]	1.33^{a}	1.21^{ab}	1.34^{a}	1.38^{a}	1.34^{a}	1.30^{a}	1.12^{b}	1.19^{a}	0.95^{c}	1.23^{a}	0.04	<0.001
Grain:leaf and husk, g/g[2]	3.7^{a}	2.9^{b}	3.3^{c}	3.3^{c}	3.2^{c}	2.9^{b}	2.8^{bd}	3.1^{bc}	2.4^{d}	3.4^{ac}	0.1	<0.001

[1]Hybrids are as follows: 5, Golden Harvest 8211 3000GT; 8, Pioneer P0541XR; 10, Croplan Genetic 5757 VT3; 21, Dekalb 59-35; 25, Midwest Genetics 76482R; 29, NK N68B-GT; 35, Dekalb 61-04; 38, Pioneer P1173HR; 46, Pioneer P1395XR; and 48, NK N74C-3000GT.

[2]Values with different superscripts diff (P<0.05).

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EFFECT OF MINERAL SUPPLEMENTATION ON THE PERFORMANCE OF STOCKER CATTLE GRAZING WINTER-WHEAT PASTURE[1]

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ABSTRACT: Two experiments were conducted to evaluate the efficacy of mineral supplementing stocker cattle grazing wheat pasture. In Exp. 1, 72 steer and heifer calves (BW = 228 ± 11.4 kg) were assigned randomly to 12, 4.9-ha pastures on November 12 at 1.2 calves/ha (4 pastures), and February 5 at 2.5 calves/ha (8 pastures) for 84 d. In Exp. 2, 38 steers (BW = 248 ± 4.8 kg) were assigned randomly to 12, 2.5-ha wheat pastures on February 24 for 84 d at 2.4 steers/ha. In Exp. 2, pastures were planted with either conventional tillage or a no-till drill. Half the pastures in both experiments received a free-choice mineral mixture (Wheat Pasture Pro; Land O'Lakes Purina Feed, LLC; St. Paul, MN; Ca, 16% and P, 4%) provided in ground-type mineral feeders (Exp 1: completely random design; Exp 2: 2 x 2 factorial); feeders were weighed weekly to determine intake. All pastures were drilled in early September 2008 (67 kg of seed/ha) and fertilized with 50 kg of urea-N/ha. Standing herbage DM was determined in each pasture on every weigh date by clipping wheat to the ground along 122 cm of drill row at 10 transects. Data were analyzed by AOV with treatment as the fixed effect and pasture as a random effect. In Exp. 1, cattle offered minerals had a 45% faster ADG ($P < 0.01$; 0.75 kg) than those not offered minerals (0.52 kg); hence, supplemented cattle weighed 8% more ($P < 0.01$; 308 kg) after grazing than non-supplemented cattle (289 kg). In Exp. 2, supplementation did not interact ($P \geq 0.44$) with tillage. As in Exp. 1, steers offered the mineral had a faster ADG (30% increase; $P = 0.03$; 1.12 kg) than steers not offered minerals (0.86 kg), and supplemented cattle weighed 6% more ($P = 0.03$; 341 kg) after grazing than non-supplemented cattle (320 kg). In both experiments, daily standing herbage DM averaged 1,536 kg/animal and never differed ($P \geq 0.13$) between treatments. Mineral intakes averaged 73 (Exp. 1) and 168 (Exp. 2) g/d, resulting in a cost of supplement to kilogram of added BW gain of $0.26 and $0.64 (assuming a mineral cost of $0.88/kg). Overall, supplementing minerals to cattle grazing winter annual wheat pasture increased ADG in a cost-effective manner.

Key Words: Steers, Supplementation, Wheat pasture

Introduction

Mineral supplementation for cattle grazing wheat (*Triticum aestivum* L) pasture can significantly affect net return to the producer both through the prevention of metabolic disorders and improved performance (Horn et al., 2002). Two minerals of greatest concern for cattle grazing wheat pasture are Ca and Mg. The analyzed mineral composition of wheat forage indicates that it contains sufficient P and Mg, excess K, and inadequate Ca for growing cattle (Stewart et al., 1981). Hence, Ca is most likely the limiting mineral for cattle grazing wheat pasture (Grunes et al., 1983).

Research from Central Oklahoma has indicated improved performance by stocker cattle when provided a complete free-choice mineral supplement high in Ca and low in P (Horn et al., 2002; Fieser et al., 2007). We conducted 2 experiments to examine the efficacy of mineral supplementation in Northwest Oklahoma.

Materials and Methods

All animal procedures were conducted in accordance with the recommendations of the Consortium (1988) and were approved by the USDA-ARS Southern Plains Range Research Station Institutional Animal Care and Use Committee.

In Exp. 1, eight 4.9-ha pastures located on the Southern Plains Experimental Range of the USDA, Agricultural Research Service near Ft. Supply, OK were planted to wheat (67 kg/ha of seed) the first 2 wk of September 2008. Before planting, seedbeds were prepared by offset disking in early June, followed by harrowing as needed to control weeds. Pastures were fertilized before the final harrowing during the last week of August according to soil test recommendations for N, P, and K from the Oklahoma State University Soil and Water Testing Laboratory (Stillwater, OK) with 50 kg/ha of N from urea.

On November 12, 4 of the 8 pastures were stocked (1.2 calves/ha) with 6 calves (n = 24; 8 heifers and 16 steers; initial BW = 193 ± 1.2 kg) and grazed until February 5 (84 d). Grazing was initiated on November 12 after plant leaves were at least 20 cm in length. The initial set of calves was removed from pasture on February 5. On February 5, 12 new steer calves (initial BW = 217 ± 1.18 kg) were stocked on each of the 8 pastures (2.5 steers/ha) and subsequently removed on April 30 (84 d). During the fall 84-d grazing period, the 4 unused pastures were grazed in a different experiment using stocking rates similar to pastures that were used in the present experiment.

Half the pastures were selected randomly in the fall and spring grazing periods and calves in selected pastures were offered a free-choice mineral supplement (Wheat Pasture Pro; Land O'Lakes Purina Feed, LLC, Saint Paul, MN) in ground-type mineral feeders (Sioux Steel Company; Sioux City, SD). The mineral mixture contained (as-fed) 15 to 17% Ca and 4% P from $CaCO_3$ and Ca_2PO_4, 5.5% Mg from MgO, 18.5 to 22.0% NaCl, 220,500 IU of

vitamin A/kg, and trace minerals (1,250 ppm of Mn from $MnSO_4$, 650 ppm of Cu from basic CuCl, 2,185 ppm of Zn from $ZnSO_4$, 22 ppm Se from $NaSeO_3^-$, and 65 ppm of I from ethylenediamine dihydroiodide). The other pastures received no salt or supplement of any kind. Mineral feeders were weighed initially and on a weekly basis thereafter to determine mineral intake.

Table 1. Performance of stocker cattle grazing wheat pasture supplemented with free-choice minerals on the Southern Plains Experimental Range near Ft. Supply, OK (Exp. 1)

	Mineral supplement			
Item/period	No	Yes[a]	SE	*P*-value
BW, kg				
d 0	229	227	22.9	0.97
d 28[b]	252	261	3.1	0.04
d 56[b]	264	281	3.5	< 0.01
d 84[b]	289	308	4.2	< 0.01
ADG, kg				
First 28 d	0.23	0.55	0.106	0.04
Second 28 d	0.46	0.71	0.044	< 0.01
Third 28 d	0.97	1.09	0.199	0.68
Overall	0.52	0.75	0.049	< 0.01
BW gain/ha, kg	65	91	6.4	0.01
Herbage mass, kg of DM/animal				
First 28 d	620	752	210.9	0.26
Second 28 d	527	632	76.6	0.13
Third 28 d	475	670	102.4	0.22
Forage CP, % of OM				
First 28 d	19.2	19.9	1.02	0.25
Second 28 d	18.8	19.0	0.95	0.78
Third 28 d	19.9	19.1	0.76	0.18
Forage IVOMD[c], %				
First 28 d	70.1	69.7	2.00	0.70
Second 28 d	68.3	69.0	1.49	0.48
Third 28 d	68.6	70.8	2.56	0.10
Mineral intake, g/d as-fed				
First 28 d	--	68	24.9	--
Second 28 d	--	54	8.2	--
Third 28 d	--	91	44.5	--
Overall	--	73	11.4	--
Minerals/kg of added BW gain[d], $	0.26	--	--	

[a]Free-choice mineral (Wheat Pasture Pro Mineral; Land O Lakes Purina Feed, LLC, Saint Paul, MN) supplied in ground-style mineral feeders (Sioux Steel Company; Sioux City, SD).

[b]Least squares means were adjusted for BW on d 0 as a covariate ($P < 0.05$).

[c]In vitro OM disappearance.

[d]Purchase price of mineral, $0.875/kg.

Initially and at 28-d intervals thereafter, calves were weighed following a 16-h withdrawal from feed and water. Samples of standing herbage mass were collected on weigh dates at 10 paced transects in each pasture by clipping forage to the ground on 2 sides of 61 cm rod placed between drill rows. Herbage samples were placed in paper sacks, dried in a forced-air oven at 56° C to determine DM, and ground in a Wiley mill to pass a 1-mm screen before analysis for total N by combustion (Vario MAX CN; Elementar Ammericas, Inc., Mt. Laurel, NJ). The forage CP was calculated by multiplying N concentration by 6.25, and ash (AOAC, 1990) and in vitro OM disappearance (**IVOMD**; White et al., 1981) also were determined.

In Exp. 2, twelve 2.5-ha pastures on the Southern Plains Experimental Range were planted to wheat (67 kg/ha of seed) the first 2 wk of September 2008. Four of the pastures were planted with conventional tillage as described in Exp. 1. The remaining 8 pastures were planted using a no-till drill; weeds were previously been controlled by glyphosate application in June and again in August. Conventionally tilled pastures were fertilized as described in Exp. 1; no-till pastures were fertilized by top dressing with 50 kg/ha of N from urea 2 wk after seedling emergence.

On February 24, pastures were stocked with 6 steers (initial BW = 248 ± 4.8 kg) on each of the pastures (1.0 steers/ha) and were removed on May 19 (84 d). As in Exp. 1, half the pastures were selected randomly, and calves in selected pastures were offered the free-choice mineral described in Exp. 1 in the ground-type mineral feeders described previously. As in Exp. 1, cattle grazing the other pastures received no salt or supplement of any kind, and mineral feeders were weighed weekly to determine mineral intake. On d 0, 42, and 84, calves were weighed following a 16-h withdrawal from feed and water. Samples of standing herbage mass were collected on weigh dates, dried, and analyzed as described in Exp. 1.

Statistical Analyses. In Exp. 1, BW, ADG, and BW gain/ha was analyzed using the MIXED procedure in SAS (SAS Inst., Inc.; Cary, NC). The model included treatment and gender as a fixed effects and pasture, grazing season (block), and their interaction as random effects. Models for BW on d 28, 56, and 84 included initial BW as a covariate ($P < 0.05$). Herbage mass, forage CP and IVOMD, mineral intake, and minerals/kg of added BW gain were analyzed using the MIXED procedure in SAS with treatment as a fixed effect and grazing season (block) as the random effect. In Exp. 2, dependent variables were analyzed using the GLM procedure in SAS in a 2 x 2 arrangement of treatments. The model contained the tillage type, mineral supplementation, and their interaction. Dependent variables were tested with pasture (block x grazing season) as the error term. Models for BW on d 42 and 84 contained initial BW as a covariate. Herbage mass, forage CP and IVOMD, mineral intake, and minerals/kg of added BW gain were analyzed using the GLM procedure in SAS with treatments in the model and using the residual error term. Statistical analysis of Exp. 2 data revealed no significant ($P > 0.10$) tillage type effect or interaction with mineral

supplementation for any dependent variable; thus, only the main-effects of mineral supplementation are presented.

Results and Discussion

In Exp. 1, initial BW (d 0) did not differ between treatments (Table 1); however, after 28 d of grazing, mineral-supplemented cattle weighed 10 kg more (P = 0.04) than cattle not receiving the mineral. By d 56 and 84, mineral-supplemented cattle weighed 16 and 22 kg more (P < 0.01), respectively, than non-supplemented cattle. Average daily gain during the first and second 28-d periods was greater ($P \leq 0.04$) for mineral-supplemented cattle than for the non-supplemented group (Table 1). During the third 28-d period, ADG did not differ between treatments, but the overall ADG (84 d) was greater ($P < 0.01$) for the mineral-supplemented calves than for the non-supplemented calves. Body weight gain per hectare was increased (P = 0.01) 26 kg by mineral supplementation compared with the non-supplemented cattle. Standing herbage mass did not differ between treatments (Table 1), and forage CP and IVOMD concentrations in pasture samples did not differ between treatments in any of the three 28-d grazing periods (Table 1). Mineral intake averaged 73 g/d, which is well within the manufacturer's suggested intake range of 57 to 114 g/d.

In Exp. 2, initial BW (d 0) did not differ between treatments (Table 2). After 42 d of grazing, however, the mineral-supplemented cattle weighed 10 kg more (P = 0.05) than the non-supplementation cattle, and by d 84, the advantage for mineral-supplemented cattle was 21 kg more (P = 0.03). Average daily gain during the first and second 42-d periods, and the overall ADG was greater ($P \leq 0.05$) for mineral-supplemented than non-supplemented calves (Table 2). In contrast to results of Exp. 1, BW gain per hectare was not affected by mineral supplementation. Standing herbage mass did not differ between treatments (Table 2). Forage CP concentration during the first 42-d grazing period was slightly greater (P = 0.04) for pastures grazed by cattle receiving no supplemental mineral than for pastures where cattle received supplemental mineral; however, during the second 42-d grazing period, forage CP concentration did not differ between treatments. Forage IVOMD concentration during the first 42-d tended to be greater (P = 0.06) in the pastures grazed by mineral-supplemented cattle than in the pastures in which the cattle were not supplemented; during the second 42-d grazing period, IVOMD did not differ between treatments. Mineral intake averaged 168 g/d, which was slightly greater than the manufacturer's suggested daily intake.

As a percentage of non-supplemented ADG, the 44 and 30% increase noted in the overall ADG in Exp. 1 and 2, respectively, are slightly higher than the 11 and 24% increases from free-choice mineral supplementation reported by Horn et al. (2002) and Fieser et al. (2007), respectively, for cattle grazing wheat pasture in Central Oklahoma. The reason for our higher percent increase in ADG compared with other researchers is the greater ADG by non-supplemented cattle in other experiments (1.0 kg/d in Horn et al., 2002; 0.50 kg/d in Fieser et al., 2007). After 84 d of grazing, final BW were 6.6 and 6.5% greater for the mineral-supplemented cattle in Exp. 1 and 2, which is comparable to the results of Horn et al. (2002; 4.2% increase) and Fieser et al. (2007; 4.8% increase).

Table 2. Performance of stocker cattle grazing wheat pasture supplemented with free-choice minerals on the Southern Plains Experimental Range near Ft. Supply, OK (Exp. 2)

	Mineral supplement			
Item/period	No	Yes[a]	SE	*P*-value
BW, kg				
d 0	248	248	4.8	> 0.99
d 42[b]	264	274	3.3	0.05
d 84[b]	320	341	6.7	0.03
ADG, kg				
First 42 d	0.42	0.65	0.079	0.05
Second 42 d	1.31	1.58	0.095	0.05
Overall	0.86	1.12	0.080	0.03
BW gain/ha, kg	116	134	15.3	0.42
Herbage mass, kg of DM/animal				
First 42 d	604	574	55.3	0.71
Second 42 d	834	519	151.4	0.18
Forage CP, % of OM				
First 42 d	18.7	17.6	0.30	0.04
Second 42 d	15.4	16.3	0.53	0.28
Forage IVOMD[c], %				
First 42 d	76.5	78.1	0.52	0.06
Second 42 d	69.1	70.2	0.48	0.17
Mineral intake, g/d as-fed				
First 42 d	--	132	26.8	--
Second 42 d	--	200	114.9	--
Overall	--	168	73.5	--
Minerals/kg of added BW gain[d]		$0.64	--	--

[a]Free-choice mineral (Wheat Pasture Pro Mineral; Land O Lakes Purina Feed, LLC; Saint Paul, MN) supplied in ground style mineral feeders (Sioux Steel Company; Sioux City, SD).

[b]Least squares means were adjusted for calf BW on d 0 as a covariate (P < 0.05).

[c]In vitro OM disappearance.

[d]Purchase price of mineral, $0.875/kg.

Forage CP concentrations exceeded suggested NRC (1996) requirements for the growth rate observed in our study, suggesting that energy was most likely limiting growth rate. In addition, IVOMD concentrations did not differ greatly among grazing periods in either experiment. The CP and IVOMD concentrations recorded in our experiment are comparable to concentrations reported for wheat forage samples at similar times of the year collected in El Reno, OK and Bushland, TX (Stewart et al., 1981), and in Marshall, OK (Fieser et al., 2007).

The ratio of IVOMD:CP in samples from Exp. 1 and 2 ranged from 3.4 to 4.5. A ratio of IVOMD:CP between 4.0 and 4.5 has been suggested to indicate a balance of ruminal available N to ruminal available energy in the diets of cattle (Hogan and Weston, 1970; Gunter et al., 1995). When this ratio is greater than 4.5, a supplement high in ruminally degradable N would be the most efficacious choice. However, with forages in which dietary N is not limiting (ratio < 4.5), a high-starch or digestible fiber supplement would be more beneficial (Nocek and Russell, 1988). The ratio of IVOMD:CP was 4.5 or less for all sampling dates in the present study. Hence, a small quantity of a high-energy supplement like corn or soybean hulls would have been the best choice if a greater ADG was desired.

Daily mineral intake was within or slightly higher than the manufacture recommended range in both Exp. 1 and 2, and similar to intake rates reported by Horn et al. (2002) and Fieser et al. (2007) for free-choice for free-choice mineral supplements not containing an ionophores. These intake rates and added ADG by the cattle resulted in ratio of mineral cost to kilogram of added ADG of $0.26 to 0.64. In contrast, Horn et al. (2002) reported a mineral cost per kilogram of added ADG ratios of $1.01. Within the first 2 wk of March 2010, the value of a kilogram of additional gain on a 317-kg steer sold at Oklahoma City was approximately $1.08 (AMS, 2010), which would make feeding a free-choice mineral similar to that offered in our 2 experiments profitable.

Overall, in our 2 experiments, supplementing a free-choice mineral mixture high in Ca and low in P to cattle grazing wheat pasture in Northwest Oklahoma increased ADG. Furthermore, our results suggest that free-choice mineral supplementation is likely to yield a positive return on investment.

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ADAPTATION OF *BRASSICA* SPP. AND FODDER RADISHES AS LATE SEASON FORAGES IN THE HIGH DESERT REGION OF OREGON.

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ABSTRACT: The objective of this study was to evaluate the yield potential and viability of winter triticale (TRT; n=1), *Brassica* spp. (BRS; n=6), and radish (RAD; n=3) varieties, as late season forages. In 2009 three planting dates (PD1, 2 & 3; July 30, Aug.14, & Aug. 28, respectively) were analyzed with 2 harvest dates (HD; approximately 60 and 90 d after planting) per PD (4 replications per variety). Plots were arranged in a randomized complete block design with a split plot. Varieties included: Winter Triticale (TRT; trical102); Dwarf Siberian Kale, Winfred (WIN, hybrid); Purple Top White Globe Turnip; Hunter (hybrid); New York Turnip; Pulsar Rape (PR); Graza Radish; Colonel Radish (CR); and Terranova Radish. Plots were seeded with a modified Great Plains drill at 4.5, 7.9, and 112.3 kg pure live seed/hectare (ha; for BRS, RAD, and TRT; respectively) into glyphosate-treated small grain stubble. Plots were fertigated with 67.3 kg nitrogen and 22.4 kg sulfur/ha after plants reached the two-leaf stage and were irrigated through Oct.15. Across all PD, TRT was the lowest yielding variety (3.70 ± 0.56, 2.51 ± 0.29, and 1.44 ± 0.49 t dry matter (DM)/ha; PD1, 2, and 3, respectively). The variety with the greatest yield differed by PD (WIN 7.49 ± 0.47, PR 5.31 ± 0.29, WIN 4.48 ± 0.43 t DM/ha; for PD 1, 2, and 3, respectively). For both PD 1 and 2, CR, BRS hybrids and PR yielded more than turnip and RAD varieties ($P \leq 0.05$), but by PD 3 all BRS varieties yielded more than RAD varieties ($P \leq 0.05$), with turnip varieties tending to have higher yields among the BRS group. The 60 d HD yielded less ($P<0.01$) than the 90 d HD for PD 1 and 3, only (5.31 vs. 6.30 ± 0.20 and 2.65 vs. 4.04 ± 0.19 t DM/ha; for 60 vs.90 d HD, PD 1 and 3; respectively). No PD X HD interaction occurred ($P \geq 0.16$). Both BRS and RAD produced good late season yields, and seem well-suited to extend the grazing season. For earlier PD, differences between varieties were as large as differences between species, but by PD3 the BRAS varieties produced greater yields than other species.

Key words: Brassica spp., fodder radish, forage

Introduction

Forage brassica (BRS; *Brassica* spp.) and fodder radish (RAD; *Raphanus sativus*) are cold-tolerant, fast-growing crops that are used extensively as a forage resource for grazing livestock in Europe, Great Britain, New Zealand and locations in the United States. Interest in brassicas have increased in recent years as a forage resource with potential to extend fall grazing for 2-3 months in the United States. Since 2003, hay prices in Oregon have increased from $97/t to $169/t (NASS; 2007), which have also increased maintenance dietary costs from $1.32/head/day to $2.30/head/day. Extending the fall grazing season would reduce the usage of harvested forage and could significantly reduce annual feed costs for cow-calf producers. Measured yields have ranged between 5.6-17.9 t DM/hectare (Piggot et. al, 1980; Bartholomew and Underwood, 1992; Reid et. al, 1994). Brassica and RAD have been successfully planted following harvest of summer annual crops in several long-season regions of the U.S. However, research investigating planting dates and cropping systems that successfully integrate BRS and RAD for extending fall grazing in short-season production locations is limited. The high-desert region of Oregon produces small grains on several thousand acres of irrigated farmland. However, grain harvest typically occurs much later (late August to early September) compared with other production areas in the United States (July and early August). Brassica and RAD are cold tolerant and can withstand temperatures as low as -6.7 °C, making them an ideal choice for short-season production areas experiencing multiple early fall frosts. Varieties of BRS and RAD that can be planted in late August to early September and still attain economically viable yields for grazing are needed. In addition, significant acreage of small grain is fall planted in the high-desert region of Oregon and harvested for hay in late June to early July. Identifying BRS and RAD varieties which provide high yield potential following cereal hay harvest is also needed.

The objective of this study was to evaluate the yield potential and viability of winter triticale (TRT; n=1), *Brassica* spp. (BRS; n=6), and radish (RAD; n=3) varieties, as late-season forages following small grain hay harvest or harvest for grain.

Materials and Methods

In 2009 nine different BRS and RAD varieties along with TRT were evaluated at three planting dates (PD1, 2 & 3; July 30, August 14, and August 28, respectively), with two harvest dates (HD; approximately 60 and 90 d after planting) per PD (4 replications per variety). The PD were selected to best match timing options producers would typically have following either small grain hay harvest or grain harvest in the high-desert region of Oregon. Treatment plots were assigned in a randomized complete block design arranged as a split plot

at the Klamath Basin Research and Extension Center, Klamath Falls, OR. Varieties tested were: *Brassica napus L.* var. Pulsar rape (PR*), Brassica napus var.* Dwarf Siberian Kale (DSK*), Brassica napus* var. Winfed (WIN; turnip x kale hybrid*), Brassica rapa* var. Purple Top White Globe turnip (PT*), Raphanus sativus var.* Graza radish (GR*),* ; *Brassica campestris spp. rapa* var. Hunter (HUN; turnip x rape hybrid*), Brassica rapa* var. New York turnip (NYT*), Raphanus sativus* var. Colonel radish (CR*), Raphanus sativus* var. Terranova radish (TR*), X Triticosecale rimpaui* Wittm. Var. Trical 102 winter triticale (TRT). Plots were seeded into glyphosate-treated small grain stubble, that had been previously harvested for hay, using a modified Great Plains© drill. Each seeded plot measured 1.72 m by 6.10 m. Seeding rates were 4.5, 7.9, and 112.3 kg/hectare (ha), pure live seed, for Brassica, radish, and winter triticale varieties, respectively. Given the small seed size for most of the varieties and the small plot area, a similar weight of cracked corn was used as a carrier to ensure more uniform plot seeding. Plots were irrigated at planting through October 15. Plots were fertilized through the irrigation system (fertigated) with 67.3 kg nitrogen and 22.4 kg sulfur/ha, using a solution consisting of 67.8% Solution 32 and 32.2 % Thiosul, after plants reached the true two-leaf stage for all PD (12, 20 and 17 d after planting for PD1, 2, and 3; respectively). The first HD for each PD were harvested by hand from 0.48 m^2 area of each plot on October 7 (69 d from PD 1), October 22 (69 d from PD 2), and October 27 (60 d from PD 3). All harvested wet plant material was placed in a paper bag and weighed prior to drying in a forced air oven at 60º C. Dried subsamples were weighed to determine DM production. From the same plots, a separate area (3.42 m^2) was mechanically harvested for the second HD on October 28 (90d after planting for PD 1), November 12 (90d after planting for PD 2), and November 30 (94 d after planting for PD 3). Total plot wet weight was measured and recorded. Sub-samples were processed as indicated above. Statistical analysis was performed on the data for each PD using the PROC MIXED procedures in SAS for a randomized complete block with split plot.

Results

Planting Date 1

For PD 1, there was a significant ($P < 0.001$) variety effect (Table 1). The WIN, CR, and PR varieties had the greatest DM Yields, ≥ 7.13 ± 0.47 t/ha. The remaining varieties, with the exception of TRT, were similar ($P > 0.05$) with a mean yield of 5.38 ± 0.49 t/ha. TRT was the lowest yielding variety at 3.70 ± 0.56 t/ha. There was also a significant effect of harvest timing, 69 vs. 90 d ($P < 0.001$). Harvesting at 69 d following planting netted a lower DM yield (5.38 ± 0.20 t/ha) compared to harvesting at 90 d (6.28 ± 0.20 t/ha) following planting. There was no variety by HD interaction ($P = 0.26$; Figure 1)

Table 1. 2009 Dry Matter Yields of *Brassica*, Radish, and Triticale Varieties for the First Planting Date.[1]

Variety[2]	Dry Matter Yield	Standard Error
	t / hectare	
WIN	7.49 [a]	0.47
CR	7.29 [a]	0.47
PR	7.13 [a,b]	0.47
HUN	5.74 [b,c]	0.47
TR	5.61 [c]	0.52
PT	5.54 [c]	0.47
GR	5.49 [c]	0.47
DSK	5.27 [c]	0.52
NYT	4.87 [c,d]	0.47
TRT	3.70 [d]	0.56

[1] Within a column means without a common superscript differ ($P < 0.05$).

[2] *Brassica napus L.* var. Pulsar rape (PR*), Brassica napus var.* Dwarf Siberian Kale (DSK*), Brassica napus* var. Winfed (WIN; turnip x kale hybrid*), Brassica rapa* var. Purple Top White Globe turnip (PT*), Raphanus sativus var.* Graza radish (GR*),* ; *Brassica campestris spp. rapa* var. Hunter (HUN; turnip x rape hybrid*), Brassica rapa* var. New York turnip (NYT*), Raphanus sativus* var. Colonel radish (CR*), Raphanus sativus* var. Terranova radish (TR*), X Triticosecale rimpaui* Wittm. Var. Trical 102 winter triticale (TRT).

Planting Date 2

There was a significant ($P < 0.001$) variety effect for PD 2 (Table 2). Five varieties (PR, DSK, CR, HUN, and WIN) had similar ($P > 0.05$) DM yields with a mean yield of 5.11 ± 0.29 t/ha. The remaining varieties (NYT, PT, TR, and GR), with the exception of TRT, were similar ($P > 0.05$) with an average DM yield of 3.88 ± 0.27 t/ha. For this PD, time of harvest (69 vs. 90 d) did not have a significant effect on DM yield ($P = 0.62$; 9.55 ± 0.13 t/ha). Additionally, there was no variety by HD interaction ($P = 0.16$; Figure 2).

Table 2. 2009 Dry Matter Yields of *Brassica*, Radish, and Triticale Varieties for the Second Planting Date.[1]

Variety[2]	Dry Matter Yield	Standard Error
	t / hectare	
PR	5.31 [a]	0.29
DSK	5.22 [a]	0.31
CR	5.07 [a]	0.29
HUN	5.00 [a]	0.29
WIN	4.96 [a]	0.29
NYT	4.10 [b]	0.29
PT	4.08 [b]	0.29
TR	3.68 [b]	0.31
GR	3.65 [b]	0.29
TRT	2.51 [c]	0.29

[1] Within a column means without a common superscript differ ($P < 0.05$).

[2] *Brassica napus L.* var. Pulsar rape (PR*), Brassica napus var.* Dwarf Siberian Kale (DSK*), Brassica napus* var. Winfed (WIN; turnip x kale hybrid*), Brassica rapa* var. Purple Top White Globe turnip (PT*), Raphanus sativus var.* Graza radish (GR*),* ; *Brassica campestris spp. rapa* var. Hunter (HUN; turnip x rape hybrid*), Brassica rapa* var. New York turnip (NYT*), Raphanus sativus* var. Colonel radish (CR*), Raphanus sativus* var. Terranova radish (TR*), X Triticosecale rimpaui* Wittm. Var. Trical 102 winter triticale (TRT).

Planting Date 3

The third planting date had a significant variety effect that was a little more complicated (Table 3). The top DM yielding variety for this PD was WIN (4.48 ± 0.43 t/ha) which was similar ($P > 0.05$) to NYT, DSK, PT, HUN, and PR. The two lowest DM yielding varieties were GR (1.86 ± 0.43 t/ha) and TRT (1.44 ± 0.49 t/ha). Time of harvest was significant for PD 3 ($P > 0.001$). Delaying harvest for an additional 30d increased DM yield at 90 d compared to 60d following planting (4.04 and 2.65 ± 0.18 t/ha for the 90 and 60 d HD, respectively). However, there was no Variety by HD interaction observed for this planting date ($P = 0.47$; Figure 3).

Discussion

Across all three PD both BRS and RAD varieties produced good late season yields, and seem well-suited to extend the grazing season. Observed yields were comparable to typical yields for perennial forages grown in this area. The WIN variety, a hybrid BRS, consistently performed as a top variety across all three PD, with DM yields ≥ 4.48 t/ha. In general, with the exception of CR, for the first two PD the turnip BRS and RAD varieties were the lowest yielding. However at PD 3 RAD performances had declined and were among the lower yielding varieties. This resulted in the turnip BRS varieties ranking among the higher yielding varieties for PD 3. Based on this year's data it would appear that by PD, variety selection is important and in general RAD and turnip varieties may not be the best choices for seeding dates similar to PD 1 and 2. However this is not true for turnip varieties at PD 3. For earlier PD, differences between varieties were as large as differences between species, but by PD3 the BRAS varieties all produced greater yields than other species. Some caution with CR and TR is warranted. The CR and TR varieties have been used as a cover crop variety to suppress soil-borne nematodes and may have anti-nutritional qualities that could be detrimental to animal health. Until this can be investigated further these varieties should be used with caution, for grazing livestock.

Table 3. 2009 Dry Matter Yields of *Brassica*, Radish, and Triticale Varieties for the Third Planting Date.[1]

Variety[2]	Dry Matter Yield	Standard Error
	t / hectare	
WIN	4.48 [a]	0.43
NYT	4.10 [a,b]	0.40
DSK	4.06 [a,b]	0.40
PT	3.99 [a,b]	0.40
HUN	3.92 [a,b]	0.40
PR	3.57 [a,b,c]	0.40
CR	3.14 [b,c]	0.43
TR	2.80 [c,d]	0.43
GR	1.86 [d,e]	0.43
TRT	1.44 [e]	0.47

[1] Within a column means without a common superscript differ ($P < 0.05$).

[2] *Brassica napus L.* var. Pulsar rape (PR), *Brassica napus var.* Dwarf Siberian Kale (DSK), *Brassica napus* var. Winfed (WIN; turnip x kale hybrid), *Brassica rapa* var. Purple Top White Globe turnip (PT), *Raphanus sativus var.* Graza radish (GR), ; *Brassica campestris spp. rapa* var. Hunter (HUN; turnip x rape hybrid), *Brassica rapa* var. New York turnip (NYT), *Raphanus sativus* var. Colonel radish (CR), *Raphanus sativus* var. Terranova radish (TR), *X Triticosecale rimpaui* Wittm. Var. Trical 102 winter triticale (TRT).

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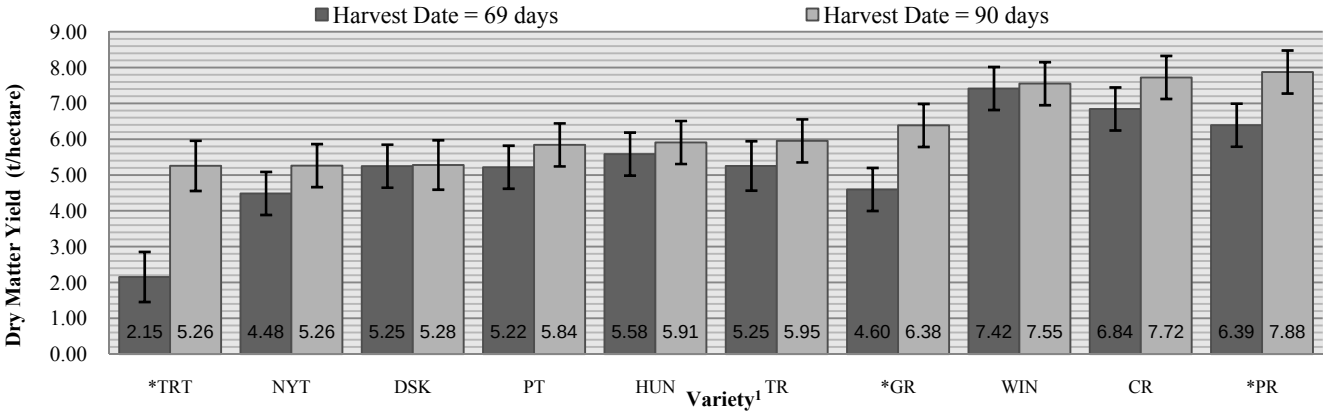

Figure 1. The effect of the interaction of variety by harvest date for *Brassica*, radish, and triticale varieties on dry matter yield at 69 and 90 d following planting for the first planting date. An overall variety by harvest date interaction was not observed ($P = 0.26$). Within a variety, if denoted with an *, a difference was detected between the 69 and 90 d HD ($P < 0.05$). [1] *Brassica napus L.* var. Pulsar rape (PR*), Brassica napus var.* Dwarf Siberian Kale (DSK*), Brassica napus* var. Winfed (WIN; turnip x kale hybrid*), Brassica rapa* var. Purple Top White Globe turnip (PT*), Raphanus sativus var.* Graza radish (GR*),* ; *Brassica campestris spp. rapa* var. Hunter (HUN; turnip x rape hybrid*), Brassica rapa* var. New York turnip (NYT*), Raphanus sativus* var. Colonel radish (CR*), Raphanus sativus* var. Terranova radish (TR*), X Triticosecale rimpaui* Wittm. Var. Trical 102 winter triticale (TRT).

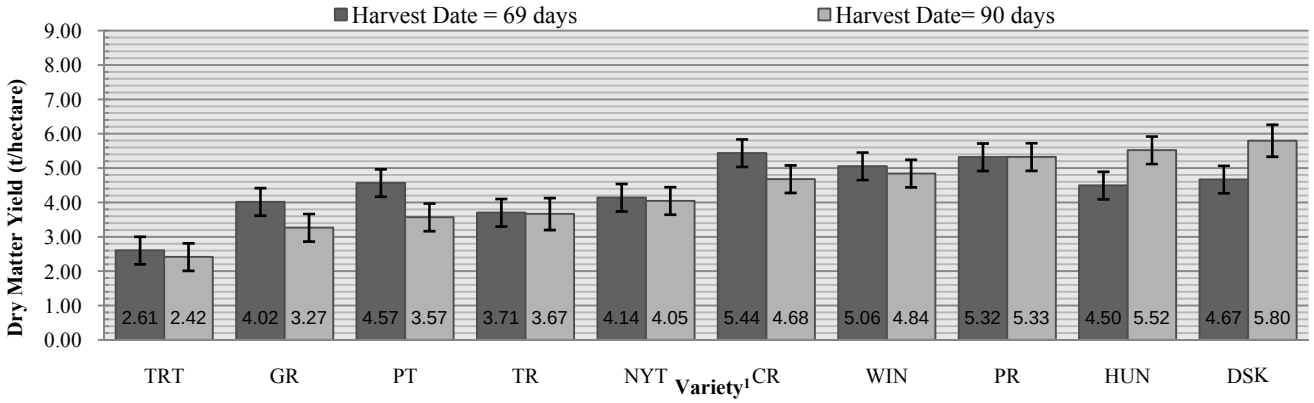

Figure 2. The effect of the interaction of variety by harvest date for *Brassica*, radish, and triticale varieties on dry matter yield at 69 and 90 d following planting for the second planting date. An overall variety by harvest date interaction was not observed ($P = 0.16$). Within a variety, if denoted with an *, a difference was detected between the 69 and 90 d HD ($P < 0.05$). [1] *Brassica napus L.* var. Pulsar rape (PR*), Brassica napus var.* Dwarf Siberian Kale (DSK*), Brassica napus* var. Winfed (WIN; turnip x kale hybrid*), Brassica rapa* var. Purple Top White Globe turnip (PT*), Raphanus sativus var.* Graza radish (GR*),* ; *Brassica campestris spp. rapa* var. Hunter (HUN; turnip x rape hybrid*), Brassica rapa* var. New York turnip (NYT*), Raphanus sativus* var. Colonel radish (CR*), Raphanus sativus* var. Terranova radish (TR*), X Triticosecale rimpaui* Wittm. Var. Trical 102 winter triticale (TRT).

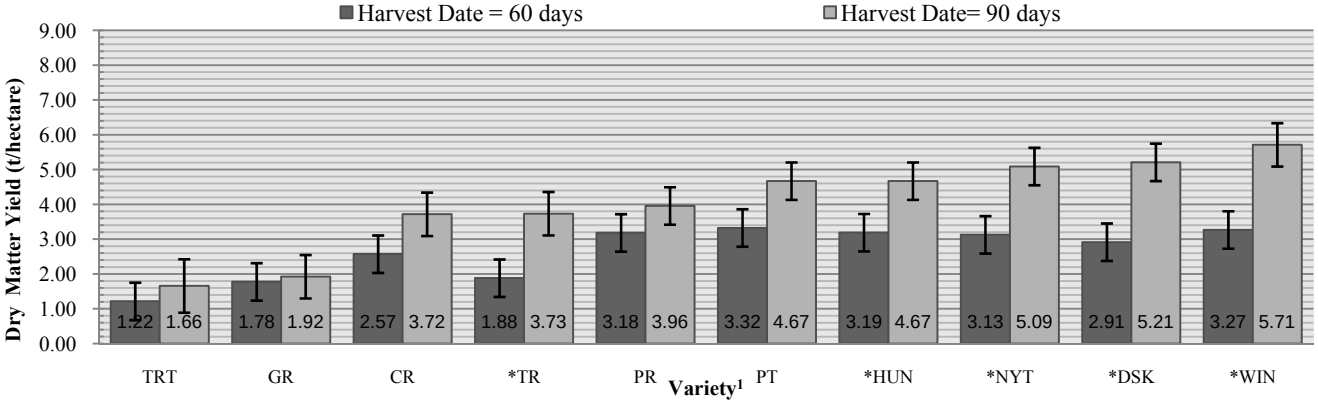

Figure 3. The effect of the interaction of variety by harvest date for *Brassica*, radish, and triticale varieties on dry matter yield at 60 and 90 d following planting for the third planting date. An overall variety by harvest date interaction was not observed ($P = 0.47$). Within a variety, if denoted with an *, a difference was detected between the 60 and 90 d HD ($P < 0.05$). [1] *Brassica napus L.* var. Pulsar rape (PR*), Brassica napus var.* Dwarf Siberian Kale (DSK*), Brassica napus* var. Winfed (WIN; turnip x kale hybrid*), Brassica rapa* var. Purple Top White Globe turnip (PT*), Raphanus sativus var.* Graza radish (GR*),* ; *Brassica campestris spp. rapa* var. Hunter (HUN; turnip x rape hybrid*), Brassica rapa* var. New York turnip (NYT*), Raphanus sativus* var. Colonel radish (CR*), Raphanus sativus* var. Terranova radish (TR*), X Triticosecale rimpaui* Wittm. Var. Trical 102 winter triticale (TRT).

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SERUM CONCENTRATIONS OF GHRELIN, IGF-I, AND PROLACTIN IN RAMBOUILLET LAMBS DURING THE PREWEANING PERIOD

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ABSTRACT: During a 60-d preweaning period in each of 2 yr, Rambouillet lambs (n = 75 and 52 for yr 1 and 2, respectively) were used to examine effects of sex (77 females, 50 males) and type of birth (TOB; 46 single, 81 multiple lambs) on serum concentrations of ghrelin (total), IGF-I, and prolactin (PRL). Lambs were born in mid-March of each year and were weighed on the day of birth (d 0; 5.1 ± 0.1 kg) and at weaning (60 d, 20.1 ± 0.4 kg). Serum was harvested by centrifugation from blood collected (jugular venipuncture) on d 1, 14, 28, 42, and at weaning. Data were examined by ANOVA for a randomized complete block design with a 2 (sex) x 2 (TOB) factorial arrangement, sampling day as a repeated measure, and year as the block. Males were heavier at birth than females ($P < 0.001$), but weaning weight and ADG were similar ($P > 0.35$). Single lambs were heavier ($P < 0.001$) at birth and weaning and had greater ADG ($P < 0.001$) than multiple lambs. Serum ghrelin was similar ($P > 0.24$) in male and female and in single and multiple lambs. However, ghrelin declined during the preweaning period with values of 557, 373, and 358 (± 9) pg/mL (quadratic, $P < 0.001$) on d 1, 28, and 60, respectively. Serum PRL and IGF-I were influenced ($P < 0.05$) by sex x day and TOB x day interactions. Males and females had similar ($P = 0.23$) IGF-I on d 1; but on d 14, 28, 42, and at weaning, males had greater ($P < 0.05$) IGF-I than did females. Serum IGF-I was greater ($P < 0.02$) in single than in multiple lambs on all sampling days. Serum PRL was similar ($P > 0.10$) in male and female lambs throughout preweaning. However, single lambs had greater ($P < 0.001$) serum PRL concentrations than did multiple lambs on d 42 and at weaning. In general, PRL and IGF-I tended to increase in a quadratic ($P < 0.01$) fashion across the preweaning period. Correlation coefficients determined on d 60 between serum IGF-I, PRL, and ghrelin concentrations and preweaning ADG were 0.65, 0.44, and -0.26 ($P < 0.005$), respectively. Sex of lamb, type of birth, and age should be considered when evaluating serum hormone profiles in rapidly growing lambs.

Key words: sheep, growth, hormone

INTRODUCTION

Increased efficiency of animals in the livestock industry is of great interest; therefore, predictions of weaning weight and ADG based on components of the endocrine system during early growth may be beneficial to producers. Growth hormone (GH) is a major regulator of postnatal growth (Griffin and Ojeda, 2004), but other hormones like ghrelin, insulin-like growth factor-I (IGF-I), and prolactin (PRL) also influence growth through direct or indirect means. Ghrelin plays a role in energy homeostasis (Tschöp et al., 2000; Miller et al., 2010), promotes birth weight and cellular proliferation in rodents (Miller et al., 2010), acts to stimulate feed intake (Sherman et al., 2008; ThidarMyint and Kuwayama, 2008; Miller et al., 2009), and is a potent GH-releasing agent (Horvath et al., 2001; Griffin and Ojeda, 2004; Sherman et al., 2008; ThidarMyint and Kuwayama, 2008). Tschöp et al. (2000) found that ghrelin-induced metabolic changes led to an efficient metabolic state resulting in increased BW and fat mass. Insulin-like growth factor-I regulates growth and cellular metabolism (Davis and Simmen, 2006), mediates the growth-promoting effects of GH which also stimulates the synthesis of IGF-I, and is positively correlated with growth rate and plasma GH (Gatford et al., 1997). Prolactin is similar in structure to GH and functions in conjunction with GH to initiate cell proliferation and differentiation (Griffin and Ojeda, 2004). Prolactin has also been suggested to be an anabolic hormone in ruminants and nonruminants (Ohlson et al., 1981). The objective of the present study was to examine serum concentrations of total ghrelin, IGF-I, and PRL in Rambouillet lambs during the preweaning period and to evaluate relationships between serum concentrations of the hormones and growth responses.

MATERIALS AND METHODS

All procedures involving animals were approved by the New Mexico State University Institutional Animal Care and Use Committee.

Animals and Management. One hundred twenty-seven spring-born Rambouillet lambs total over 2 yr (n = 75 and 52 for yr 1 and 2, respectively), were used to examine serum concentrations of ghrelin (total), IGF-I, and PRL as influenced by sex (77 females, 50 males) and type of birth (46 single, 81 multiple lambs). All animals were maintained at the West Sheep Unit on the main campus at New Mexico State University. On the day of birth (d 0), lambs were individually indentified and birth weight (5.1 ± 0.1 kg), sex, and type of birth were recorded. On d 1 after birth, each lamb was docked and received an i.m. injection of 1 mg selenium and 68 USP units of vitamin E (BO-SE, Schering-Plough Animal Health, Union, NJ). Creep feeding was introduced at an average age of 10 d and continued until weaning. Lambs were provided ad libitum access to water and alfalfa hay with a limited amount of cracked corn fed each morning. Male lambs were castrated using elastrator bands and all lambs were vaccinated against

Clostridium perfringens types C and D and *Clostridium tetani* (Bar Vac CD/T; Boehringer Ingelheim Vetmedica, Inc., St. Joseph, MO) on d 28. Once an average age of 60 d was achieved, lambs were weaned and weighed (20.1 ± 0.4 kg), and received a second clostridial vaccination.

Blood Collection. Blood samples were collected for each lamb via jugular venipuncture on d 1, 14, 28, 42, and at weaning into 9-mL sterile serum separator tubes (Corvac, Kendall Health Care, St. Louis, MO). Samples were allowed to clot at room temperature for approximately 30 min before centrifugation for 15 min at 1,500 x g and 4°C. Serum was stored frozen (-20°C) in labeled plastic vials until assayed.

Hormone Analysis. Serum concentrations of ghrelin (total) were determined in samples taken on d 1, 28, and at weaning and concentrations of IGF-I and PRL were determined in all samples taken. All hormones were measured in duplicate using double-antibody RIA. Serum ghrelin was quantified using a commercial total Ghrelin RIA kit (GHRT-89HK, Linco, St. Charles, MO). Serum IGF-I was determined as described by Berrie et al. (1995), and PRL as described by Spoon and Hallford (1989). Within and between assay CV were less than 15% for all hormone determinations.

Statistical Analysis. Data were examined by ANOVA for a randomized complete block design with a 2 (sex) x 2 (birth type) factorial arrangement of main factors. Because data were collected over 2 lambing seasons, year was considered as a block. All interactions with year were accounted for in the model and main factors were tested using animal within year by lamb birth type by lamb sex as the error term. Sampling days were consistent across years, so day was considered a fixed effect. Effects of day and interactions with day on serum hormone profiles were tested using the residual error term. When significant day effects were detected, day means were separated using linear, quadratic, cubic, and quartic contracts. All analyses were computed using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC).

RESULTS AND DISCUSSION

Weight Responses

Effects of Sex. Body weight responses of male and female lambs are presented in Table 1. No sex by type of birth interactions were observed ($P > 0.05$). Male lambs were heavier ($P < 0.01$) at birth than were females (5.6 and 5.0 ± 0.11 kg, respectively). Similar findings were reported by Miller et al. (2010). However, both actual and 60-d adjusted weaning weights were similar ($P > 0.35$) in the 2 sex groups. Likewise, preweaning ADG did not differ ($P = 0.46$) in male (0.27 ± 0.11 kg/d) and female lambs (0.28 ± 0.01 kg/d). These data conflict with those reported by Gatford et al. (1997) who found sex did not influence birth weight but did affect male weaning weight which tended to be greater than female weaning weight. Gatford et al. (1997) also reported that growth rate of males exceeded that of females during the preweaning period.

Effects of Birth Type. Lamb type of birth exerted a larger effect on weight responses than did sex of lamb (Table 1). At birth, single-born lambs weighted 5.7 kg compared with 4.9 (± 0.11) kg for multiple-born lambs ($P < 0.01$). In agreement with our data, Miller et al. (2010) also found singleton lambs to be heavier than twin lambs at birth. Single lambs continued to be heavier at weaning ($P < 0.01$) compared with multiple lambs which resulted in heavier ($P < 0.01$) preweaning ADG (0.32 and 0.24 ± 0.01 kg/d in single and multiple lambs, respectively).

Serum Hormone Responses

Ghrelin. Serum total ghrelin concentrations were not influenced ($P > 0.30$) by 2- or 3-way interactions involving sex, birth type, and sampling day. Serum ghrelin values were similar ($P = 0.25$) in male (420 ± 12.3 pg/mL) and female (439 ± 12.5 pg/mL) lambs (values pooled across all sampling days). Likewise, single and multiple lambs had similar ($P = 0.35$) ghrelin concentrations (422 and 437 ± 12.7 pg/mL, respectively). Our observations conflict with those of Miller et al. (2009) who found singleton lambs to have less circulating ghrelin than twin-born lambs. However, Kitamura et al. (2003) also observed no gender effect on ghrelin concentrations in human neonatal or umbilical cord blood.

Serum ghrelin concentrations differed ($P < 0.01$) among sampling days during the preweaning period. On d 1, 28, and 60 after birth, ghrelin values were 557, 373, and 358 (± 9.4) pg/mL, respectively (quadratic, $P < 0.01$). These total ghrelin responses suggest no major differences between sex or birth type groups, but values tend to be elevated shortly after birth and then decline during the mid to late preweaning period.

IGF-I. Serum IGF-I concentrations were not affected by a sex by birth type by sampling day interaction ($P = 0.90$). Likewise, no sex by birth type interaction was observed ($P = 0.21$). However, sex by sampling day and birth type by sampling day interactions were detected ($P < 0.03$); therefore, effects of sex and birth type on serum IGF-I were examined within day. On the day after birth, serum IGF-I was similar ($P = 0.37$) in male and female lambs (Figure 1). However, on all other sampling days, male lambs had greater ($P < 0.035$) IGF-I concentrations than did female lambs such that at weaning values were 176 and 146 (± 6.6) ng/mL in the 2 respective sex groups. In comparison, Fall et al. (1995) found IGF-I concentrations to be higher in girls than in boys at approximately 4 yr of age.

Serum IGF-I values in single and multiple lambs during the preweaning period are shown in Figure 1. On the day after birth, single lambs (109 ± 4.7 ng/mL) had a greater ($P < 0.01$) IGF-I concentration than did multiple-born lambs (91 ± 4.7 ng/mL). This difference continued throughout the remainder of the preweaning period with single lambs having a value of 189 ± 6.8 ng/mL at weaning compared with 133 ± 6.8 ng/mL for multiple lambs ($P < 0.01$). Similar data was reported by Gatford et al. (1997).

Data presented in Figure 1 also shows IGF-I trends across sampling day. In both the sex and birth type graphs, serum IGF-I increased between d 1 and 14, and then tended to gradually decline until weaning. When linear, quadratic, and cubic contrasts were computed for day responses within sex and birth type, all were significant ($P < 0.03$).

Prolactin. As with IGF-I, serum PRL concentrations were not affected by sex by birth type by sampling day or sex by birth type interactions ($P > 0.40$).

However, a birth type by day interaction was observed ($P < 0.01$) and a tendency for a sex by day effect was noted ($P = 0.09$). Sex and birth type effects on serum PRL were, therefore, examined within each sampling day. Serum PRL concentrations did not differ ($P > 0.15$) in male and female lambs on any of the sampling days (Figure 2). Similarly, neither Oxender et al. (1972) when observing bovine fetal serum nor Farmer et al. (1987) observing piglets at birth found an effect of sex on PRL concentrations. However, Campbell et al. (1993) observed differences in PRL levels between lamb sexes 41 d after weaning.

Serum PRL values in single and multiple lambs are shown in Figure 2. On the day after birth and on d 14, PRL was similar ($P > 0.10$) in the 2 birth type groups. However, on d 28, 42, and 60, single lambs had elevated ($P < 0.02$) values compared with those observed in multiple lambs. On the day of weaning, single lambs had a PRL value of 351 ± 27.0 ng/mL compared with 215 ± 27.0 ng/mL for multiple-born lambs. In comparison, Campbell et al. (1993) found PRL concentrations varied in lambs throughout the preweaning period, with greater values observed on d 16 and 60 when compared to d 38.

Examination of the 2 graphs shown in Figure 2 demonstrates the large increase in serum PRL values that occurred between d 28 and 42 in all lambs. Day responses in serum PRL values were quadratic ($P < 0.01$) in both sex and birth type groups.

Relationships among Growth and Hormone Responses

Correlation coefficients computed between total ghrelin concentrations on the individual sampling days and growth responses were low in magnitude and negative in direction (i.e., $r < -0.30$). On the other hand, correlation coefficients computed between serum IGF-I on d 1, 14, 28, 42, and 60 and preweaning ADG were 0.33, 0.56, 0.63, 0.70, and 0.65, respectively ($P < 0.001$). Correlations values between serum PRL concentrations on d 42 and 60 and preweaning ADG were 0.34 and 0.44, respectively ($P < 0.001$).

These data imply that lamb sex and type of birth should be considered when examining preweaning hormonal responses. In addition, serum IGF-I and PRL are related to lamb growth responses and may have value in predicting growth potential.

ACKNOWLEDGMENTS

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Table 1. Body weight responses, during a 60-day preweaning period, of female and male Rambouillet lambs born as a single or as a multiple[1]

	Sex				Birth type			
Item, kg	Female	Male	SE	*P*	Single	Multiple	SE	*P*
Animals, no.	77	50			46	84		
Birth weight	5.0	5.6	0.11	0.01	5.7	4.9	0.11	0.01
Weaning weight, actual	22.2	22.0	0.58	0.81	25.2	19	0.59	0.01
Weaning weight, adjusted[2]	23.5	22.9	0.58	0.36	25.3	21.1	0.59	0.01
Preweaning ADG	0.28	0.27	0.01	0.46	0.32	0.24	0.01	0.01

[1]Values are based on 127 lambs produced over 2 yr. No sex by birth type interactions were observed ($P > 0.05$); therefore, main effect means are presented.

[2]Values adjusted to a 60-d single ewe lamb, mature ewe basis.

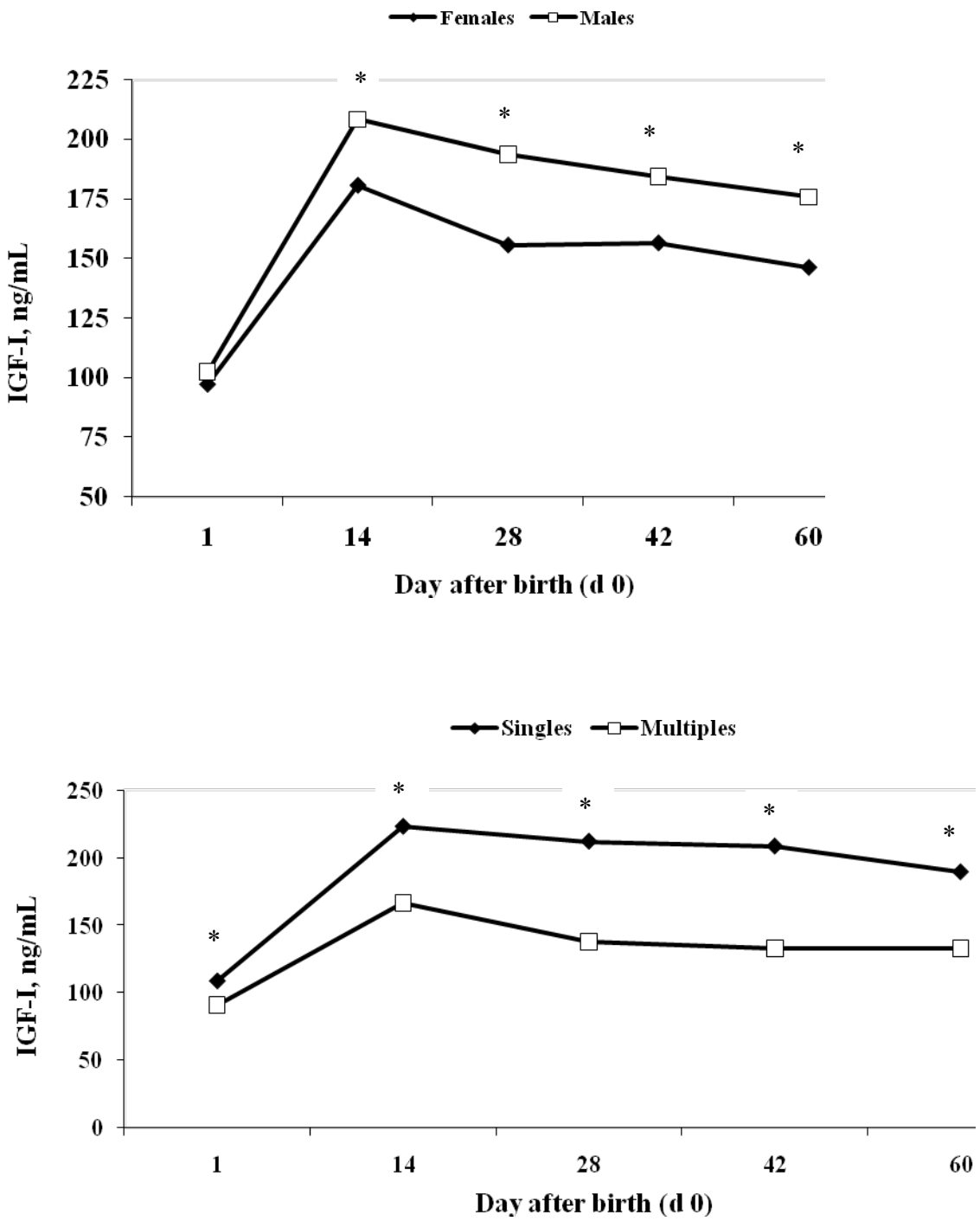

Figure 1. Serum IGF-I concentrations in female and male lambs (top panel) and in single- and multiple-born lambs (bottom panel) during a 60-d preweaning period. Sex by birth type by sampling day interactions were not detected ($P = 0.90$). On days indicated by *, differences between sexes ($P < 0.035$) and birth types ($P < 0.005$) were observed.

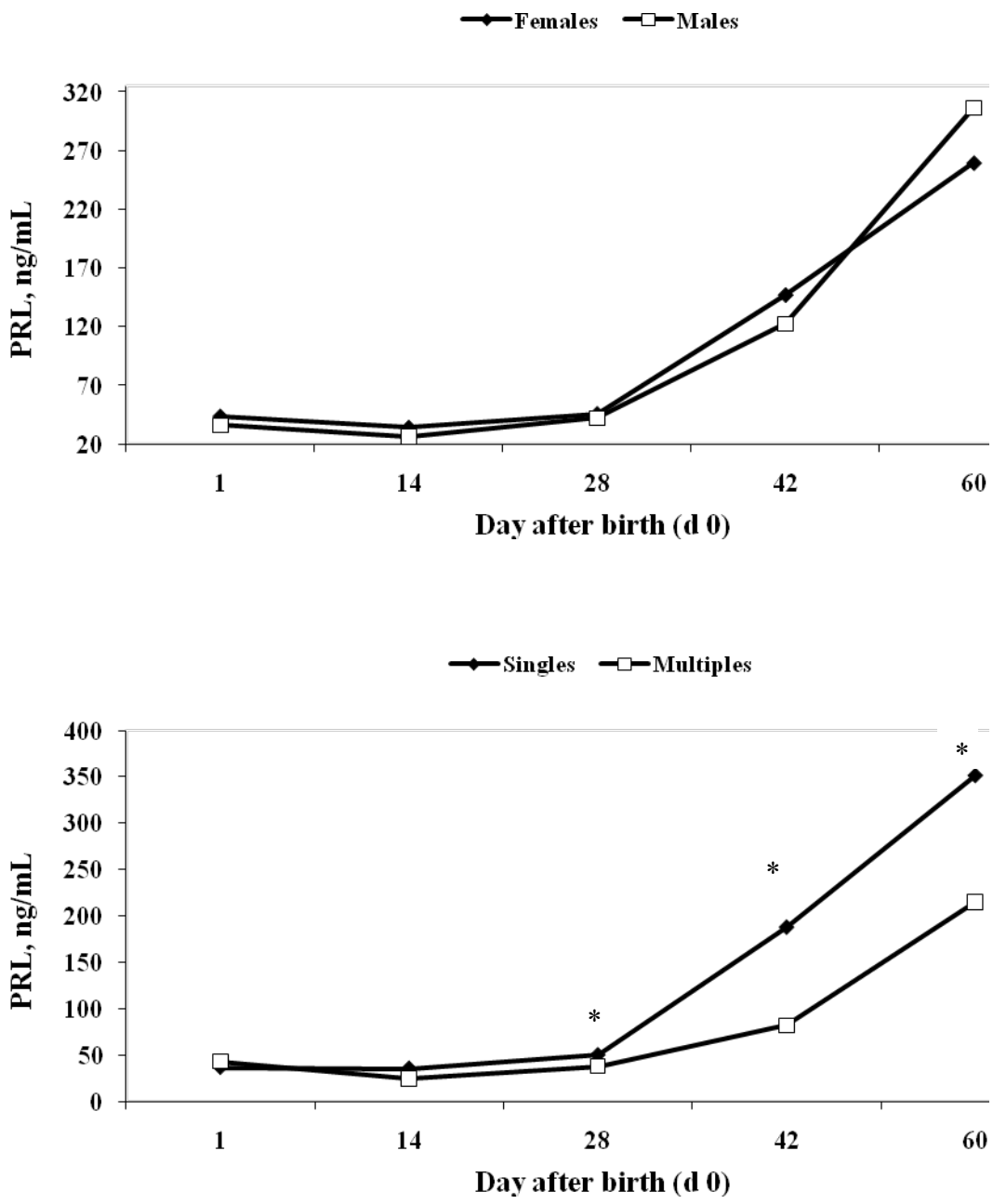

Figure 2. Serum prolactin (PRL) concentrations in female and male lambs (top panel) and in single- and multiple-born lambs (bottom panel) during a 60-d preweaning period. Sex by birth type by sampling day interactions were not detected ($P = 0.43$). Sex by day ($P = 0.09$) and birth type by day ($P < 0.001$) interactions were observed. No sex differences were observed ($P > 0.16$) on any sampling day. Serum PRL differed between single and multiple lambs on d 28, 42, and 60 ($P < 0.02$, indicated by * in bottom panel).

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EFFECTS OF HUMAN CHORIONIC GONADOTROPIN ON SERUM PROGESTERONE CONCENTRATIONS, EMBRYONIC SURVIVAL, AND LAMBING RATES IN EWS.

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ABSTRACT: This study was conducted to determine if multiple injections of human chorionic gonadotropin (hCG) will increase circulating concentrations of progesterone (P_4) in sheep following mating and prolong elevated levels through the period of fetal attachment. Fifty-nine nulliparous, primiparous, and multiparous Suffolk ewes (avg BW =79.7 ± 2.5 kg) received an intravaginal P_4 containing insert (CIDR, 0.3 g P_4) for 12 d and were mated with fertile rams on the second estrus after CIDR removal. Ewes were randomly assigned to one of two treatments. The treated group received 200 IU (0.4mL) of hCG i.m. and controls received 0.4 mL saline i.m. on d 4, 7, and 10, after onset of estrus (d 0 = mating). Blood samples were taken via jugular venipuncture beginning on d 0 and on alternate days until d 35. Serum P_4 concentrations were similar ($P > 0.10$) between treatment groups through d 5. However, beginning on d 7, ewes treated with hCG had greater ($P < 0.01$) serum P_4 concentration than controls, and P_4 remained greater ($P < 0.05$) throughout the sampling period (d 35). Of ewes receiving hCG, 68% had 4 or more total CL compared to 33% of controls ($P < 0.05$; determined by laparoscopy on d 25). Fetal numbers were determined via flank ultrasound on d 60 and 85% of hCG-treated ewes had multiple fetuses compared to 62% of controls ($P < 0.10$). In addition, 82% of hCG-treated ewes gave birth to two or more lambs compared to 63% of control ewes ($P = 0.17$). In conclusion, hCG administration on d 4, 7, and 10 after mating resulted in elevated serum P_4 concentrations from d 7 through d 35, with more hCG-treated ewes carrying multiple fetuses.

Keywords: corpus luteum, human chorionic gonadotropin, lamb crop, progesterone

INTRODUCTION

Lamb crop percentages in many commercial sheep flocks across New Mexico are generally considered to be less than those observed in other areas; an economic detriment to local sheep producers. One of several possible factors in sub-optimal lambing percentage may be increased incidence of embryonic wastage. Estimated lambing percentage in US in 2009 was 108% (NASS, 2010), whereas lamb crop percentage in New Mexico for the same period was 80%. This difference equates to a $2.79 million loss to the NM sheep industry based on the $2.21/kg of lamb and an average weaning weight of 40 kg. In normal pregnancies, maternal recognition, implantation, and embryonic survival must occur to produce an optimal lamb crop. In sheep, these events usually occur between d 11.5 and 16 after breeding (Spencer et al., 2004b). Progesterone (P_4) plays a significant role in uterine environment for conception, implantation, and maintenance of pregnancy. Once the blastocyst has hatched, it begins to release interferon-tau (IFN-τ), which is necessary for maternal recognition (Spencer et al., 2004b). Interferon-tau blocks the oxytocin receptors (OTr) thus inhibiting production of $PGF_{2\alpha}$, hindering luteolysis (Spencer et al., 2004a). If luteolysis does not occur, then the ewe should have successful implantation and gestation. Human chorionic gonadotropin is a protein that is luteogenic and mimics the effects of luteinizing hormone (LH) by binding to the LH receptors on luteal cells (Kelly et al., 1988; Santos et al., 2001), thus increasing serum P_4 concentrations when administered to livestock (Farin et al.,1988). The objectives of this study were to determine the effects of human chorionic gonadotropin (hCG) on serum P_4 concentrations and the effects of hCG on embryonic survival.

MATERIALS AND METHODS

General

All procedures involving animals were approved by the New Mexico State University Institutional Animal Care and Use committee.

Animals and Treatment

Fifty-nine mature Suffolk ewes (79.7 ± 2.5 kg BW) were used. Ewes received a P_4-impregnated intravaginal insert (EAZI-BREED CIDR, 0.3 g P_4; Pharmacia and Upjohn, Co., Hamilton, New Zealand) to synchronize estrus. Twelve days later CIDR were removed, and ewes were divided into 4 breeding groups. A vasectomized ram, fitted with a marking harness, was placed with each group of ewes to detect estrus. Vasectomized rams remained with the ewes during 1 estrous cycle. Upon removal of vasectomized rams, 4 fertile rams with marking harnesses were joined with the ewes. Day 0 represents the day ewes were initially mounted by a fertile ram (onset of estrus). Fertile rams remained with the ewes for 2 estrous cycles. Throughout the cycles, crayons were changed and rams were rotated throughout the 4 pens. Onset of estrus was detected and recorded. Ewes were randomly assigned to 2 treatment groups, control and treated with hCG (ProSpec-Tanny TechnoGene, Ltd, Rehovot, Israel, CAS: HOR-250) injections. Twenty-nine ewes were used in the control treatment group, which received 0.4 mL of saline solution i.m. Thirty ewes were included in the treated group that received 200 IU hCG in 0.4 mL of saline solution i.m. Injections for both the control and treated groups were given on d 4, 7, and 10. Ewes (hCG, n = 3; control, n = 6) which did not conceive on the first estrus with the fertile rams were removed from the study.

Blood Collection and Progesterone Assay

Beginning on d 0 and continuing every other day through d 35, blood was collected via jugular venipuncture into serum separator tubes (Corvac, Kendall Health Care, St. Louis, MO). Tubes were held at room temperature at least 30 min prior to being centrifuged at 4°C for 15 min at 1,500 x g. Serum was then stored frozen in plastic vials until assayed.

Serum progesterone concentrations were determined using RIA (Coat-A-Count, Siemens Medical Solutions Diagnostics, Los Angeles, CA; Schneider and Hallford, 1996) and were conducted by the New Mexico State University Endocrinology Laboratory. The inter-assay CV was 6.6% and the intra-assay CV was less than 9.5%.

Laparoscopies

On d 25 of estrus, ewes underwent laparoscopy to determine the number of CL present on the ovaries. Ewes were held off feed 24 h and water for 12 h. General anesthesia (Ketamine, 1 mL, i.v.) was administered, and then the ewe was placed in a supine position. The area of surgery was washed and thoroughly cleaned. Each ewe was then given 4 mL of Lidocaine (s.c.; Pro Labs Ltd, St. Joseph, MO) as a local anesthetic. The Lidocaine was given 3 cm on either side of the mid-line and approximately 2 cm from the mammary gland. A 1 cm incision was made for the surgery, which was performed using a 10 mm end view scope and 300 watts Xenon Fiber-Optic Light Source (Gyrus Acmi, Southborough, MA). Carbon dioxide gas was used to slightly inflate the abdomen cavity. Corpora lutea on each ovary were counted and recorded. Following the procedures, ewes received 4 mL of Liquamycin (s.c.; Pfizer Animal Health, New York City, NY) and a topical antibiotic called Nitrofurazone (Neogen Corp for Hess & Clark, Inc, Lexington, KY). Animals were returned to pens and closely monitored for 24 h.

Pregnancy Determination and Postpartum Measurements

Pregnancy was determined using 3.5 MHz external flank probe ultrasound (Aloka, SSD-500V, Japan) for the experiment on d 70. Lambs born per ewe were recorded at parturition.

Statistical Analysis

All data were analyzed by SAS (SAS Inst. Inc., Cary, NC). Corpora lutea number, fetal counts, and number of lambs born per ewe was analyzed using PROC FREQ with Chi Square. Progesterone concentrations were analyzed as a split-plot design with repeated measures. Treatment and ewe were in the whole plot and day and day by treatment were in the subplot. Data were analyzed by PROC MIXED with the repeated function. The autoregressive covariance was the best fit for the progesterone data.

RESULTS AND DISCUSSION

Ewes receiving hCG had an increased number of CL ($P < 0.05$) compared to control ewes (Table 1). Ewes receiving hCG, 68% had 4 or more CL compared to 33% for controls ($P < 0.05$). Santos et al. (2001) presented similar results in cattle when administering hCG. In the study by Santos et al. (2001), 86.2% of cows treated with hCG had more than one CL present compared with 23.2% of controls. Luteinizing hormone (LH) causes ovulation and development and maintenance of the CL. Human chorionic gonadotropin has the same actions as LH in sheep by binding to LH receptors on the small luteal cells (Kelly et al., 1988; Santos et al., 2001). The estrous cycle in sheep is shorter than cattle and horses; however, Evans et al. (2000) and Zieba et al. (2001) reported that follicular waves in sheep are similar to cattle and horses having 2 to 3 follicular waves (Sirois and Fortune, 1988; Donadeu and Ginther, 2002).

A treatment by day interaction ($P < 0.05$) was observed for serum P_4 concentrations; therefore, data were analyzed by day. Serum P_4 concentrations were similar ($P > 0.10$) between treatments from d 1 to d 5 (Figure 1). However, following d 6 and through the remainder of the collection period, ewes that received hCG had greater ($P < 0.05$) P_4 concentrations than the control ewes. Treatments were administered on d 4, 7, and 10 following breeding. In addition to the increased number of CL, another contributor to the elevated P_4 is the cellular composition of the small and large luteal cells (Kelly et al., 1988). Administering a high dosage (200 IU) of hCG induced a change in the

cellular composition of the CL (Kelly et al., 1988). Administration of hCG will cause small luteal cells to differentiate into large luteal cells, thus increasing serum p4 (Farin et al., 1988).

Our laboratory demonstrated that, hCG administered to ewes at various times during the first few weeks of pregnancy can enhance endogenous P_4 production (Redden et al, 2006; Yates et al., 2009). These authors concur with the current study, however, the current study resulted in a difference at d 7 in control vs. hCG ewes ($P < 0.05$) whereas, Yates et al. (2009) saw the difference starting on d 9. Importantly, Yates et al. (2009) used 100 IU hCG, whereas, the current study used 200 IU. The increased dosage may explain the difference in the response of serum P_4 concentrations among experiments. Progesterone maintains pregnancy by quieting the uterus, inhibiting myometrial contractions, enhances maternal recognition (interferon-tau; Nephew et al., 1994, Spencer et al., 2004a), and also affects implantation (Johnson et al., 2001; Lee and DeMayo, 2004; Spencer et al., 2004b). A greater ($P = 0.079$) percentage of ewes that received hCG had multiple fetuses compared to controls (Table 2; 85% vs. 62%, respectively). Spencer et al. (2004b) reported that increased P_4 concentrations enhanced the implantation process. Therefore, increased serum P_4 concentrations improved implantation and decreased reproductive wastage.

IMPLICATIONS

Human chorionic gonadotropin when administered to ewes on d 4, 7, and 10 after breeding increased the number of CL, serum P_4 concentrations, and fetal numbers at birth. These data suggest that increasing endogenous P_4 production can ultimately increase lamb crop percentage and improve profitability of sheep production systems.

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Table 1. Corpora lutea (CL) numbers (presented as percent of ewes) in response to administration of human chorionic gonadotropin (hCG) 200 IU on d 4, 7, and 10 post mating.[1]

	Treatment[2]	
Number of CL present	hCG, %	Control, %
1	0	19
2	9	26
3	23	22
4	27	22
5	27	4
6	13	7

[1] Estrus was synchronized using intravaginal progesterone containing insert (CIDR, 0.3 g P_4) for 12 d and were mated with fertile rams on the second estrus after CIDR removal. Ewes were randomly assigned to one of two treatments, hCG or control. Data were analyzed using Chi Square (value=11.247; probability=0.046)
[2]Control ewes received 0.4 mL of saline solution i.m.; hCG ewes received 200 IU hCG in 0.4 mL of saline solution i.m.

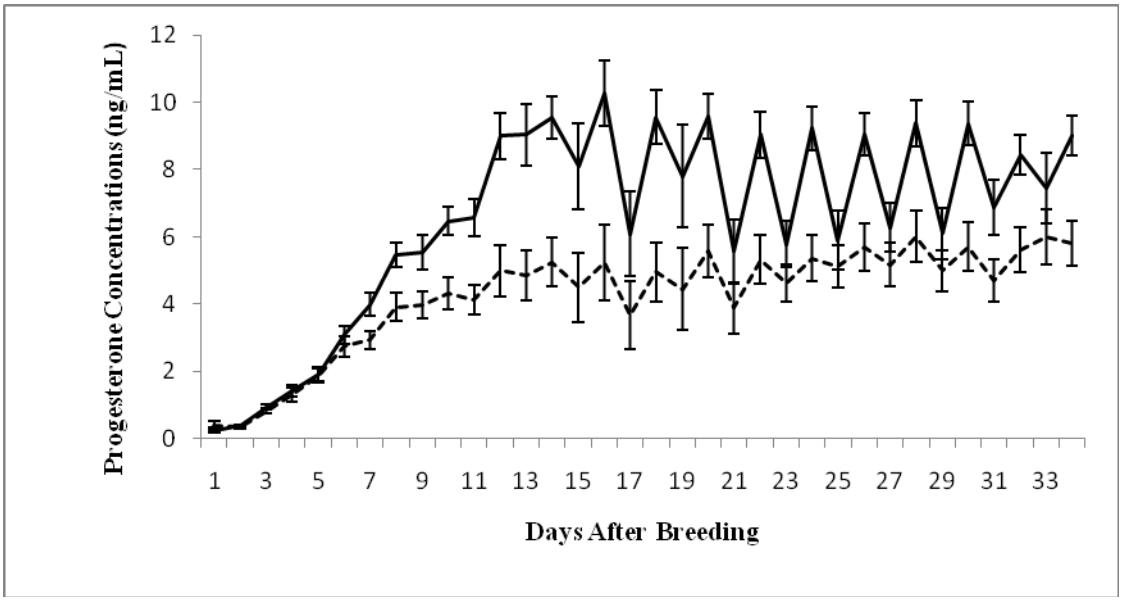

Figure 1. Average serum progesterone concentrations in hCG (-) vs. controls (--) ewes[1,2]

[1] Estrus was synchronized using intravaginal P_4 containing insert (CIDR, 0.3 g P_4) for 12 d and were mated with fertile rams on received 0.4 mL of saline solution i.m.; hCG ewes received 200 IU hCG in 0.4 mL of saline solution i.m.
[2]Data were analyzed as a spilt-plot. A treatment by day interaction was noted ($P < 0.05$).

Table 2. Fetal numbers per ewe in response to administration of human chorionic gonadotropin (hCG) 200 IU on d 4, 7, and 10 post mating.[1]

	Treatment[2]	
Fetal numbers[3]	Control, %	hCG, %
1	38	15
2	62	85

[1] Estrus was synchronized using intravaginal progesterone containing insert (CIDR, 0.3 g P_4) for 12 d and were mated with fertile rams on the second estrus after CIDR removal. Ewes were randomly assigned to one of two treatments, hCG or control. Data were analyzed using Chi Square (value=3.069; probability=0.079)
[2]Control ewes received 0.4 mL of saline solution i.m.; hCG ewes received 200 IU hCG in 0.4 mL of saline solution i.m.
[3]Fetal numbers were determined via external flank ultrasound on d 70 post breeding.

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THE EFFECTS OF FLUOXETINE ON LACTATION AND LAMB GROWTH IN SHEEP.

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ABSTRACT: Fluoxetine (a selective serotonin reuptake inhibitor; FLX) has been shown to delay in the onset of lactogenesis stage II when taken during pregnancy and/or lactation. A study was conducted to evaluate if ewes would be an appropriate model to determine the effects of FLX on milk production. Twenty-nine ewes (Avg BW 85 ± 12 kg; body condition score 2.6 ± 0.3) in late gestation were used in this study. Ewes allotted to treatments were stratified by fetal numbers and breeding date. Ewes were dosed orally daily with empty capsules as a control or capsules containing 40 mg of FLX. Dosing began on d 121 of gestation and continued until lambing. Ewes were dosed every morning at 0700 h. Following parturition and before nursing, milk and blood samples were collected from each ewe/lamb(s) pair. The first milk yield was measured 8 h after birth and subsequent milkings were conducted at 1500 and 1800 h every other day for 9 d. Milk letdown was induced by a 1 mL intravenous injection of oxytocin, 1 min prior to milking. Milk yields were measured over a 3 h period when lamb(s) were removed. We observed a treatment by parity interaction, as ewes with multiple lambs treated with FLX had greater (P = 0.01) milk yields than treated or control ewes giving birth to single lambs and control ewes giving birth to multiple lambs. Lambs were weighed at birth (d 0) and following the milk yield study (d 9). We observed no differences (P > 0.05) in birth weight or d 9 lamb weights. Lamb gain over the 9 d milking period was similar among treated and control ewes (P > 0.05). No interactions were observed between parity and treatment in lamb weights or gain. Fluoxetine treatment during late pregnancy resulted in greater milk production in ewes giving birth to multiple lambs. However, FLX had no effect on lamb weights or lamb weight gain.
Keywords: Fluoxetine, lactation, sheep

INTRODUCTION

Fluoxetine (**FLX**; Prozac, Eli Lilly & Co., Indianapolis, IN) and other selective serotonin reuptake inhibitors (**SSRI**) have become popular for the treatment of depression during pregnancy because of their safety, effectiveness, and lower occurrence of maternal side effects (Nonacs and Cohen, 2002; Simon et al., 2002). In 1987, FLX became the first SSRI introduced in North America (Catterson and Preskhorn, 1996; Hiemke and Härtter, 2000). Selective serotonin reuptake inhibitors act to increase extracellular serotonin (**5**-HT) levels sharply over a short period of time, while acting on serotonergic neurotransmissions on a continual basis. These events could lead to the reported adverse effects on pregnancy outcome and postnatal development in humans (Laine et al., 2003; Casper et al., 2003; Morrison et al., 2002). Serotonin's role in the mammary system and lactation has only recently been observed (Matsuda et al., 2004; Hernandez et al, 2008). It is likely that 5-HT is part of the autocrine-paracrine homeostatic feedback mechanism (feedback inhibitor of lactation), which resists endocrine stimulation of mammary development and milk secretion (Wilde et al., 1995; Matsuda et al., 2004). Thus, SSRI act to inhibit lactation by preventing reuptake of 5-HT, and its subsequent degradation into the its metabolite 5-hydroxy indole acetic acid. Another potential issue with SSRI is the passage of the drug across the placenta to the infant. Studies have shown that FLX can cross the placenta in the rat (Pohland et al., 1989), humans (Spencer, 1993; Mhanna et al., 1997) and sheep (Kim et al., 2004). Harding and Bocking (2001) noted that the fetal lamb and human are alike in physiologic functions. As a result, pregnant sheep are often utilized to evaluate maternal-fetal drug disposition and effects (Rurak et al., 1991). The objective of this study was to evaluate if ewes would be an appropriate model for studying the effects of FLX on lactation.

MATERIALS AND METHODS

Animals, Facilities, and Diet. Procedures were approved by the New Mexico State University Institutional Animal Care and Use Committee. Twenty-nine Suffolk ewes (Avg BW 85 ± 12 kg; body condition score 2.6 ± 0.3) in late gestation were used in this study. Ewes were penned according to fetal number until parturition and then individually penned for 5-7 d post-partum. Ewes received 2.7 kg chopped alfalfa and 0.45 kg ground corn once daily during their last trimester and through the data collection period.

Design and Treatments. The experiment was a completely randomized design with a 2X2 factorial (FLX and fetal number) arrangement of treatments. Fetal numbers were determined by external flank ultrasound at d 70 of gestation. Approximately 21 d prior to lambing, ewes were sorted and penned according to fetal number to facilitate management decisions and treatment administration commenced. Treatments consisted of no FLX (control), or

40 mg FLX. Ewes were orally dosed, with a gelatin capsule (Torpac Inc., Fairfield, NJ) with or without 40 mg fluoxetine once daily at 0700 daily until parturition. Following parturition and before nursing, blood and milk samples were taken from the ewe, and blood samples from her lamb(s). Blood samples were collected via jugular venipuncture from both ewes and lambs on d 0, 1, 3, 5, 7 and 9 following lambing using sterile serum separator tubes (Corvac, Kendall Health Care, St. Louis, MO). Blood samples were centrifuged (1,500 × g at 4 ˚C for 15 min.) and serum was harvested and stored frozen. Initial milk samples were taken before lamb(s) nursed and subsequent milk yield data were collected 8 h after birth (d 1), as well as 3, 5, 7, and 9 d postpartum at 1500 and 1800, following procedures reported by Reynolds and Brown (1991). Milk yields were measured over a 3 h period after lamb(s) were removed. At birth, lambs were individually identified by unique premise ear tag and scrapie tag; their navals dipped with iodine and birth weights recorded. Following the end of the 9 d milking period, lamb BW were recorded to measure weight gain.

Statistical Analysis. The MIXED model of SAS (SAS Inst. Inc., Cary, NC) was used to analyze milk yield, lamb birth weight, and lamb gain. Individual ewe was the experimental unit, whereas, lamb was used as the experimental unit for weight data. Milk production was analyzed as a split plot design with treatment and parity in the whole plot and day and appropriate interactions in the sub plot.

RESULTS

We observed no behavioral responses during the dosing period, parturition or lactation. Milk yield averages, as well as milk production per day are reported in Table 1. A treatment × parity interaction ($P = 0.01$) was observed. Therefore, treatment means were compared within parity. Ewes with multiple lambs receiving FLX had greater ($P < 0.05$) milk yields than treated or control ewes giving birth to single lambs and control ewes giving birth to multiple lambs. All other treatment groups were similar ($P > 0.05$) in milk yields. We observed no interactions of treatment × day, day × parity, or treatment × day × parity, ($P > 0.10$). Daily milk yield was similar ($P > 0.10$) from d 1 through d 9 (Table 1).

Lambs were weighed at birth (d 0) and following the milk yield collection period (d 9; Table 2). Treatment by parity interactions were not evident ($P > 0.10$) for birth weight, d-9 weight, and gain. Birth weight and 9-d weights were similar ($P > 0.10$) between control vs. FLX and singles vs. multiples. Birth weights, 9-d weights, and gain were similar ($P > 0.10$) between lambs born to control and FLX ewes. However, as expected, single born lambs were heavier ($P < 0.05$) at birth and d 9 than controls and had higher ($P < 0.05$) weight gain (Table2).

DISCUSSION

Serotonin has been previously reported to depress lactation in mouse, bovine, and human models (Matusda et al., 2004; Hernandez et al., 2008; Marshall et al., 2010). Matsuda et al. (2004) reported that 5-HT plays a role in mouse mammary gland development and homeostasis. When mouse mammary epithelial cells were treated with different levels of 5-HT, PRL-induced β-casein gene expression was repressed in a level-dependent manner. Also, upon inhibition of 5-HT synthesis through blockade of tryptophan hydroxylase I, milk protein gene expression was increased (Matsuda et al., 2004. Hernandez et al. (2008) reported similar findings, as they observed that 5-HT restricted milk protein mRNA expression in dairy cattle and suggested that 5-HT acts as a negative regulator of lactation.

Selective 5-HT reuptake inhibitors act to increase the bioavailability of 5-HT by preventing its reuptake into the cell, and subsequent degradation into its metabolite. In lactating mice, a local treatment of the lactating mammary gland with FLX resulted in involution of the mammary gland (Marshall et al. 2010). Additionally, a delay was noted in the onset of lactogenesis stage II in humans who had taken SSRI during pregnancy and lactation. While we did not observe a depression in lactation in ewes receiving FLX treatments during the last trimester of pregnancy it is possible that a dose of 40 mg FLX daily may have been too low to elicit a measurable decrease in lactation. In a previous study, (unpublished data), we observed that passage through the rumen reduced the level of FLX absorbed into the circulatory system more than half (15 mg) of the 40 mg daily dose of FLX. Serotonin has been shown to elicit a biphasic effect on tight junctions, the junctional complexes that close at lactation and open at involution, with lower concentrations resulting in a decrease in tight junction permeability, and higher concentrations increasing tight junction permeability (Pai and Horseman, 2008). Additionally, we did not administer FLX treatments while ewes were lactating.

While the direct effects of SSRI treatments are to increase the amount of extracellular serotonin, additional side effects are possible. Weight loss is a common side effect when adults take FLX; researchers suggested that FLX may directly decrease weight gain in infants who receive FLX through breast milk (Chambers et al., 1999). Chambers et al. (1996) suggested that weight loss during pregnancy of FLX treated women could be linked directly to decreased birth weights due to lower maternal weight gain which would limit fetal growth. In humans, reduced birth weights and postnatal weight gain were observed when women were exposed to fluoxetine during their third trimester (Chambers et al., 1996, 1999; Cohen et al., 2000; Nordeng et al., 2001). A study conducted with rats, showed that pregnant rats receiving FLX had poorer weight gain and delivered smaller pups (Vorhees et al., 1994). No differences were observed likely due to a potentially low concentration of FLX actually reaching the circulatory system.

We expected to see decreases in milk yield and lamb weight. However, we actually observed increased milk yield in FLX treated animals that had twinned, while lamb weight gain remained similar. We believe that this may be the result of a low dose of FLX actually reaching the circulatory system, resulting in a transient increase in milk yield, as previously reported. Serotonin has been noted

to have biphasic effects on mammary epithelial resistance. Thus, at lower concentrations and earlier in time, 5-HT increased mammary function, however, at higher concentrations and later in time, 5-HT decreased mammary function (Pai and Horseman, 2008). The biphasic response of 5-HT may be the reason for the increase in lactation of FLX ewes with multiple lambs. It is our hypothesis that a larger dosage may provide a measurable depression on lactation.

IMPLICATIONS

Fluoxetine when dosed orally to pregnant ewes increased milk yields in ewes that gave birth to multiple lambs. However, lamb birth weight and gain were not affected by treatment. More research is needed to evaluate different dosage levels, the role of the rumen in degradation of FLX, and consequences on lamb growth and development.

ACKNOWLEDGEMENTS

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Table 1. Average milk yields over a 9 d lactation period in Suffolk ewes treated without (Control) and with40 mg fluoxetine (FLX) during the last 21 to 28 days of pregnancy.[1]

	Single		Multiples		
Item	Control	FLX	Control	FLX	SE[2]
Milk yield, g	317.2[a]	299[a]	308.9[a]	404.9[b]	23.5
Daily milk yield, g					
d 1	333.53	294.99	263.34	418.05	54.86
d 3	343.26	298.61	311.17	383.70	55.68
d 5	271.72	320.95	327.88	401.22	44.83
d 7	326.35	258.98	312.52	421.96	56.46
d 9	311.27	321.31	329.71	399.68	44.83

[1]Milk yields were measured over a 3 h period after lamb removal. A treatment x parity interaction was observed ($P < 0.05$). Therefore, treatment means were compared within parity.Daily milk yield is presented for reference only.
[2]Most conservative standard error (N = 17).
[a,b]Row means with different subscripts differ ($P < 0.05$).

Table 2. Lamb weights and gain during 9 d lactation period from Suffolk ewes treated without (Control) and with 40 mg fluoxetine (FLX) during the last 21 to 28 days of pregnancy.[1]

	Treatment			Parity			*P*-value[4]	
Item	Control	FLX	SE[2]	Single	Multiple	SE[3]	Treatment	Parity
Birth weight, kg	5.85	6.26	0.69	6.79	5.32	0.73	0.90	0.33
9 d weight, kg	8.79	9.10	0.69	10.07	7.82	0.74	0.90	0.33
Gain, kg	2.36	3.31	0.69	3.48	2.18	0.73	0.11	0.46

[1]No interaction of treatment x parity was observed ($P > 0.05$). Therefore, only levels within main effects were compared.
[2]Most conservative standard error (N = 23)
[3]Most conservative standard error (N = 8)
[4]Probability value

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REPRODUCTIVE RATE OF SEMI-FREE RANGING BISON (*Bison bison*) AT THE NATIONAL BISON RANGE

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ABSTRACT: Recruitment of calves at the National Bison Range (NBR) near Moiese, MT has dropped from the historic average of 87 to 33 calves per 100 breeding-age cows in 2008. The purpose of monitoring the NBR bison pregnancy rate (PR) and calf recruitment is to determine where in the reproductive cycle NBR female bison fail to recruit calves. The reproductive cycle was divided into 3 stages: conception to early embryonic development; maintenance of pregnancy during the second and third trimesters; and, calving to recruitment. In 2008, transrectal ultrasonography was used to determine PR in cows (ages 4 to 12 yr) in October; 28 of 41 cows (68%) were pregnant. Pregnant cows were painted with a unique bleach number. Fecal samples were collected in Oct., Jan., Mar. and Apr. until the bleach number was illegible. Fecal samples were analyzed for progesterone (P4). Pregnancy rates estimated by fecal P4 concentration decreased ($P < 0.01$) from 100% (n = 28) in Oct. to 53% (n = 15) in Apr. The percentage lost decreased continuously throughout the second stage, with the largest percentage decrease between the first and second trimester (17%). Of the original 28 pregnant cows, the PR in April was 53%; a reduction of 47%. This closely matched calf recruitment of the herd at the 2009 roundup (64 calves for 124 cows; 52%): indicating that the accuracy for estimating pregnancy using fecal P4 was 98.2%. In 2009, PR was determined by ultrasonography of 89 cows, including 38 of the 41 cows from 2008. Pregnancy rate for 2009 was 63%, which was similar to PR in 2008 (68%). Radio collars were secured to 27 pregnant and 10 non-pregnant cows. These animals will be monitored throughout the rest of the reproductive cycle to determine calf production using fecal P4 assay. In conclusion, fecal P4 assay appear to give an accurate estimate of PR in semi-free ranging bison. Furthermore, it appears that the decrease in calf recruitment at the NBR can be, at least in part, due to fetal losses during gestation.

Key words: bison, fecal progesterone, pregnancy rate

INTRODUCTION

The 18,500 acre National Bison Range (NBR) near Moiese, MT was established by Congress in 1908. In 1909-1910, 40 bison were brought to the NBR, and by the early 1920's the herd size was approximately 300 animals National Bison Range bison have historically had little problem with recruitment, which for the purpose of this study is defined as the number of calves divided by the number of breeding-age females observed at the annual bison "roundup" that occurs during the first week of October. The National Bison Range Fenced Animal Management Plan states that over 32 yr (1956-1987) the average recruitment rate was 87%. The lowest recruitment recorded during that same period of time was 72% in 1970. During this period bison of the NBR have had little trouble with diseases that are known to affect reproduction. According to the National Bison Range Fenced Animal Management Plan, the herd was certified brucellosis free in 1983 by the Montana Department of Livestock. In 1979, it was believed that the bison experienced an outbreak of Leptospirosis characterized at the time by late calving. In 1980, calf recruitment had dropped to 74%. Personnel at the NBR initiated an annual Leptospirosis vaccination program for an unknown length of time and the problem seemed to be resolved, as calf recruitment was increased to 85% in 1981. During the 3-yr period of 2005-2007, recruitment has dropped to an average of 54%, and the cause of this decrease in production is unknown (U.S. Fish and Wildlife Service, unpublished data). The objective of this study is to determine when during the reproductive cycle of bison at the NBR are failing to recruit calves. The hypothesis is that losses in recruitment are associated with early embryonic or fetal loss during gestation.

MATERIALS AND METHODS

For the purpose of this study gestation of female bison was divided into 3 periods: 1) conception to early fetal development; 2) maintenance of pregnancy during the second and third trimesters; and, 3) calving to recruitment. In early October, pregnancy rates were determined during the NBR annual bison roundup using ultrasonic evaluation of the contents of the uterus with the Titan Ultrasound Imaging System (Sonosite, Wallawalla, WA) equipped with a selectable 5 to 10 MHz transducer. The accuracy of ultrasonic evaluation is approximately 100% at detecting pregnancy between 21 and 30 d after fertilization. Given the detection limit there is the possibility of failing to detect the presence of an embryo in those females that were bred late in the breeding season. At the 2008 roundup, 28 pregnant cows received a number on the right flank using a commercial hair-bleaching agent, while in 2009, 27 pregnant and 10 non-pregnant cows were fitted with a VHF radio collar. These methods allowed us to identify these individuals for collection of fecal samples throughout the remainder of gestation.

At the 2008 roundup, blood and fecal samples were

[1]This study was supported by the U.S. Fish and Wildlife Service and the Montana Agric. Exp. Sta.

collected from 41 cows (3 and 12 yr of age), while 45 blood and 77 fecal samples were collected at the 2009 roundup. Serum and fecal samples obtained at this time were used to validate the use and accuracy of assays for fecal progesterone concentrations. Fecal progesterone concentrations were correlated with serum concentrations of progesterone to evaluate the accuracy of fecal progesterone concentrations for determining a criterion for the minimum fecal progesterone concentration associated with pregnancy.

During the second period, cows of 2008 were monitored for maintenance of pregnancy using fecal progesterone concentrations. Limiting the invasiveness of sample collection is an important consideration when selecting a sampling method in bison. Pregnancy determination using fecal steroid concentrations has been validated using bovine (Desaulniers, et al. 1989), and bison feces (Kirkpatrick et al., 1992). Using fecal samples to determine pregnancy status circumvents the unnecessary handling of cows and limits stress during pregnancy. Fecal material was collected from adult cows and assayed for progesterone using solid phase radioimmunoassay as described in Kirkpatrick et al. (1992) and Custer et al. (1990). In the present study, samples were collected in January (second trimester) and in March (third trimester). Extraction of progesterone from fecal samples of bison was performed by the method described by Brown et al. (2005).

The method of field collections of fecal samples was for personnel to monitor marked cows and wait for a marked cow to defecate. The group of cows was then slowly pushed from that area so that fecal samples could be safely collected. Every effort was made to collect as many samples from marked or collared cows as possible.

In the third period, calving to recruitment was (2008 cows) monitored by two methods. In 2009, monthly calf counts were conducted from late March until mid September for 2008 cows. At least 200 bison were observed and classified as calves or non-calves and the observed ratio was extrapolated to the whole herd. Fecal samples from cows collected for progesterone assays during each monthly calf survey or until 2 consecutive fecal progesterone concentrations fell below the minimum criterion for progesterone established from fecal samples from bulls and anovular cows. These two rates provided a reliable estimate of fetal losses and were used to compare pregnancy rates estimated earlier in gestation. Collared cows of 2009 will be counted and monitored until it can be determined that a cow is tending a calf. A calf was or will be assumed to have been lost if it is not present with the cow in any of the subsequent surveys.

The USFWS Wildlife Health office maintains a serum archive dating back to 2000 for bison at the NBR. Progesterone concentrations of the archived serum samples collected from breeding-age females during each year's roundup were used to determine the percentage of cows showing luteal activity. These data were used to investigate if there was a correlation between the numbers of cows exhibiting luteal activity and calf recruitment rate at the following roundup.

Recruitment and pregnancy rates were analyzed by chi square analyses using the FREQ procedure of SAS (SAS, Inst., Inc., Cary, NC). Linear regressions of numbers of cows exhibiting luteal activity and numbers of calves recruited on year (2000 to 2007) were generated by using the Proc REGRESS of SAS.

RESULTS

In 2008, calf recruitment at the NBR has steadily declined ($P < 0.01$) over the last 10 yr to an all-time low of 33% in 2008 (Figure 1).

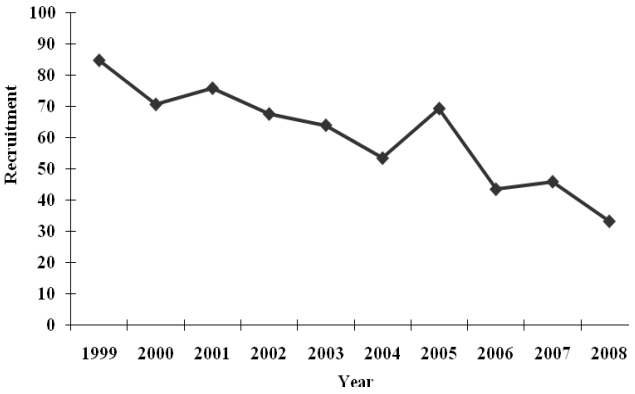

Figure 1. Calf recruitment at roundup for the National Bison Range bison herd over at 10-yr period from 2000 to 2007. Long-term average recruitment is 87 calves per 100 breeding-age cows.

During the 2008 and 2009 roundups, 41 and 89 breeding-age cows, respectively, were diagnosed for pregnancy. Pregnancy rates did not differ between years (Table 1).

Table 1. Pregnancy rates of breeding-age bison cows at the National Bison Range at October roundups in 2008 and 2009[1]

Year	Pregnant rate	Total
2008	68%[a]	41
2009	63%[a]	89

[1] Pregnancy rates determined by ultrasonography.
[a] Percentages with different superscripts differ ($P < 0.05$).

Extraction efficiencies of radiolabeled progesterone for fecal samples averaged 50%. The minimum fecal concentration of progesterone used for evaluating pregnancy was determined by adding 3 SD to the mean progesterone concentration of fecal samples collected from bulls and anovular cows. The mean concentration of these samples was 29.6 ng/g of feces.

Fecal samples were collected from bleach-numbered cows in 2008 until the numbers were illegible. In Apr., 16 of the original 28 were still visible, and by May only 3 were visible. Pregnancy rates estimated by fecal progesterone concentrations decreased ($P < 0.01$)

continuously throughout gestation from 100% (n = 28) in Oct. to 53% (n = 15) in Apr. (Table 2). The largest decrease occurred between Oct. and Jan. (17%; Table 2). Fecal progesterone estimate of pregnancy rate in Apr was 53%. This rate closely matched the observed recruitment rate at the 2009 roundup of 64 calves for 124 breeding-age cows in 2008 (52%). The agreement of pregnancy rate in Apr with recruitment rate in Oct. indicates that the accuracy for estimating pregnancy using fecal progesterone concentrations in bison cows was 98.2%.

Table 2. Pregnancy rate (%) of bleach-numbered bison cows at the National Bison Range during gestation in 2008-2009

Oct 2008[1]	Jan 2009[2]	Mar 2009[2]	Apr 2009[2]
100% [a]	83% [a,b]	68% [b]	53% [b]
(n = 28)	(n = 21)	(n = 17)	(n = 15)

[1] Pregnancy rates determined by ultrasonography.
[2] Pregnancy rates determined fecal progesterone concentrations.
[a,b] Percentages that lack a common superscript letter differ ($P < 0.05$).

Archived serum samples obtained from breeding-age female bison from 2000-2007 (n = 341) were assayed for progesterone concentrations. The percentage of breeding-age cows that had luteal activity was highly correlated (P < 0.01) to the calf production at the following roundup (Figure 2).

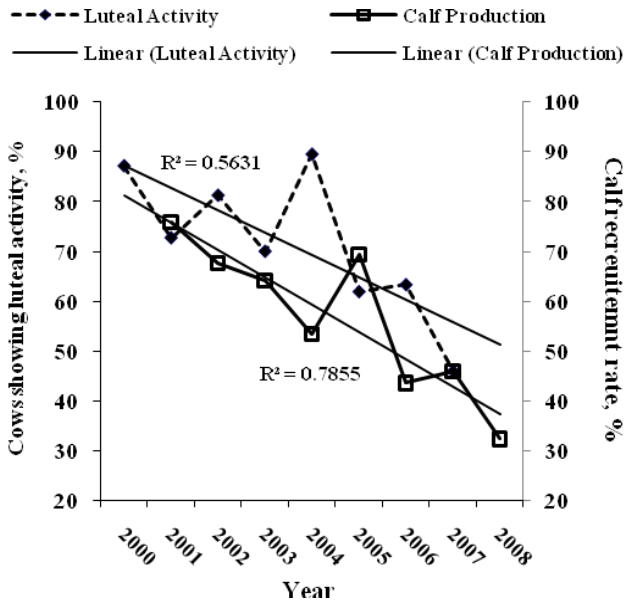

Figure 2. Linear regressions for numbers of breeding-age cows showing luteal activity (b_1= -4.5 cows/yr; $P < 0.01$) and numbers of calves recruited per 100 cows (b_1= -5.5 calves/yr; $P < 0.01$) on year at the National Bison Range from 2000 to 2008.

DISCUSSION

The list of possibilities that cause decreases in calf recruitment in bison is lengthy: disease outbreaks, mineral or vitamin deficiencies, predation or habitat capacity. The magnitude of the list of diagnostics makes it essential that the timing of the recruitment failure be established before further testing is done to determine the exact cause of the failure.

Pregnancy rates of cows, determined by ultrasonography, did not differ between 2008 and 2009 and averaged 64.6%. The historic recruitment rate for bison at the NBR was approximately 87%. The difference between the historical average pregnancy rate and the 2008 and 2009 average pregnancy rate may indicate that female bison are: 1) not bred by bulls during the breeding season, that is, they are anovular/anestrus; 2) are bred by bulls but fail to conceive or have high conceptus failure; 3) sperm quality is low and fertilization rate is poor; or 4) a combination of these that may act additively or synergistically. Thus, it appears that a portion of this reduction in recruitment rate may be related to factors that influence fertility during the breeding season or soon after cows are inseminated.

Archived serum samples from cows collected at roundups from 2000 to 2007 were used to determine the percentage of cows that exhibited luteal activity to determine if there was a relationship between numbers of cows exhibiting luteal activity in one year and calf recruitment number in following year at roundup. Indeed, there was a significant linear relationship between these variables. The number of cows that exhibit luteal activity has decreased from 2000 to 2007; likewise, the number of calves recruited in the following yr decreased over this period. Thus, numbers of cows that exhibit luteal activity at roundup seem to provide a reasonable estimate of calf recruitment rate in the following year. This relationship indicates that anestrus or anovular conditions or early conceptus loss during the breeding season may be an important consideration for the reduction in calf recruitment rates over the past 10 yr.

Furthermore, assuming no fetal loss during the second and third trimesters of pregnancy, the 65% pregnancy rate, determined by ultrasonography at roundup, should have yielded a recruitment rate of 65% the next year. However, the actual percentage of calves at roundup for 2008 cows in 2009 was 52%; a significant departure from the expected rate. This difference indicates that fetal survival was compromised during the second and third trimesters of pregnancy in bison cows at the NBR. Fecal progesterone assays seemed to give an accurate estimate of pregnancy rate in semi-free ranging bison and allowed us to evaluate the pattern of this loss during this period of gestation. Fecal progesterone concentrations in pregnant cows indicated that significant fetal loss occurred between Oct. (at roundup) and Mar. of the next year. Thus, another component for the decrease in calf recruitment in the NBR herd is fetal losses occurring during gestation through the winter months.

IMPLICATIONS

It now appears that significant loss occurs during the second and third trimesters of gestation in female bison at the NBR during the winter months. However, indirect evidence indicates that there may also be losses due to conditions associated with breeding and early conceptus failure. Results from this study could be used as the foundation for future research into the exact cause of the decrease in calf recruitment allowing managers of the NBR herd to determine if and when a change in management may be warranted.

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PRODUCTION, MANAGEMENT, AND THE ENVIRONMENT

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FEEDLOT PERFORMANCE AND CARCASS TRAITS OF HAIRSHEEP LAMBS TREATED WITH A β-ADRENERGIC AGONIST DURING SUMMER

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ABSTRACT: The objective of this study was to determine the effects of feeding the beta-agonist zilpaterol hydrochloride to female lambs on growth traits and carcass characteristics during hot ambient temperatures. Twenty female lambs from hairsheep crossbreeds with an average initial BW of 26.2 ± 0.83 kg were blocked and assigned individually to 20 pens in a closed calf rearing unit provided with fans. Treatments were: 1) Control (C: no beta-agonist), ten ewes fed a diet containing wheat grain, molasses, alfalfa hay, soybean meal, wheat straw, common salt and limestone; and 2) Treated group, ten ewes fed the same diet as control and supplemented with 10 mg of zilpaterol hydrochloride per head^{-1} day^{-1}. The ZH was mixed into 100 gr of ground wheat grain and was offered daily in the morning before offering the diet. Data were analyzed under a completely randomized block design. Climatic conditions during the 33 d of the study revealed a moderate heat stress conditions, with an average ITH of 85 units. Lambs fed ZH had similar (P>0.05) feedlot performance (daily weight gain, final weight, fed intake, feed conversion, and gain:feed ratio) than control lambs. The beta-agonist increased hot and cold carcass weights, with carcasses from ZH lambs being 13% and 12% heavier (P<0.01) than carcasses from C lambs respectively. Dressing percentage was higher in ZH lambs (53.8%; P<0.01) than in C lambs (46%). The rib-eye area was larger (P<0.05) in ZH lambs (18.9 cm^2) than in C lambs (15.5 cm^2), as well as carcass conformation (7.0 vs 6.0 units for ZH and C lambs, respectively). There was no difference (P>0.05) in carcass length, fat thickness, kidney, pelvic and heart fat, and shear force between ZH and C lambs. Hide and head weights, as well as other internal organs did not differ between treatments (P>0.05). Even though the moderate hot ambient conditions observed during the study, some carcass traits were improved in hairsheep female lambs supplemented with zilpaterol hydrochloride.

Keywords: Ewe lambs, Zilpaterol Hydrochloride, Heat stress.

Introduction

The increasing demand of mutton in Mexico has conducted to explore for new procedures to improve feedlot performance and carcass traits in sheep from hair breeds. These procedures are directed to the fattening of female lambs because of their hormone system leads to deposit excessive amounts of fat; consequently, a great percent of their increased weight during the fattening period is associated with fat production (Nourozi et al., 2008). The use of β-agonists in the feeding of female (Nourozi et al., 2008) and male (Estrada-Angulo et al., 2008) lambs has demonstrated improving growth rate, increasing skeletal muscle content and reducing body fat content. Recently, the β-agonist zilpaterol hydrochloride (ZH) was approved as feed additive for cattle in Mexico, South Africa and United States. Few studies have been conducted to evaluate the effect of ZH on feedlot performance of male sheep (Aguilera-Soto et al., 2008; Estrada-Angulo et al., 2008; Robles-Estrada et al., 2009). However, no studies have reported the effect of oral administration of ZH on feedlot parameters and carcass composition of ewe lambs. In addition, the effect of this β-agonist under conditions of heat stress has not been studied in sheep or other animal specie. Therefore, the objective of this study was to evaluate the effect of ZH on feedlot growth and carcass characteristics of ewe lambs under heat stress conditions.

Materials and Methods

Study Location and Climatic Conditions. Procedures were approved by the Norma Oficial Mexicana (NOM-051-ZOO-1995: Humanitarian slaughter of domestic and wild animals).This study was carried-on at the Experimental Livestock Unit of the Instituto de Ciencias Agrícolas, Universidad Autónoma de Baja California, located in the Mexicali Valley, state of Baja California, in the northwestern region of Mexico. The climate is considered as desert, arid, hot and extremely dry during summer, with average of maximum and minimum temperature of 43 and 16 °C, respectively. Average annual rainfall is 85 mm and average relative humidity from 20 to 50% (García, 1985). The feedlot phase was from July 25 to August 4, summer of 2009.

Animals, Facilities, and Diet. Twenty Katahdin x Pelibuey and Dorper x Pelibuey crossbred ewe lambs with an average BW of 26.2±0.83 kg and 4 months of age were individually housed in pens located in a closed calf rearing unit, which was provided with two fans installed

on the north side of the hall (180 m^3 min^{-1}). The fans operated during the entire feedlot phase. Ewes were fed a basal diet formulated for nutritional requirements of fattening during the finishing period (14% CP and 2.7 Mcal kg^{-1} ME; NRC, 2007), and consisted (feed basis) of 534 g wheat grain, 267 g alfalfa hay, 107 g soybean meal, 53.4 g wheat straw, 31.9 g cane molasses, 4.8 g common salt and 2.5 g limestone.

Treatments and Animal Management. The treatments were: T1= basal diet without ZH (control group), and T2= basal diet plus 10 mg of ZH (Zilmax, Intervet, México City, México) per animal d^{-1}. Ten female lambs were used per treatment. In order to guarantee the total intake of ZH, it was mixed with 100 g of wheat grain and offered before the basal diet in the morning. Lambs were fed twice daily at 7:00 and 15:00 h. The feedlot phase lasted 33 d, after a 15-d adaptation period in which females were adapted to the basal diet, treated against endoparasites, and injected with vitamins.

Collections. Ewes were weighted individually upon initiation and termination of the experimental period. The amount of feed offered and refused was weighed and recorded daily to determine feed intake. Also, diets offered were adjusted to allow minimal refuse. The ZH was withdrawn on day 31 of the feedlot phase (72 h before harvest). Immediately after finishing the feedlot phase, all ewe lambs were slaughtered and skin, head, rumen, small intestine, peritoneum, heart, live, lungs, kidney, internal fat (kidney-pelvic fat and thoracic), and hot carcass (HCW) were weighted and recorded. Conformation was evaluated considering a rank from 1 (bad, thin muscled throughout) to 10 (excellent, thickly muscled throughout). Carcasses were cooled for 24 h to 4 ^oC, and carcass weight (CCW) and length, ribeye area, fat thickness and shear force (Salter 235, Manhattan Kansas, USA) were recorded. Temperature (T, ^oC) and relative humidity (RH, %), in the morning (0700 h) and afternoon, (1500 h) were recorded daily within the calf rearing unit, and a temperature-humidity index (THI) was calculated using the formula proposed by Hahn (1999): THI= 0.81 * T + RH (T - 14.4) + 46.4.

Statistics. All data were analyzed with a completely randomized block design, using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC). Data are presented as least square means with differences considered significant at $P<0.05$.

Results and Discussion

Climatic Conditions. Averages of temperature, relative humidity and THI during the feedlot period were 34.1 ^oC, 50.4 % and 85 units, respectively (Figure 1). The range in THI during the study was between 77 and 90 units, but mainly above 82 units, which is considered the level where heat stress starts in sheep (Marai et al., 2007). These climatic conditions are representative of a moderate heat stress. In sheep and generally in ruminants, a physiological response to heat stress is a reduction in heat production, which in turn is caused by a reduction in feed intake and thyroid hormone secretion (Hahn, 1999). Increasing forced ventilation promotes evaporation and helps to dissipate the heat produced by the animals keeping them cooler (Marai et al., 2007).

Feedlot Traits. Growth performance was similar ($P>0.05$) between ewe lambs of both groups (Table 1). The averages of final BW, daily weight gain, feed intake and feed conversion were 32.2 kg, 170 g d^{-1}, 1.2 kg d^{-1} and 7.2 kg feed kg^{-1} BW, respectively. These results are in agreement with those reported by Aguilera-Soto et al. (2008), but differ from those reported by Nourozi et al. (2008) who treated culled Moghani ewes with two β-adrenergic agonists (terbutaline and metaproterenol) at levels of 10 and 20 mg/kg DM, finding an improvement in daily gain and feed efficiency, but no difference on DMI in treated and control lambs. Ekpe et al. (2000) mention that the receptors number of β-agonists in adipose tissue and muscle is reduced with the increase of the temperature (>30^o C), which in part explains the results of the present study.

Carcass Traits and Internal Organs. Carcass components HCW, CCW, dressing, conformation and rib-eye area were greater ($P<0.02$) in ZH ewe lambs compared with control ewe lambs. A trend to decrease internal fat ($P=0.10$) was observed in favor of the ZH group. The results are consistent with those reported previously in Moghani ewes by Nourozi et al. (2008). The β- adrenergic agonists have the ability to shift the metabolic characteristics of muscle fibers, leading to an increase in skeletal muscle tissue (Berman, 2004). Furthermore, β-agonists redirect nutrients in the direction of increase rates of muscle protein synthesis and away from adipose tissue deposition resulting in muscle accretion (Mersmann, 1998). No differences on non-carcass components weight (rumen, omasum and abomasums, small intestine, peritoneum, skin, heat, heart, live, kidney and lungs) were observed by effect of ZH supplementation. However, small intestine weight tended ($P=0.08$) to be higher in control ewe lambs. These results on internal organs are consistent with Aguilera-Soto et al. (2008), who did not find variations on percentage of liver, rumen and pluck (lungs, trachea and heart) between ram lambs treated with and without ZH. In conclusion, the ZH supplementation with 10 mg $animal^{-1}$ d^{-1} in finalization diets did not improve feedlot performance or body fat deposition of hair breed ewe lambs under moderate heat stress. However, HCW, CCW, dressing, conformation, rib-eye area and legs percentage were increased by the addition of this β-agonist. The weight of non-carcass components was not affected by the ZH oral application.

Implications

These findings imply that supplementation of the β-agonist zilpaterol hydrochloride improved carcass traits in hairsheep female lambs exposed to heat stress conditions and applying an environmental modification based on forced ventilation during the finishing phase.

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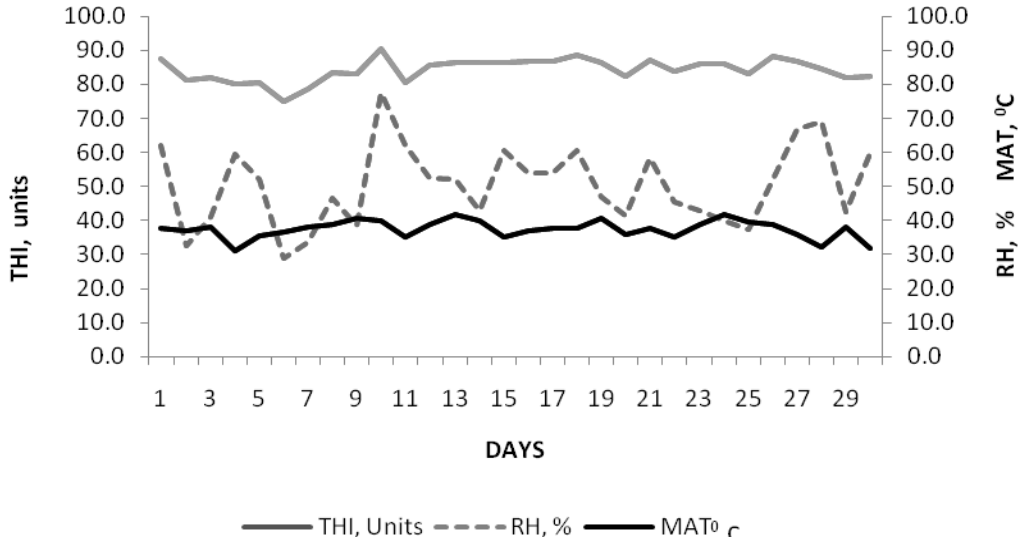

Figure 1. Averages of temperature-humidity index (THI, units), relative humidity (RH, %), and ambient temperature (MAT, ^{0}C) during the study.

Table 1. Feedlot performance in ewe lambs supplemented with zilpaterol hydrochloride (ZH) under heat stress.

Variables	Treatments*		SE
	Control	ZH	
Final BW, kg	32.45	31.87	0.49
Daily weight gain, g/d	180	160a	14.00
Feed intake (feed basis), kg/d	1.20	1.16	0.03
Feed conversion	6.85	7.63	0.50
Gain:feed	0.15	0.14	0.01

* No statistical differences between treatments (P>0.05).

Table 2. Carcass traits in ewe lambs supplemented with zilpaterol hydrochloride (ZH) under heat stress.

Variables	Treatments		
	Control	ZH	SE
Hot carcass weight, kg	14.92[a]	17.20[b]	0.37
Cool carcass weight, kg	14.47[a]	16.45[b]	0.33
Dressing, %	45.99[a]	53.81[b]	0.63
Carcass length, cm	57.46[a]	57.04[a]	0.30
Conformation[¥]	6.00[a]	7.00[b]	0.24
Rib-eye area, cm^2	15.48[a]	18.88[b]	0.78
Shear force, kg/cm^2	18.42[a]	21.97[a]	1.47
Fat thickness, cm	0.26[a]	0.25[a]	0.05
Internal fat, kg[£]	1.52[a]	1.18[a]	0.12

[a,b] Means in a row with different superscript differ (P<0.05).
[¥] Ranked from 1 (bad) to 10 (excellent); [£] kidney, pelvic and heart weight.

Table 3. Non-carcass components in ewe lambs supplemented with zilpaterol hydrochloride (ZH) under heat stress.

Variables (kg)	Treatments*		SE
	Control	ZH	
Rumen, omasum and Abomasum weight	0.99	1.03	0.08
Small intestine	0.57	0.49	0.02
Peritoneum	0.59	0.62	0.04
Skin	2.02	1.80	0.10
Heat	1.18	1.21	0.02
Heart	0.15	0.14	0.01
Live	0.89	0.83	0.02
Kidney	0.11	0.10	0.01
Lungs	0.37	0.34	0.02

* No statistical differences between treatments (P>0.05).

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CORRELATION BETWEEN PRODUCTION TRAITS AND SEXUAL BEHAVIOR IN WHITE-FACED YEARLING RAMS

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ABSTRACT: Of the 196,000 rams in the U.S., approximately 23% are expected to be non-performers. This results in an annual loss of $13.5 million to U.S. sheep producers. The objective of this study was to determine the discriminating value of production traits so that measures of production may be used as indicators of reproductive performance. White faced rams consigned to the Wyoming ram test in 2008 (n = 33) and 2009 (n = 41) were tested for expression of sexual behavior while being evaluated for production performance. At the time of behavior testing, rams were 10 mo to 1 yr of age. In 2009, rams were fed using the Grow-Safe® feeding system and feeding behavior was correlated to sexual behavior. Sexual performance was evaluated by exposing individual rams to two ewes in estrus for 30 min for a maximum of three times. Sexual behavior was categorized as: anticipatory (ano-genital sniffs, Flehmen response, fore-leg kicks and nudges) and consummatory (mount attempts, mounts and ejaculations) behavior. Rams exhibiting consummatory behavior were not re-tested. Rams were classified low (LP; n = 18), intermediate (IP; n = 23) or mounting (M; n = 33) according to the level of sexual behaviors exhitibed. Rams classified as LP and IP exhibited total anticipatory behaviors ≤ 9 (mean = 4.8 ± 2.7) or ≥ 10 (mean = 23.7 ± 10.7), respectively, but did not exhibit mounting behavior. M rams mounted a ewe at least once (anticipatory mean = 43.5 ± 24.7; consummatory mean = 9.5 ± 7.0). For production traits, each ram was assigned an index ratio based on body weight gain and adjusted for wool characteristics. Data were analyzed using GLM and CORR procedures of SAS. Sexual behavior classification did not influence ($P \geq 0.5$) index ratio, feed consumed per day, or number of feed intake episodes. Although anticipatory and consummatory behaviors (r = 0.48; $P < 0.05$) and test index ratio and feed consumption (r = 0.50; $P < 0.05$) were highly correlated, sexual behaviors were not significantly correlated with the index ratio (r = 0.08; $P = 0.5$). Measures of production performance do not appear to be reliable predictors of sexual behavior in yearling rams. Supported by USDA-NRI 2007-55618-18176

Introduction

The polygynous mating system of sheep is well suited for modern day sheep production systems because only a few males are needed to inseminate a large number of females. However, libido (sexual interest or motivation), mating competence (ability to inseminate females) and fertility (semen quality) of rams is extremely important to the success of any breeding program. The influence of ram mating behavior on conception and lambing rates has been demonstrated in pen (Perkins et al., 1992b) and field (Mattner et al., 1971; Stellflug et al., 2006) mating trials. Ram selection based solely on production traits may cost producers economic opportunities as well as slow genetic progress of the flock if those selected rams have a low propensity for sexual performance. Of the 196,000 rams nationwide, approximately 23% of all rams are predicted to be non-breeders (Fitzgerald and Perkins, 1991) resulting in an annual loss of 13.5 million dollars in ram costs alone to U.S. sheep producers. Researchers at the U.S. sheep Experiment Station suggest identification of both low- and non-performing rams would reduce the number of rams required for breeding flock maintenance by 50% (ASI, 2005).

Artificial selection for economically important traits in domestic food animals may have secondary or correlated responses on sexual performance. The effect of selection for rapid weight gain in other food animal species has reduced their agility, but the impact on sexual performance has not been documented (Price, 1987). Considering the wide variation in sexual performance among rams (Hulet, 1964), it is desirable for producers to evaluate the mating competence of individual animals before they are utilized in breeding flocks. Adult ram sexual performance does not correlate with resting levels of luteinizing hormone, testosterone (Perkins et al., 1992a), or with scrotal circumference and semen characteristics (Hulet, 1964). Standard serving capacity tests are labor intensive and not easily performed by the average sheep producer. Therefore, the sheep industry is in need of a cost effective and easily implemented tool to identify poor sexually performing rams.

We hypothesized that a good indication of aggressive feeding behavior in rams are those rams who monopolize the food resource (rams standing in the bunk which prohibits others from eating). The objective of this study was to determine the discriminating value of production traits so that measures of production may be used as indicators of reproductive performance.

Materials and Methods

Animals. White faced rams consigned to the Wyoming ram test in 2008 (n = 33) and 2009 (n = 41) were used for this experiment. At the time of behavior testing, rams were ten months to one year of age. All rams were housed at the University of Wyoming livestock facilities while on the Wyoming ram test. In 2009, rams were fed using the Grow-Safe® feeding system. This system utilizes a feed bunk equipped with a scale and a scanner which identifies the animal's electronic identification tag. Each bunk allows one animal to feed at a time. A computer system records the date and time each animal puts its head in the bunk, as well as the amount of feed the animal consumes.

Design and Data Analysis. Production traits were measured and an index ratio was calculated for each ram using the following formula:

Index = 60 (average daily gain in pounds)
+ 4.0 (365-d adjusted staple length in inches up to 5.5")
+ 4.0 (365-d adjusted clean wool in pounds)
+ wool fiber diameter and variability points

Rams were tested for sexual behavior a maximum of three times starting in January, with subsequent tests occurring one month apart in February and March. Each ram was individually tested for 30 minutes in an enclosed pen with two ewes in estrus. In order to eliminate human interference, each ram's sexual behavior was recorded using a video camera and analyzed at a later date. Sexual behavior was quantified as either anticipatory (ano-genital sniffs, Flehmen response, fore-leg kicks and nudges) or consummatory (mount attempts, mounts and ejaculations). Rams exhibiting consummatory behavior were not re-tested. Rams were then classified as low (LP; n = 18), intermediate (IP; n = 23) or mounting (M; n = 33) according to the level of sexual behaviors exhibited. Rams classified as LP and IP exhibited total anticipatory behaviors ≤ 9 (mean = 4.8 ± 2.7) or ≥ 10 (mean = 23.7 ± 10.7), respectively, but did not exhibit mounting behavior, whereas M rams mounted a ewe at least once (anticipatory mean = 43.5 ± 24.7; consummatory mean = 9.5 ± 7.0).

Statistics. Data were analyzed using GLM and CORR procedures of SAS.

Results

Twenty-four percent of rams were classified as LP, with 31.5% as IP and 44.5% as M. Sexual behavior classification did not influence index ratio ($P = 0.6$), feed consumed per day ($P = 0.6$), number of feed intake episodes ($P = 0.5$), or number of no feed intake episodes ($P = 0.17$).

Anticipatory and consummatory behaviors ($r = 0.48$; $P < 0.05$) and test index ratio and feed consumption ($r = 0.50$; $P < 0.05$) were highly correlated. Sexual behaviors were not significantly correlated with the index ratio ($r = 0.08$; $P = 0.5$).

Discussion

Low sexually performing rams were equally competitive for a limited food source (Erhard et al., 1998). Rams ranked low in a competition for limited food resources (LR) were more effective at mating estrous ewes than high ranking rams (HR) when not in the presence of other rams. However, in competitive mating tests, although all rams modified their courtship strategies, LR rams were more affected by the presence of dominant rams than HR rams were by the presence of LR rams (Ungerfeld and Gonzalez-Pensado, 2009).

These data indicate that ram sexual performance is not correlated to feeding behavior. Additionally, sexual behaviors are not correlated with production traits. Therefore, we conclude that measures of production performance do not appear to be reliable predictors of sexual behavior in yearling rams.

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MONITORING DIET QUALITY AND BODY CONDITION IN BEEF COWS GRAZING ARIZONA RANGELAND

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ABSTRACT: Nutrition is the highest input cost in beef production. Monitoring the nutritional status of range cows is difficult. Near infrared spectroscopy (NIRS) of feces has been used to predict diet quality in cattle. When fecal NIRS is coupled with decision support software such as the Nutritional Balance Analyzer (NutbalPro); nutritional status and animal performance can be monitored. Few reports on the applicability of these two methods exist for the southwestern US. Approximately 120 Hereford and 90 CGC composite (50% Red Angus, 25% Tarentaise, 25% Charolais) cows grazing in a single herd were used in a study to determine the ability of fecal NIRS/NutbalPro to project body condition score (BCS, 1 = thin, 9 = fat) under commercial scale rangeland conditions in central Arizona. Cattle were rotated across the 31,000 ha allotment at 10 to 20 day intervals. Fecal samples were collected in the pasture ~ monthly at the midpoint of each grazing period. A sample consisted of ~500g feces composited from 5 to 10 animals of each breed. Samples were frozen and later analyzed by NIRS for prediction of diet crude protein (CP) and digestible organic matter (DOM). Fecal sampling occurred from November 2007 to August 2009. Cattle BCS was recorded for 10 to 30 individuals from each breed type at the time of fecal sampling beginning in November 2008. Along with fecal NIRS predicted diet quality, animal breed type, reproductive status, and environmental conditions were input to the NutbalPro software for each fecal sampling/BCS date (November 2008 to August 2009). Diet quality varied from a minimum of 5.24% CP and 56.89% DOM in January 2009 to a maximum of 14.61% CP and 62.87% DOM in August of 2008. Diet quality correlated with observed seasonal changes and precipitation events. Projected BCS averaged 0.2 ± 0.06 score different than observed BCS ($R^2 = 0.75$, SE = 0.19, $P < 0.01$). The greatest difference in projected versus observed BCS occurred during periods of lowest diet quality. Body condition was predicted accurately enough to be useful in monitoring the nutrition of range beef cows under the conditions of this study.

Key Words: near infrared spectroscopy, feces, beef cattle, rangeland, nutrition

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Introduction

Nutritional status of the beef cow is important to her own performance (i.e. body condition, reproduction, or lactation) as well as that of her calf (birth weight, weaning weight, or subsequent feedlot gain). Emerging research also indicates that nutrition during gestation affects offspring health and productivity via "fetal programming" (Vonnahme 2007). The nutritional environment of the cow may thus have both short and long-term, obvious and subtle effects on production.

Standardized Performance Analysis (McGrann et al. 2000) indicates that providing nutrition is the highest input cost in cow/calf production (Miller et al. 2001). As with any successful business, careful evaluation of input costs is critical to the sustainability of a beef production enterprise. The top 2 management practices of low cost beef producers were: 1) reducing supplemental feed costs and, 2) rotational grazing/better pasture management (Taylor and Field 1995). Forage is often the most cost efficient way to provide nutrition to beef cows, but forage does not always meet cow requirements. Even when animal needs are matched with forage production, cows may require supplemental feed to achieve production goals. Certain types of supplementation may not be feasible under remote range conditions or may not be allowed on public land leases. Alternatively, cows may be moved to different pastures with higher forage quality or other management strategies may be employed (e.g. prescribed burning) to meet these nutritional needs. Determining the nutritional status of cows, both in real-time or, in archived data for later use, facilitates these type of management decisions.

Monitoring the nutritional status of range cows is difficult compared to cows in smaller, "tame" pastures. Clipping plant biomass and acquiring nutrient analysis provides information for forage on offer, but not necessarily the diet selected by cattle. Hand plucking requires time and skill in order to mimic diets selected by grazers. Fistulated animals provide information on diet selected but are not practical for routine management. Near infrared spectroscopy (NIRS) of feces has been used to predict diet quality in cattle (Lyons and Stuth 1992, Coates 1998, Ksiksi et al. 2000, Boval et al. 2004). When fecal NIRS is coupled with decision support software such as the Nutritional Balance Analyzer (NutbalPro); nutritional status and animal performance can be monitored (Stuth et al. 1999, Tolleson et al. 2001, 2002). Few reports on the applicability of these two methods exist for the southwestern US. Beef cows grazing on a public lands lease were used in a study to determine the ability of fecal NIRS/NutbalPro to project body condition score under commercial scale rangeland conditions in central Arizona.

Table 1. Selected breed-type characteristics used in the NutbalPro decision support model to determine projected weight change/BCS in cattle grazing Arizona rangeland.

	Breed-type	
Item	Hereford	CGC[1]
Standard Reference Weight		
kg	451	472
Peak Milk Production		
day of lactation	45	45
kg	6.8	7.3
Basal Net Energy		
Mcal	7.3	7.6

[1]CGC composite: 50% Red Angus, 25% Tarentaise, 25% Charolais

Materials and Methods

The study was conducted on the V Bar V Experimental Ranch near Rimrock, Arizona. The ranch operates on a 31,000 ha US Forest Service grazing allotment. Winters are mild (average 8° C); summers are hot (average 27° C). May and June are typically dry, followed by a monsoon in July, August, and September. Average annual precipitation varies from 254 to 508 mm/yr depending on elevation. As expected in the southwestern US, droughts are frequent.

Three major vegetation types occur on the ranch. Desert shrub is found on the western 1/3 of the allotment from approximately 978 to 1524 m asl. The middle 1/3 of the allotment, approximately 1524 to 1981 m asl, is comprised of piñon-juniper and the eastern 1/3 lies within the ponderosa pine type between approximately 2100 and 2200 m asl. Forage includes warm and cool season perennial grasses, annual grasses and forbs, and browse from various woody shrubs and sub-shrubs. Water is provided by earthen tanks or piped to metal troughs. The ranch grazes from 300 to 500 head of livestock in an adaptive rotational grazing system. Timing and intensity of livestock grazing is dictated by current precipitation and range conditions.

Animal procedures were approved by the University of Arizona Institutional Animal and Care Use Committee. Approximately 120 Hereford and 90 CGC composite (50% Red Angus, 25% Tarentaise, 25% Charolais) mature (3 to 10 yr old) cows grazing in a single herd with other cows were used. Cattle were rotated across the 31,000 ha allotment at 10 to 20 day intervals. Fecal samples were collected in the pasture approximately monthly at the midpoint of each pastures grazing period. A sample consisted of 500 ± 50g feces composited from 5 to 10 animals of each breed. Samples were frozen and later analyzed by NIRS (Lyons and Stuth 1992) for prediction of diet crude protein (CP) and digestible organic matter (DOM). Fecal sampling occurred from November 2007 to August 2009. Cattle body condition scores (BCS, 1 = thin, 9 = fat) were recorded for 25 ± 10 individuals from each breed type at the time of fecal sampling beginning in November 2008.

Along with fecal NIRS predicted diet quality; animal characteristics such as age, class, breed type, and reproductive status, along with environmental conditions such as minimum and maximum temperature, were input to the NutbalPro software (Stuth et al. 1999) for each fecal sampling/BCS date. Breed type descriptions (NRC 2000) as used in the NutbalPro model were adjusted to reflect measured milk production (authors unpublished data) and standard reference weight (CSIRO 1990) for the cattle in this study (Table 1). Projected BCS was based on the average projected weight change between the 2 endpoint sampling dates for a given period. Visual estimates of seasonal grazing utilization for each pasture were less than 40% during the study so no adjustments to dry matter intake based on forage availability were made in the model. Simple linear regression (Steel and Torrie 1980) was used to determine relationships between observed and projected BCS. Analysis of variance (Steel and Torrie 1980) was used to determine differences in diet quality and projected BCS between breed types.

Results

Predicted diet quality did not vary ($P > 0.1$) between breed types in the first year of collection, so results were averaged for each sampling date in the first year and a single composite sample was collected at each period in the second year. Diet quality varied from a minimum of 5.24% CP and 56.89% DOM in January 2009 to a maximum of 14.61% CP and 62.87% DOM in August of 2008 (Figure 1). Diet quality correlated with observed seasonal changes, precipitation events (Figure 2) and site specific vegetation characteristics (i.e. proportion of warm versus cool season forage species). Winter precipitation was approximately 50% above the most recent 7 year average for the ranch in 2007/2008. Summer precipitation was average in amount and timing during 2008. The winter precipitation for 2008/2009 was average. May 2009 was unusual in that 500% of the average precipitation was recorded for the mid elevation sites on the ranch and then only 50% of average was recorded during June to August of 2009.

Fecal NIRS/NutbalPro projected BCS averaged 0.2 ± 0.06 score different than observed BCS. The correlation between observed and projected BCS was high ($r^2 = 0.75$, SE = 0.19, $P < 0.01$). The greatest difference in projected versus observed BCS occurred during periods of lowest diet quality (Figure 3). Differences in observed versus projected BCS were not different ($P > 0.1$) between breed-types. Differences between observed and projected BCS in Hereford ranged from 0.0 to 0.4. Similar values for CGC were 0.0 to 0.7 BCS.

Discussion

Fecal NIRS predicted diet quality varied with observed environmental and vegetation characteristics for the study site and was comparable to published plant tissue sample chemistry for Arizona (Grumbles 2006, Meen 2006). Body condition was predicted accurately enough (approximately 0.2 BCS) to be useful in monitoring the nutrition of range beef cows under the conditions of this

study. Additionally, projected BCS followed the observed BCS trend in all but 2 instances; during the November to December period for Herefords, and January to February for CGC. The decision support system worked similarly for both breed-types utilized, but we did observe a greater than 0.5 BCS difference between observed and projected body condition for the CGC group in February. Fecal NIRS predicted January diet quality was low (CP = 5.24%, DOM = 56.89%). Perhaps the sample did not accurately describe actual diet quality for the time period in question. Standard errors of prediction for the fecal NIRS calibrations used in this study are approximately ± 0.5 and ± 1.5 percentage units for CP and DOM respectively. Alternatively, the CGC cattle are slightly larger and had a greater net basal metabolism requirement (Table 1) in the model. Both groups were not lactating and at approximately 210 days of gestation at this time. Projected weight loss was 1.0 and 1.1 kg/d for Hereford and CGC for the January analysis respectively. The model calculated the Hereford group to have a -0.22 kg/d balance for CP, while the CGC were estimated to be at -0.24. Similarly, due to described breed-type differences as input to the model, calculated dry matter intake as a percent of standard reference weight was 1.96 for Hereford and 1.89 for CGC. Projected performance for February was 0.05 kg/d greater for Hereford than for CGC. This combination of factors resulted in a lower projected BCS for the CGC group. Another possible contributing factor to the large difference in observed and projected BCS for CGC in February could be that only 16 CGC cows were located at this sampling time.

Implications

Our results indicate that fecal NIRS can be used to monitor diet quality of range beef cattle in the southwestern US, and that in conjunction with the NutbalPro decision support software, the method can be useful in projecting body condition score. Monitoring the nutrition of range cattle is especially important in arid or semi-arid regions, and could become even more critical if current climate projections hold true (Craine et al. 2010). Advantages of this monitoring system include relative ease and speed of obtaining current nutritional information, and the results provide a record of diet quality for future managers. This method may also provide a means to help offset subtle effects of maternal nutrition on subsequent health and performance of calves; effects that may not be detectable using traditional management techniques. Disadvantages include the need to learn new software and, calibrating inputs to the model for local cattle and conditions.

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Figure 1. Fecal NIRS predicted diet quality for cattle grazing Arizona rangeland.

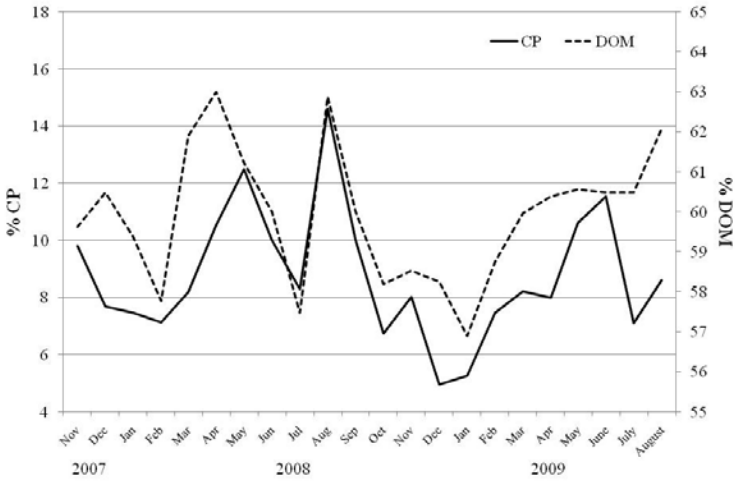


Figure 2. Seven year average precipitation for mid elevation site on V Bar V Ranch, central Arizona.

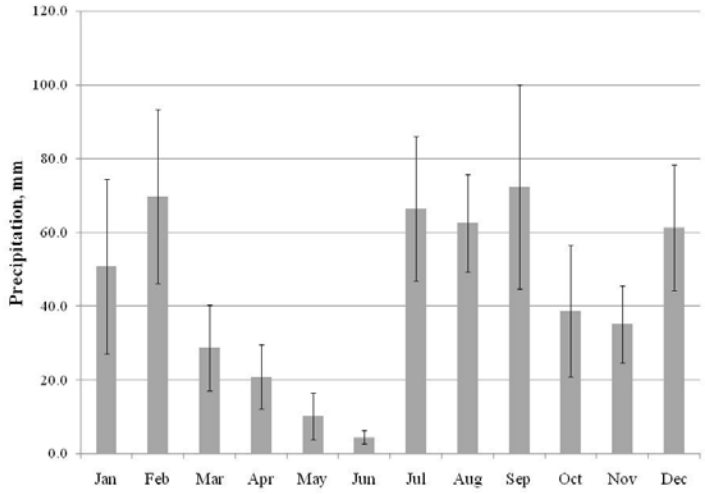
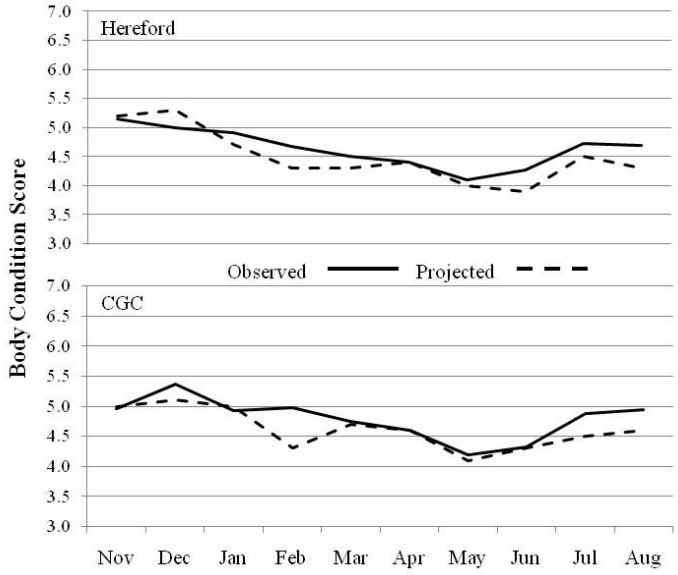


Figure 3. Observed versus fecal NIRS/NutbalPro projected body condition score in mature beef cows grazing Arizona rangeland.



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SUPPLEMENTAL CORN DRY DISTILLERS GRAINS PLUS SOLUBLES ON PERFORMANCE OF STEERS GRAZING NATIVE RANGE[a]

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ABSTRACT: Medium- to high-quality rangeland forage is low in available energy in relation to its rumen degradable protein content. To complement forage quality, energy and phosphorus are usually supplemented to cattle grazing medium to high-quality forage. Supplementation with feedstuffs rich in digestible fiber (energy) and phosphorus, such as corn distiller grains plus solubles (**DDGS**), could alleviate the deficiencies of growing forage. We hypothesized that supplementation of DDGS to cattle grazing native range during the summer season will alleviate nutritional deficiencies, and will improve cattle grazing performance. To evaluate effects of DDGS supplementation level on performance of steers grazing native range during the forage growing season, 72 (206 ± 23.6 kg; 2008) and 60 (230 ± 11.3 kg; 2009) English crossbred steer calves were used in a grazing experiment. The grazing periods lasted 56 and 58 d and started on August 11 and 18 for 2008 and 2009, respectively. Steers were blocked by BW into light, medium, and heavy. Each block was divided into 4 grazing groups. Each grazing group (6 steers in 2008 and 5 in 2009) was assigned to 1 of 4 DDGS supplementation levels: 1) 0% supplementation (no supplement), 2) 0.2%, 3) 0.4% and 4) 0.6% of BW. Total amount of supplementation per paddock for 7 d was calculated and divided by 3 to determine amount of DDGS to be fed as it was offered 3 times weekly. Supplement intake (0, 0.42, 0.82, and 1.25 ± 0.03 kg/d, for 0, 0.2, 0.4, and 0.6% of BW, respectively), and ADG (0.64, 0.75, 0.80, 0.86 ± 0.03 kg/d for 0, 0.2, 0.4, and 0.6% BW, respectively) increased linearly ($P < 0.01$) with increasing DDGS supplementation level. Levels of DDGS supplementation did not affect ($P = 0.43$) supplement conversion (4.18, 6.72, an[1]d 6.03 ± 1.26 kg as-fed supplement/kg of increased BW gain for 0.2, 0.4, and 0.6% BW, respectively). Supplemental DDGS improved performance of steers grazing native range during summer in the Southern Plains.

Keywords: DDGS, grazing native range, steers

Introduction

Supplementation of grazing animals has long been used to improve grazing production performance. During summer dormancy, or fall and winter months, when forage quality is low, the provision of nutrients to cattle to compensate for deficiencies is practiced often (Caton and Dhuyvetter, 1997). In medium to high-quality forage, such as that during summer growing season, forage is often low in available energy in relation to protein (Pordomingo et al., 1991). Supplementation of energy rather than protein seems to result in favorable responses in BW gain when consuming medium to high-quality forage (Brake et al., 1989). Common sources of supplemental energy vary widely and include grains, readily digestible fiber sources, and high-quality forages (Caton and Dhuyvetter, 1997). Corn supplementation at 0.2% of BW increased forage intake, but greater supplementation levels decreased forage intake (Pordomingo et al., 1991). Several studies involving harvested roughages have demonstrated that the starch contained in grains has detrimental effects on fiber utilization (Fick et al., 1973; Sanson et al., 1990).

With increased demand of ethanol as a biofuel, the availability of cereal grains for livestock production is decreasing (Gottschalk, 2007). Dry distillers grains and condensed solubles (**DDGS**) are byproducts of fermented cereal grains, corn especially, from the production of ethanol. An increase in the availability of these byproducts is correlated to the rapid expansion of the ethanol industry. These by-products are recognized for being high in readily digestible fiber, protein, fat and phosphorus (Morris et al., 2006). Due to the removal of starch during ethanol production, starch negative associative effects are removed (Morris et al., 2005). These characteristics make the product an attractive supplement for medium to high-quality forages. However, little is known about optimum level of DDGS supplementation to cattle grazing medium to high-quality forage and subsequent cattle performance.

The objective of this study was to evaluate the effect of DDGS supplementation on performance of steers grazing native range during summer in the Southern Plains.

Materials and Methods

Animals, Facilities, and Diet. Procedures were approved by the New Mexico State University Institutional Animal Care and Use Committee. The study was conducted in a pasture located in Dallam County, TX, 64 km east from the Clayton Livestock Research Center in Northeastern New Mexico. Sideoats (*Bouteloua curtipendula*) and

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bluegrama (*Bouteloua gracilis*) were the major plant species on the study site. Other important forage species in the area included, old world bluestem (*Andropogum gerardii*), galletagrass (*Hilaria jamesi*) and buffalograss (*Buchloe dactyloides*). The 2-yr study was conducted during 2008 and 2009 summer forage growing seasons. Seventy-two (206 ± 23.6 kg; 2008) and 60 (230 ± 11.3; 2009) English crossbred steer calves were blocked by BW into light, medium, and heavy. Each block was divided into 4 grazing groups (6 and 5 steers per group for 2008 and 2009, respectively) per pasture. Each pasture was approximately 25.5 ha total, and all pastures were divided into 4 paddocks (6.4 ha) each with electric fencing to allow rotation of steers within pasture. Steers were adapted to DDGS for 2 weeks. During adaptation, steers received sudan hay ad-libitum and 100 g/head of DDGS daily. Once transferred to experiment location, steers were allowed free access to water, 1-580 L tub per paddock. Supplemental DDGS was offered in feeders, 1 placed in each paddock according to treatment. Total amount of supplementation per paddock for 7 d was calculated and divided by 3 to determine amount of DDGS to be fed as it was offered 3 times weekly at 0900.

Design and Treatments. The experimental design was a replicated randomized complete block design consisting of 56 and 58-d grazing periods for 2008 and 2009, respectively. Treatments consisted of 4 DDGS supplementation levels: 0% (no supplement), 0.2%, 0.4% or 0.6% of BW. The total amount of supplement was consumed. Therefore, supplement intake was equal to supplement offered. Steers were weighed at beginning and at end of the experiment to measure weight gain and supplement conversion (kg of DDGS as fed • kg of increased BW gain). The amount of DDGS offered was based on initial BW.

Sample forage clippings were taken from the pasture at 3 time intervals, at the beginning of the experiment (d 0), at d 30, and at end of trial (d 56) using the rapid assessment method (0.093m^2 ring). Each paddock was divided in 3-100 m equally spaced transects (1/3 from beginning, 2/3 at middle, and 3/ at end of paddock) and obtaining 4 samples (g DMB/m^2) at 12.5 m apart within transect. A total of 432 samples were taken from the pasture, 144 samples per interval, and 12 samples per paddock. Clippings were dried at 55°C in a forced-air oven. Available standing crop within each block was determined with the use of clippings.

Laboratory Analysis. Clipping samples and DDGS were analyzed for DM, ash, NDF, CP, and ether extract to determine nutrient composition.

Statistics. Data were analyzed using the Mixed procedures of SAS (SAS Inst. Inc., Cary, NC). The model included effects of block nested within year, year, treatment and treatment x year as fixed effects and block within year as random effects. Orthogonal contrasts were conducted for linear, quadratic, and cubic effects of DDGS supplementation level, and linear and quadratic for supplement conversion.

Results and Discussion

The effect of supplemental corn DDGS on performance of steers grazing native range is shown on Table 1. Final BW increased linearly ($P < 0.0001$) and quadratically ($P = 0.0035$) with increasing DDGS supplementation level. Because the probability value shows stronger evidence for linear effect, we chose to consider the response as linear. Supplemental intake and ADG increased linearly ($P < 0.01$) with increasing DDGS supplementation level. Similar results were found by Morris et al. (2005), where yearling steers grazed Sand hill range and supplemented at 0, 0.26, 0.57, 0.77, and 1.03% of BW; a linear increase in ADG with increasing level of DDGS supplementation was found. Medium to high quality forage is often low in available energy in relation to protein (Pordomingo et al., 1991). Supplementation of DDGS corrected the energy deficiency without the negative associative effects of starch observed with grain supplementation as demonstrated by the present data and supported by (Morris et al, 2005). The forage energy gap was bridge most likely by the readily digestible fiber and fat supplied by DDGS (Morris et al., 2005). Protein from DDGS probably contributed to correct the deficiency also. It has been shown that the energy deficiency can also be alleviated by supplementing grains, but the amount of grain that can be supplemented is limited due to the presence of negative associative effects on forage utilization. Vanzant et al. (1990) found that low grain supplementation levels (0.37% of BW) do not affect forage intake when CP is not limiting, and thus addition of grain to diet may increase total DE intake. Similar results with low-quality bluestem hay verified these findings (Brake et al., 1989). The amount of grain that can be supplemented per day is limited because the starch contained in grains has detrimental effects on fiber utilization (Fick et al., 1973; Sanson et al., 1990). Such problem was not evident in the present study since ADG increased linearly.

Average daily gain was greater ($P = 0.03$) for 2008 (0.860 kg/d) than for 2009 (0.669 kg/d). The lower ADG for 2009 was caused by lower and later precipitation in 2009 than in 2008. As a result of precipitation patents less forage and of lower quality was present during the 2009 grazing period that the 2008 grazing period. Because of the lower forage availability, the number of steers per grazing group was reduced from 6 used during 2008 to 5 during the 2009 grazing period. The luck of treatment by year interaction ($P = 0.62$) might suggest that DDGS might be a viable supplement for cattle grazing low quality forage. However, more research is needed to evaluate such hypothesis.

Supplement conversion (additional BW gain per kg of DDGS supplemented) was not affected ($P = 0.45$) by DDGS supplementation level. The supplement conversion values were 4.82, 6.72, and 6.03 ± 1.23 kg as-fed supplement/kg of increased BW gain for 0.2, 0.4, and 0.6% of BW, respectively. The supplement conversion values observed in this experiment are in close agreement with those observed when high-fiber by-products feeds were

supplemented to stocker cattle grazing wheat pasture (Horn and McCollum, 1987).

Supplementation of energy to cattle grazing medium to high-quality forage can improve weight gain of cattle. Our findings suggest that supplemental DDGS improved performance of steers grazing native range during summer in the Southern Plains, and the conversion of supplemental DDGS to BW gain seems highly acceptable. Therefore, DDGS are a viable alternative as a supplement for growing cattle grazing medium to high-quality native forage in the Southern Plains.

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Table 1. Effect of supplemental corn DDGS level on performance of steers grazing native range

	DDGS supplementation level, %[a]					*P* - value[c]		Contrast[d]		
Items	0	0.2	0.4	0.6	SE[b]	TRT	Year	L	Q	C
Initial BW, kg	216.43	220.63	218.41	216.54	6.26	0.32	0.18	0.81	0.10	0.40
Final BW, kg	253.00	263.14	264.05	265.65	6.79	0.01	0.37	0.01	0.01	0.10
ADG, kg/d	0.64	0.75	0.80	0.86	0.03	0.01	0.03	0.01	0.31	0.56
Supplement intake, kg/d	0	0.42	0.82	1.25	0.03	0.01	0.84	0.01	0.81	0.83
Supplement conversion[e]	--	4.82	6.72	6.03	1.23	0.43	0.47	0.40	0.32	--

[a]DDGS supplementation was offered at: 0 (no supplement), 0.2, 0.4, and 0.6% of BW.
[b]SE with n = 6.
[c]Probabilities for the effects of DDGS supplementation level (TRT) and grazing year (Year)
[d]Probabilities for contrasts: linear (L), quadratic (Q), and cubic (C).
[e]Supplement conversion kg of as-fed DDGS supplement per kg of increased BW gain.

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PREDICTED MINERAL INTAKE UTILIZING BOTH WATER AND FORAGE ANALYSIS VARIES BY SOURCE AND LOCATION OF LIVESTOCK WATER IN EASTERN MONTANA

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ABSTRACT: Livestock water can play an important role in contributing to mineral intake of cows grazing rangelands. Mineral analysis of both forage and water is needed to accurately assess mineral intake compared to animal requirements. Therefore, 93 pasture and water source combinations were sampled in May 2009 with the objective to predict total mineral intake (forage intake and water consumption) on a DM basis at the 22,257 ha USDA-ARS Fort Keogh Livestock and Range Research Laboratory in Miles City, MT. Mineral intake was predicted of a lactating beef cow with an estimated water and forage intake of 43.15 L/d (25.4 kg/d) and 2.4% of BW, respectively. Mineral content from hand plucked forage samples were analyzed from 43 pastures representing 3 geographical locations: north (N), southeast (SE), and southwest (SW). All drinking water locations from each pasture were sampled for mineral analysis (Midwest Labs Inc.) from four sources: springs, pumped ground water, reservoirs, and flowing surface water. Location, source and the location by source interactions were evaluated and analyzed as a 3 × 4 factorial arrangement of treatments. Predicted intake of chloride, copper, dietary anion-cation difference (DACD), phosphorus, and potassium was affected ($P < 0.05$) by geographical location. Differences ($P < 0.05$) in mineral consumption due to water source were found in 5 analyzed minerals (Ca, Cl, DACD, Fe, and Mg). Location by source interactions ($P < 0.05$) were found for fluoride, selenium, sodium, and sulfur. Predicted fluoride and sulfur intake concentrations were at or above the maximum tolerable concentrations in the ground water sources in most pasture locations. Copper and zinc were below requirements for a lactating beef cow; whereas, most minerals were found at safe intake concentrations and meet a lactating cow requirements. These results suggest that developing a mineral supplement to meet grazing cattle's requirement should take into account both forage and water mineral content.

Key Words: Beef cows, Mineral intake, Water Analysis

Introduction

Beef cattle derive 85% of their diet from forage, with the remaining 15% being derived from supplements (Greene, 2000). Forage mineral composition is dependent on many factors, including soil characteristics (Brady, 1974), stage of maturity (Greene et al., 1987), grazing management and climatic conditions (McDowell et al., 1983). Rarely can dietary mineral consumption from forage alone meet all mineral requirements for grazing livestock. Thus, long-term maintenance of beef cow production may require mineral supplementation to meet requirements for optimal reproduction, immunity, lactation, and growth (Corah and Ives, 1991; Ansotegui et al., 1994). To design an accurately formulated mineral supplementation program all mineral sources should be accounted for since mineral imbalances and toxicities can severely inhibit cattle production and animal safety (McDowell et al., 1982). Seasonal testing of forage and water mineral content will help provide a more complete evaluation of predicted mineral intake to maintain animal performance and health. Therefore, 93 pasture vegetation and water source combinations were sampled in May 2009 with the objective to predict total mineral intake (forage intake and water consumption) of a lactating mature beef cow in Eastern Montana. A secondary objective was to compare predicted mineral intake with mineral requirements and maximum tolerable concentrations for a lactating beef cow.

Materials and Methods

This study was conducted in at the USDA-ARS Fort Keogh Livestock and Range Research Laboratory near Miles City, MT in May, 2009. Native vegetation on the 22,500-ha research station consists of a grama-needlegrass-wheatgrass (*Bouteloua-Stipa-Agropyron*) mix. The long-term average precipitation is 343 mm with about 60-70 % occurring during the mid-April through mid-September growing season. Randomly hand plucked forage samples collected by 2 technicians per pasture in a Z shaped pattern and spaced 30-50 m apart (300 - 400 g per technician sample) were combined, mixed and stored in late May and mineral content was later analyzed from 43 pastures representing 3 geographical locations: north (**N**), southeast (**SE**), and southwest (**SW**). Simultaneously, most drinking water locations from each pasture were sampled for domestic water suitability (Na, Ca, Mg, pH, NO_3-N, SO_4, conductivity, TDS, hardness, total coliform, Fe, Mn, Cl, Fl; Midwest Labs Inc., Omaha, NE) from four sources: springs, pumped ground water, reservoirs, and flowing surface water. Mineral intake was predicted using Beef NRC (NRC, 2000) estimates for a 409 kg lactating beef cow with an estimated water and forage intake of 43.15 L/d

(25.4 kg/d) at 2.4% of BW, respectively. An expected dietary mineral consumption was calculated for each pasture and water source combination (n = 93) using the hand plucked forage samples and water sample macro and micro mineral analysis.

Statistical Analysis

Data were analyzed as a completely randomized 3 × 4 factorial arrangement of treatments using the MIXED procedure of SAS (SAS Institute, Cary, NC) with pasture × water source combination as the experimental unit. The model included pasture location, water source, and their interaction. Significance was determined at $P \leq 0.10$.

Results and Discussion

Location Effects.

Predicted intake of chloride, copper, dietary anion-cation difference (**DACD**), phosphorus, potassium, and zinc was affected ($P < 0.05$; Table 1) by geographical location. Highest expected mineral intake for 5 of 6 of these minerals (chloride, copper, phosphorus, potassium, and zinc) was located in the northern geographical location of the experiment station. Whereas, dietary anion-cation difference was found to be the highest in the Southwest location, where calcium exhibited a tendency ($P = 0.06$) to be highest. Copper and zinc were below requirements for a lactating beef cow (NRC, 2000; Table 2); however, most minerals were found at safe intake concentrations and meet a lactating cow requirement.

Water Source Effects.

Differences ($P < 0.05$; Table 3) in forecasted mineral consumption due to water source were found in 5 analyzed minerals (Ca, Cl, DACD, Fe, and Mg). Intake of predicted chloride and DACD would be two times greater when ground water sources are drank compared to other water sources. Mineral intake requirements for a lactating beef cow were met for most minerals; however, Cu and Zn intake levels were below requirements regardless of water source. Iron intake was the highest in reservoir water sources (586.64 ± 66.10 mg/kg). Expected iron intake in all pasture location by water source was over 250 mg/kg, which may cause copper depletion in cattle (Bremner et al., 1987; Phillippo et al., 1987). Iron can interfere with absorption of copper and zinc when dietary levels are over 250 milligrams per kg dry matter (NRC 2001). Human information suggests a high concentration of iron in water may reduce palatability and therefore consumption of water. Importance is secondary only to sulfate and chloride. Besides causing reduced water palatability high iron also promotes growth of black slime in water tanks (this is the result of bacterial growth). Iron in water is nearly 100% available to the animal; whereas, iron in feed is generally only about 10% available. Once absorbed, high iron levels are suspected to promote free radical production, decreased immunity and increased incidence of infection, particularly in fresh dairy cows. Target levels of water intake for iron are 0.3 ppm or less (Beede 2006).

Location and Water Source Interaction Effects.

Location by source interactions ($P < 0.05$; Table 4) were found for fluoride, selenium, sodium, and sulfur. Predicted fluoride and sulfur intake concentrations were at or above the maximum tolerable concentrations in the ground water sources in most pasture locations. Sulfur intake was the highest (1.07 ± 0.18 % of the diet) in the Southwest location and with running water sources (creek). The maximum tolerable concentration of dietary sulfur has been estimated at 0.40 percent (NRC, 2000; Table 2). High sulfur intake can cause decreased feed and water intake (Weeth and Hunter, 1971), retard growth rate (Kandylis, 1984), and decreased copper status (Smart et al., 1986).

Predicted mineral intake in May at the Fort Keogh Livestock and Range Research Laboratory met most mineral requirements for a lactating beef cow. However, both copper and zinc were deficient in water sources and pasture location, resulting in a need for additional supplementation. Due to high intake of sulfur in some pasture location by water source interactions and high intake of iron, absorption of copper may be reduced and may increase copper requirements.

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Table 1. Effect of pasture location on predicted mineral intake (forage and water intake) of a lactating beef cow grazing native range in Eastern Montana.

	Location				
Item	North	Southeast	Southwest	SEM	*P*-value
Calcium, %	0.51	0.52	0.59	0.03	0.06
Chloride, %	0.07	0.03	0.04	0.01	0.03
Copper, mg/kg	3.18	2.14	2.52	0.30	0.04
DACD, mEq/kg	553.19	443.96	585.74	43.84	0.02
Iron, mg/kg	374.64	481.50	504.64	54.02	0.17
Magnesium, %	0.18	0.19	0.21	0.01	0.13
Manganese, mg/kg	56.19	58.10	57.08	3.65	0.92
Molybdenum, mg/kg	0.96	1.06	0.97	0.09	0.59
Nitrate-Nitrogen, %	12.90	2.38	3.57	6.75	0.44
Phosphorus, %	0.25	0.17	0.20	0.01	< 0.001
Potassium, %	1.88	1.41	1.77	0.10	< 0.001
Zinc, mg/kg	25.92	16.86	17.96	1.38	< 0.001

Table 2. Mineral requirements and maximum tolerable concentrations of a lactating beef cow[a]

Item	Unit	Early Lactation Requirements	Maximum Tolerable Concentration
Calcium	%	--	--
Chloride	%	--	1000.00
Copper	mg/kg	10.00	100.00
Fluoride	mg/kg	--	40.00-100.00
Iron	mg/kg	50.00	1000.00
Magnesium	%	0.20	0.40
Manganese	mg/kg	40.00	1000.00
Molybdenum	mg/kg	--	5.00
Phosphorus	%	0.15 – 0.30	--
Potassium	%	0.70	3.00
Selenium	mg/kg	0.10	2.00
Sodium	%	0.10	--
Sulfur	%	0.15	0.40
Zinc	mg/kg	30.00	500.00

[a]Adapted from NRC (2000).

Table 3. Effect of water source on predicted mineral intake (forage and water intake) of a lactating beef cow grazing native range in Eastern Montana.

	Source					
Item	Creek	Ground	Reservoir	Spring	SEM	*P*-value
Calcium, %	0.53	0.45	0.50	0.67	0.04	< 0.001
Chloride, %	0.03	0.11	0.02	0.03	0.01	< 0.001
Copper, mg/kg	2.44	3.00	2.89	2.13	0.36	0.13
DACD, mEq/kg	451.40	839.37	401.34	418.41	52.90	< 0.001
Iron, mg/kg	471.36	397.60	586.64	358.79	66.10	< 0.01
Magnesium, %	0.19	0.17	0.17	0.25	0.02	< 0.001
Manganese, mg/kg	60.90	55.22	56.74	55.61	4.28	0.67
Molybdenum, mg/kg	0.86	1.05	0.98	1.08	0.10	0.29
Nitrate-Nitrogen, %	1.96	1.94	1.92	19.32	7.91	0.22
Phosphorus, %	0.21	0.22	0.20	0.19	0.01	0.18
Potassium, %	1.68	1.87	1.61	1.59	0.12	0.08
Zinc, mg/kg	19.14	19.96	21.98	19.89	1.62	0.27

Table 4. Water source × pasture location interaction ($P < 0.05$) for predicted mineral intake (forage and water intake) of a lactating beef cow grazing native range in Eastern Montana.

		Source				
Item	Location	Creek	Ground	Reservoir	Spring	SEM
Fluoride, mg/kg	North	23.23	99.11	12.16	6.20	16.77
	Southeast	25.56	80.17	19.23	38.88	17.67
	Southwest	31.85	185.99	32.15	18.84	17.59
Selenium, mg/kg	North	0.09	0.11	0.18	0.48	0.07
	Southeast	0.26	0.17	0.13	0.15	0.08
	Southwest	0.08	0.08	0.10	0.22	0.08
Sodium, %	North	0.76	1.86	0.33	0.18	0.22
	Southeast	0.36	1.80	0.23	0.82	0.23
	Southwest	1.67	1.94	0.56	0.48	0.23
Sulfur, %	North	0.47	0.54	0.24	0.18	0.17
	Southeast	0.27	0.63	0.21	0.53	0.18
	Southwest	1.07	0.31	0.37	0.28	0.18

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THE RELATIVE IMPORTANCE OF WEANING MANAGEMENT AND VACCINATION HISTORY ON FINISHING PERFORMANCE AND CARCASS CHARACTERISTICS OF BEEF CALVES

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ABSTRACT: Angus x Hereford calves (n = 437; average initial BW = 208 ± 25 kg) were stratified by BW, sex, and age and assigned randomly to 1 of 3 weaning treatments that corresponded to length of time between maternal separation and shipping to a feedlot: 45, 15 or 0 d. Within each weaning-period length, calves were assigned randomly to 1 of 2 bovine respiratory disease on (BRD)-vaccination treatments: vaccinated 14 d prior to maternal separation and again at weaning (PRE) or vaccinated on the d of arrival at the feedlot and again 14 d later (POST). On a common shipping date, calves were transported 3 h to an auction market and held for 12 h. Calves were then transported 1 h to a feedlot. All calves were fed the same diets *ad libitum* during the weaning, receiving, and finishing phases of the experiment. Steers were fed to a harvest endpoint of 11.5 mm of subcutaneous fat over the 12th rib and harvested in 3 groups. Calves weaned 45 d before shipping required fewer ($P = 0.02$) days on feed than calves weaned 15 or 0 d before shipping. Finishing ADG was greater ($P < 0.01$) for calves weaned 45 and 15 d before shipping than for calves weaned 0 d before shipping, whereas ADG was similar ($P = 0.26$) between PRE and POST. Consequently, 45-d calves had greater ($P < 0.01$) harvest BW than 15- or 0-d calves. Hot carcass weight was greater ($P < 0.01$) for calves weaned 45 and 15 d before shipping than for calves weaned 0 d before shipping. Marbling score, USDA yield grade, 12th-rib fat thickness, REA, and KPH were similar ($P \geq 0.22$) between weaning and vaccination treatments. Likewise, incidence of liver abscesses was similar ($P < 0.47$) between weaning and vaccination treatments. Incidence of lung lesions was not affected ($P > 0.81$) by weaning treatment; however, POST tended ($P < 0.09$) to have greater incidence of lung lesions than PRE. Carcass weight, carcass merit, and growth performance during finishing were similar between calves weaned for 45 d or 15 d before shipping. Pre-shipping BRD vaccination did not improve growth performance or carcass merit of ranch-direct cattle relative to BRD vaccination deferred until feedlot arrival.

Key Words: carcass merit, preconditioning, weaning.

Introduction

Bovine respiratory disease (BRD) decreases the profitability associated with cattle feeding. The cost of BRD includes death loss, expense associated with BRD treatment, and reduced growth performance (Perino, 1992). Respiratory disease also decreased carcass weights, USDA quality grade, and longissimus area of feedlot cattle (Gardner et al., 1999). Treatment for apparent BRD was associated with decreased carcass weights, fat thickness, and REA compared to animals not treated; whereas reduced incidence of BRD resulted in higher carcass merit (Montgomery et al., 2009). Pre-shipment weaning and vaccination reduced the incidence and severity of BRD in feedlot steers (Cole, 1985; Pritchard and Mendez, 1990; Galyean et al., 1999).

Bolte et al. (2009a and 2009b) reported that length of the pre-shipment weaning period influenced carcass characteristics and time on feed during finishing. Therefore, we hypothesized that vaccination strategy and the length of the pre-shipment weaning period interact to influence calf performance during finishing and subsequent carcass characteristics. The objective of our experiment was to compare the effects of BRD vaccination administered prior to weaning on the ranch of origin or after arrival at a feedlot for calves weaned 45, 15, or 0 days prior to feedlot arrival.

Materials and Methods

Angus x Hereford calves (n = 437; average initial BW = 208 $\pm$ 25 kg) were used for this experiment. Calves originated from Kansas State University commercial cow-calf herds at Manhattan and Hays. Approximately 60 d prior to maternal separation, animals were stratified by BW, sex, and date of birth, and

assigned randomly to a pre-shipment weaning period (i.e., 45, 15, or 0 d). Within each weaning treatment calves were assigned randomly to 1 of 2 BRD-vaccination treatments. One vaccination treatment group was vaccinated 14 d prior to maternal separation and again at weaning; the second vaccination treatment group was vaccinated on the d of arrival at the feedlot and again 14 d later.

Initial and booster vaccinations against IBR, BVD, PI3, and BRSV were administered using a modified live product (Bovi-Shield Gold FP®, Pfizer Animal Health Exton, PA). All calves were treated for internal and external parasites using Dectomax® (Pfizer Animal Health Exton, PA) and were vaccinated against clostridial diseases (Vision 7 with SPUR®, Intervet Inc., Millsboro, DE) at the time of weaning. Calves were transported a short distance (< 48 km) to a home-ranch weaning facility. Calves were weaned in earth-floor pens (4 pens / treatment) and fed a common weaning diet during the preconditioning period. Feed bunks were read daily and intake recorded.

All calves were individually weighed and transported 4 h from their respective ranch-of-origin weaning facilities to an auction market on a common shipping date. Calves from both origins were commingled with respect to gender and treatment and were maintained on the premises of the auction market for 12 h. This commingling was employed to simulate the pathogen exposure typically encountered by market-ready calves. The following day, calves were shipped a short distance (< 8 km) to the feedlot. At arrival, calves were weighed and assigned to a receiving pen based upon their weaning and vaccination treatments. The cattle were adapted to a receiving ration and DMI was recorded daily over a 60-d receiving period.

Calves were monitored for symptoms of respiratory disease at 0700 and 1400 daily during the receiving period. Calves with clinical signs of BRD, as judged by animal caretakers, were removed from home pens and evaluated. Each calf with clinical signs of BRD was weighed, rectal temperature was measured, and was assigned a clinical illness score (scale: 1 to 4; 1 = normal, 4 = severe illness. Calves with a clinical illness score greater than 1 and a rectal temperature greater than 40.0ºC were treated and returned to their home pen. Cattle were evaluated 72 h post-treatment and re-treated based on observed clinical signs.

Calf body weights were measured 60 d after arrival at the feedlot. Following the receiving phase, calves were adapted to a common finishing ration over a 21-d period (Table 1). Steers remained in their respective receiving pens during finishing. After 165 d on feed, steers were scanned ultrasonically to determine subcutaneous fat thickness over the 12th rib. Steers were assigned to 1 of 3 harvest dates based on this scan to meet an average carcass endpoint of 11.5mm of fat depth over the 12th rib.

Calves were transported approximately 3 h to a commercial abattoir on their respective harvest date. At the abattoir, lungs were examined for lesions as described by Bryant et al. (1996) and livers were examined for presence of abscesses according to procedures described by Brink et al. (1990). Once carcasses were chilled for 48 h, carcass characteristics were measured by a trained evaluator unaware of treatments and included 12th-rib fat thickness, 12th-rib longissimus muscle area, kidney-pelvic-heart fat, USDA maturity grade, USDA yield grade, USDA quality grade, and marbling score (USDA, 1997).

Results and Discussion

Growth Performance. Calf ADG during finishing was greater ($P < 0.01$) for calves weaned for 45 or 15 d before shipping than calves weaned for 0 d before shipping (Table 2), whereas ADG was similar ($P = 0.26$) between calves vaccinated for BRD-causing organisms before shipping and those vaccinated for BRD-causing organisms at feedlot arrival (Table 4). This differed from a previous study where preconditioned calves had greater receiving ADG, but finishing gains were similar to non-preconditioned animals. (Pritchard and Mendez 1990), Calves weaned 45 d before shipping required fewer ($P = 0.02$) d on feed than those calves weaned 15 or 0 d before shipping (Table 2). Bolte et al. (2009a and 2009b) also found that longer weaning periods were associated with fewer days on feed. Consequently, calves weaned 45 d before shipping had greater ($P < 0.01$) harvest BW than calves weaned 15 or 0 d before shipping (Table 2). Timing of BRD vaccination did not affect feedlot growth performance in this experiment.

Carcass Merit. Hot carcass weight was greater ($P < 0.02$) for calves weaned 45 and 15 d prior to shipping than for calves weaned 0 d before shipping (Table 3). This increase was attributed to increased performance in the feedlot. Marbling score, USDA yield grade, 12th-rib fat thickness, REA, and KPH were similar ($P \geq 0.22$) between weaning and vaccination treatments (Tables 3 and 5). This is contrary to the findings of Bolte et al., (2009a and 2009b) in which yield grade, KPH and fat thickness increased with longer weaning periods. Deposition of internal or external fat for our ranch-direct calves was not influenced by pre-shipment weaning length or timing of BRD vaccination. Likewise, incidence of liver abscesses was similar ($P < 0.47$) between weaning and vaccination treatments. Incidence of lung lesions was not affected ($P > 0.81$) by weaning treatment; however,

cattle vaccinated for respiratory disease at feedlot arrival tended ($P < 0.09$) to have greater incidence of lung lesions than cattle vaccinated for respiratory disease before shipping. Deferring BRD vaccination until feedlot arrival, may allow sub-clinical BRD incidence to occur in such animals, however more investigation is needed.

Implications

A preconditioning period was found to increase steer ADG and harvest weights. Therefore, this increase in growth reduced the length of time on feed to a harvest endpoint. However, effects on carcass traits were minimal. Carcass weight, carcass merit, and growth performance during finishing were similar between calves weaned for 45 d or 15 d before shipping. Pre-shipping BRD vaccination did not improve growth performance or carcass merit of ranch-direct cattle relative to BRD vaccination deferred until feedlot arrival. Length of pre-shipment weaning period had greater interactions on performance and carcass merit than BRD vaccination timing. Deferred BRD vaccination potentially caused an increase in observed lung lesions upon slaughter. More research is necessary to clarify any findings.

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Table 1. Average ingredient and nutrient composition of the finishing diet

Ingredient composition	DM %
Ground sorghum grain	80.86
Sorghum silage	14.81
Soybean meal	3.23
Limestone	0.50
Rumensin® 80	0.30
Ammonium sulfate	0.11
Salt	0.10
Tylan	0.09
Nutrient composition	**DM %**
CP, %	13.43
Ca, %	0.32
P, %	0.33
NE_m, Mcal/kg	1.89
NE_g, Mcal/kg	1.25

Table 2. Performance of beef calves weaned for 0, 15, or 45 days before shipping during finishing

	Length of Weaning Period, d				
Item	0	15	45	SEM	*P* value
ADG, kg	1.58[a]	1.65[b]	1.68[b]	0.022	< 0.01
Days on feed	220	217	209	3.047	0.02
BW at harvest, kg	566[a]	576[b]	592[c]	6.120	< 0.01

[a, b, c] Treatment means within row that share common superscript are similar.

Table 3. Carcass characteristics of beef calves following ranch-of-origin weaning periods lasting 0, 15, or 45 d

	Length of Weaning Period, d				
Item	0	15	45	SEM	*P* value
Hot carcass weight, kg	337[b]	347[c]	355[d]	4.493	0.02
Marbling score[a]	47.9	46.6	49.1	1.033	0.22
USDA yield grade	3.3	3.2	3.4	0.081	0.33
12th rib fat thickness, mm	13.6	12.7	13.8	0.474	0.20
Longissimus area, cm^2	79.3	80.1	80.4	1.144	0.74
KPH, %	2.66	2.56	2.64	0.081	0.56
Calves with $\geq$ 1 liver abscess, %	18.68	23.38	25.35	-	0.47
Calves with $\geq$ 1 lung lesion, %	34.38	32.14	29.73	-	0.81

[a] Marbling score: 30 = Slight^{00}, 40 = Small^{00}, 50 = Modest^{00}; ex. 55 = Modest^{50}.
[b, c, d] Treatment means within row that share common superscript are similar.

Table 4. Performance of beef calves vaccinated against respiratory-disease pathogens prior to shipping or at feedlot arrival during a 60-d receiving period

	Vaccination Timing			
Item	Pre-shipment	Feedlot arrival	SEM	*P* value
ADG, kg	1.62	1.65	0.018	0.26
Days on feed	216	215	2.251	0.85
BW at harvest, kg	578	578	4.783	0.99

[a, b] Treatment means within row that share common superscript are similar.

Table 5. Carcass characteristics of beef calves vaccinated against respiratory-disease pathogens prior to shipping or at feedlot arrival

	Vaccination Timing			
Item	Pre-shipment	Feedlot arrival	SEM	*P* value
Hot carcass weight, kg	347	345	3.320	0.73
Marbling score[a]	47.4	48.4	0.763	0.36
USDA yield grade	3.3	3.3	0.060	0.59
12th rib fat thickness, mm	13.1	13.7	0.352	0.23
Longissimus area, cm^2	79.9	80.0	0.850	0.90
KPH, %	2.59	2.65	0.060	0.50
Calves with $\geq$ 1 liver abscess, %	24.79	19.67	-	0.63
Calves with $\geq$ 1 lung lesion, %	27.20	37.21	-	0.09

[a] Marbling score: 30 = Slight^{00}, 40 = Small^{00}, 50 = Modest^{00}; ex. 55 = Modest^{50}.

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EFFECTS OF DEGREE OF RESPIRATORY DISEASE VACCINATION ON HEALTH AND GROWTH PERFORMANCE OF RANCH-DIRECT BEEF CALVES DURING WEANING AND RECEIVING

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ABSTRACT: Angus x Hereford calves (n = 430; initial BW = 230 ± 31.8 kg) were stratified by sex, age, and BW and assigned randomly to 1 of 4 treatments: 0, 1, 2, or 3 BRD vaccinations prior to feedlot placement (NOVACC, VACC1, VACC2, or VACC3, respectively). Calves were removed from their dams 29 d prior to feedlot placement; they were weighed, vaccinated for clostridial diseases, treated for internal and external parasites, and placed in a ranch-of-origin weaning facility. Calves on VACC1, VACC2, and VACC3 treatments were given an initial BRD-vaccination at that time. Calves were revaccinated according to their respective treatments at 14-d intervals during the ranch-of-origin weaning phase of the experiment (PRESHIP). On a common shipping date, calves were transported 3 h to an auction market and held for 12 h. Calves were then transported 1 h to a feedlot. During the PRESHIP period, NOVACC calves tended ($P = 0.06$) to have greater incidence of undifferentiated fever than VACC1, VACC2, or VACC3 calves. Consequently, NOVACC calves had greater ($P < 0.01$) drug-therapy costs PRESHIP than other treatments. Calf ADG, DMI, and G:F during the PRESHIP period were similar ($P \geq 0.61$) between treatments. Upon arrival at the feedlot, calves were weighed and assigned to a receiving pen based on treatment. Calf BW was similar ($P \geq 0.48$) between treatments at feedlot placement, 27 d post-receiving, and 55 d post-receiving; moreover, calf ADG during receiving was similar ($P < 0.92$) between treatments. Degree of BRD vaccination had no affect ($P \geq 0.71$) on DMI or G:F during the receiving period. Incidence of undifferentiated fever among VACC2 calves was greater ($P < 0.01$) than that among NOVACC, VACC1, or VACC3 calves during the receiving period; therefore, drug-therapy costs of VACC2 cattle were greater ($P < 0.01$) than that of NOVACC, VACC1, and VACC3 cattle. Vaccination for BRD, regardless of degree, improved health of calves during the PRESHIP period but not DMI, ADG, or G:F. Degree of BRD vaccination influenced calf health during receiving but not DMI ADG, or G:F.

Key Words: beef calves, health, preconditioning

Introduction

Reducing incidence of bovine respiratory disease (BRD) is a common goal of a preconditioning program. In a survey of US feedlots, Woolums et al. (2005) found BRD to be the leading cause of calf morbidity and mortality. Ranch-of-origin weaning periods have been found to influence health and growth of beef calves upon feedlot reception (Bolte et al., (2008a, 2008b). Practices of vaccination, dehorning, castration, and adapting cattle to feed and water can reduce incidence of the disease (Galyean et al., 1999). Vaccination against BRD pathogens is thought to improve health of newly weaned calves. Differing strategies are utilized when administering BRD vaccination. Vaccination at weaning, followed by a revaccination is recommended (Duff and Galyean, 2007). Our objective was to determine the effect of 0, 1, 2, or 3 vaccinations for respiratory disease (i.e., 14 days apart) on health and growth performance of ranch-preconditioned, market-sourced beef steers.

Materials and Methods

Angus x Hereford calves (n= 430; initial BW = 230 $\pm$ 31.8 kg) were used for this experiment. Calves originated from the Kansas State University commercial cow-calf herds in Manhattan and Hays. Calves were stratified by body weight, sex, and birth date, and assigned randomly to a BRD vaccination treatment of 0, 1, 2, or 3 vaccinations (NOVACC, VACC1, VACC2, or VACC3, respectively).

All calves were removed from their dams at an approximate average age of 180 d and transported (< 48 km) to a home ranch weaning facility. Calves were individually weighed, tagged, treated for internal and external parasites using Dectomax® (Pfizer Animal Health

Exton, PA) and vaccinated against clostridial diseases (Vision 7 with SPUR®, Intervet Inc., Millsboro, DE) and Haemophilus somnus (Somubac®, Pfizer Animal Health Exton, PA). Initial and booster vaccinations against IBR, BVD, PI3, and BRSV were administered using a modified live product (Bovi-Shield Gold FP®, Pfizer Animal Health Exton, PA).

Vaccination against respiratory disease agents was administered to VACC1, VACC2, and VACC3 on d 0. On d 14, all calves were revaccinated with Haemophilius somnus, individual BW was recorded, and VACC2, VACC3 received booster BRD vaccine. Twenty-eight d following maternal separation all calves were revaccinated against clostridial diseases and VACC3 received their final BRD vaccination.

Calves were maintained in earth-floor pens separated by sex and treatment throughout the ranch-of-origin weaning period. Animals were adapted to a common weaning diet (Table 1) and daily intake was recorded. Calves were monitored for symptoms of respiratory disease at 0700 and 1400 daily. Calves with clinical signs of BRD were evaluated by animal caretakers, rectal temperature measured and a clinical illness score assigned (scale: 1 to 4; 1 = normal, 4 = severe illness). Calves with a clinical illness score greater than 1 and a rectal temperature greater than 40.0°C were treated and returned to their home pen. Calves were re-evaluated 72 h post-treatment and re-treated based on observed clinical signs. Drug therapy costs were calculated as cost per treatment throughout the experiment.

Following the 28 d weaning period, calf BW was recorded and animals were transported 4 h from their respective ranch-of-origin weaning facilities to an auction market. Calves from both origins were commingled and held on the premises of the auction barn for 16 h. This pathogen exposure during commingling is typical of market-ready calves. Calves were then transported (< 8 km) to a feedlot. Upon arrival, calves were weighed and assigned to a receiving pen according to sex and vaccination treatment. Calves were adapted to a common receiving ration (Table 2) and daily feed intake was recorded throughout a 55 d receiving period. Calves continued to be monitored for BRD symptoms daily at 0700 and 1400. Clinical illnesses were treated in the same manner as during the ranch-of-origin weaning period. Individual BW was recorded after 27 and 55 d on feed.

Results and Discussion

Health. Incidence of fever during the 30 d weaning (PRESHIP) period tended ($P = 0.06$) to be greater for NOVACC calves than VACC1, VACC2, or VACC3 groups. Consequently, NOVACC calves had greater ($P < 0.01$) drug-therapy costs PRESHIP than other treatments (Table 5). This reduction in clinical BRD among vaccinated calves is consistent with findings of previous research (Cole, 1985; Galyean et al., 1999). Surprisingly, VACC2 calves had greater incidence of fever ($P < 0.01$) than that among NOVACC, VACC1, or VACC3 calves during the receiving period; therefore, drug-therapy costs for VACC2 cattle were greater ($P < 0.01$) than for NOVACC, VACC1, and VACC3 cattle. Reasons for this are unclear, however BRD incidence has been found to be variable (Prichard and Mendez, 1990).

Growth Performance. Calf body weights were not affected by treatment during the weaning period ($P \geq 0.53$; Table 3) or during the feedlot receiving phase ($P \geq 0.48$; Table 4). Calf ADG during PRESHIP was similar ($P = 0.61$) between vaccination groups. Similarily, Step et al., (2008) found no difference in receiving ADG between vaccinated and unvaccinated calves. Furthermore, DMI and G:F during the PRESHIP period were similar ($P \geq 0.61$) between treatments (Table 3).

Loss of BW due to transit to the auction market and feedlot was similar ($P = 0.32$) between all BRD treatment groups (Table 3). Daily gains during receiving were not affected ($P \geq 0.84$) by vaccination treatment at d 27 and d 55. Degree of BRD vaccination had no affect ($P \geq 0.71$) on DMI or G:F during the receiving period (Table 4). Calves experienced consistent growth performance throughout the experiment. Richeson et al., (2009) reported similar results with growth traits being similar between vaccination treatment groups. Additional studies are needed to elucidate relationships between vaccination timing and frequency and calf growth performance.

Implications

Vaccination for BRD, regardless of degree, improved health of calves during the ranch-of-origin preconditioning period. However, feed intake, ADG, or feed efficiency during preconditioning or feedlot receiving was not affected by level of vaccination when compared with non-treated herd mates. However, due to the variation in outcomes from similar experiments, vaccination effects on growth performance should be evaluated further. Improved animal health was observed with a single BRD pathogen vaccination; however added benefits with subsequent treatment will need to be further investigated.

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Table 1. Ingredient and nutritional composition of the weaning diet.

Ingredient composition*	% of DM
Extender Pellets (Alfalfa)	33.00
Corn Gluten Feed	18.18
Wheat Middlings	14.63
Dried Distiller Grain	11.52
Cracked Corn	10.94
Cottonseed Hulls	7.75
Molasses	2.00
Limestone	1.85
Salt	0.10
Nutrient Composition	% of DM
Crude Protein	17.68
Calcium	1.19
Phosphorus	0.74
ADF	20.64
NDF	38.14
Ash	8.12
NE_m, Mcal/kg	1.51
NE_g, Mcal/kg	0.92

*Diet also included Bovatec 91, Vitamin A 650, and Zinc Sulfate

Table 2. Ingredient and nutritional composition of the receiving diet.

Ingredient composition*	% of DM
Rolled Milo	48.95
Hay	33.47
Wet Distillers Grain	15.08
Nutrient Composition	% of DM
Crude Protein	14.90
Calcium	0.82
Phosphorus	0.37
ADF	20.10
NDF	28.43
Ash	5.74
NE_m, Mcal/kg	1.53
NE_g, Mcal/kg	0.93

*Diet also included Salt, Rumensin 80, Tylan 40, and trace minerals

Table 3. Performance of beef calves during ranch-of-origin weaning period.

	Vaccination Treatment					
Item	NOVACC	VACC1	VACC2	VACC3	SEM	*P*-value
BW, kg						
Maternal Separation	232	224	228	230	5.85	0.53
14 d	231	224	227	232	3.86	0.55
Shipping	249	241	243	248	6.70	0.57
ADG, kg	0.60	0.60	0.55	0.66	0.05	0.61
DMI, kg/d	4.41	4.37	4.36	4.51	0.08	0.56
G:F	0.13	0.14	0.13	0.14	0.01	0.59
Transport Shrink, % BW	6.21	4.90	6.20	4.52	1.08	0.32

Table 4. Performance of beef calves during feedlot receiving period.

	Vaccination Treatment					
Item	NOVACC	VACC1	VACC2	VACC3	SEM	*P*-value
BW, kg						
Receiving	233	229	229	237	4.373	0.48
27d	265	263	263	269	4.332	0.69
55 d	298	296	295	302	4.871	0.71
ADG, kg						
27 d	1.20	1.25	1.28	1.20	0.183	0.84
55 d	1.18	1.22	1.21	1.20	0.073	0.92
DMI, kg/d	11.46	11.44	11.46	11.42	0.025	0.72
G:F	0.10	0.11	0.11	0.11	0.006	0.91

Table 5. Incidence of fever and cost of treatment during weaning and receiving.

	Vaccination Treatment					
Item	NOVACC	VACC1	VACC2	VACC3	SEM	*P*-value
Incidence of Fever, %						
Weaning Period	14.41	5.61	7.41	5.77	-	0.06
Receiving Period	0.00^{a}	0.00^{a}	4.63^{b}	0.00^{a}	-	0.01
Overall	14.41	5.61	10.18	5.77	-	0.19
Treatment Cost, $/hd						
Weaning Period	3.40^{b}	1.21^{a}	1.72^{a}	1.32^{a}	0.629	<0.01
Receiving Period	0.21^{a}	0.00^{a}	1.32^{b}	0.00^{a}	0.318	<0.01
Overall	3.77^{b}	1.21^{a}	3.04^{b}	1.32^{a}	0.773	<0.01

[a, b] Within a row, means without a common superscript differ ($P < 0.05$).

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LEVEL OF MATERNAL WINTER SUPPLEMENT AND FEED RESTRICTION DURING POSTWEANING DEVELOPMENT INFLUENCES CIRCULATING CONCENTRATIONS OF IGF-I IN HEIFERS DURING THE PERIPARTUM AND REBREEDING PERIOD [1]

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ABSTRACT: Objective of this research was to evaluate effects of 2 levels of supplemental feed provided to cows during late gestation and 2 levels of feed provided to their daughters during postweaning development on circulating concentrations of IGF-I in the daughters before calving, after calving and before breeding. Heifers were produced over a 3-yr period from dams that were fed levels of harvested feed from mid and late gestation (Dec to March) that were expected to provide marginal (MARG) or adequate (ADEQ) nutrition while grazing dormant winter forage through this period. After weaning, heifers were fed to appetite (CON) or restricted (REST) to 80 % of that consumed by CON on common BW basis during a 140-d period ending 1-mo before breeding. Heifers were managed together through breeding to Dec when they were separated so CON could be fed like ADEQ cows and REST could be fed like MARG cows up to 2 to 3-wk before start of calving in March. Concentrations of IGF-I (determined by RIA) in serum samples (n = 828) obtained 8 to 12-d before start of calving, 2 to 4-wk after calving and 0 to 18-d before to start of breeding were analyzed by the MIXED procedure of SAS using a model for repeated measures. Concentrations of IGF-I were influenced by interaction of dam and heifer treatments, being greater ($P < 0.05$) in CON heifers from ADEQ or MARG fed dams and REST heifers from MARG dams than in REST heifers from ADEQ dams. Concentrations of IGF-I were greater ($P = 0.05$) in heifers that gestated male than female calves, and in heifers that subsequently became pregnant than those that did not ($P < 0.001$). Results provide support that the dietary treatments imposed on cows resulted in a uterine programming effect in their heifers, as was evident by differences in circulating concentrations of IGF-I in heifers that were restricted fed during postweaning development.

Key Words: Heifer development, IGF-I, Uterine programming

Introduction

Previous research at Ft. Keogh determined that BW, BCS and productivity to 5 yr of age in cows reared on limited levels of harvested feed during postweaning development and subsequent winters were dependant on level of winter supplemental feed provided to the cow's dam, indicating the possibility of a uterine programming effect (Roberts et al., 2009). Separate research determined that concentrations of IGF-1 in heifers before calving, after calving and immediately before rebreeding were negatively associated with date of second calving (Roberts, 2008) Based on findings of these previous studies, objective of the present research was to evaluate effects of level of supplement fed to cows during late gestation and level of feed provided to their daughters during postweaning development on circulating concentrations of IGF-1 in the daughters before calving, after calving and immediately before breeding.

Materials and Methods

All research protocols used in this study were approved by our institutional Animal Care and Use Committee. Cows used in this study were a stable composite population (**CGC**; ½ Red Angus, ¼ Charolais, ¼ Tarentaise). Females studied represent a randomly selected population produced over a 3-yr period (2002 through 2004) by mating CGC dams and sires with consideration given to minimize inbreeding, but without emphasis on production traits.

Beginning in the fall of 2001, all cows in this herd were randomly assigned to be fed levels of harvested feed from Dec to March of each year that were expected to result in either marginal (MARG) or adequate (ADEQ) nutrition while grazing dormant winter forage through this period, based on average quality and availability of winter forage. Each group of cows was managed on separate pastures during the winter to allow differential feeding. For the winters represented in this study, pasture forage was readily available for grazing and the only additional harvested feed provided was alfalfa cake or hay, depending on year, as a supplemental source of protein. This supplement was fed either daily or every other day to achieve an average of about 1.8 kg/d for each ADEQ cow and an average of about 1 kg/d for each MARG cow. During days when access to pasture forage was limited due to snow covering, cows were fed at a rate equivalent to 10.9 or 9.1 kg alfalfa hay/d for each cow in the ADEQ or MARG treatments, respectively.

Each year at weaning, heifer calves were stratified into groups based on weaning weight and were randomly assigned to 1 of 4 (Yr 1) or 1 of 22 to 24 pens (subsequent years). In Yr 1, heifers were group fed with 26 or 27 heifers/pen. Heifers in Yr 2 through 7 were individually fed in pens that contained 6 individual feed bunks equipped with electronic Calan gates

[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.

(American Calan, Northwood, NH). Heifers were allowed a minimum of 1 mo for adaptation to experimental pens and to become trained to the head gates (Yr 2 and 3). During this time, heifers were allowed ad libitum access to the test diet fed (described below) once daily. In Yr 1, pens were randomly assigned to receive either control (n=2) or restricted (n=2) level of feeding. In Yr 2 and 3, heifers were randomly assigned within pens to either a control or restricted level of feeding for a 140-d trial. Feed restriction was initiated when heifers were approximately 8 mo of age and 227 $\pm$ 21 kg BW. Control heifers (CON) were fed to appetite and restricted heifers (REST) were fed at 80 % of that consumed by controls adjusted to a common BW basis, as determined at 4-wk intervals using the following formula: [0.80 x (mean BW of restricted/mean BW control) x mean daily feed intake (as fed basis) of controls over the 28-d period]. Total numbers of heifers in each treatment by dam treatment classification are shown in Table 1.

Composition of the diet fed during the postweaning period is shown in Table 2. Weight of feed offered was recorded daily. Orts were removed from the feed bunk and weight recorded as necessary to ensure that fresh feed was provided for each heifer on a daily basis.

At the end of the 140-d trial, heifers were combined and managed together through breeding and subsequent grazing season. At approximately 14 mo of age (30 to 40 d after end of restriction), heifers were weighed and subjected to an estrous synchronization protocol to facilitate breeding by AI followed by natural mating for the remaining duration of a 48- to 53-d breeding season. In late Nov to early Dec of each year, pregnant heifers were separated back into their treatment groups to allow for provision of harvested feed at the same levels as described above for the cows; where CON heifers were fed what was expected to be adequate level harvested feed and REST heifers were fed a marginal level of harvested feed. These winter feeding treatments continued until 2 to 3 wk before start of calving in March, when heifers were recombined and managed together.

Blood samples were collected from the tail vein from each cow at 3 time points in relation to calving or breeding; 8 to 12-d before start of calving (before calving), 2 to 4-wk after calving (after calving) and 0 to 18-d before start of second breeding season (prebreeding). Serum from these samples was used to determine circulating concentrations of IGF-1.

Concentrations of IGF-1 were determined by RIA after acid-ethanol extraction, as described previously (Roberts et al., 1997) using AFP4892898 as the primary antiserum. Samples were run in 4 different assays; two assays for the first year, and a single assay for each subsequent year. Intra-assay CV for IGF-1 was 11%. Variation among assays was accounted for in the statistical analysis.

Concentrations of IGF-1 were analyzed by the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC) using a model for repeated measures. Variables included in the model were treatment of dam, treatment of heifer, interaction of cow and heifer treatments, sex of calf, time point of sample (before calving, after calving and prebreeding), subsequent rebreeding status of heifer and assay. Cow within treatment by dam treatment classification was fit as the subject (i.e., repeated measure). Least square means and SE are presented, unless specified otherwise.

Results and Discussion

Variables that accounted for variation ($P < 0.05$) in IGF-1 included the interaction of dam and cow treatment, sex of calf, time of sample and subsequent rebreeding status of heifer. Concentrations of IGF-1 were greater ($P < 0.05$) in CON heifers from ADEQ (99.1 ± 2.6 ng/mL) or MARG (97.0 ± 2.6) dams and REST heifers from MARG dams (97.8 ± 2.6) than in REST heifers from ADEQ dams (90.2± 2.6). Concentrations of IGF-1 were greater ($P = 0.05$) in heifers that gestated male (99.3 ± 1.9 ng/mL) than female calves (92.8 ± 2.0 ng/mL), and in heifers that subsequently became pregnant (102.5 ± 2.7 ng/mL) than those that did not (89.6 ± 1.3; $P < 0.001$).

Biological implications of the interaction of cow and dam treatment on IGF-1 remain to be fully elucidated. Circulating concentrations of IGF-1 fluctuate in response to level of nutrient intake (McGuire et al., 1992), and appear to provide objective indicators of nutritional status in dairy (Ronge et al., 1988; Spicer et al., 1990) and beef (Nugent et al., 1993; Roberts et al., 1997, 2005) cattle. Because REST cows were managed together, it was expected that nutritional status of all REST cows would be similar. However, results indicate that the dietary treatment of the dams influenced the response of cows to lower levels of harvested feed inputs provided under the REST management. Based on the design and results of the study, it appears that influence of the dam appears to be mediated through some type of uterine programming.

Additional support that dam treatment influences nutritional response to the REST level of feeding was reported previously; where the proportion of heifers in the present study that successfully reproduced and remained in the herd out to 5 yr of age was lower for REST cows from ADEQ dams (Roberts et al., 2009). The lower levels of IGF-1 observed in REST cows from ADEQ dams may provide a mechanism leading up to the differences in retention over time. This conclusion is consistent with previous research which demonstrated an inverse association among circulating concentrations of IGF-1 prior to first calving with time of second calving (Roberts, 2008), and the observation that cows in the present study that failed to rebreed had lower IGF-1 than cows that did rebreed.

Information concerning influence of calf sex on circulating concentrations of IGF-1 is limited. Results in the present study that concentrations of IGF-1 were greater in heifers that gestated male calves than female calves is in contrast to previous results of Holland and coworkers (1988) who reported greater concentrations of IGF-1 in heifers with a female fetus than a male fetus. Reasons for this discrepancy are not apparent.

Implications

Results provide support that the dietary treatments imposed on cows can result in a uterine programming effect on their heifers, as was evident by alterations in circulating concentrations of IGF-1 following restricted feeding during postweaning development. This observation extends our

previous findings that productivity of cows managed on 2 levels of harvested feed inputs was influenced by the level of harvested feed provided to their dams.

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Table 1. Year of birth (YOB) and number of control and restricted fed heifers from dams that were provided adequate (ADEQ) or marginal (MARG) levels of harvested feed throughout the winter

		-------Control-------		-----Restricted-----	
Yr	YOB	ADEQ	MARG	ADEQ	MARG
1	2002	20	25	25	19
2	2003	28	23	21	23
3	2004	30	19	24	22
All		78	67	70	64

Table 2. Composition (%, DM basis) of diets fed during the 140-d feeding period for Yr 1, 2 and 3

	Yr 1	Yr 2 and 3
Corn silage	52	67
Alfalfa	38	18
Supplement[1]	10	15
DM	47.5	36
CP	13.3	15

[1]Containing protein and macro and micro minerals.

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WINTER GRAZING SYSTEM AND SUPPLEMENTATION OF BEEF COWS DURING LATE GESTATION INFLUENCE HEIFER PROGENY

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ABSTRACT: A 2x2 factorial study evaluated effects of cow winter grazing system and last trimester supplementation on heifer progeny. Composite cows (yr 1 n = 109; yr 2 n = 114; yr 3 n = 116) grazed either range (**WR**) or corn residue (**CR**) during winter and within grazing treatment received 0.45 kg/d (DM) 28% CP cubes (**PS**) or no supplement (**NS**). Heifer calves (yr 1 n = 56; yr 2 n = 56; yr 3 n = 54) grazed dormant pasture for 114 d post-weaning and were individually fed for 87 d prior to natural service breeding (45 d). Dam PS reduced ($P = 0.04$) heifer birth date and CR increased ($P = 0.07$) heifer birth BW. Both PS and CR increased ($P \leq 0.05$) heifer weaning BW; however, adjusted weaning BW was only lower ($P = 0.03$) if the dam grazed WR with NS. Heifer ADG during the individual feeding period was greater ($P = 0.03$) in heifers from CR NS dams. Heifers from PS dams were younger ($P = 0.09$) at puberty and more tended ($P = 0.11$) to be pubertal by breeding if the dam grazed WR with PS. Heifers from WR NS dams weighed less ($P \leq 0.09$) at breeding and pregnancy diagnosis than WR PS. Pregnancy rate tended ($P = 0.13$) to be greater for heifers born to PS dams. Individually fed heifer DMI was not affected ($P = 0.17$) by treatment; however, heifers from dams that grazed CR with PS gained the least ($P = 0.03$) during individual feeding and had the lowest ($P = 0.04$) G:F. In contrast, there were no differences ($P > 0.10$) in efficiency when expressed as RFI. The heifer's first calf production was unaffected ($P > 0.10$) by dam treatment. Heifers from dams that grazed WR with NS tended to have lower ($P = 0.09$) BW prior to the second breeding season but similar ($P = 0.97$) pregnancy rates. Cows grazing CR with NS produced the most valuable heifer calf at weaning, however; heifers from cows that grazed WR with NS cost the least to develop per pregnant heifer. Winter grazing system and late gestation supplementation impacted heifer progeny BW, feed efficiency, and reproduction.

Key W ords: Fetal programming, Maternal nutrition, Supplementation

Introduction

Previous reports indicate no reproductive benefits from protein supplementation of spring calving beef cows grazing dormant Sandhills range during late gestation (Stalker et al., 2006; Larson et al., 2009) despite the fact nutrient requirements are greater than nutrient content of the grazed forage (NRC, 2000). Supplementation of the dam during late gestation does increase progeny weaning BW and increases fertility of heifer progeny (Stalker et al., 2006; Martin et al., 2007). Corn crop residue remaining after grain harvest provides a winter grazing alternative more economical than feeding harvested forage (Adams et al., 1996) that can reduce breakeven costs of weaned calves and reduce development cost of heifer progeny (Anderson et al., 2005). A study with steer mates to heifers utilized in the current study found late gestation supplementation altered postweaning growth, carcass composition, and calf health in the feedlot, potentially through fetal programming (Larson et al., 2009).

The fetal programming hypothesis states postnatal growth and physiology can be influenced by stimuli experienced *in utero* (Barker et al., 1993). Previous research (Martin et al., 2007) utilizing the same cowherd indicates dam protein supplementation increases heifer BW and fertility. There is potential for maternal nutrition to affect not only cow productivity but lifelong productivity of the heifer calf.

The objective of the current study was to determine the effects of grazing dormant Sandhills range or corn crop residue with or without supplementation on gain, feed efficiency, and reproduction in heifer calf progeny.

Materials and Methods

Cow and Calf Management. The University of Nebraska-Lincoln Institutional Animal Care and Use Committee approved all procedures and facilities used in this experiment.

A detailed description of management practices is available (Larson et al., 2009) and only a brief description will be presented here. A 3 yr study utilized composite Red Angus x Simmental cows and their progeny at Gudmundsen Sandhills Laboratory (**GSL**), Whitman, NE (preweaning data collection) and West Central Research and Extension Center (**WCREC**), North Platte, NE (post-weaning data collection). Cows were used in a completely randomized design with a 2 x 2 factorial arrangement of treatments to determine effects of grazing dormant Sandhills winter range (**WR**) or corn crop residue (**CR**) and receiving CP supplement (**PS**) or no supplement (**NS**) on cow and heifer progeny performance. One hundred nine pregnant, spring-calving cows (498 ± 15 kg initial BW) between 3 and 5 yr of age were stratified by age and weaning BW of their previous calf and assigned randomly to treatment in yr 1. Cows remained on the same treatment for the length of the study, unless removed due to reproductive failure or injury. Pregnant 3-yr-old cows were stratified by age and weaning BW of their previous calf and assigned randomly to treatment to replace cows removed from the study and to increase numbers as forage availability allowed. Data are

reported for 2005 (109 cows), 2006 (114 cows), and 2007 (116 cows).

From late November until early March each year, cows grazing winter range were divided into 4, 32-ha upland pastures, 2 pastures received CP supplement, 2 did not. A detailed description of the study site is available (Stalker et al., 2007). From November to March each year, cows grazing CR were maintained in 4 fields; 2 fields received CP supplement, 2 did not. Cows were shipped approximately 84 kilometers to corn residue fields on November 15th and returned to GSL on February 25th each year. Irrigated corn fields were planted in April and harvested in October, with an average annual yield of 12,544 kg/hectare. On a pasture or field basis, cows received the equivalent of 0.45 kg/d of a 28% CP (DM basis) supplement 3-times/wk or no CP supplement from December 1 until February 28 on WR or until February 25th on CR. The supplement contained 62.0% dried distillers grains plus solubles, 10.6% wheat middlings, 9.0% cottonseed meal, 5.0% dried corn gluten feed, 5.0% molasses, 3.0% calcium carbonate, and 2.0% urea on a DM basis. Additionally, the supplement was formulated to meet vitamin and trace mineral requirements of the 3-yr-old cows and supply 80 mg animal^{-1}d^{-1} monensin (Rumensin, Elanco Animal Health, Indianapolis, IN).

After winter grazing, cows were managed in a single group and fed hay harvested from subirrigated meadows and CP supplement. The average calving date was March 26. Cows returned to upland range in late May and remained in a single group throughout the breeding season until the subsequent winter grazing period. Cows were exposed to fertile bulls at a ratio of approximately 1 bull to 25 cows for 60 d each year, beginning on approximately June 5. Cow and calf vaccination protocols were previously reported (Larson et al., 2009).

Heifer Calf Management. Treatments included only dam winter grazing system and late gestation CP supplementation; no further treatments were applied to calves. Approximately 14 d following weaning, calves were transported to the WCREC, North Platte, NE. Heifers remained in a single group for approximately 55 d following transport to the WCREC, North Platte, NE and grazed a dormant winter pasture. Subsequently, heifers were offered a diet containing 20% wet corn gluten feed (**WCGF**) and 80% prairie hay (DM basis) *ad libitum* for 45 d. Interim BW and blood samples were collected every 14 d. Heifers from WR cows in yr 1 and a subset of heifers from WR and CR dams in yr 2 and 3 were assigned randomly to 1 of 4 pens containing Calan individual feeding systems (American Calan, Northwood, NH) to evaluate individual feed efficiency.

After a 30-d adaptation and training period, heifers were individually fed for a minimum of 84 d. Heifers were exposed to ambient temperature and light conditions. Three d consecutive BW were taken at the beginning and end of the feeding period following a 5 d limit feeding period.

Following completion of the individual feeding period in early May each year, heifers returned to GSL. Heifers were exposed to bulls (1:25; bull:heifer) for 45 d. Estrus was synchronized with a single injection of $PGF_{2\alpha}$ administered 108 hours after bulls were placed with the heifers. Pregnancy diagnosis was performed via transrectal ultrasonography approximately 45 d following the breeding season.

Statistical Analysis. As treatments were applied on a field basis, winter pasture (n = 4/yr) or corn residue field (n = 4/yr) were considered the experimental units for heifer performance and reproductive data. In addition, CP was or was not provided to 2 winter pastures and 2 corn residue fields per yr (n = 4·CP treatment^{-1}·yr^{-1}). Data were analyzed using PROC MIXED of SAS (SAS Inst., Inc., Cary, NC). The statistical model included winter grazing system, CP supplementation and the interaction. Cow age was included as a covariate for heifer calf data collected until weaning where it represented a significant ($P \leq 0.15$) source of variation. Pasture nested with the effect of yr x grazing treatment x CP treatment was included as a random variable in all analyses. In addition, pen nested within rep x yr was included for data collected during and immediately after individual feeding, including gain, feed efficiency, and first season reproductive data.

Results and Discussion

Heifer Performance and Reproduction. Heifer performance data is displayed in Table 1. Dams receiving PS calved 4 d earlier ($P = 0.04$) than NS cows; however, birth date was unaffected ($P = 0.51$) by winter development system. Cows grazing CR tended to give birth to heavier ($P = 0.07$) calves than WR cows, but PS did not affect ($P = 0.49$) calf birth BW. Heifer progeny weaning BW and adjusted weaning BW were greater ($P \leq 0.04$) if the dam grazed CR. Adjusted weaning BW was lowest ($P = 0.03$) if the dam received NS while grazing WR. Weaning BW of steer mates from dams grazing WR with NS was lower than all other treatment groups (Larson et al., 2009). Supplementation appears to be necessary to attain maximal production of offspring from dams grazing WR.

Neither PS nor winter development system affected ($P > 0.10$) heifer ADG from weaning until the time they entered the Calan gates or from weaning until breeding. There does not appear to be any compensatory gain of heifers from WR-NS dams which supports a fetal programming hypothesis indicating a potential physiologic or genetic change in growth not remedied by dietary changes. Heifers from dams previously grazing CR with PS had a lower ($P = 0.03$) ADG during the individual feeding period than all other heifers. Pre-breeding BW of WR-NS heifers tended to be lower ($P = 0.11$) than other treatments. The reduced BW at weaning appears to be maintained to prebreeding, which agrees with previous research (Martin et al., 2007). Post-weaning ADG was similar ($P \geq 0.25$) among treatments resulting in continued lower ($P = 0.09$) BW at pregnancy diagnosis for WR-NS heifers which is similar to findings of Martin et al. (2007). Steer progeny mates from cows receiving NS during gestation displayed more illness during post weaning development than counterparts from PS dams. However, there was no effect ($P \geq 0.21$) of winter system or PS on illness between birth and weaning or between weaning and breeding in heifer progeny.

First season reproductive data for heifer progeny are presented in Table 2. Heifers from dams receiving PS during late gestation tended ($P = 0.09$) to be younger at puberty than heifers from dams receiving NS; however, age at puberty was not affected ($P = 0.32$) by winter development system. Body weight at puberty was similar ($P \geq 0.50$) among treatments. As heifers from PS dams reach puberty at a younger age, regardless of BW, perhaps the intrauterine environment influences prenatal reproductive development. There also tended ($P = 0.11$) to be fewer heifers pubertal at breeding from dams previously grazing WR with NS which may be at least partially due to the lower BW at this time as reducing BW at breeding reduces the number of heifers attaining puberty by breeding (Funston and Deutscher, 2004; Martin et al., 2008). Potentially related to pubertal status, heifers from NS dams tended ($P = 0.13$) to have lower pregnancy rates during the 45 d breeding season. Martin et al. (2007) also reported providing PS to dams grazing WR improves subsequent pregnancy rate of heifer progeny. In the current study, pubertal status and pregnancy were modified by dam nutrition. Thus, these and previous data (Martin et al., 2007) provide evidence of a fetal programming effect on reproduction. Winter development system did not affect final pregnancy rate ($P = 0.96$).

Heifer Feed Efficiency. Dry matter intake was similar ($P \geq 0.17$) for heifers born to dams previously grazing WR or CR with or without PS. The ADG of heifers from dams grazing CR with PS was lower ($P = 0.03$) during the individual feeding period, compared to all other heifers. Thus, heifers from CR-PS dams gained less efficiently (G:F, $P = 0.04$) than heifers from dams in other treatment groups. In contrast, there were no differences ($P > 0.10$) in efficiency when expressed as RFI. Heifers from CR-PS dams represent the most adequately nourished group while heifers from WR-NS dams are the most restricted. It appears late gestation dam nutrition may alter the efficiency of heifer offspring.

Heifer Progeny Calf Production. Heifer BW and BCS prior to calving were similar ($P \geq 0.14$) among treatment groups. Birth date, birth BW, and percentage of calves born in the first 21 d was also similar ($P \geq 0.29$) among treatment groups. Prior to the second breeding season, heifers from dams previously grazing WR with NS tended ($P = 0.09$) to have lower BW than other treatment groups; however, BCS was not different ($P \geq 0.16$). As heifer BW prior to calving was similar, the difference in BW prior to the second breeding season may indicate a difference in nutrient partitioning among treatment groups during the early post partum period. This hypothesis is supported by the observation that at weaning, heifer BW and BCS were similar among treatment groups ($P \geq 0.20$). Weaning BW and 205 d adjusted BW of calves born to heifer progeny was similar ($P \geq 0.28$) among treatments. Similar to previous data, reducing prebreeding BW by either post weaning ADG restriction (Funston and Deutscher, 2004; Martin et al., 2008) or modulation of late gestation dam nutrition (Martin et al., 2007) may impact first pregnancy outcome, pregnancy rate after the second breeding season was similar ($P \geq 0.97$) among treatments.

Implications

As rising input prices continue to impact cow/calf production, beef producers will consider alternative feed resources. It is imperative to understand not only how these changes will affect the dam, but also what the lifelong impacts may be for the offspring. There appear to be fetal programming effects of winter grazing system and late gestation supplementation of the dam on the unborn fetus. Winter grazing system and late gestation supplementation impact heifer progeny BW, feed efficiency, and reproduction.

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Table 1. Effects of grazing winter range or corn residue and protein supplementation during the last trimester of gestation on heifer growth performance

	Treatment[1]							
	WR		CR			Treatment *P*-value[2]		
Trait	PS	NS	PS	NS	SEM	Sys	Supp	S*S
n	6	6	6	6	-	-	-	-
Calf birth date, Julian d	84	86	80	87	2	0.51	0.04	0.24
Calf birth BW, kg	35.1	33.8	35.7	36.0	0.9	0.07	0.49	0.27
Calf weaning BW, kg	230	218	234	231	6	0.03	0.04	0.17
Adj. calf weaning BW, kg	217[a]	206[b]	217[a]	220[a]	4	0.02	0.15	0.03
Post-weaning ADG, kg	0.50	0.49	0.48	0.50	0.05	0.86	0.72	0.25
Pre-breeding BW, kg	323	308	322	325	15	0.17	0.24	0.11
Pregnancy diagnosis BW, kg	367	354	368	374	11	0.06	0.54	0.09

[1]WR = dams grazed dormant winter range during late gestation; CR = dams grazed corn residue during late gestation; PS = dams supplemented with the equivalent of 0.45 kg/d 28% CP cake during late gestation; NS = dams not supplemented.
[2]Sys = winter grazing system main effect; Supp = protein supplementation main effect; S*S = winter grazing system by protein supplementation treatment interaction.

Table 2. Effects of grazing winter range or corn residue and protein supplementation during the last trimester of gestation on heifer reproduction

	Treatment[1]							
	WR		CR			Treatment *P*-value[2]		
Trait	PS	NS	PS	NS	SEM	Sys	Supp	S*S
n	6	6	6	6	-	-	-	-
Age at puberty, days	355	370	348	361	9	0.32	0.09	0.95
BW at puberty, kg	279	281	284	288	11	0.50	0.72	0.90
Pubertal by breeding, %	91	74	79	84	7	0.71	0.38	0.11
Pregnant, %	91	77	88	83	7	0.96	0.13	0.45

[1]WR = dams grazed dormant winter range during late gestation; CR = dams grazed corn residue during late gestation; PS = dams supplemented with the equivalent of 0.45 kg/d 28% CP cake during late gestation; NS = dams not supplemented.
[2]Sys = winter grazing system main effect; Supp = protein supplementation main effect; S*S = winter grazing system by protein supplementation treatment interaction.

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INFLUENCING STEER PERFORMANCE THROUGH MATERNAL NUTRITION

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ABSTRACT: A 2-yr study was conducted to determine the effects of maternal nutrition on male progeny. Two locations of a commercial ranch in the Nebraska Sandhills were utilized. Crossbred spring-calving multiparous cows at one location (yr 1 = 754; yr 2 = 700) received higher levels of supplement (**HN**) and cows at the second location (yr 1 = 673; yr 2 = 766) received lower levels of supplement (**LN**). Cows were managed in a year-round grazing system with HN cows receiving the equivalent of 1.1 kg/d supplement (28% CP) and LN cows receiving 0.4 kg/d supplement delivered three times weekly from December through February and meadow hay through calving in March and April. After weaning, a random group (yr 1 = 100, yr 2 = 100) of male progeny from each management regimen were placed in a feedlot and slaughtered 218 d later. There were significant ($P < 0.05$) interactions between yr x treatment for performance and carcass characteristics. There was no difference ($P = 0.17$) in initial BW between HN and LN calves. Re-implant and final BW were greater ($P = 0.09$; 0.07) for HN calves compared to LN calves (437 vs. 428 ± 3 kg; 625 vs. 614 ± 4.4 kg). Calf ADG tended ($P = 0.12$) to be greater for HN calves. Calves from yr 1 had greater ($P < 0.01$) ADG from initiation to re-implant, whereas yr 2 calves had greater (P = 0.02) ADG from re-implant to slaughter. Steer HCW and marbling score were greater ($P = 0.07$; 0.05) for HN calves. Steer 12-th rib fat, LM area, final yield grade, and percent USDA Choice were similar ($P > 0.10$) among treatments. Final yield grade and percent grading USDA Choice were greater ($P < 0.01$) for yr 2 calves compared to yr 1. The proportion of HN calves and yr 2 calves grading USDA quality grade of modest or greater was greater ($P = 0.07$; < 0.01) compared to LN calves (21 vs. 11%) and yr 1 calves (24 vs. 8%), respectively. Level of dam nutrition during the last trimester of gestation influenced subsequent steer progeny final BW, HCW, and percent USDA average Choice or greater in this study.

Key Wor ds: Maternal nutrition, Carcass quality, Beef cattle

Introduction

A major goal in beef cattle production is to minimize costs yet maximize profitability. Utilizing dormant forages throughout the winter reduces production costs by increasing grazing season length and decreasing the amount of harvested forages needed in beef cattle production systems (Adams et al., 1994), however, nutrient content of the dormant forage is low and does not meet the energy demands of cows during the last trimester of gestation (NRC, 1996). Providing protein supplementation through winter grazing has been a common practice to maintain cow BCS (Stalker et al., 2006; Martin et al, 2007; Larson et al., 2009). Providing protein supplementation has increased progeny weaning BW (Stalker et al., 2006; Martin et al., 2007), improved post weaning calf health, increased HCW, and the proportion of calves achieving USDA quality grades of Choice or greater (Larson et al., 2009). These results indicate maternal nutrition during gestation can influence postnatal growth and health, which is hypothesized as fetal programming (Barker et al., 1993). The objective of the current study was to evaluate the effects of two dam protein supplementation levels while grazing dormant Sandhills forage on subsequent steer progeny growth, feed efficiency, and carcass quality.

Materials and Methods

The University of Nebraska-Lincoln Institutional Animal Care and Use Committee approved the procedures and facilities used in this experiment.

This 2-yr study was conducted at two units of the Rex Ranch, Ashby, NE. Pregnant mulitparous composite beef cows comprised of 50% Red Angus, 25% Simmental, and 25% South Devon or other breeds were managed in a year-round grazing system. Cows grazed dormant forage pastures from November to late February with a protein supplement (28% CP cubes) delivered three times weekly. The supplement was dried distillers grains plus solubles based (62%, DM basis), and similar to that reported by Larson et al. (2009). Cows were offered supplement and meadow hay at both locations at the discretion of the manager with one location (yr 1 = 754; yr 2 = 700) receiving higher levels of supplement (**HN**; 1.19 kg/d yr 1; 0.93 kg/d yr 2) and cows at the second location (yr 1 = 673; yr 2 = 766) being fed lower levels of supplement (**LN**; 0.39 kg/d yr 1; 0.43 kg/d yr 2). During calving (March and April) cows received meadow hay in the form of large round bales with HN cows receiving 6.33 kg/d in yr 1 and 5.46 kg/d in yr 2 and LN cows receiving 4.65 and 6.55 kg/d in yr 1 and yr 2, respectively. After weaning (early to mid September), calves grazed meadow pasture while receiving 1.36 kg/d of the CP supplement until shipping (yr 1 = November 12; yr 2 = November 18). A random sample of steers from each treatment group (yr 1 = 100; yr 2 = 100) were shipped approximately 212 km to the West Central Research and Extension Center, North Platte, NE. Steers were weighed on 2 consecutive days after arrival to calculate initial BW and implants were administered providing 20 mg of estradiol benzoate and 200 mg progesterone (Synovex S, Fort Dodge Animal Health,

Overland Park, KS). Steers were limit fed a starter diet for 5 d then transitioned to a finishing diet over a 21 d period. Approximately 100 d prior to slaughter steers were implanted with 24 mg estradiol and 120 mg trenbolone acetate (Revelor S, Intervet, Millsboro, DE). Steers were slaughtered at a commercial abattoir 218 d after entering the feedlot. Final BW was calculated from HCW and carcass data were collected after a 24h chill.

Economic Analysis. To determine the effect of the two supplementation levels on profitability, a partial budget analysis was conducted. Supplementation costs were valued at the actual purchase price plus a delivery charge ($0.07/kg). Meadow hay values were taken from Nebraska state average monthly price based on USDA Agricultural Marketing Service (USDA-AMS, 2007a; 2008a). Calf sale prices were the Nebraska weighted average feeder cattle price reported for the given year at the time of entry into the feedlot as reported by the USDA Agricultural Marketing Service (USDA-AMS, 2007b; 2008b). Feedlot ration was valued at $0.14/kg. Veterinary charges, trucking, yardage, and implant were charged as non-feed costs at $0.50/d. The value of the steer at harvest was based on the Nebraska dressed steer price for the day of harvest (USDA-AMS 2008c; 2009a) with grid premium and discounts applied as reported by USDA Agricultural Marketing Service (USDA-AMS, 2008d; 2009b).

Statistical Analysis. Treatments were applied on a location level (n = 2) or yr (n = 2) to dams and was considered the experimental unit for steer performance and carcass data. Data were analyzed using PROC MIXED (SAS Inst. Inc., Cary, NC). The statistical model included dam treatment, year, and the interaction. Proportion of steers grading USDA Choice and USDA quality grade of modest or higher were analyzed using χ^2 procedures in PROC FREQ of SAS.

Results and Discussion

Steer feedlot performance data is presented in Table 1. Initial BW did not differ ($P = 0.17$) between HN and LN calves, however initial weight for calves from yr 1 was greater ($P < 0.01$) than calves from yr 2. Reimplant BW and final BW were greater ($P = 0.09$; 0.07, respectively) for calves from HN compared to LN cows. Data from Larson et al. (2009) and Stalker et al. (2006) indicate that steer calves from dams supplemented protein while grazing dormant winter range have greater BW at initial feedlot entry compared to calves from non supplemented cows. Calves from those studies were placed in the feedlot 14 d post weaning whereas calves in this study were not shipped to the feedlot until approximately 8 weeks after weaning and were allowed to graze sub-irrigated meadows and received 1.36 kg/d of 28% CP supplement. Stalker et al. (2006) and Larson et al. (2009) studies also provided either 0.45 kg/d supplement or no supplement. In the present study, cows were provided supplement at both locations with HN cows receiving 40% more supplement than LN cows, and LN cows receiving supplement levels similar to Stalker et al. (2006) and Larson et al. (2009).

Overall ADG for calves from yr 1 were greater ($P = 0.05$) than yr 2. Calves from yr 1 had greater ($P < 0.01$) ADG from initiation to re-implant, whereas yr 2 calves had greater ($P = 0.02$) ADG from re-implant to slaughter (1.91 vs. 1.83 ± 0.02 kg/d).

Calf DMI was calculated using the DMI prediction equation established by Tedeschi et al. (2006) where DMI = 4.18 + (1.98 x ADG) + (0.0013 x ($MBW^{0.75}$) + (0.019 x **EBF**) where EBF represents estimated body fat percentage. Estimated body fat percentage was calculated using the equation developed by Guiroy et al. (2001) where EBF = 17376107 + (11.8908 x 12-th rib fat depth) + (0.0088 X HCW) + (0.81855 x [(marbling score/100) + 1] – (0.4356 x LM area). Dry matter intake and BW gain efficiency were not significant ($P = 0.27$) when comparing calves from HN or LN cows. Calves from yr 1 were more ($P < 0.01$) efficient compared to yr 2 calves.

Steer carcass data is summarized in Table 2. Hot carcass weights were greater for steers from HN compared to steers from LN cows ($P = 0.07$) and calves from yr 1 compared with yr 2 ($P < 0.07$). Calves from HN cows and yr 1 calves had greater ($P \leq 0.05$) marbling scores compared to calves from LN cows and yr 2, respectively. There were no differences ($P = 0.26$) in 12-th rib fat, LM area, yield grade, or the proportion of calves grading USDA Choice when comparing calves from HN to LN cows. Calves from yr 1 had greater ($P = 0.08$) marbling scores, 12-th rib fat, and LM area compared to yr 2 calves. Calves from yr 2 had greater ($P < 0.01$) yield grades, proportion of calves grading USDA Choice, and USDA Choice or greater compared to yr 1. High nutrition cows also had a greater ($P = 0.07$) proportion of calves that graded USDA Choice or greater compared to LN cows.

Economic Analysis. Data for the economic analysis are summarized in Table 3. Data represent actual values for the years of the study (2007 - 2009). If calves were sold in November HN calves were valued at $7.79/calf greater than calves from LN cows, however, net returns for HN calves were only $1.44/calf greater than those for LN calves due to an increase in the supplement amount provided to dams ($6.60 vs. $2.55). Net returns through the feedlot phase were $7.62/steer greater for calves born to HN cows compared to LN cows. Fed cattle base prices were $20.81/cwt higher in yr 1 compared to yr 2. Differences in the proportions grading USDA Choice and USDA Choice or greater were greater for yr 2 calves (Table 2) which improved the carcass values of the yr 2 calves. Similarly the proportion of HN calves grading USDA Choice or greater (Table 2) was greater than LN born calves which likely had a direct effect on the greater returns for HN steers. These data are similar to that reported by Larson et al. (2009) where calves from protein supplemented dams had 15% greater proportion grading USDA Choice or greater and a net feedlot return of nearly $30/steer more when compared to steers from dams not supplemented.

Implications

Providing increased late gestation supplementation to the dam did not affect calf initial BW at feedlot entry; however, final BW and carcass characteristics were affected. Calves from HN cows had greater final BW and HCW than calves from LN cows. In addition, more calves

from HN supplemented cows graded USDA Choice or greater. Increasing maternal supplementation during the last trimester of gestation increased final BW, HCW and USDA quality grade resulting in greater feedlot returns.

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Table1. Effects of maternal protein supplementation level on progeny steer feedlot performance

	Treatment[1]		Year			P-value	
Trait	HN	LN	Yr 1	Yr 2	SEM	Treatment	Year
n	2	2	2	2			
Initial BW, kg	228	224	237	214	2	0.17	<0.01
Reimplant BW, kg	435	428	451	411	3	0.09	<0.01
Final BW[2], kg	625	614	643	596	4	0.07	<0.01
ADG							
Initial to reimplant, kg/d	1.83	1.80	1.89	1.74	0.018	0.20	<0.01
Reimplant to slaughter, kg/d	1.89	1.85	1.83	1.91	0.023	0.22	0.02
Overall, kg/d	1.85	1.82	1.86	1.81	0.017	0.12	0.05
DMI[3], kg,d	13.45	13.35	13.42	13.47	0.064	0.27	0.63
G:F, g gain/kg	128.50	127.37	133.50	122.36	1.118	0.35	<0.01

[1]HN = dams supplemented with the equivalent of 1.1 kg/d 28% CP cube (DM basis) during late gestation and 5.9 kg/d meadow hay during calving; LN = dams supplemented with the equivalent of 0.4 kg protein supplement during late gestation and 5.6 kg/d meadow hay during calving.

[2]Final BW calculated based on a common dressing percentage (63%) and a shrink of 4% calculated to account for transport BW loss.

[3]DMI calculated using the prediction formula presented by Tedeschi et al. (2006) where DMI = 4.18 + (1.98 x ADG) + (0.0013 x ($MBW^{0.75}$) + (0.019 x EBF).

Table 2. Effects of maternal protein supplementation level on progeny steer carcass data

	Treatment[1]		Year			P-value	
Trait	HN	LN	Year 1	Year 2	SEM	Treatment	Year
n	2	2	2	2	-	-	-
HCW, kg	378	371	389	360	6	0.07	<0.01
Marbling score[2]	384	365	399	349	7	0.05	<0.01
12-th rib fat, cm	1.20	1.19	1.24	1.15	0.04	0.93	0.08
LM area, cm^2	87.89	86.49	93.70	80.67	0.88	0.26	<0.01
Yield grade	2.88	2.89	2.73	3.04	0.07	0.95	<0.01
Quality grade, % Sm[3] or greater	62	64	47	80		0.78	<0.01
Quality grade, % Md[4] or greater	21	11	8	24		0.07	<0.01

[1]HN = dams supplemented with the equivalent of 1.1 kg/d 28% CP cube (DM basis) during late gestation and 5.9 kg/d meadow hay during calving; LN = dams supplemented with the equivalent of 0.4 kg protein supplement during late gestation and 5.6 kg/d of meadow hay during calving.
[2]Where 400 = small[0].
[3]Sm = small quality grade, USDA low Choice.
[4]Md = modest quality grade, USDA average Choice.

Table 3. Cost and returns from maternal protein supplementation from last trimester of gestation to weaning and weaning to harvest.

	Treatment[1]		Year			P-value	
Item	HN	LN	Year 1	Year 2	SEM	Treatment	Year
n	2	2	2	2	-	-	-
Cow- calf phase							
Costs, $/cow							
Protein supplement	6.60	2.55	4.92	4.23	-	-	-
Meadow hay	48.33	46.03	44.34	50.02	-	-	-
Returns, $/calf							
Calf sale price[2]	549.41	541.62	621.69	465.42	4	0.48	< 0.01
Net return	494.48	493.04	572.43	411.17	-	-	-
Feedlot phase							
Costs, $/steer							
Purchase cost[3]	585.16	577.24	657.90	504.90	4	0.17	< 0.01
Feedlot feed cost[4]	522.24	516.44	518.58	517.05	-	-	-
Returns, $/steer							
Carcass value	1166.59	1144.25	1275.15	1035.69	9	0.07	<0.01
Net return	59.19	51.57	98.67	13.74	-	-	-

[1]HN = dams supplemented with the equivalent of 1.1 kg/d 28% CP cube (DM basis) during late gestation and 5.9 kg/d meadow hay during calving; LN = dams supplemented with the equivalent of 0.4 kg protein supplement during late gestation and 5.6 kg/d meadow hay during calving.
[2]Value of steer and heifer calves after grazing meadow hay and receiving 1.36 kg/d 28% CP cube (DM basis) for approximately 8 weeks.
[3]Value of steer calves only.
[4]Value based on $0.14/kg feed cost for 218 days and including yardage at $0.50/d.

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PERFORMANCE OF MEDIUM AND SMALL FRAME STEERS UNDER PASTURE AND PASTURE-FEEDLOT FINISHING

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ABSTRACT: This study evaluated the performance of Medium Frame (**MF**) and Small Frame (**SF**) steers under 2 finishing systems: 1) Full-season pasture finishing; and 2) Early-season grazing followed by feedlot finishing. Forty yearling steers were frame-scored. Frame scores 4, 5, and 6 were classified as MF and frame scores 2 and 3 classified as SF. Day 1 (14 May 2009) the steers were placed in 6 native range pastures, 3 supplied with a salt-limited, sunflower screening-oat supplement and 3 non-supplemented. Each pasture contained approximately equal numbers of MF and SF steers (average BW 373 and 297 kg, respectively). Frame within pasture was the unit of replication. On d 48 all steers were weighed and half of the MF and SF in each pasture (chosen at random within frame and pasture) were removed for feedlot finishing and divided into 2 pens of MF and 2 pens of SF steers with pens as unit of replication. Pasture-finish steers were removed from pasture on d 152, weighed and scanned by ultrasound for percent intramuscular fat (**IMF**). Feedlot steers were harvested when ultrasound indicated 4.00% IMF or 12.8 mm of back fat. The first 48 d on pasture, supplementation did not affect ADG ($P = 0.40$) and ADG for MF and SF steers was 1.0 and 0.8 kg, respectively ($P = 0.17$). For pasture-finish steers in the d 48 to d 152 period, ADG was greater in supplemented than control pastures (0.9 vs. 0.7 kg; $P = 0.002$) and ADG was greater for MF than SF steers (0.9 vs. 0.7 kg; $P = 0.001$), but no frame by supplement interaction was found ($P = 0.81$). Pasture-finish steers average IMF of 3.7% was not impacted by frame ($P = 0.70$) or supplement ($P = 0.78$). In the feedlot, MF steers tended to have greater final BW (614 vs. 511 kg; $P = 0.14$) and hot carcass weight (372 vs. 310 kg; $P = 0.14$) than SF steers. However, MF and SF steers did not differ in ADG (1.5 vs. 1.4 kg; $P = 0.27$), days on feed (123 vs. 131 d; $P = 0.66$) DM G:F (0.116 vs. 0.119; $P = 0.94$) or yield grade (2.8 vs. 2.6; $P = 0.40$). All feedlot steers produced USDA choice carcasses. Results show MF and SF steers can both perform well under pasture and pasture-feedlot finishing systems.

Key Words: Feedlot, Frame Size, Pasture Finishing, Steers

Introduction

As reported elsewhere in these proceedings, mating virgin heifers to sires of lower birth weight potential can reduce dystocia (difficult births) in first-calf heifers (Mantz and Nyren, 2010). However, lower birth weight calves with smaller mature body weights often exhibit decreased ADG and light finish weights when placed on a finishing ration shortly after weaning (Colburn et al., 1997; Brethour et al., 2002).

Utilizing a growing and grazing period before placing on a finishing ration can increase finish weights (Janovick-Guretzky et al., 2005). Utilizing a growing period before placing cattle on a finishing ration can increase marbling scores at a constant back fat (Brethour, 1992).

There is a growing interest in finishing cattle on pasture and forage rather than grain. This is because the fatty acid composition of carcasses from forage-finished animals is deemed to have beneficial impacts on human health (French et al., 2000; Poulson, et al., 2004; Faucitano et al., 2008). The present study evaluated the performance medium frame (**MF**) and small frame (**SF**) steers under 2 finishing systems: 1) Full-season pasture finishing; and 2) Early-season grazing followed by feedlot finishing.

Materials and Methods

Livestock and Pasture Management

Forty yearling steers born to first-calf heifers at Central Grasslands Research Extension Center in 2008 were utilized in this study. Following weaning October, 2008 the steers were backgrounded in a common pen on a ration of 70% corn silage and 30% chopped hay (as-fed basis). Steers were frame-scored according to Beef Improvement Federation guidelines (BIF, 2002). Steers with yearling frame scores of 4, 5, and 6 were classified as MF and steers with yearling frame scores of 2 and 3 were classified as SF. The majority of MF steers were sired by Angus sires and the majority of SF steers were sired by Lowline sires. None of the steers received hormone implants or beta agonists during any stage of their life. On d 1, (14 May 2009), the steers were placed in 6 native range pastures. Three of the pastures were supplied with a salt-limited supplement and 3 of the pastures were non-supplemented. Each pasture contained approximately equal numbers of MF and SF steers (average initial BW 373 and 297 kg, respectively). Initial stocking rate was 2.0 ha per steer which is considered a very light stocking rate for these pastures comprised

primarily of silty and silty-overflow range sites (Patton et al., 2009).

Day 48 all steers were weighed and half of the MF and half of the SF steers in each pasture, chosen at random within pasture and frame size, were removed for feedlot finishing and placed into 2 pens of MF steers and 2 pens of SF steers. The remaining steers were left to be pasture-finished. Pasture-finish steers were removed from pasture d 152, weighed and scanned by ultrasound for percent intramuscular fat (**IMF**).

Feedlot steers were scanned by ultrasound for % IMF and back fat every 30 days starting at 60 days on feed. Feedlot steers were harvested and carcass data collected, when ultrasound indicated either 4.00% IMF or 12.8 mm of back fat.

Pasture Supplements and Feedlot Rations

The initial pasture supplement (14% CP DM basis) contained equal portions of sunflower screenings and whole oats with 5% calcium carbonate, and 5% of an 8.5% phosphorus range mineral. Salt was added as needed to meet targeted intake of 1.8 kg per steer daily. From d 1 to d 105 the actual supplement intake averaged 1.3 kg per steer daily. Starting on d 105 the protein content of the pasture supplement was increased to 18% CP DM basis to compensate for the expected seasonal decline in CP content of range forage. This was accomplished by replacing half of the sunflower screenings and half of the whole oats with sunflower meal treated with 6% concentrated separator byproduct. At that time the targeted supplement intake was also increased to 3.6 kg per steer daily. However, from d 105 to d 152 the actual supplement intake was 7.4 kg per steer daily. Throughout the grazing season steers in the non-supplement pastures had ad libitum access to trace mineralized salt and the 8.5% phosphorus range mineral.

Feedlot steers had unlimited access to both a grass-alfalfa hay (12% CP DM basis) and a mixture of coarse-ground corn and a commercial intake limiter. The commercial intake limiter also supplied natural protein, non-protein nitrogen, salt, vitamins, minerals, monensin and tylosin. After an initial adjustment period with a higher proportion of intake limiter, the mixture contained 90% corn and 10% intake limiter and the mix averaged 14% CP. Medium frame steers selected a diet that was 80% concentrate and 20% hay (DM basis) and the SF steers selected a similar (P = 0.51) diet of 76% concentrate and 24% hay.

Statistical Analyses

Average daily gains of steers on pasture and the percent IMF for pasture-finish steers were analyzed as split-plot designs using SAS GLM (SAS Institute, Cary, NC) with pasture supplement treatment as the whole-plot factor and steer frame size the split-plot factor. Units of replication were designated as the average ADG or percent IMF for steers of the same frame size within the same pasture.

Feedlot steers were analyzed for initial and final BW, days of feed, gain to feed, carcass weight, yield grade and quality grade as a one-way (steer frame size) Analysis of Variance using SAS GLM (SAS Institute, Cary, NC). Average values of the steers within each pen were designated as the units of replication.

Results

Pasture Performance

From turnout to d 48 when half of the steers were removed for feedlot finishing, providing supplement to steers on pasture did not improve ADG (P = 0.40). During that time period ADG of the MF steers tended (P = 0.17) to be greater than that of the SF steers, 1.0 and 0.8 kg respectively.

From d 48 through d 152 the pasture-finish steers which were supplemented had greater ADG than non-supplemented steers (0.9 vs. 0.7 kg; P = 0.002). During that time period MF steers had greater ADG than SF steers (0.9 vs. 0.7 kg; P = 0.001). However there was no supplement by steer frame size interaction (P = 0.81). Pasture-finish steers had an average ultrasound IMF of 3.7% which was not impacted by frame size (P = 0.70) or pasture supplement (P = 0.78).

Feedlot Performance

Medium frame steers had a greater initial BW (P = 0.04) than SF steers and tended (P = 0.14) to have a greater final BW (Table 1). However, MF and SF steers did not differ (Table 1) in average days on feed (P = 0.66), ADG (P = 0.27) or G:F (P = 0.94).

Evaluating the carcasses of steers finished in the feedlot (Table 2) MF steers tended (P = 0.14) to have greater carcass weights than SF steers but did not differ in dressing percent (P = 0.24), yield grade, or USDA quality grade (P = 1.00). Carcasses of all steers finished in the feedlot graded USDA choice.

Discussion

Pasture Performance

The decline in ADG as the season progressed in the present study was much less dramatic than that observed by Grings et al. (2002). The very light stocking rates and favorable precipitation patterns in 2009 may have allowed late-season ADG to remain relatively high. Although the late-season ADG of the SF steers was less than that of MF steers, when viewed from the standpoint of ADG relative to initial BW the decreased ADG would not suggest the SF steers were less efficient.

Although supplementation improved late-season ADG, trouble regulating the supplement intake in the late season resulted in the added gain costing $3.13 per kg of added gain. The added gain would not pay for the supplement at prevailing cattle prices. It was surprising that although the pasture supplement improved ADG it did not improve the average % IMF of steers. This is a reflection of the extreme variance in the IMF of steers in the supplemented pastures. One of the supplemented pastures had all steers determined to grade USDA choice by ultrasound scanning and all graded choice when harvested. However the other 2 supplemented pastures had steers determined by ultrasound to grade 50% choice and 0% choice. Forage samples taken in the pastures would not suggest that forage quality could be driving the

variation in IMF of steers from supplemented pastures. The extreme pasture-to-pasture variation in IMF was likely due to the small number of steers in each pasture and steers of high marbling ability not being evenly distributed among pastures.

Perhaps what is most surprising about the pasture-finishing portion of the study was that there was no difference % IMF between the MF and SF steers. It is commonly believed that smaller-framed cattle are better suited to forage-based production systems (Provenza, 2008). Smaller frame sizes are often equated with earlier maturity (MacNeil et al., 1999). However most of the SF steers in our study were sired by Lowline sires. The Lowline breed was established by selecting Angus cattle for minimum yearling weight and are not considered early maturing (Oklahoma State University, 2008).

Feedlot Performance

The non-significant P-values for differences in ADG, final body weight and carcass weight between MF and SF steers found in our study may have been due to the small number of replications (2 pens for each frame size) rather than a lack of a biological response. In future trials the number of pens for each frame size will be increased to 3, increasing statistical power. However, the highly non-significant P-values for G:F suggests that no significant differences in feed efficiency would have been produced with more replications. When fed to a constant carcass fatness conventional and comprest Herefords were equally efficient in converting feed to gain (Stonaker et al., 1952).

The percentage of carcasses grading USDA choice (100%) in our study was much higher than that observed by Brethour and Mullen (1989) in a similar integrated backgrounding-grazing-finishing study. However, our steers were fed 30-40 days longer than the steers in their study suggesting that they would have achieved a higher percentage of choice carcasses with more days on feed.

All of our steers produced carcasses that exceeded minimum carcass weight of 249 kg needed to avoid discounts for light carcasses. A concern with finishing cattle at older ages is that larger-framed steers will produce overweight carcasses leading to discounts. Currently some beef packers begin discounting heavy carcasses at 430 kg while others begin discounting at 476 kg. Only one of our steers produced a carcass over 430 kg and none produced a carcass over 453 kg. Thus in a program of backgrounding and half-season grazing followed by feedlot finishing, steers of up to a frame score 6 can produce acceptable carcass weights—at least if hormone implants or beta agonists are not used.

Implications

Medium frame and SF steers both performed satisfactorily under both the pasture and pasture-feedlot finishing systems. Thus, our first year of results would not suggest the superiority of either frame size or even a frame size by finishing system interaction. The pasture and pasture-feedlot finishing regimens outlined here both present opportunities for increasing the value of smaller-framed offspring of low-birth weight, calving-ease sires.

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Table 1. Initial weight, final weight, days on feed, average daily gain (ADG) and gain to feed ratio (G:F) for medium and small frame steers in the feedlot during 2009.

Steer Frame Size	Initial Weight	Final Weight	Days on Feed	ADG	G:F
	(kg)	(kg)		(kg)	
Medium Frame	420	614	123	1.5	0.116
Small Frame	333	511	131	1.4	0.119
P-Value	0.04	0.14	0.66	0.27	0.94

Table 2. Carcass weight, dressing percent yield grade or percent of carcasses grading USDA Choice for medium and small frame steers finished in the feedlot in 2009.

Steer Frame Size	Carcass Weight	Dressing	Yield Grade	USDA Choice
	(kg)	(%)		(%)
Medium Frame	821	60.66	2.8	100
Small Frame	684	60.71	2.6	100
P-value	0.14	0.24	0.4	1.0

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INFLUENCE OF SHADING OF FEEDLOT PENS ON PERFORMANCE OF GROWING BULL-CALVES DURING WINTER IN NORTHWEST MEXICO

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ABSTRACT: The objective of this study was to determine the influence of shading in feedlot pens on feedlot performance of growing bull-calves during winter in Northwest Mexico. Sixty bull-calves (BW = 225 ± 1.2 kg) were used in a 105-d feedlot experiment. In accordance to a randomized complete blocks design, bull-calves were blocked by initial-BW (light and heavy), and in groups of five were assigned to receive one of two allotment schedules which consisted the treatments: a) Six 6 × 12 m pens with no shade (control), and b) Six 6 × 12 m pens provided with 6 × 4 m of metallic-sheets ceiling (shade). Experimental data was analyzed by ANOVA for a randomized complete blocks design. Final BW was improved (P = 0.05) for calves allowed shade compared with controls (399 vs. 380 kg). ADG was increased (P = 0.04) 12% in shaded animals (1.655 vs. 1.477 kg/d for shaded and control, respectively). Dry matter intake was not affected (P > 0.80) by treatment (8.319 vs. 8.322 kg/d). Feed to gain ratio was increased (P < 0.01) in 11% for shaded bull-calves (5.015 vs. 5.619 kg of DM/kg of BW gain, for shade and control, respectively). Retained net energy for maintenance from the diet, was 12% higher (P = 0.07) in shaded bull-calves (1.957 vs. 1.747 Mcal/kg of DM for shade and control, respectively). Animals in control no shade treatment expenses 8% more NEm (P = 0.06) that expected (Observed/expected NEm ratio = 0.92). It is concluded that use of shading on feedlot pens improves performance of growing bull-calves in Northwest Mexico during the winter season.

Key words: Bull-calves, Feedlot-performance, Shade.

Introduction

When air temperature is increased away from its thermoneutral zone the bovines suffer heat stress (NRC, 2000; Beatty et al., 2006), hot weather has adverse effects on the performance livestock and enlarge beef cattle requirements of energy for maintenance (Ames et al., 1980; Morrison, 1983; NRC, 2000). Solar radiation influence greatly heat load (Mader et al., 2006) and alter the ability of the animal to maintain thermal balance (Brosh et al., 1998). The use of shade inside of feedlot-pens is an alternative practice to alleviate partially the heat stress of cattle (Garret et al., 1962; Mader et al., 1999). The benefit of shade has been questioned for use in temperate regions (Boren et al., 1961; Bond and Laster, 1975; Mader et al., 1999). The experiments conducted under strong hot weather both in Southern USA and Northwest of Mexico, shown advantage of use of shade on feedlot performance; (Garrett et al, 1960; Mitlohener et al., 2001; Barajas et al., 2009). However, there is little information about the potential utility of shade during cool season in those areas, Barajas et al. (2004) found that the use of shade improved average daily gain and feed efficiency in bulls finished from January to March. The state of Sinaloa, localized at Northwest of Mexico in a dry tropical weather, is the most important region dedicate to feedlot industry in Mexico. In this area, historically from January to April mean temperature is close to 22 ºC, and the maxima temperature commonly rebases 30 ºC (CNA, 2010), so that the knowledge of potential utility of shade for cattle across the cool season is matter of interest academic and cattle feeders in this region.

The objective of this study was to determine the influence of shading in feedlot pens on feedlot performance of growing bull-calves during winter in Northwest Mexico

Material and Methods

Location

The experiment was conducted during 105 days from January to April, 2009 at Experimental Station for Beef Cattle in Dry Tropic Weather of the Universidad Autonoma de Sinaloa. The research facilities are located at Feedlot Yard Ganadera Los Migueles, S.A. de C.V. in Culiacan, Sinaloa situated in Northwest Mexico (24º 51' N. and 107º 26' W. ; 57 m o.m.s.l..; mean temperature 25 ºC, and 645 mm annual rainfall).

Animals Management

Sixty bull-calves (BW = 225 ± 1.2 kg) proximately 50% *Bos indicus* with remainder of Simmental, Angus Charolais, and Brown Swiss in undeterminate proportion were used. Bulls-calves were weighed, implanted (Component TES with Tylan®;ELANCO Co.), vaccinated to prevent infections by *Manheimia sp*., *Clostridium* and *Haemophilus somnus*, dewormed, and injected with vitamins A, D and E . Groups of five calves were randomly placed in 12 pens (6 x 12 m), each of them fitted with a 2.4 m feed bunk and 0.6 m waterer. Animals had *ad libitum* access to feed and water.

Treatments

In accordance to a randomized complete blocks design described by Hicks (1973), in groups of five the calves were assigned to be placed in pens providing or not shade. Pens (6 x 12 m) were ground floor each of them fitted with a 2.4 m feed bunk and 0.6 m waterer. Shade (six pens) was provided with five metallic-layers (0.9 x 4 m) fitted 3.6 m over ground, provided pen space and shade area by head were 14.4 m^2 and 3.6 m^2, respectively. Pen in not shade treatments had the same dimensions, but without ceiling.

Experimental procedure

Diet composition is presented in Table 1. Cattle had *ad libitum* access to the diets that were offered once daily (1600 h), had *ad libitum* access to clean water. Feed intake was measured as feed offered minus weekly refusals. Feed samples (4 kg) were collected weekly directly from mixer wagon, oven dried (105 °C for 24 h), and dry matter intake calculated. Animals were weighed on days 1, 28 and at the end of the experiment.

Table 1. Composition of basal diets used in feedlot performance experiment.

Ingredients	Diets, days in feedlot			
	1-14	15-28	29-84	85-105
Corn straw	9.80	8.25	18.24	13.08
Corn silage (few grain)	50.61	33.91	-	-
Ground corn	18.61	41.89	64.44	67.83
Soybean meal	11.75	7.39	4.53	3.01
Meat and Bone meal (Pork)	4.90	4.93	4.12	3.01
Sugar cane molasses	-	-	5.87	5.86
Tallow	-	-	-	4.42
Ganabuffer [1]	1.07	0.89	-	-
Ganamin Total [1]	3.26	2.74	2.80	2.79
Total	100%	100%	100%	100%
	Calculated Analyses (DM basis) [2]			
DM, %	45.9	54.8	89.2	89.6
CP, %	15.2	13.8	14.1	12.9
NEm, Mcal/kg	1.41	1.64	1.89	2.07
NEg, Mcal/kg	0.84	1.04	1.25	1.40

[1] Ganabuffer® (Buffer agent blend) and Ganamin Total ® (Vitamins and mineral premix) containing 25 g of sodium-monensin from Rumensin 200 ® (Elanco), and Ganabuffer ® (Buffering agents blend), are trademarks (Técnica Mineral Pecuaria, S.A. de C.V.; Guadalajara, Jal., México).

[2] Calculated from tabular values (NRC, 2000).

Statistical Analysis

Experiment was analyzed as a randomized complete blocks design (Hicks, 1973), considering each pen as the experimental unit. General AOV/AOCV procedure of Statistix® 8 program (Analytical Software, Tallahassee, FL) was used to perform the analyses, and *P*-value for F-test was obtained.

Results and Discussion

Across 105-d experiment, mean air temperature was 22.08 ºC, and mean maxima temperature was 31.65 ºC (CNA, 2010), then is assumed that cattle was out of its thermoneutral zone (NRC, 2000; Beatty et al., 2006).

The influence of shade on feedlot-performance of bulls is shown in table 2. Shade increased (P = 0.04) in 12% average daily gain and enhanced 10% feed/gain ratio (P < 0.01) in relationship with unshaded cattle. In cattle finished during cool season in the same place were was performed actual experiment, Barajas et al. (2004) observed improvement of 16% on ADG and feed efficiency in shade protected bulls respect to cattle placed in unshaded pens. This result is agreed with improvement of feedlot performance observed in other experiments conducted under heat weather condition (Garret *et al*., 1960; Mitlohener *et al.*, 2001; Barajas et al., 2009).

Dry matter intake was not affected by shade (P > 0.80). The lack of influence of shade on food intake is in concordance with observed in several experiments under hot weather condition (Brosh et al., 1998; Mader et al., 1999; Barajas et al., 2009).

The absence of shade in pen decreased (P = 0.07) in 12% and 16% respectively retained NEm and NEg of the diet, compared with bulls placed in shaded pens. The usage efficiency of dietary-NEm (Observed/expected NEm) was 11% higher (P = 0.06) in shade protected cattle. Increments in the amount of net energy retained from the diet as consequence of shade in feedlot-pen has been previously observed (Barajas, et al., 2004; Barajas et al., 2009).

Sun light exposition increases 8% NEm expenditures in cattle located in shade deprived-pens (Observed/expected NEm = 0.92). Solar radiation influence greatly heat load (Mader et al., 2006), and heat stress enlarge beef cattle requirements of energy for maintenance (Ames et al., 1980; Morrison, 1983; NRC, 2000).

Implications

Results suggest that even under cool weather condition, during the less hot season in the Northwest of Mexico, the use of shade shown advantages, improving feedlot performance of growing bulls.

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Table 2. Influence of shade in pen on performance of bull-calves during 105 days complete back growing period (January-April, 2009).

Variable	Treatments		SEM [1]	P-value
	Shade	No Shade		
Bull-calves, n	30	30		
Pen replicates, n	6	6		
Days in trial	105	105		
Body weight, kg				
Day 1	225.45	225.53	0.20	0.73
Day 105	399.17	380.57	5.70	0.05
Average daily gain, kg/d	1.655	1.477	0.06	0.04
Body weight gain, kg	173.73	155.03	5.44	0.04
Dry matter intake, kg/d	8.319	8.322	0.12	0.83
Feed/gain ratio, kg/kg	5.051	5.619	0.12	< 0.01
Dietary net energy observed, Mcal/kg				
Maintenance	1.957	1.747	0.07	0.07
Gain	1.305	1.121	0.06	0.07
Observed/expected net energy				
Maintenance	1.03	0.92	0.04	0.06
Gain	1.08	0.94	0.05	0.06

[1] Standard error of the mean

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PRELIMINARY EVALUATION OF GRANDSIRE MARBLING POTENTIAL AND ULTRASOUND USE ON BACKGROUNDING AND FINISHING PERFORMANCE, AND CARCASS MERIT

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ABSTRACT: Forty-one crossbred calves (285 ± 32 kg) were backgrounded and finished to determine the impact of grandsire marbling potential and ultrasound use on predicting carcass merit. Dams were sired by either a high marbling EPD Angus bull (HIGH; Marbling EPD: +0.44, Acc: 0.23) or a low marbling EPD Angus bull (LOW; Marbling EPD: +0.02, Acc: 0.30) as evaluated by the American Angus Association, then bred to a common sire. Weaned calves were backgrounded on a barley-based diet in a common pen for 60 d. Calves were ultrasonographed for marbling (UMARB), muscle depth (UMD), and backfat (UBF) at the beginning (d0) and end of the backgrounding period (d60), and again at 72 d into the feedlot phase (d135). Gain and carcass data were evaluated as a 2x2 factorial design with grandsire and sex as main effects and calf age as a covariate. Correlations between ultrasound measurements and carcass data were used to determine the relevancy of ultrasound timing to carcass merit. Daily gain was similar (P>0.10) between grandsire groups during both phases. Heavier carcass weights, increased backfat, and larger ribeye area (REA; P<0.05) were evident in HIGH calves. No differences (P>0.10) were detected for KPH, marbling score or yield grade between LOW and HIGH calves. A strong (r>0.50) positive relationship between UBF, carcass backfat, and yield grade at d60 and d135 (P<0.05) emerged across grandsires. Final marbling score had a weak positive relationship with UMARB at d0 and d60 (P<0.05), but a strong positive relationship at d135 (P<0.05). HIGH calves had stronger positive relationships between UMARB and final marbling score during both the backgrounding and finishing phases as compared to LOW calves. Though this data set is limited, it indicates that grandsire marbling potential may impact carcass merit through factors other than marbling, and use of ultrasound during the backgrounding phase to predict final carcass merit may be limited and dependent on marbling predisposition.

Keywords: Marbling, ultrasound, beef cattle

Introduction

Over the past decade or so consumer acceptance and subsequent preference for high marbled beef cuts have resulted in "value-added" premiums for beef cattle producers that supply highly marbled cattle (NCBA, 2005). As a result beef cattle producers have begun using sires proven to produce calves that have higher marbling potentials. Typically research has evaluated the terminal calf crops from these breeding selections, but less is known about the influence of carcass traits on retained heifer production and their subsequent calf crops. Feedlot data (Vieselmeyer et al., 1996) indicates that marbling potential has minimal impact on feedlot feed conversions, but differences in growth potential can differentially impact feed conversions (Streeter et al., 1999). From that aspect, how do these carcass traits potentially impact the growth efficiency of retained daughters? If these daughters have lower feed conversions then that could result in a cowherd that requires more supplemental feed to maintain reproductive performance and pounds of calf weaned. The current study would be considered a case study and is evaluating the impact of two Angus grandsires with different marbling potentials (based on EPD's) on their daughter's initial calf crop.

Materials and Methods

General. All procedures involving animals were approved by the Oregon State University Institute of Animal Care and Use Committee. The calf crop used in the trial originated from dams sired by either a high marbling EPD Angus bull (HIGH; Marbling EPD: +0.44, Acc: 0.23) or a low marbling EPD Angus bull (LOW; Marbling EPD: +0.02, Acc: 0.30) as evaluated by the American Angus Association. These dams were then bred to a common sire and the resulting offspring's performance was evaluated during a 60d backgrounding and subsequent finishing phase. A total of 41 head (n = 19 steers, 22 heifers; 285 ± 32 kg) were fed in a common pen during both phases. During the backgrounding period calves received a barley-based diet twice a day to ensure an ADG of 0.91 or greater (NRC, 1996). Gain performance was based on BW obtained at the beginning (d0) and conclusion (d60) of the backgrounding phase, midway (d135) through the finishing phase and at time of harvest (based on carcass weight). Calves were harvested when more than half the pen was determined to have 1.0 cm of backfat cover, based on visual appraisal by management.

Ultrasound measurements. Ultrasonography was used to evaluate efficacy of predicting carcass merit prior to the finishing phase. On d0, 60 and 135, measurements for intramuscular fat or marbling (UMARB), longissimus muscle depth (UMD), and subcutaneous fat or backfat (UBF) were obtained at the 12^{th} to 13^{th}-rib interface by an experienced technician. Ultrasound images were generated using an Aloka 500V (Aloka Co., Ltd, Wallingford, CT) B-mode instrument

equipped with a 3.5-MHz, 125 mm general purpose transducer array (UST-5011U-3.5). Images were collected by a single technician with software from the Cattle Performance Enhancement Company (CPEC, Oakley, KS). Estimates of UBF, UMD, and UMARB were based on image analysis programming (Brethour, 1994) contained within the CPEC software program.

Statistical analysis. Gain and carcass data were evaluated as a 2x2 factorial design with grandsire marbling EPD and sex as main effects and calf age as a covariate using the General Linear Model procedures of SAS (SAS Inst. Inc., Cary, NC). Pearson Correlation Coefficients between ultrasound measurements and carcass data were developed using the Correlation procedures of SAS.

Results and Discussion

Grandsire data. Table 1 summarizes both performance and carcass merit for both LOW and HIGH calves. No differences ($P > 0.10$) were detected for ADG during either the background or feedlot phases. The HIGH calves had heavier carcass weights, increased backfat and greater ribeye area ($P < 0.05$). No differences ($P > 0.10$) were detected for KPH, marbling score or calculated yield grade. The carcass data suggests that differences in grandsire marbling EPD's may not translate into daughters that produce calves with higher or lower marbling potential.

Table 2 summarizes the pre-planned correlation coefficients between ultrasound timing and carcass merit based on grandsires. A moderate to high positive relationship was demonstrated between UMARB and carcass marbling score throughout the backgrounding and finishing phases for both grandsire groups. The stronger relationship (0.55 vs 0.71) at d135 between UMARB and carcass marbling score in HIGH calves suggests that calves with a predisposition to deposit intramuscular fat may do so later in development and therefore are detected via ultrasonification during the finishing phase. The data also suggests that using ultrasound during the finishing period (and thus sorting cattle for different marketing windows) is strongly correlated with final carcass merit (especially backfat and marbling score). Due to the small size of this dataset some relationships resulting from grandsire influence may not be apparent at this time.

Gender data. Table 1 summarizes both performance and carcass merit for steers and heifers. As expected steers tended ($P < 0.10$) to have higher ADG during the finishing period, and produced a heavier carcass ($P < 0.05$). The steer calves also had larger ribeye area and better yield grade. Even with a small dataset the heifers tend ($P < 0.10$) to have higher marbling scores versus the steers.

Table 3 summarizes the pre-planned correlation coefficients between ultrasound timing and carcass merit based on gender. Unlike the grandsire data stark differences were detected in using ultrasound to predict final carcass merit early in the post-weaning period. The heifer data indicates strong relationships ($r > 0.50$) between UMD and REA, UMARB and marbling score, and both UMD and UMARB with yield grade early in the backgrounding period (d0). By the end of the backgrounding period (d60) the data still indicates a strong relationship between UMD and REA, but also between UBF and both backfat and yield grade. Though not as strong ($r = 0.44$), UMARB was still highly associated with marbling score. These same relationships were not seen in the steer calves early in the feeding period. By d135 the relationships between UBF and backfat, UMD and REA and UMARB and marbling score were becoming consistently stronger ($r > 0.30$) across both steers and heifers, but the relationship was much more consistent and strong ($r > 0.50$) for heifers. The one inconsistency with the heifer data is the relationship between UMD and REA during d135 ($r < 0.30$). Many of these inconsistencies are probably due to the small size of the dataset, and therefore more cattle need to be added to determine reliable relationships, along with timing.

Implications

Though the dataset is small and represents only two different grandsires, the results suggest that grandsire selection can influence performance of calf crops from the retained daughters. Further research must to be conducted to better understand how selection of sires based on carcass merit traits influence daughters that are retained in the cow herd and their subsequent calf crops. This data also suggests that the use of ultrasound prior to feedlot entry to predict and sort calves for marketing outcomes is possible, but may be influenced by genetics, gender, and their independent and/or complementary impact on compositional development (i.e. rate and site of fat deposition, etc.).

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Table 1. Summary of gain performance and carcass characteristics based on grandsire and gender influences.

	Grandsire		Gender		P values[a]		
Item	**LOW**	**HIGH**	**Steers**	**Heifers**	Grand sire	Gender	Grand sire x Gender
Background ADG, kg/d	0.99	1.12	1.08	1.04	NS	NS	NS
Finishing ADG, kg/d	1.73	1.81	1.84	1.70	NS	0.07	0.05
Carcass weight, kg	343	370	370	343	<0.01	<0.01	0.03
Backfat, cm	1.38	1.68	1.48	1.58	0.02	NS	NS
Ribeye area, cm^2	34.0	36.3	37.0	33.3	0.01	<0.01	0.06
KPH, %	2.20	2.26	2.25	2.21	NS	NS	NS
Marbling score[b]	491	483	465	510	NS	0.06	NS
Yield grade[c]	2.89	3.13	2.85	3.17	NS	0.05	NS
Carcass value, $/45.4 kg[d]	130.25	128.49	128.37	130.37	NS	NS	NS

[a]NS = P > 0.10

[b]300 = slight (Se), 400 = small (Ch^-), 500 = modest (Ch^0), 600 = moderate (Ch^+)

[c] Calculated as: yield grade = 2.5 + (2.5*backfat) + (0.0038*carcass weight) + (0.2*KPH) – (0.32*ribeye area)

[d]Calculated as sale price plus/minus premiums/discounts for carcass weight, quality grade, yield grade and value-added programs.

Table 2. Correlation coefficients of ultrasound measurements on d0, 60 and 135 with carcass traits based on grandsire marbling EPD.

	LOW				**HIGH**			
	Backfat	REA[a]	Marbling score	Yield grade[b]	Backfat	REA[a]	Marbling score	Yield grade[b]
				day 0[c]				
UBF[f]	0.13	0.08	0.25	0.16	0.33	-0.03	0.34	0.35
p-value	*0.65*	*0.77*	*0.37*	*0.58*	*0.10*	*0.87*	*0.09*	*0.08*
UMD[g]	0.78	0.32	0.50	0.70	0.40	0.38	0.26	0.12
p-value	*<0.01*	*0.25*	*0.06*	*<0.01*	*0.04*	*0.06*	*0.20*	*0.54*
UMARB[h]	0.32	-0.12	0.48	0.43	0.57	0.22	0.41	0.49
p-value	*0.25*	*0.66*	*0.07*	*0.11*	*<0.01*	*0.27*	*0.04*	*0.01*
				day 60[d]				
UBF[f]	0.70	-0.03	0.63	0.77	0.49	-0.18	0.36	0.56
p-value	*<0.01*	*0.92*	*0.01*	*<0.01*	*0.01*	*0.37*	*0.07*	*<0.01*
UMD[g]	0.27	0.49	0.02	0.24	0.28	0.30	0.10	0.06
p-value	*0.34*	*0.06*	*0.96*	*0.40*	*0.16*	*0.14*	*0.63*	*0.75*
UMARB[h]	0.30	-0.11	0.44	0.37	0.07	-0.41	0.41	0.26
p-value	*0.28*	*0.71*	*0.10*	*0.18*	*0.74*	*0.04*	*0.04*	*0.20*
				day 135[e]				
UBF[f]	0.46	0.37	0.03	0.47	0.63	0.20	0.10	0.46
p-value	*0.10*	*0.19*	*0.91*	*0.09*	*<0.01*	*0.33*	*0.63*	*0.02*
UMD[g]	0.54	0.66	0.39	0.71	0.43	0.14	0.58	0.32
p-value	*0.04*	*0.01*	*0.16*	*<0.01*	*0.03*	*0.50*	*<0.01*	*0.11*
UMARB[h]	0.43	0.00	0.55	0.47	0.43	0.01	0.71	0.40
p-value	*0.12*	*0.99*	*0.04*	*0.09*	*0.03*	*0.98*	*<0.01*	*0.05*

[a]Ribeye area

[b]Calculated as: yield grade = 2.5 + (2.5*backfat) + (0.0038*carcass weight) + (0.2*KPH) – (0.32*ribeye area)

[c]Start of backgrounding phase

[d]Completion of backgrounding phase

[e]Finishing phase (72 days on feed)

[f]Ultrasound estimate of subcutaneous fat depth

[g]Ultrasound estimate of longissimus dorsi muscle depth

[h]Ultrasound estimate of intramuscular fat deposition (marbling)

Table 3. Correlation coefficients of ultrasound measurements on d0, 60 and 135 with carcass traits based on gender.

	Steers				Heifers			
	Backfat	REA[a]	Marbling score	Yield grade[b]	Backfat	REA[a]	Marbling score	Yield grade[b]
				day 0[c]				
UBF[f]	0.29	0.25	0.10	0.18	0.39	0.15	0.34	0.39
p-value	*0.23*	*0.30*	*0.70*	*0.45*	*0.07*	*0.49*	*0.12*	*0.07*
UMD[g]	0.45	0.33	0.55	0.38	0.70	0.60	0.32	0.52
p-value	*0.05*	*0.17*	*0.01*	*0.11*	*<0.01*	*<0.01*	*0.14*	*0.01*
UMARB[h]	0.18	0.11	0.22	0.27	0.77	0.32	0.63	0.73
p-value	*0.47*	*0.65*	*0.37*	*0.27*	*<0.01*	*0.15*	*<0.01*	*<0.01*
				day 60[d]				
UBF[f]	0.42	-0.08	0.23	0.58	0.81	0.25	0.61	0.77
p-value	*0.07*	*0.74*	*0.35*	*<0.01*	*<0.01*	*0.26*	*<0.01*	*<0.01*
UMD[g]	0.22	0.09	0.07	0.26	0.30	0.52	0.14	0.19
p-value	*0.36*	*0.72*	*0.78*	*0.29*	*0.18*	*0.01*	*0.54*	*0.40*
UMARB[h]	0.03	-0.16	0.25	0.35	0.34	0.03	0.44	0.26
p-value	*0.90*	*0.52*	*0.30*	*0.14*	*0.13*	*0.90*	*0.04*	*0.24*
				day 135[e]				
UBF[f]	0.64	0.07	-0.07	0.69	0.61	0.67	0.15	0.47
p-value	*<0.01*	*0.78*	*0.78*	*<0.01*	*<0.01*	*<0.01*	*0.51*	*0.03*
UMD[g]	0.16	0.36	0.22	-0.04	0.64	0.21	0.58	0.67
p-value	*0.54*	*0.16*	*0.39*	*0.88*	*<0.01*	*0.34*	*<0.01*	*<0.01*
UMARB[h]	0.17	0.27	0.45	0.20	0.63	0.19	0.63	0.58
p-value	*0.50*	*0.30*	*0.07*	*0.43*	*<0.01*	*0.41*	*<0.01*	*<0.01*

[a]Ribeye area
[b]Calculated as: yield grade = 2.5 + (2.5*backfat) + (0.0038*carcass weight) + (0.2*KPH) – (0.32*ribeye area)
[c]Start of backgrounding phase
[d]Completion of backgrounding phase
[e]Finishing phase (72 days on feed)
[f]Ultrasound estimate of subcutaneous fat depth
[g]Ultrasound estimate of longissimus dorsi muscle depth
[h]Ultrasound estimate of intramuscular fat deposition (marbling)

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INCIDENCE OF QUALITY DEFECTS IN MARKET BEEF AND DAIRY COWS AND BULLS SOLD THROUGH LIVESTOCK AUCTION MARKETS IN THE WESTERN UNITED STATES[1]

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ABSTRACT: The incidence of Beef Quality Assurance-related defects in market beef and dairy cows and bulls selling at auction was determined during 2 seasons in 2008. Traits were evaluated by 9 trained personnel during sales at 10 livestock auction markets in Idaho (n = 5; beef and dairy), California, (n = 4; dairy only), and Utah (n = 1; beef and dairy). Overall, 18,949 unique lots (8,213 beef cows, 1,036 beef bulls, 9,177 dairy cows, and 523 dairy bulls,) consisting of 23,479 head (9,299 beef cows, 1,091 beef bulls, 12,429 dairy cows, and 660 dairy bulls,) were evaluated. Market cattle weighed 548 ± 103.6 kg (beef cows), 751 ± 176.1 kg (beef bulls), 658 ± 129.7 kg (dairy cows), and 731 ± 150.8 kg (dairy bulls). Mean BCS for beef cattle (9-point scale) was 4.7 ± 1.24 (cows) and 5.3 ± 0.94 (bulls), and for dairy cattle (5-point scale) was 2.6 ± 0.76 (cows) and 2.9 ± 0.56 (bulls). Some 16.5% of beef cows and 4.1% of beef bulls were thin (beef BCS 1 to 3) while 34.8% of dairy cows and 10.4% of dairy bulls had a dairy BCS of 2.0 or less. Among beef cattle, 85% of cows and bulls were considered to not be lame. However, 45% of dairy cows and 26% of dairy bulls were considered lame. Hot-iron brands were observed in 60.6 % of beef cows and 57.3% of beef bulls, but only in 27.9 and 29.1% of dairy cows and bulls, respectively. Some stage of ocular neoplasia was observed in 0.6% and 0.3% of beef cows and bulls (respectively) and 0.25% of dairy cows and 0.0% of dairy bulls. Cattle classified as visibly sick included 0.84% of beef cows, 2.95% of dairy cows, 0.10% of beef bulls, and 1.15% of dairy bulls. Lots that were no-saled included 0.15% of beef cow lots, 1.5% of dairy cow lots, and no bull lots. Results suggest that incidence rates of quality defects among both market beef and dairy cattle selling at auction in the Western United States are substantial.

Key words: auction market, Beef Quality Assurance, market beef cattle, market dairy cattle

Introduction

Twenty percent of all cattle harvested in the U.S. during 2009 were market beef cows (3.0 million), market dairy cows (2.6 million), or market bulls (525,000; USDA, 2009). Quality improvements in some classes of market cattle were documented during the 2007 National Market Cow and Bull Beef Quality Audit (**NMCBBQA**; Hale et al., 2007), compared to previous audits in 1994 (NCBA, 1994) and 1999 (Roeber et al., 2000). However, 31% of cattle evaluated in the holding pens in 2007 still had at least one visible quality defect, and market dairy cows had the most defects compared to beef cows, beef bulls, and dairy bulls (Hale et al., 2007).

The incidence of Beef Quality Assurance (**BQA**)-related defects among market cow and bulls in packing plant holding pens has been well documented (NCBA, 1994; Roeber et al., 2000; Delmore et al., 2006; Hale et al., 2007). However, literature that includes the incidence of BQA defects in market cows and bulls prior to harvest but after leaving the farm or ranch is limited. Further, in the U.S. the majority of market cows and bulls are sold immediately prior to harvest through livestock auction markets, based on the presence of auction market back tags among 67% of NMCBBQA-2007 cattle (Hale et al., 2007).

Therefore, this experiment was conducted in order to document the incidence of BQA-related defects in market beef and dairy cows and bulls sold through livestock auction markets, and to establish a baseline for quality defect incidence and magnitude among market cattle in the western U.S.

Materials and Methods

Market cows and bulls were evaluated for BQA-related variables while offered for sale in ring at major livestock auction markets with regular weekly sales in Idaho (n = 5; beef and dairy), California, (n = 4; dairy only), and Utah (n = 1; beef and dairy). Locations were selected based on the number of market cattle typically sold each week, accessibility by data collectors, and willingness of markets to participate. Verbal approval was acquired from each auction market prior to initiation of data collection. During each of 2 seasons in 2008 (spring = March 11 through May 9; fall = August 26 through November 4), data were collected on market beef and dairy cows and bulls offered for sale at 5 to 8 sales per location during each season.

Data were collected by 9 professionals trained in uniform collection procedures for both objective and subjective data collection consistent with previous audits (NCBA, 1994; Roeber et al., 2000; Hale et al., 2007). Data collected on every lot included: type (beef or dairy), lot size, total lot weight, selling price, sex, predominant breed, BCS using the 9-point beef (1 = emaciated, 9 = obese; Richards et al., 1986) or 5-point dairy (1 = emaciated, 5 = obese; Wildman et al., 1982) scale, and locomotion score

[1]This project was funded in part by cattle producers through their $1-per-head beef checkoff via the Cattlemen's Beef Board, Idaho Beef Council, and California Beef Council.

(**LS**) using a 5-point scale (1 = normal, 5 = extremely lame; Sprecher et al., 1997). The presence of specific BQA-related defects was also recorded, including brand presence and size/number, horn presence and length, and ocular neoplasia (cancer eye) using a 6-point scoring system (0 = none, 5 = prolapsed eyeball; Hale et al., 2007). Animals that were passed out or no-saled were also recorded. Data were only collected on bulls and cows intended for immediate harvest. For lots containing 2 or more animals, one animal was randomly chosen and evaluated for all traits.

Statistical Analyses. The frequency that observed factors occurred (by sex and type) was determined using PROC SURVEYFREQ procedures of SAS. Prior to analysis, dummy variables (Gujarati, 2003) were used to test for observer bias and regional differences.

Results and Discussion

Incidence rates of BQA-related traits in market beef and dairy cows and bulls were collected on a total of 18,949 unique lots (9,247 beef; 9,700 dairy), which consisted of 23,479 animals (10,390 beef; 13,089 dairy). In total, 89% of beef lots (89% of beef animals) and 95% of dairy lots (95% of dairy animals) consisted of market cows.

Black was the predominant hide color among 60.9% of market beef cows and 71.3% of market bulls. Red hides (including white-faced cattle) were observed in 30.8 and 20.1% of market cows and bulls, respectively. White was the next most frequent hide color (2.3% of cows, 3.1% of bulls), while other colors made up 8.5 and 8.2% of market cows and bulls, respectively. Among dairy cattle, the vast majority of market dairy cows and bulls had the Holstein hide pattern (95.4 and 93.6%) followed by Jersey (3.7 and 4.1%). Other dairy breeds (e.g. Brown Swiss, Guernsey, Ayrshire, Milking Shorthorn, etc.) were represented in only 0.8 and 2.3% of cows and bulls, respectively.

According to Hale et al. (2007), in the most recent NMCBBQA black hides were the most common among market beef cattle (44% cows, 52% bulls), followed by red (32% cows, 29% bulls) and white (6% cows, 10% bulls). Among market dairy cows and bulls, the authors reported that Holstein was the most common hide pattern (93 and 90%, respectively).

Tables 1 and 2 contain the distribution of BW among market beef and dairy cattle, respectively. Market beef cows and bulls had a mean BW ± SD of 548 ± 103.6 kg and 751 ± 176.1 kg, while market dairy cows and bulls weighed 658 ± 129.7 kg and 731 ± 150.8 kg, respectively. Previous audits did not evaluate animals for BW prior to harvest, but instead collected hot carcass weight data. The 455 to 727 kg category included 79.6% of market beef cows, and 73.8% of market beef bulls weighed 545 to 954 kg. However, 16.0% of market beef cows and 14.5% of market beef bulls weighed less than 455 and 545 kg, respectively. Similarly, 70.2% of market dairy cows weighed 545 to 818 kg and 81.5% of market dairy bulls weighed 545 to 954 kg, while 19.5% of dairy cows and 13.1% of dairy bulls weighed less than 545 kg.

The mean BCS ± SD for market beef cows and bulls (on the 9-point beef scale) was 4.7 ± 1.24 and 5.3 ± 0.94, respectively (Table 3). In comparison, 2,800 beef cows and 431 beef bulls evaluated for BCS during the most recent NMCBBQA had a mean BCS that was slightly lower than the current study at 4.5 and 4.9, respectively (Hale et al., 2007). In the current study, 77.2% of beef cows and 88.8% of beef bulls were BCS 4 to 6; however, 16.5% of cows and 4.1% of bulls were BCS 1, 2 or 3. In contrast, Hale et al. (2007) reported that only 58% of beef cows and 75% of beef bulls were BCS 4 to 6, with 30% of beef cows and 14% of beef bulls being BCS 1, 2 or 3. The authors also indicated that 12% of beef cows and 11% of beef bulls had a BCS of 7 or greater. Only 6.2% of cows and 7.2% of bulls in the current study had a BCS of 7 or greater. Much fewer beef cows and bulls in the current study were emaciated (BCS = 1) vs. the NMCBBQA-2007 (0.3 vs. 0.9% for cows, 0.0 vs. 0.5% for bulls, respectively).

Market dairy cows and bulls had a mean BCS (on the 5-point dairy scale) of 2.6 ± 0.76 and 2.9 ± 0.56, respectively (Table 4). In comparison, mean BCS values of 2.5 and 3.4 were reported for market dairy cows and bulls in the recent NMCBBQA (Hale et al., 2007). The target BCS range of 2.5 to 3.5 (identified by Hale et al., 2007) included 58.8% of dairy cows and 83.3% of dairy bulls in the current study. In comparison, NMCBBQA dairy cattle in these categories included 49.5% of cows and 54.9% of bulls (Hale et al., 2007).

Unfortunately, in the current study 34.8% of market dairy cows and 10.4% of dairy bulls had an inadequate BCS of 2.0 or less. The incidence of emaciated dairy cattle (BCW = 1) was lower in the current study vs. the NMCBBQA-2007 (cows 1.7 vs. 6.0%; bulls 0.0 vs. 1.6%). However, only 6.5% of dairy cows and 6.0% of dairy bulls had a BCS of 4.0 or greater, which was numerically lower than the NMCBBQA-2007 (cows 9.0%, bulls 36.3%).

The distribution of LS for market beef and dairy cows and bulls are included in Table 5. The mean LS ± SD were 1.2 ± 0.50 and 1.2 ± 0.61 for beef cows and bulls and 1.7 ± 0.87 and 1.5 ± 0.89 for dairy cows and bulls, respectively. Eighty-five percent of beef cows were considered to be not lame (LS = 1), which was nearly identical to the 84% of beef cows observed in the NMCBBQA-2007 that were not lame (Hale et al., 2007). However, the authors reported only 69% of beef bulls to be not lame, which was much lower than observed in the current study (85%). Further, the incidence of beef bulls with an LS or 4 or 5 in the NMCBBQA-2007 was three times that of the current study (6.3 vs. 2.0%).

Among dairy cattle, only 55% of cows and 74% of bulls were considered not lame. Interestingly, similar percentages of 51 and 77% of dairy cows and bulls, respectively, documented by the NMCBBQA-2007, were not lame. It is concerning that almost half (44.7%) of the dairy cows in the current study were lame at some level. More specifically, 4.2% of all dairy cows and 7.2% of all dairy bulls had severe lameness (LS of 4 or 5). This is comparable to the 8.1 and 3.9% of cows and bulls (respectively) with an LS of 4 or 5 in the NMCBBQA-2007. As well, Pennsylvania dairy farmers indicated that 5% of the cows in their herds were non-ambulatory each year, based on a statewide survey (Tozer et al., 2004). The authors further indicated that the principal reason for non-

ambulatory cows was metabolic disorders among smaller herds and injuries in larger herds.

Animals were assigned an LS of 4 or 5 if they favored one or more feet/legs (LS 4) or would not put any weight on one foot/leg (LS 5; Sprecher et al., 1997). In both cases, these animals were not capable of effectively navigating an auction market without tremendous increased risk of further injury and potentially becoming non-ambulatory. Since "Animal welfare and handling issues" ranked third during the interview portion of the NMCBBQA-2007 (Hale et al., 2007), it is clear that market cattle with an LS of 4 or 5 should not be sold via an auction market. Instead, market cows or bulls should be sold in a timely manner (with an LS 3 or better), rehabilitated at the farm in a separate pen for a finite period of time, and(or) euthanized on-farm before lameness becomes advanced (LS 4 or 5).

Evidence of a hot-iron brand was observed in the majority of beef cows and bulls (60.6 and 57.3%, respectively), but in just over one-quarter of dairy cows and bulls (27.9 and 29.1%, respectively; Table 6). In comparison, NMCBBQA-2007 researchers reported that 31 and 38% of beef cows and bulls (respectively) had a branded hide, which was lower than observed in the current study. The authors also reported that brands were on 10% of dairy cows, which was much lower than observed in the current trial, and 28% of dairy bulls which was comparable to Table 6. Major brands (a very large brand or several brands) were observed in 20.5 and 16.4% of market cows and bulls (respectively), but in 1.3 and 1.7% of dairy cows and bulls (respectively). Brand location was not evaluated in the current study.

As seen in Table 6, most cows (91.0% beef, 95.0% dairy) and bulls (86.4% beef, 83.9% dairy) did not have horns. These rates were slightly higher than in the NMCBBQA-2007 (81% of beef cows, 80% of beef bulls, and 90% of dairy cows were hornless), with the exception of exception of dairy bulls (55% were hornless). Among cattle with horns, most beef cows and bulls had horns that were greater than 12.7 cm long, while most dairy cows and bulls had horns that were less than 12.7 cm long, which was consistent with NMCBBQA-2007 data. Based on the large percentage of dairy bulls observed with horns less than 2.54 cm (16%) or 2.54 to 12.7 cm (24%) long in the NMCBBQA-2007, data suggest that dehorning may not have been done properly vs. the current study.

Less than 1% of cattle were observed with some stage of ocular neoplasia: 0.6 and 0.3% of beef cows and bulls (respectively), 0.25% of dairy cows, and 0.0% of dairy bulls. Higher incidence rates of ocular neoplasia were reported by NMCBBQA-2007 researchers, based on it being observed in 3.8% of beef cows, 2.8% of beef bulls, 1.7% of dairy cows, and 0.9% of dairy bulls. In the current study, of the animals with ocular neoplasia, 66% of beef bulls and 52% of dairy cows were at a pre-cancerous stage (score of 1 or 2); however, 86% of beef cows with ocular neoplasia were at a cancerous stage (score of 3, 4, or 5). In the NMCBBQA-2007, among cattle with ocular neoplasia, 67% of beef cows, 42% of beef bulls, 72% of dairy cows, and 100% of dairy bulls were at the cancerous stage. Amazingly, in the current study 0.12% of beef cows and 0.01% of dairy cows were still offered for sale at auction even though the eyeball was prolapsed from the orbit (score of 5). In comparison, an ocular neoplasia score of 5 was observed in 0.5% of beef cows, 0.3% of beef bulls, 0.1% of dairy cows, and 0.0% of dairy bulls evaluated during the NMCBBQA-2007 (Hale et al., 2007).

An alarming number of animals subjectively characterized as visibly sick in the auction ring were offered for sale (Table 6). Cows were classified as sick if they were lethargic, extremely weak, panting significantly, had down ears, or were extremely gaunt. Cattle classified as sick included 0.84% of beef cows, 2.95% of dairy cows, 0.10% of beef bulls, and 1.15% of dairy bulls.

A limited number of beef cow lots (0.15%) offered for sale to auction market buyers were no-saled or passed out since no buyers would buy them at any price. Of most concern was that 1.5% of dairy cow lots offered for sale were no-saled. These cows typically did not sell due to the presence of one or more major BQA defects. A small percentage (0.15%) of beef cow lots, and no bull lots, were no-saled.

Implications

This study provides dairy and beef producers with information about the incidence of market cow and bull quality defect incidence in the western U.S. Based on the relatively high incidence of Beef Quality Assurance-related defects documented in this study, producer education related to management practices is warranted including reinforcing the recommendation to cull animals in a timely manner to avoid quality defects.

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Table 1. Body weight distribution of market beef cows and bulls evaluated at auction[1]

Beef cows		Beef bulls	
Weight class (kg)	%	Weight class (kg)	%
< 364	3.2	< 409	3.0
364-454	12.8	409-545	11.5
455-545	34.0	545-681	17.9
545-636	32.3	682-818	30.3
636-727	13.3	818-954	25.6
727-818	3.4	955-1,090	10.7
≥ 818	1.0	≥ 1,091	1.1

[1]Data were collected during 79 sales at 6 locations in Idaho (n = 5) and Utah (n = 1) during 2 seasons.

Table 2. Body weight distribution of market dairy cows and bulls evaluated at auction[1]

Dairy cows		Dairy bulls	
Weight class (kg)	%	Weight class (kg)	%
< 455	5.4	< 409	1.1
455-545	14.1	409-545	12.0
545-636	23.3	545-681	20.7
636-727	26.3	682-818	37.5
727-818	20.6	818-954	23.3
818-909	8.7	955-1,090	4.6
≥ 909	1.6	≥ 1,091	0.8

[1]Data were collected during 125 sales at 10 major livestock auction markets with regular weekly sales in California (n = 4), Idaho (n = 5), Utah (n = 1) during 2 seasons.

Table 3. Body condition score (BCS) distribution of market beef cows and bulls evaluated at auction[1]

BCS[2]	Cows (%)	SE	Bulls (%)	SE
1.0	0.3	0.0621	0.0	0.00
2.0	3.6	0.2055	0.3	0.1675
3.0	12.6	0.3661	3.8	0.5933?
4.0	26.7	0.4889	12.2	1.0187
5.0	32.4	0.5171	37.2	1.5043
6.0	18.1	0.4252	39.4	1.5211
7.0	5.1	0.2439	6.8	0.7824
8.0	1.0	0.1113	0.4	0.1933
9.0	0.1	0.0404	0.0	0.00

[1]Data were collected during 79 sales at 6 locations in Idaho (n = 5) and Utah (n = 1) during 2 seasons.
[2]BCS beef scale: 1 = emaciated, 9 = obese (Richards et al., 1986).

Table 4. Body condition score (BCS) distribution of market dairy cows and bulls evaluated at auction[1]

BCS[2]	Cows (%)	SE	Bulls (%)	SE
1.0	1.7	0.14	0.0	0.00
1.5	11.6	0.33	0.8	0.38
2.0	21.5	0.43	9.6	1.29
2.5	21.1	0.43	30.3	2.01
3.0	23.7	0.44	33.0	2.06
3.5	14.0	0.36	20.5	1.77
4.0	4.8	0.22	5.2	0.970
4.5	1.5	0.13	0.0	0.00
5.0	0.2	0.04	0.8	0.38

[1]Data were collected during 125 sales at 10 major livestock auction markets with regular weekly sales in California (n = 4), Idaho (n = 5), Utah (n = 1).
[2]BCS dairy scale: 1 = emaciated, 5 = obese (Wildman et al., 1982).

Table 5. Locomotion score (LS) distribution of market beef and dairy cows and bulls evaluated at auction[1]

	Beef				Dairy			
			Bulls		Cows		Bulls	
LS[2]	Cows (%)	SE	(%)	SE	(%)	SE	(%)	SE
1	84.9	0.40	84.6	1.31	55.3	0.52	73.9	1.94
2	12.1	0.36	10.8	0.97	26.5	0.46	14.8	1.57
3	2.3	0.17	2.6	0.50	14.0	0.36	4.1	0.88
4	0.6	0.09	1.6	0.39	4.0	0.20	6.6	1.10
5	0.1	0.03?	0.4	0.20	0.2	0.05	0.6	0.34

[1]Data were collected during 125 sales at 10 major livestock auction markets with regular weekly sales in California (n = 4), Idaho (n = 5), Utah (n = 1).
[2]LS scale: 1 = normal, 5 = severely lame (Sprecher et al., 1997).

Table 6. Incidence rates for selected Beef Quality Assurance (BQA) defects in market beef and dairy cows and bulls evaluated at auction[1]

	Beef				Dairy			
	Cows		Bulls		Cows		Bulls	
BQA defect	(%)	SE	(%)	SE	(%)	SE	(%)	SE
Branded	60.64	0.54	57.34	1.54	27.88	0.468	29.06	1.987
Major brand(s)	20.50	0.45	16.41	1.15	1.25	0.116	1.72	0.569
No horns	90.97	0.32	86.39	1.07	94.99	0.228	83.94	1.607
Horns < 2.54 cm	0.83	0.10	1.06	0.32	1.79	0.138	3.63	0.819
Horns 2.54-12.70 cm	2.35	0.17	2.32	0.47	2.58	0.166	9.18	1.264
Horns > 12.70 cm	5.86	0.26	10.23	0.94	0.64	0.083	3.25	0.776
No ocular neoplasia	99.40	0.09	99.71	0.17	99.75	0.052	100.00	0.000
Ocular neoplasia score 1	0.10	0.03	0.00	--	0.10	0.033	0.00	0.000
Ocular neoplasia score 2	0.06	0.03	0.19	0.14	0.03	0.019	0.00	0.000
Ocular neoplasia score 3	0.22	0.05	0.00	--	0.08	0.029	0.00	0.000
Ocular neoplasia score 4	0.10	0.03	0.10	0.10	0.03	0.019	0.00	0.000
Ocular neoplasia score 5	0.12	0.04	0.00	--	0.01	0.011	0.00	0.000
Visibly sick	0.84	0.10	0.10	0.10	2.95	0.177	1.15	0.466
No sale[2]	0.15	0.04	0.00	--	1.48	0.126	0.00	0.000

[1]Data were collected during 125 sales at 10 major livestock auction markets with regular weekly sales in California (n = 4), Idaho (n = 5), Utah (n = 1).
[2]No sale = passed out.

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BREEDING PERFORMANCE OF RAMS IN TWO WYOMING PRODUCER FLOCKS

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Poor mating behavior results in increased ram costs, extended lambing seasons, and decreased genetic progress from sires with desired production traits. Producers recognize the importance of ram libido; however, time, labor, and facility constraints generally limit its routine evaluation. Although approximately 23% of all rams were predicted to exhibit poor-mating behaviors, breeding performance of individual rams in multi-sire flocks typical of Wyoming range operations has not been determined. Therefore, goals of the current experiment were to determine the incidence of low- and high sexually performing rams and numbers of lambs sired by each ram in two representative range flocks. All rams successfully passed breeding soundness evaluations conducted prior to the onset of the breeding season. Blood samples were collected from all rams, and approximately one-third of the lambs and their dams for paternal genotyping using microsatellite markers. Assuming each ram had equal opportunity to mate with ewes in estrus, number of lambs expected to be sired by each ram was established by calculating 99% confidence intervals for the mean in each flock. In flock one, sires (n = 24) for 290 lambs (80% of lamb samples) were successfully identified. Of those rams, 7 (29%) sired less than, 11(46%) equal to, and 6 (25%) sired more lambs than predicted (siring 6.9, 47.6, and 45.5% of the sampled lambs, respectively) based on the 99% confidence interval. In the second flock, sires (n = 13) for 170 lambs (85% of lamb samples) were successfully identified. Similar to flock one, 3 (23%) rams sired less than, 7 (54%) equal to, and 3 (23%) sired more lambs than predicted siring 8.2, 54.4, and 39.4% of the sampled lambs, respectively. These data emphasize the importance of identifying and eliminating poor-sexually performing rams to reduce sire costs. In addition, the identification and use of high-sexually performing rams with desired genetic traits is a requisite to the timely incorporation of those traits into a flock. Supported by USDA-NRI 2007-55618-18176

Introduction

Ram selection is fundamental to the profitability of a flock and is based on desired physical and performance traits. Selection processes, however, rarely include an evaluation of sexual behavior even though the ability and desire to mate with ewes in estrus is required for incorporation of superior genetics into a flock. Differences in mating behavior exist among individuals of all species studied (Meisel and Sach, 1994). Price (1987) suggested that as many rams could be culled for poor mating behaviors as are culled for physical limitations or poor semen quality. Stellflug et al. (2006) confirmed that twice as many poor-performing rams were needed to obtain breeding results equal to a single high-sexually performing ram. Low mating behavior results in the need for additional rams, extends the lambing season, and decreases the number of lambs born per ewe lambing (SID, 1996; Carr et al., 2001). Based on serving capacity tests, Hulet et al. (1964) classified 29.6% of rams at the USDA-ARS Sheep Experiment Station (USSES) as non-performers. Nearly 30 years later, Fitzgerald and Perkins (1991) reported that 28.1% of the rams were non-performers at the same station.

Even though the influence of ram mating behavior on conception and lambing rates has been demonstrated in pen (Perkins et al., 1992) and field (Mattner et al., 1971; Stellflug et al., 2006) trials, it is important to determine the

incidence of rams with poor-mating behavior in producer flocks to evaluate their impact on breeding success, genetic progress, and profitability. Therefore, the current experiment was conducted to determine the incidence of low- and high-sexually performing rams in two representative Wyoming producer-flocks.

Materials and Methods

Prior to the onset of the breeding season, blood samples were collected from rams that successfully passed breeding soundness examinations (SID, 1996). At lambing, blood samples were collected from a subset of the ewes and one of their lambs. Flocks one and two used 24 and 13 rams to breed 1200 and 400 ewes, respectively. Paternal genotyping of lambs was determined using microsatellite markers described by Stellflug et al. (2006) for flock one or microsatellite markers available in the UC Davis Veterinary Genetics Laboratory (http://www.vgl.ucdavis.edu) for flock two. Assuming each ram had equal opportunity to mate with ewes in estrus, number of lambs expected to be sired by each ram was established by calculating 99% confidence intervals for mean lambs sired in each flock. Rams that sired numbers of lambs within the bounds of the respective confidence intervals were classified as intermediate-sexually performing rams. Rams that sired greater or less than numbers of lambs predicted by the confidence intervals were categorized as "outliers" and were designated as high- or poor-sexually performing rams, respectively. Since the sire of only one lamb per ewe was determined, number of lambs sired and ewes mated was assumed equivalent.

Results and Discussion

Sires for 80 (n = 290) and 85% (n = 170) of the lamb samples were identified by paternal genotyping in flocks one and two, respectively. In flock one, seven rams (29%) sired less and six rams (25%) more lambs than predicted (Fig. 1). Likewise in flock two, 23% (n = 3) of the rams sired less and 33% of the rams sired more lambs than predicted (Fig. 2). The remaining 11 (46%) and 7 (54%) rams in flocks one and two, respectively, sired intermediate numbers as predicted by the 99% confidence intervals for each flock. The incidence of poor-, intermediate- and high-sexually performing rams were similar to values previously reported at the USSES (Stellflug et al., 2006).

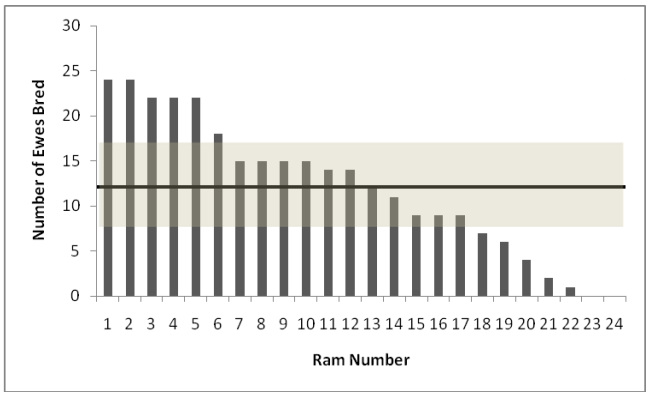

Figure 1. Prolificacy of individual rams (n= 24) in Flock 1 as determined by paternal genotyping.

The proportion of the lamb crop sired by each ram category is listed in Table 1. The small number of high-sexually performing sires in each flock sired nearly as many lambs as intermediate performing rams. Less than 10% of the ewes conceived to low-sexually performing rams.

In conclusion, proportions of high-, intermediate- and low-sexually performing rams in producer flocks are similar to earlier reports. Methods to eliminate low-sexually performing rams and identify high-sexually performing rams are needed to reduce ram costs, promote the incorporation of desired genetics in a flock, and improve the profitability of sheep producers.

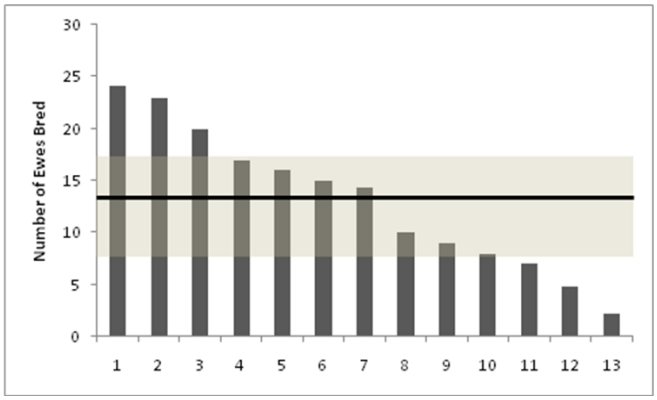

Figure 2. Prolificacy of individual rams (n = 13) in Flock 2 as determined by paternal genotyping.

Implications

Rams with poor breeding behaviors need to be culled to decrease costs of lamb production and enhance incorporation of desired genetics. Selection of rams with high breeding behaviors could drastically reduce the number of sires required for a flock.

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Table 1. Proportion of lamb crop sired by poor-, intermediate-, and high-sexually performing rams in two producer flocks.

Performance Category	Flock (n)	Lamb crop % (n)[1]
Poor	**1 (n = 7)**	**6.9 (n = 20)**
	2 (n = 3)	**8.2 (n = 14)**
Intermediate	**1 (n = 11)**	**47.6 (n = 138)**
	2 (n = 7)	**54.4 (n = 89)**
High	**1 (n = 6)**	**45.5 (n = 132)**
	2 (n = 3)	**39.4 (n = 67)**

[1]Total number of lambs sired by rams within flocks for each behavior category.

RUMINANT NUTRITION

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EFFECT OF SUPPLEMENTAL CORN DRY DISTILLER GRAINS PLUS SOLUBLES ON DIGESTIBILITY OF STEERS GRAZING NATIVE RANGE DURING SUMMER GROWING SEASON

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ABSTRACT: Sixteen English-crossbred steers (360 ± 28.9 kg) fitted with ruminal cannulas grazing native range during the summer growing season were used in a completely randomized design to evaluate effects of corn distiller grains plus solubles (**DDGS**) supplementation level (0, 0.2, 0.4, and 0.6% BW) on forage intake, digestibility, and rumen fermentation characteristics. The experiment was conducted during the first and second weeks of October, 2008. Steers grazed a single native range pasture with supplements offered individually once daily at 0700. Forage OM, NDF, CP, and EE intake decreased ($P \leq 0.05$) linearly with increasing DDGS supplementation level. Total CP and EE intake increased ($P < 0.01$) with increasing DDGS supplementation level. Digestibility of OM, CP, and NDF increased (linear; $P < 0.01$) with increasing DDGS supplementation level while digestion of EE increased (linear and cubic effect; $P \leq 0.04$) with increasing DDGS supplementation level (40.8, 54.3, 51.0, and 70.1 ≥ 3.9% for 0, 0.2, 0.4, and 0.6 % of BW, respectively). Forage masticate in situ soluble linearly increased ($P < 0.01$) and slowly degradable CP fraction linearly decreased ($P > 0.01$) with increasing DDGS supplementation level. Forage in situ masticate DM and NDF disappearance rate increased (quadratic; $P \leq 0.05$) and DDGS in situ DM disappearance rate increased (linear; $P > 0.03$) with increasing supplementation levels. Forage and DDGS UIP (% of CP), ruminal pH, and VFA concentration were not affected ($P \geq 0.25$) by DDGS supplementation level. These results indicate that DDGS supplementation improved total CP and EE intake and digestibility of OM, NDF, CP, and EE of steers grazing native range during the forage growing season. Therefore, DDGS represent a viable supplement for cattle grazing native range during the forage growing season when forage has medium or high quality.

Keywords: DDGS, grazing, native range, steers

Introduction

Supplementation of grazing animals has long been used to improve grazing production performance. During summer dormancy, or fall and winter months, when forage quality is low, provision of nutrients to cattle to compensate for deficiencies is practiced often (Caton and Dhuyvetter, 1997). In medium to high-quality forage, such as that during summer growing season, forage is often low in available energy in relation to protein (Pordomingo et al., 1991). Supplementation of energy rather than protein seems to result in favorable responses in BW gain when consuming medium to high-quality forage (Brake et al., 1989). Common sources of supplemental energy vary widely and include grains, readily digestible fiber sources, and high-quality forages (Caton and Dhuyvetter, 1997). Corn supplementation at 0.2% of BW increased forage intake, but greater supplementation levels decreased forage intake (Pordomingo et al., 1991). Several studies involving harvested roughages have demonstrated that the starch contained in grains has detrimental effects on fiber utilization (Fick et al., 1973; Sanson et al., 1990).

With increased demand for ethanol as a biofuel, the availability of cereal grains for livestock production is decreasing (Gottschalk, 2007). Dry distillers grains plus condensed solubles (**DDGS**) are byproducts of fermented cereal grains, corn especially, from the production of ethanol. An increase in the availability of these byproducts is correlated to the rapid expansion of the ethanol industry. These by-products are recognized for being high in readily digestible fiber, protein, and phosphorus (Morris et al., 2006). Due to the removal of starch during ethanol production, DDGS' concern regarding starch and forage digestibility are removed (Morris et al., 2005). These characteristics make the product an attractive supplement for medium- to high-quality forages. However, little is known about the optimum level of DDGS supplementation to cattle grazing medium to high-quality forage and effects on characteristics of digestion.

The objective of this study was to evaluate the effect of DDGS supplementation on forage intake and digestion of steers grazing native range during summer in the Southern Plains.

Materials and Methods

Animals, Facilities, and Diet. Procedures were approved by the New Mexico State University Institutional Animal Care and Use Committee. Sixteen mixed-breed steers (361 ± 28.4 kg) fitted with ruminal cannulas were used in a randomized complete block design. Treatments consisted of 4 DDGS supplementation levels: 0% (no supplement), 0.2%, 0.4%, or 0.6% of BW. Nutrient content of DDGS averaged 29.7% CP, 27.4% NDF, 10.2% ADF, 12.1% fat (EE), 5.9% starch, 0.04% Ca, 0.92% P, and 0.60% of S on a DM basis. The experiment consisted of a 15-d experimental period during the latter part of the forage

growing season (beginning of October 2008). The first 10 d of the experimental period were used for adaptation to native range pasture grazing and supplement, and the last 5 d for sample collection. The experiment was conducted from September 25 to October 9 which represents the latter part of the forage growing season. Steers grazed a single native range pasture (Clayton Livestock Research Center, Clayton, NM; sideoats, bluegrama, old world bluestem, galletagrass, and buffalograss; *Bouteloua curtipendula, Bouteloua gracilis, Andropogon gerardii, Hilaria jamesii*, and *Buchloe dactyloides*, respectively), and individually received the DDGS supplement once daily at 0700. Steers were allowed access to the supplement for 30 min after which uneaten supplement was placed into the rumen through the ruminal cannula.

Collections. Fecal output was estimated with chromic oxide as an undigestible marker. Gelatin capsules containing chromic oxide (8 g) were dosed ruminally twice daily (0700 and 1900) on d 6 through 15 of the experimental period. Eight fecal samples from rectal grabs were collected in a 4-d period to represent 1 every 3 h in a 24-h period. Fecal samples were collected from all steers as follows: d 11, 1300; d 12, 0100 and 1900; d 13, 1600 and 2200; d 14, 0700; d 15, 0400 and 1000. Fecal samples from each steer were composited within steer for analysis. Two of the 16 cannulated steers grazing native range were gathered into a holding pen for ruminal evacuation at 0600 1 d before the experimental period. Digesta was placed in plastic bags lining 133-L plastic containers. Evacuated steers were allowed to graze native range pasture for 2 h. Then, steers were re-gathered and masticate samples were collected and dried in a forced air oven (55 °C) to a constant weight, and ground in a Wiley mill (2-mm screen, Wiley mill model 4, Thomas Scientific, Swedesboro, NJ). Five gram samples of DDGS or forage were weighed and sealed with an impulse sealer into dacron bags (10 x 20 cm, 50 ± 15 µm pore size; Bar Diamond, Parma, ID). On d 12 to 15 of the experimental period, forage and DDGS in situ bags were ruminally incubated within nylon lingerie washing bags (30.5 x 25.4 cm) for 72, 48, 36, 24, 14, 9, 5, 2, and 0 h in all steers. All bags were removed at 0 h and rinsed with tap water to remove large particulate matter. A top-loading washing machine in a delicate cycle setting was used to rinse in situ bags. The machine was filled with 45 L of cold water, and bags were agitated for 1 min, after which the machine was drained, and bags were spun for 2 min. The procedure was repeated 5 times for all bags. Bags were dried in a forced air oven at 55 °C, weighed and stored at room temperature for analysis of DM, NDF, CP, and purines. At 1900 on d 15 of the experimental period a 2-kg subsample of ruminal content was obtained 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 at - 10°C for later bacterial isolation.

Laboratory Analysis. Fecal and rumen content samples were thawed, after which fecal samples were mixed, and sub-sampled (10% of total). Rumen content, fecal, DDGS, 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 with a Wiley mill. Fecal, DDGS, and masticate samples were analyzed for DM, OM, and CP (Methods 930.15, 942.05, and 990.02, respectively; AOAC, 1997). Analysis to determine NDF concentrations were performed according to Robertson and Van Soest (1991) using an Ankom 200 fiber analyzer (Ankom Co., Fairport, NY). Ether extract determinations were performed according to procedures described by Galyean (1997). Starch content of DDGS was determined according to the procedures of MacRae and Armstrong (1986). Masticate and DDGS in vitro OM digestibility was determined according to Tilley and Terry (1963), with the use of a composite inoculate from 2 ruminally cannulated cows consuming alfalfa hay. Rumen bacteria were isolated from a 2-kg sample of rumen contents. Rumen contents were placed and blended in a high-speed food processor at maximum speed for 1 min. The mixture was strained through 4 layers of cheesecloth. The strained liquid was centrifuged at 1,000 x g for 20 min to remove feed particles and protozoa. Bacteria were separated from supernatant by centrifugation at 20,000 x g for 20 min. Isolated bacteria were placed in a forced air oven (50°C) to dry for 1 h and analyzed for DM, ash, N (as previously described) and purines (Zinn and Owens, 1986).

Calculations. Supplement fecal output was calculated by multiplying supplement intake by in situ supplement DM indigestibility at 48 h. The dilution concentration of Cr daily dose in the feces was used to determine total fecal output. Forage fecal output was calculated by subtracting supplement fecal output from total fecal output. Forage DM intake was calculated by dividing forage DM fecal output by forage in situ DM indigestibility after 48 h. Nutrient intake of forage and supplement were calculated by multiplying the respective intake times the concentration of each nutrient (DM basis). Fecal nutrient output was calculated by multiplying total fecal output times the concentration of each nutrient in the feces on a DM basis. Total nutrient intake was determined by the addition of nutrients in forage estimate intake and DDGS consumed. The Ørskov and McDonald (1979) model (d = a + b (1 – e-kd)) where a is the insoluble fraction, b is the slowly degradable fraction, d is the extent of digestion, and kd is the rate of degradation, was used to evaluate in situ CP data. Protein remainders in forage and DDGS in situ bags were adjusted for microbial protein contamination. The nitrogen to purine ratio of ruminally isolated bacteria and purine content of in situ remaining contents was used to calculate microbial protein contribution. The model described by Mertens and Loften (1980) was used to estimate in situ DM and NDF disappearance rate (%).

The undegradable intake protein (UIP) values for forage and DDGS were calculated using an equation adapted from Broderick (1994): UIP (% of CP) = {[kp/(kd + kp)] x in situ slowly degradable CP fraction} + insoluble CP fraction , where kp is the particle passage rate, and kd is the rate of protein degradation. In situ insoluble CP fraction was calculated by subtracting CP effective digestibility from 100.

Statistics. Data were analyzed as a completely randomized design with the GLM procedures of SAS (SAS Inst. Inc., Cary, NC). Supplementation level (DDGS) was included as a fixed effect in the model. Orthogonal contrasts were used to test for linear, quadratic, and cubic

effects of increasing DDGS supplementation level. The mixed procedures of SAS was also used to analyze the ruminal fermentation data (pH, NH_3-N, and VFA) using a split plot design. Effects in the model included treatment, time, and treatment x time interaction. The repeated effect was collection time and steer within treatment was used as the error term for the split-plot. Individual steer was the experimental unit in all analyses.

Results and Discussion

Effects of supplemental DDGS on forage intake and digestion of beef steers grazing native range during the summer growing season are shown in Table 1. Forage OM, NDF, CP, and EE intake decreased ($P \leq 0.05$) linearly with increasing DDGS supplementation level. However, close examination of the means suggests that the decline occurs at 0.6 % of BW DDGS supplementation level. Leupp et al. (2009) supplemented DDGS at 0, 0.3, 0.6, 0.9, and 1.2 % of BW to steers fed smooth brome hay and reported a linear decrease in hay OMI with values decreasing 0.47 kg for every 1 kg of DDGS offered. In the present data, forage OMI values decreased 1.05 kg for every 1 kg of DDGS offered when receiving 0.6 % of BW supplementation. Similar results were observed by Loy et al. (2007) while supplementing DDGS at 0.4% of BW to heifers fed chopped hay grass. However, supplementation of DDGS did not affect ($P = 0.78$) total OM intake. Similarly, Pordomingo et al. (1991) found that when steers were supplemented with increasing levels of corn (0, 0.2, 0.4, and 0.6% of BW), no effect was found on total OMI. On the other hand, increases in total OM intake have been reported with DDGS supplementation to cattle consuming moderate quality hay (Loy et al., 2007; Leupp et al., 2009). Supplement OM, NDF, CP, and EE intake increased ($P < 0.01$) as was designed. The increase was a result of the greater CP and EE content of DDGS. Total CP and EE intake increased ($P < 0.01$) linearly with increasing DDGS supplementation level. Similar results have been reported previously (Donaldson et al., 1991; Leupp et al., 2009; Corrigan et al., 2009).

Digestibility of OM, CP, and NDF increased (linear; $P < 0.01$) while digestion of EE increased (linear and cubic effect; $P \leq 0.04$) with increasing DDGS level. Because the linear effect for EE digestibility was stronger, the effect is considered linear. This is likely a result of DDGS being more digestible than the forage grazed. Similarly, Sanson and Clanton (1989) and Elizalde et al., (1999) reported a linear increase in total OM digestibility in steers supplemented cracked corn (0.4 to 1.2 % of BW daily) or whole shelled corn (0.75 % of BW daily), respectively. Moreover, Leupp et al. (2009) reported a linear increase in OM, CP, and NDF digestibility with increasing DDGS supplementation level to steers consuming moderate quality hay. However, starch supplementation, in pure form or as that contained within grains results in decreases fiber digestibility (Sanson et al., 1990; Heldt et al., 1999; Chase and Hibberd, 1987; Heldt, 1998; Kartchner et al., 1980). In the present study, a negative effect on digestibility was not expected because DDGS is low in starch contents. Starch from the grain is utilized to produce ethanol during processing, thus the remaining by-products have only a small to no amount of starch (Renewable Fuels Association, 2005). The DDGS utilized in this study only contained 5.9 % of starch.

Forage masticate in situ DM and NDF disappearance rate decreased (quadratic; $P < 0.05$; Table 1) with the lowest value at 0.2% of BW supplementation level, and DDGS in situ DM disappearance increased (linear; $P = 0.03$; Table 1) with increasing supplementation level. Forage in situ soluble CP fraction increased linearly ($P = 0.01$) while in situ slowly degradable CP fraction linearly decreased ($P = 0.05$) with increasing DDGS supplementation level. Supplementation level did not affect ($P \geq 0.35$, Table 1) forage in situ CP degradation rate or effective degradability, DDGS in situ CP kinetics, or forage and DDGS UIP content (% of CP). Forage in situ NDF digestibility decreased ($P < 0.05$; Table 1) quadratically which disagrees with the linear increase ($P < 0.01$) in total tract NDF digestibility with increasing DDGS supplementation level. As total tract NDF digestibility increased linearly with increasing DDGS supplementation level, it was expected that forage NDF digestibility would remain unaffected or increase as was previously reported (Leupp et al., 2009; Loy et al., 2007). Greater DDGS NDF digestibility was most likely the reason for the discrepancy.

Implications

Dry distiller grains plus condensed solubles may be supplemented up to 0.4 % of BW without negatively affecting forage intake. If stocking rates are increased or forage availability is low, supplementation of DDGS above 0.4 % of BW, which decreases forage intake, can be a strategy to compensate for the lower forage intake. Enhanced performance of grazing cattle is expected with DDGS supplementation due to the improvement of total tract digestibility. Therefore, DDGS are a viable alternative as a supplement for growing cattle grazing medium- to high-quality native forage in the Southern Plains.

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Table 1. Effect of corn dry distiller grains plus condensed soluble (**DDGS**) supplementation on forage intake and digestion, rate of in situ DM and NDF disappearance, CP kinetic parameters of native range masticates and DDGS, and UIP from masticates and DDGS in beef steers grazing native range during summer growing season

	DDGS supplementation level, %[a]						Contrast[b]		
Item	0	0.2	0.4	0.6	SE[c]	P-value	L	Q	C
Supplement DM intake, kg/d	0.00	0.68	1.34	2.00	0.06	< 0.01	< 0.01	0.89	0.88
OM intake, kg/d									
Forage	10.81	10.51	10.93	8.87	0.51	0.05	0.04	0.11	0.19
Supplement	0.00	0.63	1.22	1.84	0.06	< 0.01	< 0.01	0.89	0.84
Total	10.81	11.14	12.15	10.71	0.51	0.23	0.76	0.11	0.19
Total OM intake, g/kg of BW	31.60	31.99	33.89	13.58	2.73	0.78	0.92	0.39	0.59
NDF intake, kg/d									
Forage	6.35	6.17	6.42	5.22	0.30	0.05	0.04	0.11	0.19
Supplement	0.00	0.54	1.07	1.59	0.05	< 0.01	< 0.01	0.88	0.91
Total	6.35	6.72	7.48	6.81	0.30	0.12	0.14	0.11	0.19
CP intake, kg/d									
Forage	1.05	1.02	1.06	0.89	0.05	0.01	0.03	0.11	0.19
Supplement	0.00	0.17	0.33	0.49	0.01	< 0.01	< 0.01	0.80	0.91
Total	1.04	1.18	1.39	1.36	0.05	< 0.01	< 0.01	0.12	0.20
EE intake, kg/d									
Forage	0.26	0.25	0.26	0.21	0.01	0.08	0.05	0.19	0.20
Supplement	0.00	0.09	0.18	0.26	0.01	< 0.01	< 0.01	0.77	0.89
Total	0.26	0.33	0.43	0.47	0.02	< 0.01	< 0.01	0.20	0.25
Fecal output, kg/d									
OM	4.94	5.09	5.43	4.63	0.25	0.20	0.61	0.08	0.25
NDF	4.03	4.13	4.36	3.68	0.21	0.21	0.39	0.10	0.30
CP	0.49	0.54	0.62	0.61	0.01	< 0.01	< 0.01	0.06	0.10
EE	0.15	0.16	0.21	0.14	0.01	0.01	0.59	0.01	0.01
Digestibility, % of intake									
OM	54.28	54.37	55.35	56.81	0.43	< 0.01	< 0.01	0.14	0.83
NDF	36.38	38.64	41.87	45.99	1.28	< 0.01	< 0.01	0.48	0.99
CP	52.70	53.58	55.12	55.05	1.24	< 0.01	0.15	0.71	0.69
EE	40.81	54.31	50.99	70.07	3.89	< 0.01	< 0.01	0.49	0.04
Forage									
Soluble CP, %	36.71	39.79	38.79	42.13	1.01	0.02	0.01	0.89	0.09
Slowly degradable CP, %	56.51	47.74	52.83	45.27	2.99	0.08	0.05	0.84	0.07
CP degradation rate, %/h	3.07	3.02	3.35	3.39	0.57	0.95	0.62	0.94	0.80
CP effective degradability, %	93.22	87.53	91.62	87.39	3.20	0.49	0.37	0.82	0.23
DDGS									
Soluble CP, %	-	19.80	17.82	17.91	1.69	0.66	0.45	0.63	-
Slowly degradable CP, %	-	59.19	61.07	52.41	8.48	0.76	0.59	0.62	-
CP degradation rate, %/h	-	2.86	3.59	4.23	0.67	0.39	0.18	0.96	-
CP effective degradability, %	-	78.99	78.88	70.31	7.73	0.67	0.45	0.67	-
Ruminal disappearance, %/h									
Forage									
DM	3.61	1.14	1.80	2.63	0.48	0.02	0.31	0.01	0.19
NDF	2.29	1.29	1.80	2.26	0.33	0.17	0.78	0.05	0.32
DDGS									
DM	-	1.94	3.10	3.69	0.46	0.07	0.03	0.63	-
Forage UIP, % of CP	38.78	41.87	38.99	38.14	1.81	0.52	0.59	0.32	0.35
DDGS UIP, % of CP	-	61.74	53.29	55.08	4.04	0.35	0.31	0.34	-

[a]DDGS supplementation was offered at: 0 (no supplement), 0.2, 0.4, and 0.6% of BW.
[b]Probabilities for contrasts: linear (L), quadratic (Q), and cubic (C).
[c]SE with n = 4

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NATURAL AND CONVENTIONAL DIET AND MANAGEMENT EFFECTS ON STEER FEEDLOT PERFORMANCE, CARCASS TRAITS AND ECONOMICS[1]

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ABSTRACT: Seventy-six naturally raised Angus-cross steers were used to determine the effects of natural (**NAT**) vs. conventional (**CON**) diet and management strategies on feedlot performance, carcass traits and economics. Animals were stratified by BW and allotted to one of 12 pens (6 pens/treatment). Growing and finishing diets were formulated to provide 1.14 Mcals NE_g/kg, 13.0% CP (DM basis; growing) and 1.43 Mcals NE_g/kg, 12.9% CP (DM basis; finishing) respectively. The NAT supplement contained an active yeast (*Saccharomyces cerevisiae*) and the CON supplement contained monensin. Two estrogenic implants (Ralgro, Component ES) were utilized in sequence in CON steers. Data were analyzed as a completely randomized design (PROC MIXED, SAS Inst. Inc., Cary, NC) with pen serving as experimental unit. Initial BW (BW = 248±1.5 kg) was not different (P = 0.31) between treatments. Feed intake during the background phase was greater for NAT (P = 0.02); however, CON had greater DMI during finishing (P = 0.001). Conventional steers had greater ADG and heavier final BW during the growing and finishing periods (P = 0.02). Conventional animals had lower feed costs ($P \leq 0.005$) and gained more efficiently ($P \leq 0.02$) than NAT steers. Hot carcass weight, marbling score, rib-eye area, and KPH differed ($P \leq 0.04$) across treatment. Conventional steers had \$42.88 greater carcass value and \$0.56/kg lower breakevens ($P \leq 0.02$) vs. NAT steers. While pen returns were not different statistically (P = 0.13), NAT steers had a \$72.30 greater loss per head as compared with CON steers. These data suggest that cattle managed with NAT production practices require higher market prices for equal returns to feeding to compensate for slower growth rates and greater cost of gain.

KEY WORDS: beef, carcass, economics, natural

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Introduction

Natural beef production, a niche market producing cattle without the use of pharmaceutical technology (antibiotics, implants, and ionophores), has become more prevalent in the last two decades. Demand for natural meat is attributed to high-income consumers concerned about the health, safety, and production attributes of their purchased beef products (Boland et al., 2002). United States consumer spending on natural and organically produced meat, poultry, and fish topped \$ 2.1 billion in 2005 with continued growth expected (Kuhlmann, 2007). Additionally, anecdotal reports of large premiums paid for calves marketed as natural have circulated in the marketplace. Springer et. al. (2009) reported premiums averaging \$4.76 and \$5.79/cwt for natural cattle paid by feed yards and marketing companies in their survey, respectively. While considerable data exists quantifying the benefits of antibiotics, implants (Duckett and Andrae, 2001) and ionophores (Lawrence and Ibarburu, 2007; Elam and Preston, 2004; Goodrich et al., 1984), little research data is available that compares production differences for natural versus conventional management strategies (Sawyer et. al, 2003). This study compared feedlot performance, carcass traits, and economics for natural vs. conventional protocols.

Materials and Methods

Backgrounding phase. The NDSU Animal Care and Use Committee approved all animal handling and care protocol. Seventy-two naturally raised Angus-cross steer calves were purchased locally from one ranch (\$2.38/kg). Calves were age and source verified according to CalfAID protocol (Doni Tibor, Oct. 21, 2008). After delivery to the NDSU Hettinger Research Extension Center feedlot, calves were allowed to rest and acclimate for 7 d on a common diet (1.14 Mcal/kg NE_g/kg, DM basis; no antibiotics or ionophores were included). Individual animal weights were measured on two consecutive days before morning feeding, averaged, and used as the starting BW. After weighing, calves were stratified by weight (BW = 249±1.5 kg) and within stratification, assigned randomly to one of two treatments (6 pens/treatment): (1) natural diets, natural management protocol (**NAT**) and (2) conventional diets, conventional management protocol (**CON**). Treatments were applied in a completely randomized design with feedlot pen serving as the experimental unit. Each feedlot pen housed six steer calves.

On d -1, calves were dewormed (Dectomax Pour-on Solution, Pfizer Animal Health, New York, NY) and

vaccinated for respiratory diseases (Bovi-shield 4, Pfizer Animal Health), clostridial and *H. somnus* diseases (Ultrabac 7/Somubac, Pfizer Animal Health), and Mannheimia disease (One Shot, Pfizer Animal Health). On d 21, CON calves were implanted with an estrogenic implant (Ralgro, 36 mg zeranol; Schering-Plough Animal Health Corp., Union, NJ) and all calves were revaccinated for respiratory diseases (Bovi-shield 4, Pfizer Animal Health), clostridial and *H. somnus* diseases (Ultrabac 7/Somubac, Pfizer Animal Health), and Mannheimia disease (One Shot, Pfizer Animal Health).

On d 0-21, calves were fed receiving rations with respective treatment supplements (CON RCV or NAT RCV diets; Table 1). The NAT RCV diet contained a non-medicated custom calf supplement (Scranton Equity Exchange, Scranton, ND) and an active *Saccharomyces cerevisiae* yeast (subspecies *boulardii* CNCM I-1079; 0.5 g·steer^{-1}·day^{-1}; ProTernative Stress Formula yeast; Ivy Natural Solutions, Overland Park, KS). The NAT growing diet (NAT Grow, Table 1), fed from d 22 to d 85, contained a different yeast product (*Saccharomyces cervisiae* CNCM I-1077; 0.4 g·steer^{-1}·day^{-1}; ProTernative Continuous Fed yeast; Ivy Natural Solutions, Overland Park, KS) and the same non-medicated custom calf supplement. Calves receiving NAT treatments did not receive any growth-promoting implants, animal byproducts, and ionophores (USDA, AMS, 2009).

The CON rations were formulated with the same ingredients; however, the rations included a custom calf supplement (Scranton Equity Exchange, Scranton, ND) containing monensin sodium (770 mg/kg monensin; Elanco Animal Health, Indianapolis, IN) and no active yeast concentrate. Decoquinate crumbles (Alpharma Corp., Fort Lee, NJ in Deccox Coxi-Crums, Scranton Equity Exchange, Scranton, ND) were included in both treatments to prevent coccidiosis at 159 grams per head per day. Deccox is approved for use by the North Dakota Natural Beef LLC (Fargo, ND) natural beef program. Calf diets were formulated to provide 1 kg of daily gain (NRC, 2000). Diets were fed as a totally mixed ration (TMR) once daily (0900 h) with adjustments to intake made daily. Water was provided in automatic electrically heated fenceline water fountains.

Calves were checked daily with data recorded for bloat scores (Paisley and Horn, 1998) and respiratory illness. Calf weights were taken prior to morning feeding on d -1, 0, 21, 22, 48, 83 and 84. Initial and final weights were determined by averaging two consecutive weigh d (unshrunk weights), while interim BW were used to monitor calf health during the background period. Diet samples from the background phase were collected periodically from each pen at feed delivery (d 2, 7, 15, 43, 49, 62, 74 and 82), composited by treatment and analyzed by a commercial laboratory (Midwest Laboratories, Omaha, NE) for nutritional components.

Finishing phase. Seventy-two steers were shipped to the NDSU Carrington Research Extension Center for finishing on d 88. Upon arrival, steers were realloted to one of six pens within treatment (6 steers/pen). For the first 25 d post arrival, CON and NAT cattle were transitioned to higher energy finishing diets (NRC, 2000; Table 2). Conventional treatment steers were reimplanted with a second estrogenic implant (Component ES, 20 mg estradiol benzoate, 200 mg testosterone; Ivy Laboratories-Vet Life, Overland Park, KS) on d 110. Steers were fed respective diets as a TMR once daily with adjustments to intake made daily. Water was provided in automatic electrically heated fenceline water fountains. Steers were weighed every 28 d (d 110, 138, 166, 195, 235 and 248) and feed delivery to each pen was recorded daily until harvest. Steers were harvested when the cattle were observed visually to have obtained 60% choice by trained research personnel. Final steer weights were recorded prior to shipping to the commercial abattoirs. Conventional steers were harvested at Tyson Foods, Dakota City, NE on d 236; NAT steers were harvested on d 248 at North Dakota Natural Beef LLC, New Rockford, ND. Individual carcass data was collected (CON = d 237; NAT = d 249) by trained university personnel following a 24-hr chill.

Table 1. Ingredient composition and nutrient concentration of calf receiving and growing diets

	CON[1]		NAT[2]	
Item	RCV	Grow	RCV	Grow
Ingredient, % DM Basis				
Cracked corn	31.9	31.8	32	32
DDGS[3]	12.6	12.6	12.4	12.4
Mixed hay	39.9	39.7	39.8	39.5
Oat silage	9.1	9.1	9.1	9.1
Natural supplement[4]	-	-	6.7	7
Conventional supplement[5]	6.5	6.8	-	-
Analyzed Composition				
DM, %	77.1	74.9	77.4	75.8
CP, % DM basis	14.8	13	14.8	13
NE_g, Mcal/kg	1.14	1.23	1.17	1.23

[1, 2]CON = conventionally fed and managed steers; NAT = naturally fed and managed steers.

[3]DDGS = dried distillers grains with solubles (Poet Nutrition, Inc., Sioux Falls, SD).

[4]Natural supplement contained (DM basis): 60% non-medicated custom calf pellet (Scranton Equity Exchange, Scranton, ND); 21.5% decoquinate crumbles (999 mg/kg decoquinate; Alpharma, Corp., Fort Lee, NJ in Deccox Coxi-Crums, Scranton Equity Exchange, Scranton, ND); 7.1% calcium carbonate; 7.1% sodium bicarbonate, and 4.3 % *Saccharomyces cerevisiae* yeast (*boulardii*, CNCM I-1079, 0.5 g·steer^{-1}·day^{-1}, RCV diet and CNCM I-1077, 0.4 g·steer^{-1}·day^{-1}, Grow diet; Ivy Natural Solutions, Overland Park, KS). Concentrations in parenthesis are expressed on a 90% DM basis.

[5] Conventional supplement contained (DM basis): 61.8% custom calf pellet containing Rumensin (770 mg/kg; Elanco Animal Health, Indianapolis, IN; Scranton Equity Exchange, Scranton, ND); 22.1% decoquinate crumbles (999 mg/kg decoquinate; Alpharma, Corp., Fort Lee, NJ in Deccox Coxi-Crums, Scranton Equity Exchange, Scranton, ND); 8.8% sodium bicarbonate, and 7.3% calcium carbonate. Concentrations in parenthesis are expressed on a 90% DM basis.

Data Analysis. Economic values for feedstuffs and other service fees were obtained from purchased costs, local and current cash grain bids and the USDA NASS North Dakota monthly commodity prices (www.nass.usda.gov/nd). Breakeven and closeout information was calculated using the NDSU Extension CalfWEB closeout analysis program (www.chaps2000.com/calfweb/closeout.asp). Steer feedlot performance, carcass traits and economic data were analyzed as a completely randomized design using PROC MIXED procedures of SAS (SAS Inst. Inc., Cary, NC), with pen serving as the experimental unit. Treatment

means were separated by least square means following a protected F-test ($P < 0.05$).

Table 2. Ingredient composition and nutrient concentration of calf finishing diets

Item	CON[1]	NAT[2]
Ingredient, % DM basis		
Calcium carbonate	0.5	0.57
Canola meal	2.89	2.93
Corn	58.42	58.71
Corn silage	7.21	7.57
MDGS[3]	22.19	22.29
Natural supplement[4]	-	0.28
Conventional supplement[5]	1.21	-
Wheat straw	7.58	7.65
Nutrient composition		
DM, %	75.09	75.94
CP, % DM basis	12.9	12.9
NE_g, Mcal/kg	1.43	1.43

[1,2]CON = conventionally fed and managed steers; NAT = naturally fed and managed steers.
[3]MDGS = modified distillers grains with solubles
[4]Natural supplement contained *Saccharomyces cerevisiae* strain I-1077 (400 mg·steer^{-1}·d^{-1}; Ivy Natural Solutions, Overland Park, KS). Concentrations in parenthesis are expressed on a 90% DM basis.
[5]Conventional supplement contained rumensin (300 mg·steer^{-1}·d^{-1}; Elanco Animal Health, Indianapolis, IN). Concentrations in parenthesis are expressed on a 90% DM basis.

Results and Discussion

Feedlot Performance. One CON calf was treated for respiratory illness in the first two weeks of the study; however, no NAT calves were treated for respiratory illnesses. One intact NAT calf was removed from the group prior to shipment for harvest for not meeting natural requirements. The effect of diet and management strategies on calf growing and finishing performance is shown in Table 3. Initial BW (BW = 248±1.5 kg) was not different ($P = 0.31$) between treatments. Feed intake during the growing phase was greater for NAT ($P = 0.02$); however, CON had greater DMI during finishing ($P = 0.001$). Sawyer et al. (2003) observed higher feed intakes for implanted cattle versus no implant; additionally, they observed no differences for DMI among steers fed feed additives compared to those fed no feed additives. Feed intake for CON steers during the growth phase in this study may have been influenced by the monensin supplementation. Conventional steers had greater ADG and heavier final BW during the growing and finishing periods ($P \leq 0.03$). Goodrich et al. (1984) reported that cattle fed monensin containing diets gained 1.6% faster, consumed 6.4% less feed and required 7.5% less feed/100 kg gain than those without monensin and that the responses to the use of monensin and implants (in combination) in cattle was additive. Conventional animals had lower feed costs ($P \leq 0.005$) and gained more efficiently ($P \leq 0.02$) than NAT steers in this study. Wileman et al. (2009) described similar G:F results in their analysis of modern technologies used in beef production. Lawrence and Ibarburu (2007) noted implant usage has the biggest cost savings to the feedlot sector, saving over $68 per head in production costs, while ionophores decrease production costs by $12 to $13 per head. This agrees with Elam and Preston's (2004) findings of a $30 to $67 per head return with implant usage and a $12 per head economic benefit from using ionophores. Veterinary medical costs were similar across treatments, averaging $7.44 per head ($P = 0.62$; Table 3).

Carcass traits and economics. The effect of diet and management strategies on carcass traits and economics is highlighted in Table 4. Although 12th rib fat and yield grades were similar across treatments ($P \geq 0.39$), other carcass traits measured differed ($P \leq 0.04$). As expected, CON steers had heavier HCW and larger rib-eye areas ($P \leq 0.001$), while NAT steers had greater marbling scores ($P = 0.02$) with more KPH ($P = 0.04$). Comparable carcass characteristics were observed and described by Sawyer et al. (2003) for implanted steers. Conventional steers had $42.88 greater carcass value and $0.56/kg lower breakevens ($P \leq 0.02$) vs. NAT steers. The premium paid for NAT calves that graded choice or better was $0.33/kg (data not reported). Similarly, Sawyer et al. (2003) reported higher harvest prices paid for non-implanted cattle and an $80.37/hd greater gross return for implanted steers. While pen returns were not different statistically ($P = 0.13$), NAT steers had a $72.30 greater loss per head as compared with CON steers. Higher feed ingredient costs and harvesting the cattle in June during the downward cycle for the fed cattle market may have contributed to the feeding losses reported.

Implications

Cattle producers interested in pursuing the natural, niche market must evaluate how their own costs of eliminating the use of pharmaceutical technologies (antibiotics, implants and ionophores) will alter their production methods, systems, and overall ranch profitability. These data suggest that cattle managed with natural production practices require higher market prices for equal returns to feeding to compensate for slower growth rates and greater cost of gain. Continued evaluation of breakeven costs and pen closeouts for naturally raised verses conventionally raised calves is necessary, especially in times of high feed costs.

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Table 3. Effect of diet and management strategies on calf growing and finishing performance

Item	Treatment[1] CON	NAT	SEM	*P*-value
	------Grow Period------			
No. head	36	36	-	-
No. pens	6	6	-	-
Days on feed, d	85	85	-	-
Initial weight, kg	247	250	1.5	0.31
Final weight, kg	358[b]	348[a]	2.7	0.03
Intake, kg·hd^{-1}·d^{-1}	9.3[b]	10[a]	0.17	0.02
ADG, kg·d^{-1}	1.3[b]	1.2[a]	0.04	0.02
G:F	0.14[b]	0.12[a]	0.003	0.001
Feed cost, $/kg BW gain[2]	1.12[a]	1.50[b]	0.04	< 0.001
Vet med costs, $· hd^{-1}	7.63	7.24	0.54	0.62
	------Finish Period------			
No. head	36	36	-	-
No. pens	6	6	-	-
Days on feed, d	235	248	-	-
Initial weight, kg	389[b]	379[a]	2.4	0.01
Final weight, kg	629[b]	589[a]	4.5	< 0.001
Intake, kg·hd^{-1}·d^{-1}	11.2[b]	9.8[b]	0.21	0.001
ADG, kg·d^{-1}	1.81[b]	1.48[a]	0.02	< 0.001
G:F	0.16[b]	0.15[a]	0.003	0.02
Feed cost, $/kg BW gain[3]	1.30[a]	1.43[b]	0.02	0.005

[a,b]Within a row, means without a common subscript differ ($P < 0.05$).
[1]CON = conventionally fed and managed steers; NAT = naturally fed and managed steers.
[2]Growing diet ingredient costs: cracked corn = $ 0.20/kg; decoquinate crumbles $ 0.79/kg; natural commercial calf supplement = $ 0.35/kg; medicated commercial calf supplement = $ 0.51/kg; calcium carbonate = $ 0.24/kg; ground mixed hay = $ 0.11/kg; oat silage = $ 0.022/kg; salt block = $ 0.22/kg; sodium bicarbonate = $ 0.62/kg; DDGS = $ 0.20/kg; ProTernative SF = $ 2.66/kg, and ProTernative CF = $ 2.40/kg.
[3]Finishing diet ingredient costs: corn = $ 0.22/kg; MDGS = $ 0.105/kg; corn silage $ 0.04/kg; wheat straw = $ 0.04/kg; canola meal = $ 0.23/kg; conventional supplement = $ 0.45/kg; natural supplement = $2.40/kg, and calcium carbonate = $ 0.194/kg.

Table 4. Effect of diet and management strategies on carcass traits and economics

Item	Treatment[1] CON	NAT	SEM	*P*-value
No. head	36	35	-	-
No. pens	6	6	-	-
Harvest BW, kg	601	551	-	-
Dressing %	65.11	63		
HCW, kg	391[b]	347[a]	2.9	< 0.001
Marbling Score[2]	487[a]	516[b]	7.52	0.02
12th rib fat, cm	1.47	1.35	0.13	0.39
Rib-eye area, cm^2	90.3[b]	83.7[a]	0.78	0.001
KPH, %	2.42[a]	2.63[b]	0.07	0.04
USDA yield grade	3.25	3.12	0.15	0.53
Carcass price, $/kg	2.88	3.15	-	-
Carcass value, $/hd	1,132.30[b]	1,089.42[a]	9.66	0.01
Breakeven, $/kg	2.03[a]	2.59[b]	0.06	0.02
Net loss, $/hd	82.87	155.17	30.10	0.13

[a,b]Within a row, means without a common subscript differ ($P < 0.05$).
[1]CON = conventionally fed and managed steers; NAT = naturally fed and managed steers.
[2]Modest = 400 to 499; Moderate = 500 to 599.

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PARENTERAL SUPPLEMENTATION OF CROSS BRED BRAHMAN STEERS WITH COPPER AND ZINC IN THE WESTERN PLAINS OF VENEZUELA

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ABSTRACT: To evaluate parenteral Cu and Zn supplementation on daily body gain (DBG), body measurements (BM) and blood chemistry of cattle, an experiment was carried out in the western plains of Venezuela, with 60 cross bred Brahman steers with an average BW of 201.6±20 kg. The animals were uniformly divided in four groups and assigned to four treatments: 1) oral mineral supplementation (OMS); 2) OMS with injected Cu (OMS-Cu); 3) OMS with injected Zn (OMS-Zn); and 4) OMS with injected Cu and Zn (OMS-Cu-Zn). Fifty mg of Cu and 80.2 mg of Zn/100 kg were injected subcutaneously every 73 and 28 days, respectively. The experiment lasted 129 days. The animals were kept under grazing conditions, in pastures of *Brachiaria arrecta* and *B. mutica* with a stocking rate of 0.9 animals/ha. In addition animals had access to a complete mineral mix and to a broiler litter, molasses and urea supplement (800 g/d) with 23.2% CP. Body weight changes were measured every 28 days. At the same time blood and forage samples were taken for chemical analyses. Changes in heart girth (HG) and wither height (WH) were measured at the beginning and at the end of the experiment. Data were analyzed by ANOVA in a complete randomize design using a 2x2 factorial arrangement. Forage contained 4.0±1.4% CP; 77.8±2.7% NDF; 5.6±2.5 ppm Cu and 22.5±6.2ppm Zn. Poultry litter supplement had 71.5 ppm Cu and 328.8 ppm Zn. No differences were found among treatments for DBG, with an average of 363.1±273.8 g/d, showing (P<0.05) an interaction time x Cu, with greater gains of supplemented animals in the transition dry-wet season (552.6±201 vs 487.4±131.1 g/d), and lower in the wet season, when compared with the unsupplemented animals (535.9±263.9 vs 632.1±191.6 g/d). No differences in BM and blood chemistry were found. It is concluded that under the conditions of the experiment, subcutaneous Cu and Zn supplementation had no effect on animal performance and blood chemistry.

Key words: parenteral supplementation, daily gain, body measurements.

Introduction

Beef cattle production in Venezuela is carried out under grazing conditions, in pastures with poor quality forages and seasonal variations of quality and amount of dry matter available to animals. Among nutrients deficiencies, beside protein and energy, minerals are limiting, particularly Ca, P (Chicco and French, 1959; Lopez et al., 2008), Cu (Chicco and Godoy, 1987; Lopez et al., 2008), Na (Morillo et al., 1989) and Zn (McDowell et al., 1989). In addition there is an excess of Fe and Mn (Chicco and Godoy, 1987; Depablos et al., 2009) that may impair the utilization of other minerals, particularly Cu (Chicco y Godoy, 2005). Mineral supplementation is not a common practice in the country, and usually the commercial mineral mixes contain Fe and Mn, that may aggravate the antagonistic effects on other minerals. Beside, in some areas, poultry litter is used as a nitrogen source to compensate for the low protein content of forages, adding more Fe and Mn in the diet that, in addition to the mineral supplement, may interfere even more with the utilization of other minerals, particularly Cu and Zn. Under certain circumstances, therefore, it appears to be convenient to evaluate other ways to provide minerals to animals, such as subcutaneous injections, to increase greater availability at tissue levels and to avoid interactions in the gastrointestinal track. For these reasons, the main objective of this research was to evaluate the effect of parenteral supplementation with Cu and Zn on daily body gain **(DBG)**, body measurements **(BM)** and blood chemistry in cross bred Brahman steers grazing forages with low content of these minerals, in the western region of Venezuela.

Materials and Methods

The experiment was carried out in the western plains of Venezuela, with 60 cross bred Brahman steers averaging 201.6 ± 20 kg BW. The animals were divided in four uniform groups and assigned to four treatments: 1) oral mineral supplementation **(OMS)**; 2) OMS with injected Cu **(OMS-Cu)**; 3) OMS with injected Zn **(OMS-Zn)**; and 4) OMS with injected Cu and Zn **(OMS-Cu-Zn)**. Copper (50 mg/100 kg BW) and Zn (80.29 mg/100 BW) were injected subcutaneously every 73 and 28 days, respectively. The experiment lasted 129 days. The animals were kept, as a whole group, under grazing conditions, in a rotational system with 2 days in and 33

days out of the paddocks, in pastures with *Brachiria arrecta, B. mutica, B. decumbens y B. humidicola,* with a stocking rate of 0.9 animals/ha. In addition animals had free access to a mineral mix and to a limited amount of broiler litter, urea and molasses supplement (800 g/d) with 23.2% CP (Table 1).

Table 1. Ingredients and chemical composition of poultry litter supplement.

Ingredients	%
Poultry litter[1]	79
Molasses	12
Urea	3
Minerals[2,3]	6
CP[4]	23,2
RPD[4]	20,3
UDP[4]	2,9
ME (Mcal/kg)[4]	1,74

[1]Mineral content: 2.95% N; 1.6% Ca; 1.12% P; 0.34% Mg; 0.49% S; 0.35% Na; 2.20% K; 71.5ppm Cu; 328.8 ppm Zn; 976 ppm Fe; 258.3 ppm Mn.
[2]Mineral content: 30% Ca; 0.02% P;0.12% Mg; 0.06% Na; 0.03% K; 198 ppm Cu; 34 ppm Zn; 809 ppm Fe; 198 ppm Mn.
[3]The same mineral mix was offered *ad lib.*
[4]Calculated values.

Forage samples were taken every 28 days to determine amount of available DM and chemical analyses. Forage samples were taken using a metallic frame of 0.375 m^2, randomly distributed in the pastures. Crude protein and ash (AOAC, 1990) and NDF and ADF (Van Soest and Wine, 1967) were determined as well as Ca, Mg, Na, K, Zn, Cu, Fe, Mn by atomic absorption spectrophotometry (AOAC, 2000), P by a colorimetric procedure (Chen et al., 1956) and S by turbidimetric method (Tabatabai and Bremner, 1970).

Animal body weights were measured and blood samples were taken every 28 days. To determine DBG animals were kept with no feed and water for 18 h previous weighting. Changes in heart girth **(HG)** and wither height **(WH)** were measured at the beginning and at the end of the experiment. Blood samples from six animals per treatment ad random selected were extracted by jugular puncture. Serum was maintained at -20°C for further analysis of Cu and Zn by atomic absorption spectrophotometry (AOAC, 2000). The same animals were maintained throughout the experiment for blood sampling.

Data were analyzed by ANOVA in a complete randomize design using a 2x2 factorial arrangement.

Results and Discussion

Forage DM available to animals was 4483.6; 3675.4 and 3929.2 kg/ha for dry, transition dry-wet and wet seasons, respectively, and 85.4; 70 y 74.8 kg/animal/d, for the same seasons with no differences among periods (P>0.05). Therefore, forage DM was no limiting for grazing cattle since the available forage was higher than 2000 kg/ha (Minson, 1990) and 30 kg/animal/d (Lamela, 1992), values suggested to be adequate for animal performance in pastures. However, forage had a CP content lower than 7%, that may have a negative effect on intake (Milford and Minson, 1965).

Significant differences (P<0.05) among seasons were found for CP, NDF, ADF and Cu. Crude protein and Cu increased from dry to wet season, while NDF and ADF were lower in the transition dry-wet season. Copper and Zn were lower than suggested requirement levels (NRC 2000), particularly in the dry season. However animals had free access to a mineral mix in addition to a poultry litter supplement which should have provided additional mineral elements to overcome the deficiency of the forage (Table 2). Iron and Mn were higher than requirements, which is a common finding in tropical areas (Chicco y Godoy, 1987; McDowell et al., 1989; Depablos et al., 2009).

Table 2. Nutrient content of forage.

Nutrient	Season		
	Dry	Transition dry-wet	Wet
CP (%)	3.83 ± 0.49[b]	5.33 ± 1.42[ab]	5.71 ± 1.60[a]
NDF (%)	78.87 ± 1.48[ab]	75.36 ± 2.64[b]	79.32 ± 2.32[a]
ADF (%)	45.53 ± 0.87[a]	40.29 ± 3.47[b]	42.30 ± 1.88[ab]
Ash (%)	6.00 ± 1.60	6.75 ± 1.22	6.89 ± 0.98
Ca (%)	0.09 ± 0.02	0.17 ±0.11	0.06 ± 0.04
P (%)	0.23 ± 0.03	0.29 ± 0.07	0.27 ± 0.07
Mg (%)	0.09 ± 0.02	0.08 ± 0.03	0.06 ± 0.04
Na (%)	0.13 ± 0.06	0.10 ± 0.08	0.20 ± 0.11
K (%)	0.36 ± 0.14	0.44 ± 0.19	0.69 ± 0.31
S (%)	0.16 ± 0.03	0.20 ± 0.07	0.15 ± 0.04
Cu (ppm)	3.33 ± 1.55[b]	6.66 ± 1.63[a]	6.83 ± 2.71[a]
Zn (ppm)	18.83 ± 2.85	25.33 ± 8.23	23.50 ±0.11
Fe (ppm)	87.83 ± 65.1	82.16 ± 41.7	124.0 ± 100
Mn (ppm)	307.3 ± 94.6	239.6 ± 105	213.6 ± 60.3

[a, b] Means in the same row with different superscripts are different (P<0.05).

Daily body gains (Table 3) were not influenced by treatment with an overall mean of 363.1 g/day. A significant effect (P<0.05) of time on DBG was registered, with greater gains between 28 and 101 days of the experiment. In addition, a significant (P<0.05) interaction was found between Cu and time, with greater body gains of Cu injected animals (Figure 1) when compared with those that did not received parenteral supplementation of this element (Figure 1) at day 73, corresponding to the transition dry-wet season (552.6 vs 487.4 g/d). In this period total CP and soluble N in forage were higher, suggesting the possibility that a CuS complex could be formed, reducing Cu availability to animals (Ward, 1978).

Table 3. Body weight and daily body gains of cross bred Brahman steers with parenteral Cu and Zn supplementation

Day	BW (kg)				DBG (g/d)				Average (g/d)
	OMS	OMS-Cu	OMS-Zn	OMS-Cu-Zn	OMS	OMS-Cu	OMS-Zn	OMS-Cu-Zn	
0	202.6	201.0	201.4	201.5	--------	--------	------	--------	
28	209.3	206.1	208.1	205.6	258.9	194.8	256.4	156.4	**216.6**[b]
73	230.8	233.3	230.5	228.1	477.0	604.4	497.7	500.7	**520.0**[a]
101	248.0	246.1	246.2	243.2	661.5	492.3	602.5	579.4	**583.9**[a]
129	249.8	251.5	250.2	246.6	66.6	192.8	145.2	121.4	**131.5**[c]
Average (g/d)					**366.1**	**371.1**	**375.5**	**339.5**	**363.1**

[a, b, c] Means in the same column with different superscripts are different (P<0.0 5)

When a second dose of Cu was injected at day 73, and the rainy season was established (day101 of the experiment), animals that have not received additional Cu showed better performance than the treated ones (632.1 vs 535.9 g/d). Viejo and Casaro (1993) also indicated that a second Cu injection had a lower effect on animal performance than the first dose. However, even though forages had low content of Cu, poultry litter supplement in addition to the mineral mix offered *ad lib* should have provided these element to satisfy requirements (54. 7 y 210. 3 mg/d of Cu and Zn, respectively; calculated values)

There was no effect on changes of BM due to treatments, with overall average values of 3.99 and 9.05 cm for HG and WH, respectively.

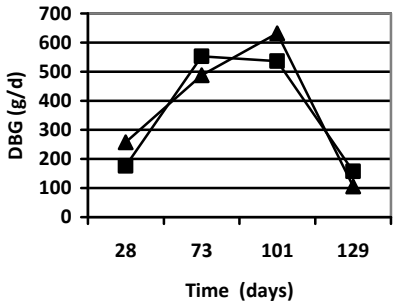

Figure 1. Effect of the interaction time x Cu on daily body gains of cross bred Brahman steers with (■) and without injected copper (▲).

Table 4. Changes of body measurements of cross bred Brahman steers with Cu and Zn parenteral supplementation

	OMS	OMS-Cu	OMS-Zn	OMS-Cu-Zn	Average
WH (cm)					
Initial	117.6	116.6	116.4	118.6	**117.3**
Increment	4.39	3.82	3.20	4.54	**3.99**
HG (cm)					
Initial	140.0	139.5	140.4	140.3	**140.1**
Increment	8.79	9.42	9.81	8.16	**9.05**

Serum Cu and Zn values were not influenced by treatments with an overall mean of 0.65 and 1.17 µg/mL, respectively. Serum concentrations of minerals are controlled by homeostatic mechanisms and under the conditions of this experiment, with no effect of treatments on body changes, unlikely blood values could have changed. Similar findings were reported by Ferrer et al. (1989). However, serum Zn showed a tendency to have lower values in the rainy season, reaching significance at day 101 (P<0.05). Depablos et al. (2009) also reported lower Zn serum values in the wet season.

Table 5. Serum mineral content of cross bred Brahman steers with parenteral Cu and Zn supplementation.

Mineral	Treatment	Days					Average
		0	28	73	101	129	
Cu (µg/mL)	**OMS**	0.57	0.58	0.68	0.65	0.62	**0.62**
	OMS-Cu	0.61	0.58	0.67	0.69	0.62	**0.64**
	OMS-Zn	0.65	0.65	0.68	0.67	0.64	**0.66**
	OMS-Cu-Zn	0.62	0.73	0.74	0.70	0.61	**0.68**
	Average	**0.61**	**0.64**	**0.69**	**0.68**	**0.62**	**0.65**
Zn (µg/mL)	**OMS**	1.17	1.28	1.79	0.45	0.58	**1.05**
	OMS-Cu	1.23	1.36	1.04	0.50	1.07	**1.04**
	OMS-Zn	1.02	2.10	1.66	0.55	0.66	**1.20**
	OMS-Cu-Zn	1.18	2.35	1.88	0.79	0.83	**1.40**
	Average	**1.15^{ab}**	**1.77^{a}**	**1.59^{a}**	**0.57^{b}**	**0.79^{ab}**	**1.17**

[a,b] Means in the same row with different superscripts are different (P<0.05)

Implications

It is concluded that under the conditions of this experiment, Brahman steers grazing forage with low content of CP, Cu and Zn, with *ad lib* mineral mix and a limited amount of a protein supplement containing mainly poultry litter, did not show any beneficial effect by subcutaneously injections of Cu and Zn. It appears that supplements overcame Cu and Zn deficiencies of grazed forage.

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EFFECT OF CALVING SEASON AND WINTERING SYSTEM ON COW AND CALF WEANING PERFORMANCE

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ABSTRACT: A four year study using two hundred seventeen cows/year (5/8 Red Angus, 3/8 Continental) was conducted to evaluate effects of calving season and wintering system on cow performance. Cows were assigned to one of five treatments: 1) spring calving cows (**SP**) wintered on native range, 2) SP wintered on cornstalks, 3) summer calving cows **(SU)** wintered on native range, 4) SU wintered on cornstalks, and 5) fall calving cows (**FA**) wintered on cornstalks. Calves were weaned at 221, 298, and 247 d of age for SP, SU, and FA, respectively. Cow BW and BCS were recorded three times during production: 21 d pre-calving, 50 d post calving (pre-breeding), and weaning. Data were analyzed as a completely randomized design and binomial measurements were analyzed using proc freq. Wintering system did not affect calf weaning BW (P = 0.72), cow BW (P = 0.57), cow BCS (P = 0.61) or rebreeding rates (P = 0.86). Across calving season, pre-breeding BW was lowest for SP (480 kg), intermediate for SU (570 kg), and greatest for FA (589 kg; P < 0.01). At weaning BW was lower for SP compared to SU (P = 0.03) and FA (P = 0.14) which were similar (P = 0.64). At pre-calving BW was greatest for FA (629 kg; P < 0.01), intermediate for SU (569 kg), and lowest for SP (533 kg; P < 0.01). Cow BCS in the different calving seasons followed the same pattern as BW. Rebreeding performance was numerically lower for FA (90.2%; P = 0.22) compared to SP and SU (93.2 vs. 94.3%). Calf ADG from birth to weaning was greatest for SP and lowest for SU (P < 0.01). However, calf BW at weaning was greatest for SU (254 kg; P < 0.01) compared to SP (238 kg) and FA (234 kg) due to differences in weaning age. In the current study, wintering system did not affect cow performance. Calving season significantly affected cow BW, BCS, and influenced rebreeding performance. In addition wintering system effected calf BW and ADG.

Key Words: Calving season, Cow-calf systems, wintering system

Introduction

The amount of harvested feed required to maintain cows in the Nebraska Sandhills is directly related to calving date (Adams et al., 1996; Clark et al., 2004). Traditionally, cows are bred to calve in February and March which leads to lactation occurring in early spring. In early spring, range resources are dormant and low in protein and energy (Geisert et al., 2008). To meet nutrient requirements of the cows, producers feed hay and other purchased feeds that can lead to increased cost for spring calving cows (Stockton et al., 2007). However, changing calving date could decrease the use of harvested forages and purchased feed resources by matching the cow's requirements with the time of year that forage resources are greater in protein and energy, potentially decreasing cost for cow-calf producers. The use of corn residue can be advantageous to beef production systems by providing low cost feed that does not compete with grain demand (Guteirrez-Ornelas, 1989). As corn price increases there is potential for increased corn acres leading to increased cornstalk availability. The use of cornstalks in cow-calf production could increase the capacity of a ranch as cows are moved from the ranch in the winter. This allows producers to utilize most of their forage in the spring and summer months and not have to stockpile winter grass. Secondly, the use of cornstalks offers some flexibility for cow-calf producers when managing drought. Traditionally, drought has caused producers to decrease herd numbers or put cows into dry lot using harvested forage and purchased feeds. Instead of culling or dry lotting cows, which can be more expensive (Griffin et al., 2008), cornstalks offers producers an inexpensive feed that can help maintain herd numbers and decrease the use of harvested forages and purchased feeds. Therefore, the objectives of this study were to 1) determine the effect of calving season and 2) wintering program on cow performance.

Material and Methods

Cow Management. A four year study was conducted using an average of two hundred seventeen cows (5/8 Red Angus, 3/8 Continental) from the Gudmundsen Sandhills Laboratory (Whitman, NE) were assigned to one of five treatments. Treatments were: 1) spring calving cows (SP) wintered on native range, 2) SP wintered on cornstalks, 3) summer calving cows (SU) wintered on native range, 4) SU wintered on cornstalks, or 5) fall calving cows wintered on cornstalks. Average calving dates were March 24th, June 15th, and August 5th for SP, SU, and FA, respectively.

Spring calving cows wintered on native range were allowed to graze native sandhills range from mid-May until the end of February. At the beginning of March, SP wintered on range were fed meadow hay until mid-May. Spring calving cows wintered on cornstalks were allowed to graze native Sandhills range from mid-May until mid-October when cows were transported to cornstalks in the Platte river valley. At the end of February, SP wintered on

cornstalks were returned to the ranch and fed meadow hay until mid-May. Summer calving cows wintered on native range were allowed to graze native Sandhills range for the entire year. However, SU cows wintered on cornstalks were transported to cornstalks in mid-October and returned to the ranch at the end of March. Summer calving cows wintered on cornstalks were allowed to graze native Sandhills range from April until the beginning of October. During late winter to early spring SU and FA were not fed hay; however, SU calving cows wintered on range were supplemented 1.14 kg/hd daily of 28% CP dried distillers grain cube to meet protein requirements (Table 1). Additionally, SU wintered on cornstalks and FA were supplemented 0.45 kg/hd daily.

Table 1. Composition of 28% CP distillers grain cube[a]

Item, % DM-basis	
Dried distillers grains plus solubles	62
Wheat midds	11
Cottonseed meal	9
Corn gluten feed	5
Molasses	5
Urea	2
Calcium carbonate	3
Binder	3

[a]Formulated to have 22000 IU/kg of Vitamin A and 36 mg/kg Rumensin (Elanco Animal Health Greenfield, IN).

At calving, calves were assigned a calving difficulty score from 1 to 5 (1= no assistance, 2= minor assistance; 3=difficult assistance, 4 = caesarean section, 5 = abnormal presentation) and a calf vigor score from 1 to 5 (1=nursed unassisted, 3 = nursed with assistance, and 5 = dead at birth). Calves from SP cows were weaned on October 31st (221 d of age). Calves from SU and FA were weaned on April 10th, when calves were 298 and 247 d of age, respectively. For SU and FA March 10th was when cows grazing cornstalks during the winter returned to the ranch.

For each system, cow BW and BCS were recorded at three different periods during the year: 21-d before calving (pre-calving), 59-d post calving (pre-breeding), and at weaning. Calf BW was recorded at birth, dam pre-breeding, and weaning.

Statistical Analysis. Data from this study were analyzed as a completely randomized design using the Mixed procedure of SAS (SAS Inst. Inc., Cary, NC). All binomial data including rebreeding performance, calf vigor score, and calving data were analyzed using proc Freq. Experimental unit for this study was group of cows within treatment. To determine the effect of calving date on cow performance the model included calving season with year as a random effect. Contrast statements were used to evaluate the difference between calving season (SP vs. SU, SP vs. FA, and SU vs. FA). Spring calving cows and SU were used to determine the difference between wintering on cornstalks and wintering on native Sandhills range, since FA were only wintered on cornstalks. The model to test for differences between wintering systems included wintering system with year included as a random effect. Data are presented as least squares means with differences considered significant at $P < 0.05$.

Results and Discussion

Calving Season. Calving difficulty ($P = 0.14$) and calf vigor ($P = 0.73$) were not different among calving seasons. Pre-calving BW was greatest for FA (629 kg), intermediate for SU (690 kg), and lowest for SP (533 kg; $P < 0.01$). Body weight at pre-breeding was greatest for FA (589 kg) when compared to SP ($P < 0.01$) and SU ($P < 0.01$). Additionally, SU was 90 kg heavier ($P < 0.01$) than SP. Cow BW at weaning was lowest for SP when compared to FA ($P = 0.14$) and SU ($P < 0.01$) which were not different from each other ($P = 0.64$).

Pre-calving BCS differed ($P < 0.01$) among calving seasons with FA having the greatest followed by SU and SP (Table 2). At pre-breeding, SP had the lowest BCS ($P < 0.01$) compared to SU and FA which were not different ($P = 0.82$). There was no difference ($P = 0.22$) in BCS at weaning among calving seasons.

There was no difference in calf BW at birth among the different calving seasons ($P = 0.26$; Table 2). Spring calves were 13 kg and 11 kg lighter at pre-breeding than summer and fall calves ($P < 0.01$), respectively. Calf weaning BW was similar ($P = 0.36$) for SP and FA calves; however, because of increased days of age, summer calves were 20 kg and 16 kg heavier than fall ($P < 0.01$) and spring ($P < 0.01$) calves, respectively. Calf ADG from birth to weaning was 0.18 kg/d and 0.12 kg/d greater for spring calves ($P < 0.01$) when compared to summer and fall calves, respectively, In addition, fall calves had greater ADG from birth to weaning compared to summer born calves (0.79 vs. 0.73 kg/d; $P < 0.01$). Adjusted 205 d weaning BW for calves was greatest for spring calves ($P < 0.01$), intermediate for fall calves and lowest for summer calves ($P < 0.01$).

Percent of cows calving was not different across calving season (P = 0.16; Table 2). In addition, calving season did not impact cow rebreeding performance ($P = 0.22$). However, when evaluating the number of calves weaned per cow, FA produced fewer calves per cow when compared to SP ($P = 0.05$) and tended to produce fewer calves per cow than SU ($P = 0.08$). However, when comparing the number of calves weaned per cow for SU and SP there was not a difference ($P = 0.67$).

Differences in BW and BCS for the cows throughout the different periods of the year were expected because of how cow requirements (NRC, 1996) and nutrients from forage resources match or do not match throughout the year. In this study, protein requirements for the cows were met using supplementation of a 28% CP distillers grains cube. Therefore, differences in BW and BCS were because of differences in energy supply from the forage and energy demand of the cows during the production year. Energy status is an extremely important factor that can affect cow performance. During peak lactation which is April and May for SP, energy requirements would be the greatest. Range TDN content peaks in May (Geisert et al., 2008). When comparing SU and FA, energy requirements are greatest during July and

August for SU and September and October for FA. In the months of September and October range nutrient value has declined to dormant season nutrient levels. Rebreeding performance is directly related to the energy status of the cow (Randel; 1990). In this study, FA did not have reduced rebreeding performance but there were differences in calves weaned per cow when comparing FA to SU and SP. In this study that was a result of a slight numerical reduction in rebreeding performance and percent of cows to calve from FA. In addition, energy status of the cows across calving season is evident from differences in BCS throughout the production year. For SP, BCS remains relatively constant with a change in BCS from 5.3 at pre-calving to a BCS of 5.1 at weaning. For SU and FA, there was a larger difference from pre-calving to weaning with a 1.0 and 1.6 unit change in BCS for SU and FA, respectively, throughout the production year.

Wintering System. Calf vigor (P = 0.57) and calving difficulty (P = 0.91) were not different between cows wintered on Sandhills native range or cornstalks. Additionally, cow BW and BCS at pre-calving (P > 0.57), pre-breeding (P > 0.70), and weaning (P > 0.61) were not different between wintering systems (Table 3).

Wintering system did not influence calf BW at birth (P = 0.64), at start of the breeding season (P = 0.64), or at weaning (P = 0.63). Additionally, calf ADG (P = 0.72) from birth to weaning and adjusted 205 d weaning BW (P = 0.77) was not different between wintering systems. Neither percent of cows to calve nor number of calves weaned per cow were influenced by wintering system (P > 0.65). In addition, there were no differences in cow rebreeding performance (P = 0.86) when comparing wintering system.

Body weight and BCS for cows grazing cornstalks in the winter was similar when compared to cows grazing native Sandhills range. Similar results were presented by Anderson et al. (2003) who found that BW and BCS were not different between cows wintered on cornstalks or stockpiled pasture. In addition, in the current study supplementation strategies during the winter were slightly different when comparing wintering systems. Cows wintered on range were supplemented 1.14 kg/hd daily of 28% CP dried distillers grain cube to meet protein requirements. Additionally, cows wintered on cornstalks were supplemented 0.45 kg/hd daily of the same cube. However, this difference in supplementation did not produce any differences in performance suggesting that with slight differences in supplementation cows wintered on native Sandhills range and cows wintered on cornstalks were on a similar plane of nutrition.

Implications

Results from this study imply that calving season can have an effect on cow BW and BCS throughout the production year. Additionally, season of calving does not have an impact on rebreeding performance but FA may produce fewer calves per cow because of numerically lower rebreeding rates and percent of cows to calve. When wintering cows on cornstalks a producer can expect similar performance to wintering on range with less supplementation.

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Table 2. Effect of calving season on cow performance

Item	SP[b]	SU[c]	FA[d]	SEM	*P* value[a] SP vs. SU	SP vs. FA	SU vs. FA
n	88	74	55	---	---	---	---
Cow BW							
Pre-calving, kg	533	569	629	10	< 0.01	< 0.01	< 0.01
Pre-breeding, kg	480	570	589	5	< 0.01	< 0.01	< 0.01
Weaning, kg	501	525	519	11	0.03	0.14	0.64
Cow BCS							
Pre-calving	5.3	5.9	6.6	0.1	< 0.01	< 0.01	< 0.01
Pre-breeding	5.3	6.1	6.0	0.1	< 0.01	< 0.01	0.82
Weaning	5.1	5.1	5.0	0.1	0.28	0.22	0.72
Calf BW							
Birth, kg	37	38	38	1	0.42	0.26	0.63
Weaning, kg	238	254	234	4	< 0.01	0.36	< 0.01
Adj. weaning, kg[e]	223	186	200	3	< 0.01	< 0.01	< 0.01
Calf ADG[f], kg/d	0.91	0.73	0.79	0.01	< 0.01	< 0.01	< 0.01
Calved, %	98.4	97.1	94.4	2.7	0.57	0.16	0.33
Calves/ cow[g]	0.96	0.95	0.86	0.05	0.67	0.05	0.08
Rebreeding, %	93.2	94.3	90.2		0.22	0.22	0.22

[a]*P* value = differences across treatments determined using contrast statements except for calf vigor, difficulty, and rebreeding % which chi square distribution was used.
[b]SP = spring calving cows (average calving date = March 24th).
[c]SU = summer calving cows (average calving date = June 15th).
[d]FA = fall calving cows (average calving date = August 5th).
[e]Adj. weaning = calf weaning weight adjusted to 205 d.
[f]Calf ADG = ADG for the calf from birth to weaning.
[g] Calves/ cow = calves weaned per cow.

Table 3. Effect of wintering system on cow performance

Item	Cornstalks	Native range	SEM	*P* value
n	82	81	---	---
Cow BW				
Pre-calving, kg	546	555	12	0.57
Pre-breeding, kg	527	522	19	0.86
Weaning, kg	516	510	9	0.61
Cow BCS				
Pre-calving	5.5	5.6	0.2	0.61
Pre-breeding	5.6	5.7	0.2	0.70
Weaning	5.1	5.1	0.1	0.80
Calf BW				
Birth, kg	37	37	1	0.64
Weaning, BW	244	247	5	0.63
Adj. weaning[a], kg	203	205	7	0.77
Calf ADG[b], kg/d	0.80	0.82	0.04	0.72
Calved, %	97.8	97.7	1.6	0.94
Calves/ cow[c]	0.95	0.96	0.1	0.65
Rebreeding, %	93.8	93.5	---	0.86

[a]Adj. weaning = calf weaning weight adjusted to 205 d.
[b]Calf ADG = ADG for the calf from birth to weaning.
[c]Calves/ cow = calves weaned per cow.

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EFFECT OF WHEAT STRAW LEVEL AND PROCESSING METHOD ON SITE AND EXTENT OF DIGESTION BY CATTLE CONSUMING FINISHING FEEDLOT DIETS

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ABSTRACT: Holstein steers (n = 4; 216 kg BW), fitted with ruminal and duodenal cannulas, were used to evaluate wheat straw inclusion level (7 and 14%; DM basis) and roughage processing method (ground vs pellet) on characteristics of digestion of steam-flaked corn finishing diets. The experimental design was a 4 x 4 Latin square with a 2 × 2 factorial arrangement of treatments. Wheat straw was ground in a tub grinder with a 3.81-cm screen, while the pellet dimensions were 2 cm long × 0.5 cm diameter. An interaction was detected between straw level and processing method for DM intake ($P < 0.01$). With 14% straw, processing method did not affect ($P = 0.83$) DM intake. With 7% straw, DM intake was lower (2.3%, $P < 0.01$) for pelleted straw than for ground. Digestibility of ruminal OM (6%), true ruminal N digestibility (9.7%), total tract OM (3.9%), and total tract N (4.2%)were greater ($P \leq 0.05$) for diets that contained 7% wheat straw than for those that contained 14%. Ruminal starch digestibility (88.7, and 84.9 ± 0.74%, for pelleted and ground, respectively) was greater ($P = 0.04$) and ruminal pH (5.44 and 5.76 ± 0.22, for pelleted and ground, respectively) was lower ($P = 0.05$) for diets that contained pelleted straw than for those that contained ground straw. Steers fed 7% wheat straw had greater OM and N digestibility. However, greater ruminal starch digestibility and lower pH of steers consuming pelleted wheat straw might be responsible for the lower DM intake observed for steers consuming pelleted wheat straw at 7%. Wheat straw is a viable roughage source for feedlot diets. However, when included at low levels, the pelleted form does not elicit the optimum rumen function stimulation.

Key w ords: Digestion, feedlot cattle, processing, wheat straw

Introduction

Wheat is the principal crop of the Mexicali Valley. After the grain is harvested, much of the straw is left in the field. The relatively low available energy value of wheat straw has restricted its use in cattle diets or as a roughage source for finishing cattle (Lesoing et al., 1980). Roughages are included in feedlot diets to reduce digestive and metabolic problems (Galyean and Defoor, 2003). Feedlot receiving diets typically include approximately 35% roughage to allow adaptation of ruminal bacteria to concentrate diets (Owens and Goetsch, 1988; Berry et al., 2004). Most finishing diets generally contain 4.5 to 13.5% (DM basis) roughage (Vasconcelos and Galyean 2007). Roughage is added to high-concentrate diets to stimulate chewing which is associated with increased saliva output (Balch, 1958), and 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 gain efficiency decreases because energy density of diets decreases with increasing roughage level (Bartle et al., 1994). Therefore, wheat straw needs to be included at a minimum level required for appropriate rumen function stimulation. Different methods of processing wheat straw might allow decreasing its inclusion in the diet without negatively influencing the characteristics of digestion. The objectives of this experiment were to evaluate the influence of wheat straw inclusion level and processing method on characteristics of digestion of steam-flaked corn finishing diets.

Materials and Methods

Four Holstein steers (216 kg) fitted with ruminal and duodenal cannulas were used in a 4 × 4 Latin square design. Treatments were arranged in a 2 x 2 factorial. Factors were inclusion level (7 and 14%, DM basis) and processing method (ground or pelleted). Wheat straw was ground in a tub grinder with a 3.81-cm screen, while the pellet dimensions were 2 cm long × 0.5 cm diameter. Steers were maintained in individual pens (3.9 m^2) with individual feeders and ad libitum access to water. Diets were fed at 0800 and 2000 and contained 0.35% chromic oxide as a digesta marker. The experiment consisted of four 14-d periods. Experimental periods lasted 14 d, with 10 d for adaptation to the diets and 4 d for collection. During the collection, duodenal and fecal samples were taken from each steer, twice daily over a period of 4 successive days as follow: d 1, 0750 and 1350; d 2, 0900 and 1500; d 3, 1050 and 1650 and d 4, 1200 and 1800. Individual samples consisted of approximately 500 mL duodenal chyme and 200 g (wet basis) fecal material. Samples from each steer and within each collection period were composited for analysis. During the final day of each collection period, ruminal samples were obtained from each steer at approximately 4 h after feeding for ruminal pH and VFA analysis. Upon completion of the experiment, ruminal fluid was obtained from all steers and composited for isolation of ruminal bacteria via differential centrifugation (Zinn and Owens, 1986). Samples were subjected to all or

part of the following analysis: DM (oven drying at 105° C until no further weight loss); ash, Kjeldahl N (AOAC, 1997); purines (Zinn and Owens, 1986); chromic oxide (Hill and Anderson, 1958); starch (Zinn, 1990); NDF (Robertson and Van Soest (1991). Microbial OM (MOM) and N (MN) leaving the abomasum were calculated using purines as a microbial marker (Zinn and Owens, 1986). Organic matter fermented in the rumen (OMF) was considered equal to OM intake minus the difference between the amount of total OM reaching the duodenum and MOM reaching the duodenum. Feed N escape to the small intestine was considered equal to total N leaving the abomasum minus ammonia-N and MN and, thus, included any endogenous contribution. Methane production was calculated based on the theoretical fermentation balance for observed molar distribution of VFA and OM fermented in the rumen (Wolin, 1960). Primary assumptions are that VFA, CO_2, and methane are the sole end products of fermentation and that glucose represents the fermentable substrate (OM fermented is expressed as glucose equivalent). The Mixed procedures of SAS were used for all computations (SAS Inst. Inc., Cary, NC). Data were analyzed as a Latin Square design. The model included roughage level, processing method, level × method, and period as fixed effects, and steer as random effect. If significant ($P < 0.05$) F-statistics were detected, means were separated using the method of least significant difference.

Results and Discussion

Treatment effects on characteristics of digestion are shown in Table 2. An interaction was detected between straw level and processing method for DM intake ($P < 0.01$). With 14% straw, processing method did not affect ($P = 0.83$) DM intake. With 7% straw, DM intake was lower (2.3%, $P < 0.01$) for pelleted straw than for ground. The lack of increase in DM intake with increased roughage level is disconcerting. The response is inconsistent with generalized relationships between diet energy density and DM intake (Fox and Black, 1984). However, this effect has been observed previously (Kreikemeier et al., 1990; Zinn et al., 1994). The lower DM intake for the diet containing pelleted than that containing ground wheat straw at 7% can be interpreted as if the rumen function was not appropriately stimulated by treatment. However, that treatment showed the greater ruminal starch digestibility. Therefore, most likely the decrease in DM intake for pelleted wheat straw at 7% was a result of obtaining same energy from the diet with lower DM consumption. Cattle fed high-concentrate diets attempt to eat to a constant energy level (Bartle et al., 1994). Digestibility of ruminal OM (6%), true ruminal N digestibility (9.7%), total tract OM (3.9%), total tract NDF digestibility (4.0%), and total tract N (4.2%) were greater ($P \leq 0.05$) for diets that contained 7% wheat straw than for those that contained 14%. Increase of rumen and total tract digestibility was expected because steam-flaked corn replaced wheat straw with decreasing roughage level. Steam-flaked corn provides greater digestibility than wheat straw (NRC, 2000). However, previous studies (Cole et al., 1976; Zinn, 1986; Calderon-Cortez and Zinn, 1996) have shown none or very little effects of roughage level (7 to 20%) on ruminal or total tract digestion of OM, NDF, starch, and N. Ruminal starch digestibility (88.7, and 84.9 ± 0.74%, for pelleted and ground, respectively) was greater ($P = 0.04$) and ruminal pH (5.44 and 5.76 ± 0.22, for pelleted and ground, respectively) was lower ($P = 0.05$) for diets that contained pelleted straw than for those that contained ground straw. The lower ruminal pH for pelleted is a result of greater ruminal starch digestibility for pelleted than for ground wheat straw. Little effects on ruminal starch and pH were reported by increasing roughage particle size when roughage was included at 8 or 16% (Calderon-Cortez and Zinn, 1996). In contrast, Thompson et al. (1965) observed a 7% greater ruminal pH in steers fed a steam-flaked corn-based diet containing 18% long vs ground alfalfa hay.

Implications

Wheat straw is a viable roughage source for feedlot diets. When included at low levels, the pelleted form resulted in greater ruminal starch digestion which allowed for lower DM intake. The inclusion of 7% pelleted wheat straw in the diet most likely allowed the animal to extract the same amount of energy from the lower DM consumed.

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Table 1. Composition of experimental diets

	Treatment			
	14 % wheat straw		7% wheat straw	
Ingredients, % (DM basis)	Ground	Pelleted	Ground	Pelleted
Steam-flaked corn	70.00	70.00	77.00	77.00
Wheat straw, ground	14.00		7.00	
Wheat straw, pelleted		14.00		7.00
Cane molasses	6.00	6.00	6.00	6.00
Pelleted canola	3.70	3.70	3.70	3.70
Yellow grease	2.80	2.80	2.80	2.80
Limestone	1.40	1.40	1.40	1.40
Urea	1.30	1.30	1.30	1.30
TM salt[a]	0.35	0.35	0.35	0.35
Chromic oxide	0.35	0.35	0.35	0.35
Magnesium oxide	0.10	0.10	0.10	0.10

[a]Trace mineral salt: $CoSO_4$, 0.068%; $CuSO_4$, 1.04%; $FeSO_4$, 3.57%, ZnO, 0.75%; $MnSO_4$, 1.07%; KI, 0.52%; and NaCl, 93.4%.

Table 2. Effect of wheat straw level and processing method on site and extent of digestion by cattle consuming finishing feedlot diets

	Treatments							
	14% wheat straw		7% wheat straw			*P*-value[1]		
Item	Ground	Pelleted	Ground	Pelleted	SE	Method	Level	M × L
Steer replication	4	4	4	4				
Intake, g/d								
DM	4,322	4,323	4,375	4,276	478.92	0.01	0.61	0.01
OM	4,084	4,064	4,175	4,077	454.33	0.01	0.01	0.01
NDF	684	662	507	492	65.48	0.03	0.01	0.74
N	87	86	87	85	9.54	0.01	0.01	0.01
Starch	2,331	2,393	2,159	2,456	255.11	0.01	0.03	0.01
Flow to the duodenum, g/d								
OM	1,967	1,996	1,875	1,770	234.86	0.52	0.09	0.42
NDF	515	473	435	403	85.64	0.43	0.25	0.93
Starch	325	298	350	257	45.78	0.08	0.83	0.38
N	98	106	100	99	11.22	0.16	0.34	0.19
Microbial N	65	64	70	64	8.08	0.23	0.49	0.51
Feed N	34	41	29	34	4.14	0.02	0.06	0.66
Ruminal digestion, %								
OM	51.99	52.03	54.76	56.03	1.23	0.67	0.02	0.62
NDF	27.95	23.93	3.68	31.16	10.93	0.55	0.42	0.16
Starch	85.82	87.76	84.08	89.54	1.03	0.04	0.99	0.12
Feed N	61.49	51.99	67.31	58.24	2.73	0.11	0.05	0.94
Microbial efficiency[2]	21.85	21.70	22.48	21.16	1.02	0.48	0.96	0.58
OM	805	813	661	660	80.20	0.95	0.07	0.95
NDF	384	378	252	310	32.18	0.42	0.01	0.34
Starch	39	47	26	29	8.56	0.59	0.09	0.75
N	23	25	21	20	2.60	0.58	0.06	0.47
Total tract digestion, %								
OM	80.38	80.12	84.06	83.23	1.06	0.69	0.01	0.78
NDF	86.08	86.11	90.95	88.44	1.09	0.25	0.01	0.27
Starch	98.37	98.06	98.80	98.77	0.32	0.66	0.10	0.66
N	73.38	72.24	76.14	75.78	1.40	0.64	0.05	0.78
Ruminal pH	5.96	5.37	5.57	5.50	0.23	0.01	0.33	0.09

[1]P-value: Method = effect of roughage processing method (ground or pelleted); Level = effect of roughage level (14 or 7%); M × L = method × level interaction.

[2]Microbial N, g/kg of OM fermented.

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EFFECTS OF POLYUNSATURATED FATTY ACID (PUFA) SUPPLEMENTATION ON PERFORMANCE AND ACUTE-PHASE RESPONSE OF TRANSPORTED BEEF STEERS

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ABSTRACT: The objective was to compare ADG, DMI, and acute-phase response of steers supplemented or not with PUFA for 30 d prior to shipping to the feedyard. Seventy-two Angus steers weaned at 7 mo of age (d -55) were stratified by BW on d -30 of the study, and randomly allocated to 18 drylot pens (4 steers/pen). Pens were assigned to receive a grain-based supplement (avg. 1.5 kg/steer/d) without (**CO**) or with 0.15 kg/steer/d of a PUFA source (**PF**; Megalac-R®, Church and Dwight, Princeton, NJ) or a SFA source (**SF**; Megalac®, Church and Dwight). Treatment intakes were formulated to be iso-caloric, iso-nitrogenous, and offered daily from d -30 to d 0. Mixed alfalfa-grass hay was offered in amounts to ensure ad libitum access during the same period. On d 0, steers were loaded onto a commercial livestock trailer and transported for approximately 350 km over a 6 h period. However, steers remained in the truck for a total of 24 h before unloaded into a commercial growing lot (d 1), where steers were maintained in a single pen, managed similarly, and received a diet not containing PF or SF. Forage DMI was evaluated daily from d -30 to d -1. Shrunk BW was collected on d -33, 1, and 144 for preconditioning and growing lot ADG calculation. Blood samples were collected on d 0, 1, and 3, and analyzed for plasma concentrations of interleukin 1 and 6, tumor necrosis factor (TNF)-α, haptoglobin, ceruloplasmin, cortisol, and fatty acids. No treatment effects were detected for preconditioning ADG ($P = 0.54$) or G:F ($P = 0.56$), but DMI was often reduced for PF steers compared with CO and SF (treatment × day interaction; $P < 0.01$). Concentrations of PUFA were greater in PF steers compared to CO and SF prior to and after transportation (treatment × day interaction $P < 0.01$). Following transportation, concentration of TNF-α increased for CO, did not change for SF, but decreased for PF steers (treatment × day interaction, $P < 0.01$). During the growing lot, PF steers tended to have greater ADG compared to CO steers ($P = 0.06$) In conclusion, PUFA supplementation during preconditioning had detrimental effects on DMI, but reduced plasma concentrations of TNF-α following transportation, and improved growing lot ADG.

Introduction

Three of the most stressful events encountered by a feeder calf are weaning, transportation, and feedlot entry. These events, which may occur together or in a short period of time, lead to physiological, nutritional, and immunological changes that highly affect subsequent calf health and feedlot performance (Loerch and Fluharty, 1999). One example is the acute-phase response, an important component of the innate immune system that can be detrimental to growth rates in cattle (Cooke et al., 2009). Consequently, management strategies that prevent and/or alleviate the acute-phase response have been shown to benefit cattle productivity and overall efficiency of beef operations (Arthington et al., 2008).

Supplementation of rumen-protected PUFA to feeder heifers prior to and after transportation decreased concentrations of acute-phase proteins during the 7 d following feedyard entry (Araujo et al., 2009). These results indicated that PUFA supplementation might be an alternative to alleviate the acute-phase response stimulated by transportation and feedlot entry. However, heifers and steers supplemented with PUFA experienced, during the feedyard phase only, reduced ADG and feed intake (Araujo et al., 2008; Araujo et al., 2009) compared to cohorts offered iso-caloric and iso-nitrogenous control diets.

Therefore, one alternative to conciliate the beneficial effects of PUFA supplementation on the acute-phase response without reducing feedlot performance would be supplementing PUFA prior to shipping/feedlot entry only. We hypothesized that feeder steers supplemented with PUFA prior to shipping would experience alleviated acute-phase response following feedlot entry, resulting in enhanced feedyard performance. The objectives of this study were to evaluate plasma concentrations of acute-phase proteins, cytokines, and cortisol, in addition to health and growth rates of feeder steers supplemented or not with a PUFA source for 4 wk prior to shipping to the feedlot.

Materials and Methods

The experiment was conducted in accordance with an approved Oregon State University Animal Care and Use Protocol, and was divided into a preconditioning (d -30 to 0) and a growing phase (d 1 to 144). The preconditioning phase was conducted at the Eastern Oregon Agricultural Research Center, Burns. The growing phase was conducted at a commercial growing lot (Top Cut; Echo, OR).

Seventy-two Angus steers weaned at 7 mo of age (d -55) were stratified by BW on d -30 of the study, and randomly allocated to 18 drylot pens (4 steers/pen). Pens were assigned to 1 of 3 treatments (6 pens/treatment): 1) corn and soybean meal-based supplement containing 0.15 kg/steer of a PUFA source (**PF**; Megalac-R®; Church and Dwight, Princeton, NJ), 2) corn and soybean meal-based supplement

containing 0.15 kg/steer of a SFA source (**SF**; Megalac®; Church and Dwight), and 3) corn and soybean meal-based supplement containing no fat source (**CO**). Supplements were offered daily, at a rate of approximately 1.5 kg/steer, throughout the preconditioning phase (d -30 to 0). Supplement intakes were formulated to be iso-caloric and iso-nitrogenous, whereas mixed alfalfa-grass hay was offered in amounts to ensure ad libitum access during the same period. On the morning of d 0, steers were combined into 1 group, loaded into a commercial livestock trailer, and transported to the growing lot (Top Cut). The travel time was approximately 10 h, but steers were maintained in the truck for a total of 24 h before being unloaded (d 1) in order to simulate the stress challenge of a long-haul. During the growing phase (d 1 to 144), all steers were maintained in a single pen, managed similarly and received the same diet, which did not contain any of the preconditioning treatments.

Blood samples were collected on d 0 (prior to loading), 1 (immediately upon arrival), and 3, via jugular venipuncture into commercial blood collection tubes (Vacutainer, 10 mL; Becton Dickinson, Franklin Lakes, NJ) containing sodium heparin. Steer rectal temperature was assessed with a digital thermometer (GLA M750 digital thermometer; GLA Agricultural Electronics, San Luis Obispo, CA) concurrently with each blood collection. All blood samples were harvested for plasma and stored at −80°C until assayed for concentrations of cortisol (DPC Diagnostic Products Inc., Los Angeles, CA), ceruloplasmin (according to Demetriou et al. (1974), haptoglobin (according to Makimura and Suzuki, 1982), fatty acid composition (according to Kramer et al., 1997), and proinflammatory cytokines interleukin (IL)-1, IL-6, and tumor necrosis factor(TNF)-α (SearchLight; Aushon Biosystems, Inc., Billerica, MA).

Performance and physiological data were analyzed using the PROC MIXED procedure of SAS (SAS Inst., Inc., Cary, NC) and Satterthwaite approximation to determine the denominator df for the tests of fixed effects. The model statement used for plasma measurements and DMI contained the effects of treatment, day, and the interaction. Data were analyzed using pen(treatment) as the random variable. The specified term for the repeated statement was day and the covariance structure utilized was autoregressive, which provided the best fit for these analyses according to the Akaike information criterion. Concentrations of plasma cytokines were transformed to log to achieve normal distribution, according to Shapiro-Wilk test from the UNIVARIATE procedure of SAS (W > 0.90). The model statement used for ADG and G:F analysis contained only the effects of treatment, whereas the random variable was pen(treatment) Results are reported as least square means and separated using PDIFF. Significance was set at $P \leq 0.05$, and tendencies were determined if $P > 0.05$ and ≤ 0.10. Results are reported according to treatment effects if no interactions were significant, or according to the highest-order interaction detected.

Results & Discussion

During the preconditioning phase, a treatment × day interaction was detected (P < 0.01) for DMI (Figure 1) because PF steers often had reduced DMI compared to the other treatments. However, no treatment effects were detected on preconditioning ADG and G:F (Table 1). These results support previous efforts indicating that PUFA supplementation reduced DMI in cattle (Simas et al., 1995; Bateman et al., 1996; Araujo et al., 2008), but did not affect ADG or feed efficiency measures (Araujo et al., 2009).

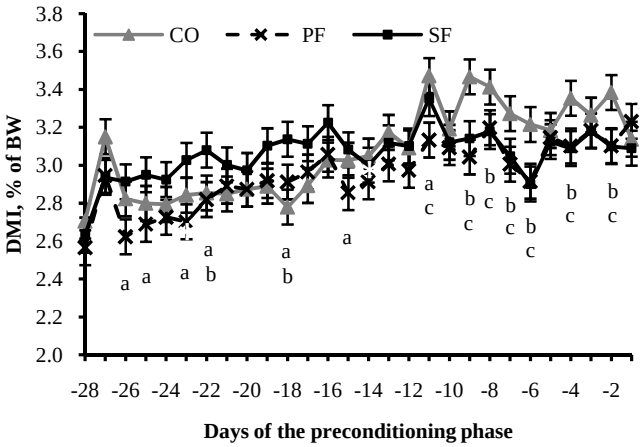

Figure 1. Daily DMI, as a percentage of BW, of steers offered diets without (CO) or with the inclusion of a rumen-protected SFA or PUFA (PF) source during the preconditioning phase. A treatment × day interaction was detected (P < 0.01). Days with letter designation indicates the following treatment differences (P < 0.05): a = SF vs. PF, b = SF vs. CO, and c = CO vs. PF.

No treatment effects were detected for rectal temperatures and plasma concentrations of haptoglobin, ceruloplasmin, and cortisol (Table 1). These results indicate that PUFA supplementation did not decrease plasma concentrations of acute-phase proteins, as previously reported by Araujo et al. (2009). Further, similar cortisol concentrations suggest that steers from all treatments experienced a similar stress challenge due to transport and feedyard entry (Crookshank et al., 1979; Sapolsky et al., 2000).

Table 1. Preconditioning ADG and G:F, and rectal temperatures, plasma concentrations of acute-phase proteins, cytokines, and cortisol of steers offered diets without (CO) or with the inclusion of a rumen-protected SFA (SF) or PUFA (PF) source during a 30-d preconditioning phase.

	Treatments				
Item[1,2]	CO	SF	PF	SEM	P =
ADG, kg/d	0.83	0.87	0.78	0.06	0.54
G:F, kg/kg	0.141	0.147	0.137	0.009	0.70
Rectal temperature. °C	39.64	39.66	39.72	0.05	0.49
Haptoglobin, 450 nm	3.99	4.43	5.41	0.96	0.58
Ceruloplasmin, mg/dL	26.2	26.2	27.1	0.88	0.68
Cortisol, ng/mL	36.7	36.7	28.7	4.0	0.29
IL-6, pg/mL (log)	0.88	0.56	0.79	0.26	0.67
IL1, pg/mL (log)	1.51	1.12	1.46	0.14	0.16

[1] Blood samples and rectal temperatures were collected on d 0 (before truck loading), 1 (immediately following unloading), and 3 (2 d following feedyard entry).

[2] ADG was calculating using shrunk values obtained on d -30 and d 1 of the study. Total DMI and BW gain from d -28 to d 1 were utilized to calculate G:F.

A treatment × day interaction was detected (P < 0.01) for plasma TNF-α. Following transportation, concentration of TNF-α increased for CO, did not change for SF, but decreased for PF steers (Table 2). No treatment effects were detected for plasma concentrations of IL-1 and IL-6 (Table 1). But when plasma concentrations of all cytokines are summed and analyzed jointly, given that their proinflammatory activities are redundant and synergistic (Whiteside, 2007), a treatment × day interaction was detected (P = 0.05), given that following transportation, cytokine concentrations increased for CO, did not change for SF, but decreased for PF steers (Table 2).

Table 1. Plasma concentrations of TNF-α and combined proinflammatory cytokines (TNF-α, IL-1, and IL-6) of steers offered diets without (CO) or with the inclusion of a rumen-protected SFA (SF) or PUFA (PF) source during a 30-d preconditioning phase.

	Day of collection			
Item[1,2]	0	1	3	SEM
Plasma TNF-α, pg/mL (log)				
CO	1.74 [a]	1.88 [a]	2.23 [b]	0.21
SF	1.91 [a]	2.10 [a]	1.95 [a]	0.21
PF	1.90 [ab]	2.00 [a]	1.55 [b]	0.21
Combined cytokines, ng/mL (log)				
CO	1.99 [a]	2.10 [a]	2.45 [b]	0.18
SF	2.00 [a]	2.18 [a]	2.08 [a]	0.18
PF	2.15 [ab]	2.27 [a]	1.95 [b]	0.18

[1] Blood samples were collected on d 0 (before truck loading), 1 (immediately following unloading), and 3 (2 d following feedyard entry).
[2] Within rows, values bearing different letters differ (P < 0.05).

A treatment × day interaction was also detected (P = 0.04) for plasma PUFA concentrations. On d 0, PF steers tended (P = 0.10) and had greater (P < 0.01) plasma PUFA concentrations compared to SF and CO steers, respectively. On d 1 and 3, plasma PUFA concentrations were greater in PF steers (P < 0.01) compared to both treatments.

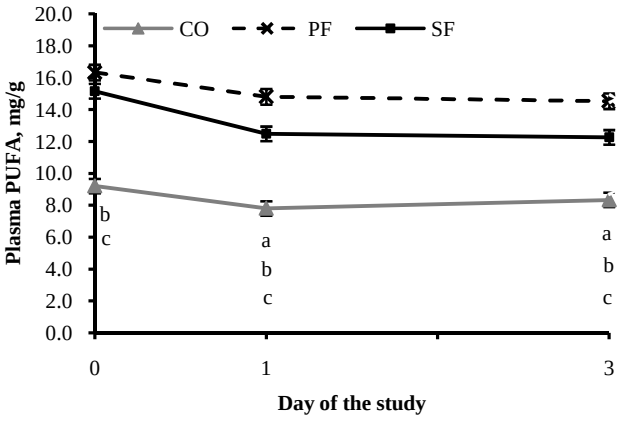

Figure 2. Plasma concentrations of PUFA (mg/g) of steers offered diets without (CO) or with the inclusion of a rumen-protected SFA (SF) or PUFA (PF) source during the preconditioning phase (d -30 to d 0). On d 0, steers were transported to a feedyard, where preconditioning treatments were not offered. A treatment × day interaction was detected (P = 0.04). Days with letter designation indicates the following treatment differences (P < 0.01): a = SF vs. PF, b = SF vs. CO, and c = CO vs. PF.

During the growing lot phase, PF steers tended (P = 0.06) to have greater ADG compared to CO steers (1.23 vs. 1.17 kg/d; SEM = 0.02), but similar (P = 0.43) to SF steers (1.20 kg/d). No differences were detected for growing lot ADG between PF and SF steers (P = 0.28). This increase in ADG between CO and PF steers can be attributed, at least in part, to the beneficial effects of PUFA supplementation on the acute-phase response following transportation and feedlot entry. The acute-phase response can be detrimental to performance of feeder calves, particularly during the receiving period of the feedlot (Duff and Galyean, 2007; Arthington et al., 2008), whereas PUFA are believed to modulate the immune system by altering inflammatory reactions (Miles and Calder, 1998). Within the immunomodulatory effects of PUFA, linolenic acid promotes the synthesis of eicosanoids that do not elicit an inflammatory response, such as PGE_3, and also stimulate synthesis of TH_2 anti-inflammatory cytokines such as IL-4, IL-10, and IL-13. Conversely, linoleic acid promotes the synthesis of PGE_2, which is a potent stimulator of the acute-phase protein response, and the TH_1 proinflammatory cytokines (IL-1, IL-6, and TNF-α) that trigger hepatic synthesis of acute-phase proteins (Yaqoob and Calder, 1993; Carroll and Forsberg, 2007; Schmitz and Ecker, 2008). According to the manufacturer, the PUFA source offered to steers in the present study contained linoleic and linolenic acids (28.5 and 3.0 %, respectively; DM basis). Although a greater amount of linoleic acid was present in the PUFA source offered herein, animal requirements for linoleic and linolenic acids are still unknow. Therefore, linolenic acid might be required in reduced amounts to trigger an anti-inflammatory response and overcome the proinflammatory effects of linoleic acid, what would explain the results reported in herein. However, further research is required to address this matter.

Implications

Inclusion of a rumen-protected PUFA source into preconditioning diets reduced the some aspects of the acute-phase response triggered by transport and feedyard entry, and improved growing lot performance of feeder calves. Therefore, PUFA supplementation might be an alternative to enhance health parameters and feedlot performance of growing cattle.

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LATE GESTATION SUPPLEMENTATION OF BEEF COWS: EFFECTS ON COW AND CALF PERFORMANCE

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ABSTRACT: We conducted a 2-yr study to evaluate the influence of cow BCS and dried distillers grains (DDGS) supplementation during late gestation on cow and calf productivity. The experimental design was a 2 X 2 factorial; 2 BCS (4 or 6) and supplemented or not supplemented. Approximately 12.7 kg/cow of low quality meadow hay (6.4% CP) was provided each day and supplemented cows received 1.81 kg/hd of DDGS every Monday and Wednesday and 2.72 kg/hd on Friday. On each supplementation day, supplemented cows were gathered and sorted into pens based on their respective blocking structure. After completing consumption of their allocated supplement, cows were returned to a common pasture. Performance data and binomial data were analyzed as a Randomized Complete Block using PROC MIXED and PROC GLIMMIX in SAS, respectively. Calf birth weight was greater with BCS 6 cows compared with BCS 4 ($P = 0.002$) and for supplemented compared with unsupplemented cows ($P = 0.05$). In addition, weaning weight was greater for BCS 6 compared with BCS 4 ($P = 0.05$) and calf weaning weight and ADG to weaning were greater for the offspring of supplemented compared with unsupplemented cows ($P \leq 0.02$). We noted no differences in post-weaning calf performance or carcass characteristics ($P > 0.10$). However, BCS 6 cows had approximately 10% more live calves at birth and at weaning ($P < 0.001$) compared with BCS 4 cows. Also, pregnancy rate was 91% for BCS 6 compared with 79% for BCS 4 cows ($P = 0.005$). Supplementation during late gestation resulted in an estimated net return of $7/cow if calves were sold at weaning compared with not supplementing. More importantly, because of additional weaned calves, the estimated net return for BCS 6 cows at weaning was $71/head more than BCS 4. Likewise, with retained ownership, BCS 6 cows yielded a net return of $130/head more than BCS 4 cows. This research demonstrates the potential consequences of not maintaining cows in good BCS (> 5) at calving; greater calf losses, less weaned calves, decreased pregnancy rate, and lower economic return.

Introduction

Protein supplementation of late-gestation beef cows consuming low-quality forages has been shown to increase cow body weight and BCS at calving (Sanson et al., 1990; Bohnert et al., 2002). Also, cows with a BCS less than 4 may breed late or not at all in a controlled breeding season. As a result, it is recommended to have cows in good body condition prior to calving to maximize reproductive performance. Recent research has suggested that providing supplemental protein to mature cows during the last 90 d of gestation improves calf survivability and yields greater economic return with retained ownership (Stalker et al., 2006) and improved weaning weight and fertility in heifers (Martin et al., 2007). This is novel work that demonstrates supplementation of the cow during the last third of gestation can affect the productivity of the offspring which was in utero during supplementation. The aforementioned cows began protein supplementation with an average BCS of 5 or greater. Based on this information, we hypothesize that cows in poor body condition (BCS $\leq$ 4) will respond more favorably to supplementation than cows in good condition (BCS $\geq$ 5).

The objectives of the current study were to determine the influence of cow BCS and dried distillers grains (DDGS) supplementation during the last third of gestation on cow reproductive performance, calf growth and performance through the feedlot, and steer calf carcass characteristics. Also, if supplementation is to be profitable it must improve net returns; therefore, we estimated the economic impact of treatments.

Materials and Methods

A 2-yr project, in accordance with an approved Oregon State University Animal Care and Use Protocol, was conducted to evaluate the effects of BCS and late-gestation DDGS supplementation of cows consuming low-quality forage. Each year, 120 cows were used in a 2 × 2 factorial design. The factors were cow BCS (4 or 6; 1 to 9 scale) and supplementation (with or without supplementation). Each year during a pre-study period (approximately 60 d prior to study initiation) 120 cows that had been palpated pregnant were stratified by BCS, blocked by age and weight (6 blocks; 20 cows per block), and randomly allocated to 1 of 4 treatments: BCS 4 with no supplementation (BCS4 NS), BCS 4 with supplementation (BCS4 S); BCS 6 with no supplementation (BCS6 NCP); BCS 6 with supplementation (BCS6 CP). The cows were then managed as two separate groups based on BCS treatment (BCS 4 or BCS 6). The 2 BCS groups were placed in separate pastures and nutritionally managed to reach their respective target BCS by the study start date (approximately January 1). During the pre-trial period all cows received meadow hay (approximately 6% CP; DM basis) and the BCS 6 cows

were supplemented with alfalfa (approximately 20% CP) as needed to help reach the target BCS by study start date. Initial cow pre-trial weight for all cows was 501 ± 45 kg (BCS 4 = 501 ± 43 kg; BCS 6 = 501 ± 48 kg) and average pre-trial cow BCS was 4.30 ± 0.32 (BCS 4 = 4.28 ± 0.26; BCS 6 = 4.31 ± 0.36).

In early January each year, all 120 cows were placed into a 26 ha flood meadow pasture that had been harvested for hay the previous summer. All cows received approximately 13 kg/d of low-quality (6.4 % CP; DM basis) meadow hay through calving. Supplemented cows received DDGS (31% CP; DM basis) every Monday (1.8 kg/hd), Wednesday (1.8 kg/hd), and Friday (2.7 kg/hd) so that the total amount of DDGS provided daily over the week averaged 0.91 kg/hd. On each supplementation day, cows were gathered at 0700 h and cows not receiving supplement were turned back out to pasture while supplemented cows were sorted into supplement pens based on their respective treatments and blocking structure (12 total pens; 6 pens each for BCS 4 and BCS 6 supplemented treatments; 5 cows/pen; 60 total supplemented cows). The amount of supplement provided was adjusted as cows calved.

Approximately 1 mo prior to calving, all cows were vaccinated with Vira Shield 5 and Clostri Shield 7 (Novartis Animal Health US, Inc.). Approximately 30 d after calving, all cows were treated for internal and external parasites using Dectomax injectable (Pfizer Animal Health). Additionally, all cows were vaccinated with Vira Shield 5 + VL5 (Novartis Animal Health US, Inc.) at weaning.

At branding (approximately 30 d of age), all calves were vaccinated with Clostrishield 7 and Virashield 6 + Somnus (Novartis Animal Health US, Inc.). At weaning, calves were vaccinated with One Shot Ultra 7, Bovi-Shield Gold 5, and TSV-2 (Pfizer Animal Health). In addition, they received Dectomax injectable for treatment of internal and external parasites. Four weeks later, all calves received a booster of Bovi-Shield Gold 5 + Somnus, Ultra Choice 7, and TSV-2 (Pfizer Animal Health).

Upon calving, cows were weighed and body condition scored. Calves were weighed and a sample of blood collected for determination of serum IgG level within 24 to 48 h of birth. In addition, all bull calves were castrated at this time. After being weighed, all cow/calf pairs were placed into an adjacent 26 ha pasture and provided approximately 14 kg/hd of meadow hay until all cows had calved and calves were approximately 30 d of age. At that time, all of the cow-calf pairs were transported to the Northern Great Basin Experimental Range (NGBER) and managed as a single herd until weaning when calves averaged approximately 140 d of age. Angus and Hereford bulls were used during a 60-d breeding season. All cows and bulls were managed in a single pasture of approximately 810 ha during the breeding season. The cow to bull ratio was 20:1 and the breeding season began June 1 each year.

At weaning, all cows were weighed and body condition scored and all calves were weighed. All weaned calves were transported from the NGBER and placed on a pasture that had been rake-bunched (approximately 7% CP; Turner and DelCurto, 1991) the previous summer. In addition, DDGS were provided to the weaned calves on Monday (0.91 kg/hd), Wednesday (0.91kg/hd), and Friday (1.4 kg/hd). After approximately 45 d, the weaned steer calves were placed in a commercial growing lot for approximately 60 d and then finished in a commercial feedlot in Northeast Oregon. In addition, cows were rectally palpated in mid-October each year for determination of pregnancy. The response variables that were analyzed included: 1) cow weight and BCS change, 2) cow pregnancy rate, 3) calf birth weight, 4) calf serum IgG level within 24 to 48 h of birth, 5) calf performance to weaning, 6) steer performance in the growing lot and feedlot, 7) steer carcass quality, and 8) net returns based on cow BCS and CP Supplementation.

The values used for determination of partial budgets to evaluate the economic ramifications of treatments were \$93.70/t for meadow hay and \$220.46/t for DDGS. Growing lot feed costs were \$1.20/(hd·d) and \$0.88/(hd·d) for 2007 and 2008, respectively. In addition, feedlot feed costs were \$2.89/(hd·d) and \$2.74/(hd·d) for 2007 and 2008, respectively. The sale value of steers at weaning (\$117.88/45 kg of BW) and upon leaving the growing lot (\$102.52/45 kg of BW) was based on the 5-yr average (2004 to 2008) October price for 181 and 272 kg feeder steers, respectively, as reported in the Washington Weekly Combined Cattle Report accessed through the Livestock Marketing Information Center (Denver, CO). The carcass value of steers was determined similarly with the exception of using the 5-yr average (2004-2008) price for June from the National Weekly Direct Slaughter Cattle Report (\$139.84/45 kg of hot carcass wt).

Cow and calf performance data were analyzed as a Randomized Complete Block using the PROC MIXED option in SAS (SAS Inst., Inc., Cary NC). The model included treatment, block, year, treatment × block, treatment × year, and block × year. Data were analyzed using pen (treatment × year) as random variable. Treatment differences were evaluated using the following contrasts: BCS 4 vs BCS 6; Supplemented vs Not Supplemented; and the interaction of BCS and Supplementation.

Binomial data (cow pregnancy rate, live calves at birth and weaning, and proportion of carcasses grading choice) were analyzed as a Randomized Complete Block using the PROC GLIMMIX procedure of SAS. The model, random variable, and contrasts used were the same used previously for the cow and calf performance data.

Results & Discussion

The total number of cows that were removed from the study because of death, loss of a calf, or palpated not pregnant was 19, 15, 4, and 6 for BCS4 S, BCS4 NS, BCS6 S, and BCS6 NS, respectively (Table 1). In addition, the number of calves lost through slaughter was 9, 8, 2, and 3 for BCS4 S, BCS4 NS, BCS 6S, and BCS6 NS, respectively.

Cow Performance

The initial weight of BCS 6 cows was approximately 62 kg heavier than the BCS 4 cows ($P < 0.001$; Table 2). Likewise, the initial BCS of treatments came close to meeting our targeted values of 6 and 4 for

BCS 6 and BCS 4 cows, respectively; the BCS 6 cows averaged 5.7 while BCS 4 cows averaged 4.3 ($P < 0.001$). At calving, the difference in weight and BCS between BCS 6 and BCS 4 cows remained ($P < 0.001$). However, we did note a supplementation effect with both cow weight and BCS at calving. The supplemented cows weighed more ($P < 0.001$) and carried more BCS ($P < 0.001$) than unsupplemented cows. At weaning, the BCS 6 cows were still heavier (30 kg; $P < 0.001$) and had a greater BCS (0.6; $P < 0.001$) than BCS 4 cows. In addition, the supplemented cows had a greater BCS than unsupplemented cows ($P = 0.02$).

Table 1. Losses of cows and calves

	BCS 4		BCS 6	
Item	Supplement	No Supplement	Supplement	No Supplement
Cows				
n	60	60	60	60
Prepartum	1[c]	0	0	0
Parturition	0	0	0	0
Cow Lost fetus during study	2	1	0	0
Lost calf prior to turnout	5[d]	3[d]	0	0
Palpated not pregnant	11	11	4	6
Total (all causes)	***19***	***15***	***4***	***6***
Calves				
Prepartum	2	1	0	0
Parturition	5[d]	3[d]	0	0
Weaning	1[e]	1[e]	1[e]	0
Growing lot[a]	1[f]	0	1[g]	1[h]
Finishing lot[b]	0	3[f,f,g]	0	2[f]
Total (all causes)	***9***	***8***	***2***	***3***

[a] = Only remaining steer calves were placed in growing lot; n = 27, 26, 35, and 25 for supplemented and unsupplemented BCS 4 and supplemented and unsupplemented BCS 6, respectively

[b] = Only remaining steer calves were placed in finishing lot; n = 26, 27, 34, and 24 for supplemented and unsupplemented BCS 4 and supplemented and unsupplemented BCS 6, respectively

[c] = Cow got on back and suffocated; [d] = Calves born dead, no dystocia observed; [e] = Cause of death unknown; [f] = Calves died of pneumonia; [g] = Calf died of bloat; [h] = Crippling injury

Table 2. Cow performance relating to cow BCS and supplementation (Supp) during late gestation[a]

	BCS 4		BCS 6			P-value		
Item	Supp	No Supp	Supp	No Supp	SEM	BCS 4 vs BCS 6	Supp vs UnSupp	BCS X Supp
Initial wt., kg[b]	503	502	562	567	4.5	<0.001	0.65	0.46
Calving wt., kg	531	495	570	538	5.0	<0.001	<0.001	0.63
Wt. at Weaning, kg	522	512	551	543	5.4	<0.001	0.10	0.81
Initial BCS[c]	4.32	4.39	5.67	5.75	0.05	<0.001	0.14	0.83
Calving BCS	4.57	4.33	5.51	5.18	0.05	<0.001	<0.001	0.36
Weaning BCS	4.74	4.61	5.30	5.19	0.05	<0.001	0.02	0.84
Days to calving	76	79	76	76	2.5	0.58	0.55	0.43
Live calf at birth, %	86.7	93.3	100.0	100.0	2.7	<0.001	0.22	0.22
Live Calf at Weaning, %	85.0	91.7	98.3	100.0	3.0	<0.001	0.16	0.40
Pregnancy rate, %	77.2	80.7	92.8	90.0	4.6	0.005	0.93	0.48

[a] Pretrial period was 11/1/06 to 1/4/07 in yr 1 and 11/8/07 to 1/3/08 in yr 2; During pretrial, BCS 4 and BCS 6 cows were managed as 2 separate groups and fed to reach target BCS by study start date

[b] Initial pretrial wt. Averages: Overall = 501 ± 45 kg; BCS 4 = 501 ± 43 kg; BCS 6 = 501 ± 48 kg

[c] Initial Pretrial BCS Averages: Overall = 4.30 ± 0.32; BCS 4 = 4.28 ± 0.26; BCS 6 = 4.31 ± 0.36

No difference in the proportion of live calves at birth and weaning were observed due to supplementation ($P > 0.15$); however, a difference was noted because of BCS treatment. The percentage of live calves at birth for the BCS 6 cows averaged 100% compared with 90% for the BCS 4 cows ($P < 0.001$). Also, the percentage of live calves at weaning averaged 99% and 88% for BCS 6 and BCS 4 cows, respectively. Therefore, if we extrapolate our data to a couple of theoretical cow herds entering the last third of gestation with an average BCS of 6 or 4, we could expect to have almost 11% more calves at weaning with the BCS 6 herd; an extra 11 calves per hundred cows.

Cow pregnancy rate was not affected by supplementation treatment ($P = 0.93$); however, there was a difference between the BCS 6 and BCS 4 treatments. The average pregnancy rate for BCS 4 cows was 79% compared with 91% for the BCS 6 cows ($P = 0.005$). Our breeding season was 60 d, so it is possible that a longer breeding season may have resulted in a greater overall pregnancy rate but the calving interval would be longer, cows would not have a calf within a 365-d interval, and the consistency and weight of the calves at weaning would be less.

Calf Performance

Calf birth weight increased with cow BCS (41 vs 38 kg for BCS 6 and 4, respectively; $P = 0.002$; Table 3) and with supplementation (41 vs 39 kg for supplemented and not supplemented, respectively; $P = 0.05$). However, no incidents of dystocia were noted during the study. There was no treatment effect on calf serum IgG level at birth ($P \geq 0.10$).

Calf weaning weight was greater for BCS 6 compared with BCS 4 cows ($P = 0.05$) and for supplemented cows compared with those cows not receiving supplement ($P = 0.01$). In addition, calf ADG to weaning was greater for calves from dams that received supplement during the last third of gestation ($P = 0.02$). This agrees with previous work indicating that supplementation of cows pre-calving increases weaning performance of calves (Stalker et al., 2006).

Table 3. Calf performance relating to cow BCS and supplementation (Supp) during late gestation

	BCS 4		BCS 6			P-value		
Item	Supp	No Supp	Supp	No Supp	SEM	BCS 4 vs BCS 6	Supp vs UnSupp	BCS X Supp
Birth wt., kg	39.0	38.5	42.6	40.2	0.72	0.002	0.05	0.21
IgG, mg/dL[a]	5,880	6,348	5,836	6,088	231	0.49	0.10	0.62
Weaning wt., kg	188	179	192	186	3.2	0.05	0.01	0.58
Weaning age, d	140	137	140	141	2.8	0.46	0.65	0.53
ADG to weaning, kg	1.07	1.03	1.07	1.04	0.014	0.81	0.02	0.70
Growing lot initial wt., kg	207	199	214	208	5.5	0.11	0.18	0.86
Growing lot final wt., kg	256	247	264	256	6.1	0.14	0.16	0.94
Growing lot ADG, kg	0.63	0.60	0.64	0.59	0.036	0.97	0.26	0.74
Feedlot initial wt., kg	256	247	264	256	6.1	0.14	0.16	0.94
Feedlot final wt., kg[b]	587	580	593	579	11	0.79	0.32	0.74
Feedlot ADG, kg	1.83	1.91	1.90	1.88	0.09	0.84	0.71	0.54
Feedlot days on feed	178	166	177	166	7	0.84	0.10	0.86
Hot carcass wt., kg	370	365	374	365	7.2	0.79	0.32	0.74
Backfat, cm[c]	1.78	1.68	1.62	1.68	0.10	0.32	0.83	0.36
LM area, cm^2	87.1	84.5	87.1	86.4	1.81	0.65	0.37	0.66
KPH, %	2.07	1.99	1.93	2.24	0.11	0.62	0.25	0.05
Marbling[d]	423	403	434	420	14	0.33	0.24	0.84
Yield grade	3.4	3.4	3.3	3.4	0.15	0.49	0.86	0.70
Choice, %	57.6	38.6	65.7	62.4	11	0.13	0.28	0.42
Retail product, %[e]	48.7	48.8	49.0	48.9	0.36	0.50	0.88	0.66

[a] Immunoglobulin G concentration in calves between 24 to 48 h after birth measured by radial immunodiffusion

[b] Calculated from hot carcass weight assuming a 63% dressing percentage

[c] Thickness measured at the 12th rib

[d] Marbling score: 400 = small[00], 500 = Modest[00]

[e] USDA Retail Yield Equation: 51.34 – (5.78*inches backfat) – (0.0093*pounds hot carcass weight) – (0.462*percentage kidney, pelvic, and heart fat) + (0.74*ribeye area in square inches)

No notable treatment effects were observed in steer calf performance in the growing lot or feedlot ($P \geq 0.10$). The only carcass characteristic affected by treatment was KPH which decreased with supplementation for BCS 4 cows and increased with supplementation for BCS 6 cows ($P = 0.05$). The reason for this observation is not readily apparent. None of the other carcass characteristics were affected by treatment ($P \geq 0.13$).

Economics

Table 4 lists the estimated net returns of treatments broken down in 4 production phases; cow-calf, growing lot, feedlot, and retained ownership. The most notable affect on net returns was because of cow BCS. The BCS 6 cows returned approximately $71/cow more than the BCS 4 cows if calves were sold at weaning and approximately $130/cow more if we retained ownership of the calves through the feedlot. The primary reason for the disparity in net returns is due to more live calves at weaning. Supplementation had minimal effects on net returns with the greatest benefit noted in the cow-calf phase where supplemented cows had a $7/cow greater net return than unsupplemented. Nevertheless, it is interesting to note the approximately 500% greater health costs in the feedlot for calves from unsupplemented compared with supplemented cows ($8.28 vs.$1.65/head).

Table 4. Economics relating to cow BCS and supplementation (Supp) during late gestation

	BCS 4		BCS 6		BCS	Supp.
Item	Supp.	No Supp.	Supp.	No Supp.	Difference[a]	Difference[b]
Cow-Calf Phase						
Returns						
More Calves Weaned[c]	0.00	0.00	54.14	52.50		
Weaned Calf Value	488.98	465.32	499.87	484.78		
Costs						
Supplement	15.25	0.00	15.25	0.00		
Hay	90.73	96.10	90.80	90.10		
Net Returns	***383.00***	***369.22***	***447.96***	***447.18***	***71.46***	***7.28***
Growing Lot Phase						
Returns						
Calf Value	577.91	558.23	596.96	578.97		
Costs						
Purchase Cost	488.98	465.32	499.87	484.78		
Growing Lot Feed Costs	82.90	82.90	82.90	82.90		
Growing Lot Health Costs	1.95	0.93	1.80	2.14		
Net Returns	***4.08***	***9.08***	***12.39***	***9.15***	***4.19***	***(0.88)***
Feedlot Phase						
Returns						
Carcass Value	1140.04	1125.78	1152.11	1124.73		
Costs						
Purchase Cost	577.91	558.23	596.96	578.97		
Feedlot Feed Costs	501.48	468.35	495.10	468.36		
Feedlot Health Costs	0.58	4.59	2.72	11.98		
Net Returns	***60.07***	***94.61***	***57.33***	***65.42***	***(15.97)***	***(21.32)***
Retained Ownership						
Returns						
More Carcasses[c]	0.00	0.00	124.77	121.81		
Carcass Value	1140.04	1125.78	1152.11	1124.73		
Costs						
Supplement	15.25	0.00	15.25	0.00		
Hay	90.73	96.10	90.80	90.10		
Growing Lot Feed Costs	82.90	82.90	82.90	82.90		
Growing Lot Health Costs	1.95	0.93	1.80	2.14		
Feedlot Feed Costs	501.48	468.35	495.10	468.36		
Feedlot Health Costs	0.58	4.59	2.72	11.98		
Net Returns	***447.15***	***472.91***	***588.31***	***591.06***	***129.66***	***(14.26)***

[a] Difference in net returns between the average of BCS 6 and BCS 4 treatments

[b] Difference in net returns between the average of supplemented and non-supplemented treatments

[c] Increased returns resulting from increased percentage of live calves at weaning (10.83%) for the average of BCS 6 treatments compared with the BCS 4 treatments

Implications

Supplementation of beef cows during the last third of gestation resulted in cows with greater BCS at birth and weaning compared with not supplementing. In addition, calves from cows that received supplement were heavier at weaning and had greater ADG from birth to weaning. However, the greatest effect of cow productivity was because of cow BCS entering the last third of gestation. The BCS 6 cows were in better condition at calving and weaning, they had approximately 10% more live calves at birth and weaning, and they had an 11% greater pregnancy rate than BCS 4 cows. As a result, estimated net returns for BCS 6 cows were approximately $71/cow greater than BCS 4 if calves were sold at weaning and $130/cow if ownership of calves was retained through the feedlot. These data demonstrate the potential economic importance of managing cows to achieve a good BCS ($\geq$ 5) prior to entering the last third of gestation.

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EFFECTS OF PREPARTUM RUMEN-PROTECTED CHOLINE SUPPLEMENTATION ON PERFORMANCE OF BEEF COWS AND CALVES

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ABSTRACT: The objective of our study was to evaluate the effect of prepartum ruminally-protected choline (**RPC**) supplementation on cow and calf performance. Angus crossbred cows and heifers (n = 403; average initial weight = 533.2 ± 4.0 kg) grazing native range were blocked by weight and parity and assigned randomly to 1 of 2 treatments: a 40% CP soy-corn supplement (CON) or a 40% CP soy-corn supplement containing RPC. Treatments were applied during a 60-d period that immediately preceded the earliest predicted calving date; each cow was fed 2.38 kg/hd/d of CON or RPC 6 × per week. The feeding rate of choline averaged 4.5 g/cow/d. Body weight, BCS, and ultrasonically-measured longissimus muscle characteristics of cows and BW of calves were recorded at intervals from January to October. Changes in cow BW, BCS, backfat thickness, and intramuscular fat between the outset of the trial and pregnancy diagnosis were similar ($P \geq 0.25$) between treatments. Cows fed RPC tended to lose more ($P = 0.10$) longissimus muscle depth between the outset of the trial and pregnancy diagnosis. Conversely, BW of cows fed RPC tended to be greater ($P = 0.07$) at pregnancy diagnosis than that of cows fed CON. Calf BW at birth, at pregnancy diagnosis, and at weaning were not different ($P \geq 0.39$) between treatments; however, ADG from pregnancy diagnosis to weaning tended ($P = 0.06$) to be greater for calves of RPC-fed dams than for calves of CON-fed dams. Within parity class, timed-AI pregnancy and overall pregnancy were not affected ($P \geq 0.14$) by treatment. Under the conditions of our study, prepartum RPC supplementation had minimal effects on performance of beef cows and calves.

Key Words: Beef cows, Choline, Supplementation

Introduction

Prepartum supplementation of spring calving beef cows is a vital part of cow-calf enterprises, often affecting subsequent reproductive success. Most research in the area of prepartum supplementation has focused on provision of either energy or protein; however, only modest attention has been applied to the use of supplemental micronutrients. There is little information available to support the strategic use of micronutrients in prepartum supplements for beef cows. One such micronutrient is choline.

Choline is classified generally as a B vitamin and is an essential nutrient. Phosphatidylcholine and other choline-containing lipids help maintain the structural integrity of cellular membranes and play a vital role in metabolism of dietary fat. Choline-containing phospholipids are also important precursors for intracellular-messenger molecules and cell-signaling molecules. Choline, as a precursor to acetylcholine, is also important in nerve impulse transmission. Choline can also function as a general methyl-group donor.

Choline is commonly found in feedstuffs and forages but is highly degradable in the rumen. For choline supply to be effectively increased, it must be offered in a form that is resistant to ruminal digestion. This can be achieved by encapsulating choline in lipid. Therefore, the objective of our study was to evaluate the effect of prepartum ruminally-protected choline supplementation on cow and calf performance.

Materials and Methods

Animals, Treatments, and Diet. All procedures using in the handling and care of animals used for this experiment were approved by the Kansas State Animal Care and Use Committee.

Angus crossbreed cows and heifers (n=438; initial BW 533 ± 3.73 kg) managed in 2 locations were used in our study (190 cows and 43 heifers at Manhattan, KS and 149 cows and 56 heifers at Hays, KS). At the beginning of January, females were blocked by age, body condition score (BCS: 1 = emaciated, 9 = obese; Wagner et al., 1988), and expected calving date and assigned randomly to 1 of 2 supplement-treatment groups: a 40% CP soy-grain supplement (**CON**) or a 40% CP soy-grain supplement containing RPC (Table 1). Treatments were applied during a 60-d period that immediately preceded the earliest predicted calving date; each cow was fed 2.38

kg/hd/d of CON or RPC 6 × per week. The feeding rate of choline averaged 4.5 g/cow/d.

Cows were evenly distributed by treatment, BCS, and expected calving date into 7 pastures. Cows were gathered from their pastures at 0700 and sorted into pens by treatment and offered their respective supplements. After parturition, treatment was discontinued.

Table 1. Chemical composition of supplements

Item	Ruminally-protected choline	Control
Dry Matter %	89.22	88.59
Crude Protein %	40.66	37.12
Calcium %	0.39	0.22
Phosphorus %	0.57	0.54
NDF %	10.26	9.91
ADF %	4.27	4.45
Starch %	12.35	15.78

Data Collection. Cow BW, BCS, and ultrasound measurements were obtained at the beginning and end of the supplementation period. Backfat (**BF**) thickness, longissimus muscle depth (**LMD**), and intramuscular fat (**IMF**) measurements were taken at the 12^{th}-13^{th} rib interface using an Aloka 500V (Aloka Co., Ltd, Wallingford, CT) B-mode ultrasound instrument equipped with a 3.5-MHz general-purpose transducer array (UST 5021-125 mm window). Software used to generate images was obtained from Cattle Performance Enhancement Company (**CPEC**, Oakley, KS). Estimates of BF, LMA, and IMF were produced using methods of image analysis described by Brethour (1994). Cow BW and BCS were recorded at calving, the initiation of estrous synchronization, AI pregnancy diagnosis, weaning, and final pregnancy diagnosis. Calf BW were also recorded at those times.

Estrous Synchronization and Breeding. Ovulation was synchronized using the Co-synch + CIDR protocol and cows were then mass mated. Cows were exposed to bulls 10 d after fixed-time AI for the remainder of a 45-d breeding season in Hays and a 60-d breeding season in Manhattan. Conception to fixed-time AI was determined via ultrasound 35 d after insemination and final pregnancy rate was determined via rectal palpation 60 d after the end of the breeding season.

Statistical Analyses. Cow and calf performance were analyzed as a randomized complete block. The model included effects for treatment, pasture, and treatment within pasture. Treatments within individual pastures were the experimental unit. Treatment within pasture was used as the error term. When protected by a significant F test ($P < 0.1$), least squares treatment means were separated using the method of Least Significant Difference.

Pregnancy rates were analyzed using PROC CATMOD (SAS Inst. Inc., Cary, NC). The model used to assess differences in fixed-time AI pregnancy rates and overall pregnancy rates included effects for treatment, parity, and cycling status. Simple arithmetic means for pregnancy rates were reported.

Treatment differences in performance and pregnancy data were discussed when $P < 0.05$; trends and tendencies were discussed when $P > 0.05$ and < 0.10.

Results

Cow Performance. Changes in cow BW, BCS, BF, and IMF between the beginning of the study and final pregnancy diagnosis were similar ($P \geq 0.25$) between treatments. Cows fed RPC tended to lose more ($P = 0.10$) LMD than cows fed the control supplement during the 60-d prepartum period. Conversely, RPC-supplemented cows tended ($P = 0.07$) to have greater BW at AI pregnancy diagnosis than CON-supplemented cows. Within parity class, timed-AI and overall pregnancy rates were not affected ($P \geq 0.19$) by treatment (Table 2).

Calf Performance. Calf BW from birth to weaning were not different ($P \geq 0.39$) between treatments (data not shown). Similarly, adjusted 205-day BW were not different ($P = 0.51$) between treatments (Table 3). Calf ADG from birth to dam estrous synchronization and birth to weaning were similar ($P \geq 0.09$); however, calf ADG from AI pregnancy diagnosis to weaning tended to be greater ($P = 0.06$) for calves from RPC-supplemented cows than calves from control-supplemented cows.

Table 3. Calf ADG and adjusted 205-d BW

Item	Ruminally-protected choline	Control	SE	*P*
Early ADG, kg (birth to 08/01)	1.07	1.1	0.02	0.09
Late ADG, kg (08/02 to 10/05)	1.05	0.98	0.02	0.06
Overall ADG, kg (birth to 10/05)	1.05	1.04	0.01	0.64
Adjusted 205-d BW, kg	262	260	3.5	0.51

Discussion

Similar to our study, prepartum supplementation of RPC 40 d prior to the onset of calving at a rate of 4 g/hd/d had no effect on cow BW, BW change, BF, LMD or IMF (Jaeger et al., 2009). Furthermore, Zahra et al., (2006) reported that 56 g/hd/d RPC supplementation of dairy cows had no effect on prepartum DMI. Within the

range of supplement intakes evaluated by these researchers and in our study, RPC appeared to have limited effects on cow production parameters. The loss of LMD in RPC supplemented cows observed in our study is in contrast to the report of Jaeger et al., (2009) where changes in LMD were not observed.

Pinotti et al., 2003 reported that supplementing RPC to transition dairy cows appeared to change liver function, as the additional choline increased esterification of NEFA to triglycerides and their export as VLDL. This was reflected in greater milk yield by RPC-treated cows. Erdman and Sharma (1991) indicated similar results; increasing levels of choline supplementation in dairy cows resulted in increasing milk yield. Therefore, the higher average daily gain of RPC calves from AI pregnancy diagnosis to weaning in our study could be attributed to greater dam milk yield.

Jaeger et al., (2009) reported greater timed-AI conception rates among RPC-supplemented cows than among cows fed a control supplement; however, conception rates in our study were unaffected by RPC supplementation.

Implications

Supplementation of ruminally-protected choline to prepartum beef cows had no affect on body weight, body weight change, body condition score, backfat thickness, intramuscular fat, fixed-time AI conception rate, or overall pregnancy rate. Conversely, ruminally-protected choline supplementation was associated with decreased longissimus muscle depth of cows. Calves from ruminally-protected choline supplemented cows tended to have greater average daily gains during the latter portion of the grazing season. Under the conditions of our study, prepartum ruminally-protected choline supplementation had minimal effects on performance of beef cows and calves.

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Table 2. Cow performance

Item	Ruminally-protected choline	Control	SE	*P*-value
Cow BW change, kg				
Overall (01/22 to 10/05)	7.49	4.62	4.05	0.80
Cow BCS change (BCS 1 to 9 Scale)				
Overall (01/22 to 10/05)	0.44	0.53	0.038	0.25
Cow body composition change				
Backfat, mm	-0.02	-0.04	0.05	0.88
Longissimus muscle depth, mm	-1.09	-0.22	0.45	0.10
Marbling score	-0.36	-0.44	0.03	0.39
Timed-AI Pregnancy (%)	45.8	44.7	-	0.83
Overall Pregnancy (%)	87.5	91.6	-	0.19

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EFFECT OF SUPPLEMENTAL PROTEIN SOURCE DURING THE WINTER ON PRE- AND POSTPARTUM GLUCOSE METABOLISM

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ABSTRACT: Circulating serum glucose concentrations as well as glucose utilization have been shown to be affected by forage quality. Supplemental protein provided to grazing range cows while consuming low quality forage may improve glucose metabolism. The objective of our study was to determine the effects of winter protein supplement strategy on serum glucose half-life, insulin response, as well as identify the effects of previous gestational protein supplementation on mid lactation milk yield. The study was conducted two consecutive calving seasons utilizing 5-yr old Angus and Angus crossbred cows (n = 8/trt each yr, 530 kg average BW). Cows were supplemented until calving with 1) a control 36% CP (35% UIP of CP) cottonseed meal based cube (CON), hand-fed at 454 g/d delivered 3d/wk ($16/45.4 kg), or 2) a self-fed 50:50 loose mineral and fishmeal 33% CP (60% UIP of CP) small supplement (SSP), formulated for a targeted consumption of 113g/d ($52/45.4 kg). After calving, cows were supplemented similarly (CON at 908 g/d offered 3 d/wk). Supplemental protein source affected (P = 0.03) glucose half-life, whereby the SSP cows had a lower half-life compared to CON (62 and 85 min respectively). Supplement also influenced insulin area under the curve (AUC; P < 0.01) with CON having a larger area compared to the SSP treatment (95.18 ± 4.9 and 75.02 ± 4.8 respectively). Prepartum glucose AUC (P = 0.10) and insulin half-life (P = 0.75) were unaffected by supplement treatment. Milk yield or components was not affected (P > 0.05) by supplement; however year showed a significant (P < 0.05) effect on these parameters. Milk yield was decreased from 7531 g ± 299 in yr 1 to 4328 g ± 293 in yr 2, possibly due to lower forage quality (~3% CP vs. ~8% CP in yr 1). These results suggest that supplemental undegradable intake protein, during times of low quality forage, may improve glucose clearance.

Keywords: beef cattle, glucose, protein, supplementation

INTRODUCTION

Diet quality and dam physiological state have been shown to alter insulin sensitivity in beef cows (Bines and Hart, 1982; Endecott et al., 2004). Ruminal fermentation of dormant forage is characterized by predominately acetate production and a lower proportion of propionate (Cronje et al., 1991). As a result, acetate may accumulate in the blood along with increased concentration of ketones and free fatty acids which have been implicated in insulin resistance (Dresner et al., 1999; Tardif et al., 2001). Winter supplementation is often a crucial part of managing spring calving herds on western rangeland. A major reason is due to the mature forage being low in protein and possibly energy (Krysl et al., 1987; Soder et al., 1995). Protein supplementation has been indicated to increase circulating glucose concentrations (Miner et al., 1990), as well be a potential solution for improving insulin sensitivity (Waterman et al., 2006). Our objective was to investigate the effect of winter protein supplementation strategy on serum glucose half-life, insulin response, as well as identify the effects of previous gestational protein supplementation on mid lactation milk production.

MATERIALS AND METHODS

This study was conducted from January to May during two consecutive calving seasons (2008 and 2009) at the New Mexico State University Corona Range and Livestock Research Center, Corona, NM. The average elevation at the study site is 1,900 m. Annual precipitation averages 370 mm, with 70% of this precipitation occurring between May and October (Torell et al., 2008). The results of the current study being presented contribute to a larger integrated systems investigation evaluating maternal nutrition on calf health and performance (Harrelson et al., 2009). All animal handling and experimental procedures were in accordance with the New Mexico State University Institutional Animal Care and Use Committee guidelines.

Thirty-two Angus and Angus crossbred cows (530 ± 9 kg BW) were utilized in the two study seasons (sixteen cows in each year). Due to calf losses unrelated to experimental treatments, or late calving cows, only 14 cows were utilized in yr 1 and 12 cows were used in yr 2 postpartum. Cows were selected based on BW and supplemental treatment within a constant age group for each yr of the study, at which time they were 4.5 yr of age during the prepartum phase. Supplemental treatments supplied prior to calving were 1) traditional 36% CP hand-fed supplement (**CON**) or 2) NMSU self-fed small supplement package (**SSP**).

The CON was a range cube with 36% CP of which 35% was UIP. Composition was 57% cottonseed meal, 21% wheat middlings, 10% soybean meal, 9% molasses, 1.2% urea and fortified with trace minerals and vitamins. The CON was fed at 454 g/d delivered 3 d/wk to cattle in 2 paddocks. The SSP was formulated to contain 33% CP (60% of CP as UIP), and composed of 50% fishmeal, 33 %

minerals, and 17% salt. This supplement was continuously available for self-feeding with a targeted consumption of 113 g/hd daily.

Prepartum experimental supplementation was terminated 2 weeks before the start of parturition (mid-February). The duration of winter supplementation was 61 d in yr 1 and 50 d in yr 2. The start of the period of supplementation of the 2 yrs varied due to differences in perceived winter stress. After parturition supplementation was similar for all cows (CON fed 3×weekly at 908 g/d).

To assess the impact of supplement size and composition on aspects of metabolic function and potential carryover effects, glucose kinetics and milk production were measured. Glucose half-life and sensitivity to endogenous insulin was evaluated via a glucose tolerance test (**GTT**). Prepartum GTT was conducted approximately 51 d before calving, while postpartum GTT was conducted approximately 53 d after calving. Due to differences in calving dates, two postpartum GTT's were conducted, one in late April and the other in early May in order to standardize days postpartum when GTT was applied. A 12-gauge hypodermic needle (Ideal Instruments, Schiller Park, IL) was utilized to puncture the jugular vein. One-half of 2.5m of tygon tubing (0.10 cm i.d., 0.18 cm o.d., Cole Parmer Instrument Co., Vernon Hills, IL) was threaded through the needle and into the jugular vein. The remaining portion was secured to the neck and down the middle of the back of each cow via tape. A blunt 18-gauge needle (Salvan Dental Specialties, Charlotte, NC) was inserted in the end of the catheter and a 10-mL syringe was used as the tubing end cap. Catheters were placed into each animal the morning of the GTT. A 50% dextrose solution was infused at 0.25 mL/kg BW via the 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 dextrose infusion. Catheters were flushed with 10 mL of a 9% saline solution post dextrose infusion as well as immediately before and after each collection time. Sample collection time -1 was collected before dextrose infusion and time 0 was immediately after infusion. Blood samples (10 mL) were collected at each time point and placed in Corvac serum separator tubes. Blood samples were centrifuged at 2,000 × *g* at 4°C for 20 min. Serum was stored in plastic vials at -20°C until glucose and insulin analyses were conducted. Glucose was analyzed with a commercial kit (enzymatic endpoint, Thermo Electron Corp., Waltham, MA). Insulin was analyzed by solid-phase RIA (DCP kit, Diagnostic Products Corp., Los Angeles, CA) as reported by Reimers et al. (1982). Intra- and inter-assay CV for both insulin and glucose were < 10%. Serum glucose and insulin areas under the curve (**AUC**) were calculated using trapezoidal summation. Glucose half-life was estimated by determining the time required for a 50% decrease in peak serum concentrations.

Each year, the cows appraised for glucose tolerance as well as an additional 6 (yr 1) or 8 (yr 2) cows were machine milked approximately 48 d postpartum. Timing of milking was targeted for peak lactation which is approximately 56 d postpartum. Milk yield measurements were collected 1 wk before GTT. This measure was employed to identify the carryover influence that prepartum supplements may have on the partitioning of nutrients towards milk production. Milking procedures were a modified weigh-suckle-weigh technique as described by Appeddu et al. (1997). Milk weights were recorded in order to determine 24-h milk production. Milk samples were collected and analyzed for lactose, butterfat, protein, and solids non-fat by a commercial dairy testing laboratory (Silliker Inc., Dimmitt, TX).

Glucose kinetics data were analyzed as a completely randomized design using the MIXED procedure of SAS (SAS Inc., Cary, NC). Cow was the experimental unit and the Kenward-Roger degrees of freedom method was utilized. Supplement strategy, physiological state (pre or postpartum), year, and their interactions were utilized in the model as fixed effects. Calf birth weight was also included in the model as a covariate. Glucose and insulin AUC measurements were calculated using trapezoidal summation. Milk production and constituent data were analyzed in a similar fashion, excluding the effect of physiological state and interactions associated with this.

RESULTS AND DISCUSSION

No significant interactions ($P > 0.25$) between supplement, physiological state and year were observed, therefore only the main effects will be presented. The influence of supplemental strategy on glucose kinetics and milk production are presented in Table 1. Supplement type affected glucose half-life ($P = 0.03$) and insulin AUC ($P < 0.01$), and trend to affect glucose AUC ($P = 0.10$). Cows supplemented with SSP possessed a faster glucose half-life (61.6 vs. 85.2 min ± 7.5, respectively), as well as a smaller glucose AUC (13,176 vs. 14,669 ± 620, respectively) and insulin AUC (75.0 and 95.2 ± 4.9, respectively) compared to CON. Merging these results implies that cows receiving SSP were more insulin sensitive than CON supplemented cows. Even though the SSP cows showed a more rapid glucose clearance, this value is almost double the normal glucose half-life of 35 min described by Kaneko (1997). Therefore, the cows that received the SSP would still be considered insulin resistant, though less so than the CON supplemented cows. Insulin half-life ($P = 0.75$) and insulin to glucose ratio ($P = 0.17$) were unaffected by supplement strategy. Previous research by Waterman et al. (2006) showed similar changes in glucose kinetic when supplementing more UIP in supplements of lactating young range cows. In our study, milk production and constituents were unaffected ($P > 0.25$) by supplement strategy fed prepartum. Mulliniks et al. (2008) reported no change in milk production or constituents when insulin sensitivity was improved via supplements supplied postpartum, whereas our supplements were supplied prepartum. Greater milk production might be expected in cows with a higher glucose half-life because they would have a higher concentration of circulating glucose and an increased supply available for the mammary gland. Higher circulating glucose would increase the glucose supply available to the mammary cells, and since glucose is converted to lactose and becomes the osmotically control factor of fluid milk production (Vilotte, 2002), longer half-lives would allow for more glucose to be utilized for milk production.

The effects of year on glucose kinetics and milk production are also displayed in Table 1. All parameters of glucose kinetics, except glucose half-life, were affected ($P < 0.01$) by year. Year 2, exhibited higher values for all glucose parameters, all of which suggest that the cows were more insulin resistant in yr 2 compared to yr 1. Glucose half-life was also higher in yr 2 compared to yr 1 (80.1 vs. 66.6 min ±7.5, respectively). Milk production was also affected by year ($P < 0.01$), as cows in yr 2 produced less milk and had lower amounts of milk constituents compared to yr 1. Twenty-four hour milk production was 7,531 g in yr 1 but was reduced to 4,328 g in yr 2, a reduction of 43%. Lower milk yields in the second yr may be directly related to forage quality differences between years 1 and 2. Grass CP for yr 1 was 8%, whereas in yr 2 it was approximately 4%. With the forage quality, and therefore the year effect, these data indicate that as forage quality decreases, insulin resistance increases. Waterman et al. (2007) found results similar to these, whereby cows tended to have decreased glucose half-lives during the seasons of higher forage quality compared to those when forage quality was depressed. Another observation from this data is that decreased forage quality negatively impacts milk production and constituents. Since ruminal fermentation of dormant forage results in higher proportions of acetate than propionate (Cronje et al., 1991), it is important for protein to be present in order to be used as glucogenic precursors. Undegradable intake protein can alter metabolic acetate to glucogenic precursor ratio (Cronje et al., 1991). A metabolic problem can arise with decreased gluconeogenesis resulting in the upsurge of ketone bodies and non-esterified fatty acids concentrations. These compounds can have an impact on insulin sensitivity (Tardif et al., 2001) as well as increase the demand for glucose needed in oxidative metabolism. Poor forage quality appears to have decreased the amount of energy available and balance of energy intermediates for promoting milk production, therefore leading to a decrease in milk production (Jenkins and Ferrell, 1992).

Table 2 illustrates the effects of physiological state on glucose kinetics. Physiological state had no effect ($P > 0.19$) on any glucose kinetic parameter. Numerically, glucose half-life was higher prepartum compared to postpartum (77.4 and 69.4 min ± 7.5, respectively), as was insulin half-life (37.6 and 34.8 min ± 3.2, respectively). These results suggest that physiological state (gestation or lactation) had similar influence on altering insulin resistance.

IMPLICATIONS

Supplementing gestating beef cows that are consuming dormant forage with a higher proportion of undegradable intake protein in a self-fed supplement may effectively sustain insulin sensitivity, possibly allowing for improved energy metabolism, metabolic health and better animal production during late gestation. This study suggests that a possible mechanism by which poor diet quality has a negative impact on production is by reducing insulin sensitivity.

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Table 1. Effect of supplementation strategy and year on glucose kinetics and milk production.

	Year			Supplement			*P*-Value[1]	
Item	2008	2009	SEM	CON	SSP	SEM	Year	Supp
Glucose Metabolism								
Glucose half-life, min	66.6	80.1	7.5	85.2	61.6	7.5	0.21	0.03
Glucose AUC[2]	10,850	16,996	624	14,669	13,176	620	<0.01	0.10
Insulin half-life, min	26.4	46.1	3.2	35.5	37.0	3.2	<0.01	0.75
Insulin AUC[2]	95.2	75.0	4.9	95.2	75.0	4.9	<0.01	<0.01
Insulin:glucose ratio	0.0093	0.0006	0.0005	0.0075	0.0064	0.0005	<0.01	0.17
Milk Production								
24 h production, g	7531	4328	295	6153	5705	295	<0.01	0.29
Butterfat, g	245	122	17	196	171	17	<0.01	0.33
Lactose, g	375	211	14	305	281	14	<0.01	0.25
Protein, g	194	109	9	159	144	9	<0.01	0.26
Solid non-fats, g	637	357	26	518	476	26	<0.01	0.27

[1]Protected F-statistic for the effect of year (Year) and supplement strategy (Supp).
[2]Area under the curve.

Table 2. Effect of physiological state on glucose kinetics.

Item	Pre	Post	SEM	*P*-Value[2]
Glucose half-life, min	77.4	69.4	7.5	0.46
Glucose AUC[3]	13,809	14,036	623	0.80
Insulin half-life, min	37.6	34.8	3.2	0.55
Insulin AUC[3]	80.5	89.7	4.9	0.19
Insulin:glucose ratio	0.0068	0.0071	0.0005	0.65

[1]Pre = prepartum, Post = postpartum
[2]Protected F-statistic for the effect of physiological state.
[3]Area under the curve

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IN SITU DIGESTIBILITY OF GRASS HAY AFTER HEIFER DIETS WERE ABRUPTLY SWITCHED FROM 35 OR 70% CONCENTRATE TO 100% FORAGE

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ABSTRACT: Twelve ruminally-cannulated Hereford-cross heifers (non-pregnant, 2-yr-old, 508 ± 2 kg) were randomly assigned to 3 individually-fed, pre-experiment diets (4 heifers/diet). Diets were: 1) all forage, (**CONTROL**); 2) 35% concentrate, (**35%**), and 3) 70% concentrate (**70%**). Heifers were fed the diets for ~100 d before the start of the trial. Pre-experiment diets consisted of grass-alfalfa hay (11.8% CP) and corn (9.8% CP), with soybean meal-urea supplement added to make the diets isonitrogenous at 13% CP. On d 0, diets were abruptly switched to grass hay (6.2% CP, fed at 2% BW). In situ digestibility runs were conducted starting on d -8 and ran continuously (d 0, 3, 6, 9, 12, 15, 18, 21) after the diet switch. Duplicate sample bags filled with 5 g of grass hay and a blank bag were incubated for 0, 24, 48, and 96 h. Pre-experiment diet × in situ run interactions occurred ($P \leq 0.04$) for OM and NDF digestibility. Organic matter digestibility of grass hay before the diet switch (d -8) was lower ($P \leq 0.10$) for 70% than for 35% or CONTROL; 48-h: 68.5, 66.7, and 52.8 ± 2.5%; 96-h: 76.3, 75.2, and 61.4 ± 0.7% for CONTROL, 35%, and 70 % respectively) A comparable pattern was observed for NDF digestibility; 48-h: 67.7, 65.6, and 48.9 ± 3.1%; 96-h: 77.0, 75.9, and 58.6 ± 0.9% for CONTROL, 35%, and 70%, respectively. In contrast, after the diet switch (d 0), OM digestibility of grass hay was similar for all diets ($P \geq 0.10$; 48-h: 66.5, 66.0, and 68.7 ± 2.5%; 96-h: 75.9, 76.1, and 76.0 ± 0.7% for CONTROL, 35%, and 70%, respectively). Digestibility of NDF exhibited a similar pattern for 70% than 35% or CONTROL; 48-h: 65.5, 64.4, and 68.0 ± 3.1%; 96-h: 76.2, 76.3, and 77.1 ± 0.9% for CONTROL, 35%, and 70%, respectively. Organic matter and NDF digestibilities in subsequent in situ runs were similar ($P > 0.10$), regardless of pre-experiment diet. Rate of digestion was not influenced by pre-experiment diet ($P = 0.65$; avg 4.3 ± 0.2%/h). Forage digestibility was depressed when heifers were fed a high-concentrate diet; however, this effect disappeared within 96 h of feeding an all forage diet.

Keywords: forage digestibility, rumen, beef cattle

Introduction

There is an abundance of literature pertaining to changing cattle diets from forage to concentrates. Lyle et al. (1981) summarized that cattle consuming high grain diets have lower ruminal pH levels, higher total VFA concentrations, and higher propionate levels compared to acetate and butyrate. Also, the effects of cereal grain supplementation are widely known. Chase and Hibberd (1987) reported that as supplemental ground corn increased, there was a linear decrease in digestibility of cellulose and hemicellulose in low quality grass hay. On the other hand, corn did not affect OM digestibility in steers grazing summer pastures (Pordomingo et al., 1991). Kartchner (1981) found no significant effects on DMD when cows grazing winter range were fed supplemental energy (cracked barley). However, little is known about the changes that may occur when ruminants are abruptly switched from a concentrate-containing diet to one of all forage. This situation might be common where heifers or bulls are developed in confinement, then turned out to pasture for the breeding season. Beck et al. (2003) found that steers limit-fed high concentrate diets were able to adapt to pasture as well as steers fed hay-based diets. Conversely, Tolley et al. (1988) reported that steers and heifers lost weight in the first 2 wk after being switched from a high energy diet to a low energy diet.

Therefore, objectives for the present experiment were to characterize ruminal function in heifers after an abrupt diet switch from diets containing 35 or 70% corn to a diet containing forage only compared to animals that were maintained on a forage diet alone.

Materials and Methods

Procedures were approved by the Fort Keogh LARRL Animal Care and Use Committee. Twelve ruminally-cannulated Hereford-cross heifers (non-pregnant, 2-yr-old, 508 ± 2 kg) were randomly assigned to one of three pre-experiment diets (4 heifers/diet). Pre-experiment diets were: 1) all forage (**CONTROL**); 2) 35% concentrate (**35%**); and 3) 70% concentrate (**70%**). The all forage diet consisted of chopped grass and alfalfa hay (75% and 25% respectively). The concentrate diets included grass/alfalfa hay, corn (9.8% CP) and urea. Soybean meal was added to the 70% diet to make the diets isonitrogenous at 13% CP. Melengesterol acetate (**MGA**), vitamins, and minerals were included in all the diets. Melengesterol acetate was fed at 0.23 kg · heifer^{-1} · d^{-1} in a pelleted form to deliver 0.5 mg ·

[1]USDA, Agricultural Research Service, Northern Plains Area, is an equal opportunity/affirmative action employer. All agency services are available without discrimination. This research was conducted under a cooperative agreement between USDA-ARS and the Montana Agric. Exp. Stn. Mention of a proprietary product does not constitute a guarantee or warranty of the product by USDA, Montana Agric. Exp. Stn., or the authors and does not imply its approval to the exclusion of other products that also may be suitable. The authors gratefully acknowledge W. Kelly and S. Reil for their technical assistance.

heifer^{-1} · d^{-1}. Heifers were individually fed at 0700 h for ~100 d before the trial began. On day 0, diets were immediately switched to chopped grass hay (6.2% CP) fed at 2% BW with MGA and a vitamin/mineral premix. Mineral supplement contained 34.0% salt, 19.1% dicalcium phosphate, 18.5% calcium carbonate, 8.8% dried distillers grain, 7.8% potassium chloride, 7.0% magnesium oxide, 2.0% trace mineral premix, 1.5% mineral oil, 0.81% selenium, 0.32% copper sulfate, 0.21% manganese sulfate, and 0.04% vitamin A. Cattle had ad-libitum to fresh water.

Nylon bags (Dacron, 10 cm × 20 cm; pore size 53 ± 10 µm) were used to test in situ grass hay digestion by the heifers during the diet switch. Beginning on d 0 at 0900 h duplicate sample bags filled with 5 g of grass hay and 1 blank bag were inserted into the ventral rumen sac and allowed to incubate for 24, 48, or 96 h. In situ bags were also inserted 8 d before the diet switch in order to establish baseline digestibilities. Nylon bags were placed in a polyester lingerie bag and anchored with ~1 m of string attached to a rubber stopper. Bags were placed in the rumen at specific intervals and removed simultaneously at the end of the incubation period and immediately submersed in cold water to stop microbial fermentation. Bags were then rinsed under cold tap water until the effluent was clear. Rinsed bags were placed in a -20° C cooler until frozen after which they were freeze-dried for 72 h. Residue was removed from the nylon bag and analyzed for DM (AOAC, 1990), OM (AOAC, 1990), and NDF (ANKOM 200 fiber analyzer, ANKOM Technology, Fairport, NY). Grass hay was also analyzed for DM, OM, and NDF. Dry samples were ashed at 550° C in a muffle furnace. Organic matter and NDF disappearances were calculated from the dry in situ bags.

Rumen fluid samples were collected on the same days as the in situ runs at h -1, 2, 4, 8, 12, and 16 relative to feeding. Rumen liquid (40 mL) was strained through 4 layers of cheesecloth, a pH reading was taken, and the fluid was separated into 2 vials. One vial contained 2 mL of 1 *N* HCL and was analyzed for ammonia (adapted from Broderick and Kang, 1980). The other vial contained no additive and was stored at -20° C until analysis for VFA (data not included). Blood (~10 mL) was collected via coccygeal venipuncture using serum separator tubes (Corvac, Sherwood Medical, St. Louis, MO). Tubes were spun at 2000 × *g* for 30 min. Serum was decanted into duplicate tubes to be stored at -20° C. Serum was analyzed for glucose, serum urea N (**SUN**), and NEFA concentrations using commercially available kits.

In situ data were analyzed using the Mixed procedure of SAS with diet, run and diet × run interactions in the model. Run served as the repeated measure, with cow(diet) as the subject and compound symmetry as the covariance structure. Serum metabolite, rumen pH and ammonia data were analyzed using the mixed procedures of SAS with diet, sampling date, diet × sampling date, hour(sampling date), and diet × hour(sampling date) in the model. Cow(diet) served as the random effect. Hour(sampling date) was the repeated measure, with sampling date × cow(diet) serving as the subject. Compound symmetry was the covariance structure.

Results and Discussion

Results reported do not include 2 heifers (70%) that went off feed before the start of the trial. Pre-experiment diet × in situ run interactions occurred ($P \leq 0.04$) for OM and NDF digestibility. Organic matter digestibility of grass hay before the diet switch (d -8) was lower ($P \leq 0.10$) for 70% than for 35% or CONTROL; (Figure 1). A comparable pattern was observed for NDF digestibility. After the diet switch (d 0), OM and NDF digestibility of grass hay in subsequent in situ runs were similar regardless of pre-experiment diet. Low digestibilities were observed for the high-concentrate containing diet during the baseline period, similar to results observed by Chase and Hibberd (1987). However, cows on the 70% concentrate diet were able to rapidly adapt to the forage-only diet, as digestibilities were similar for all cows regardless of pre-experiment diet by 96 hours after the diet switch.

Rate of digestion was not influenced by pre-experiment diet ($P = 0.65$; avg 4.3 ± 0. 2%/h). Day of in situ run influenced rate of digestion ($P = 0.01$; Figure 2). Generally, rate of digestion decreased throughout the experiment except on d 9 when there was an increase.

A pre-experiment diet × sampling day interaction occurred ($P < 0.01$) for ruminal pH (Figure 3). Heifers on 70% had a lower pH than CONTROL and 35% on d -2 and 0. This was expected due to the higher proportion of concentrate in the 70% diet. By 3 days after the diet switch, 70% had a higher pH than other treatments and remained higher for the remainder of the trial. None of the pH values observed were physiologically abnormal. An hour(sampling day) interaction also occurred ($P < 0.01$) for ruminal pH (data not shown). Ruminal pH was highest at -1 h with depressions between 2-4 h after feeding and increased again between 8-16 h, with the magnitude of diurnal changes varying by sampling day.

A diet × hour(sampling day) interaction occurred ($P < 0.01$) for ruminal ammonia (Figure 4). Rumen ammonia concentrations declined rapidly for all cows, regardless of diet, probably due to the removal of higher nitrogen-containing diet ingredients (i.e., alfalfa hay, soybean meal, urea). When sampled before and immediately after the diet switch, ruminal ammonia concentrations for CONTROL and 35% cows peaked at 2 h after feeding and declined thereafter. Cows from the 70% treatment also exhibited a peak at the 2 h sampling, but ammonia concentrations spiked again at 12 and 16 h post-feeding. These differences were not observed in later sampling dates.

A diet × sampling day interaction occurred ($P < 0.05$) for serum glucose (Figure 5). Within each sampling day, glucose concentrations were similar for all cows regardless of pre-experiment diet. However, the response for each diet varied by sampling day. There was an hour(sampling day) interaction for serum glucose ($P < 0.01$; data not shown). Generally, glucose was highest at -1 h before feeding, dipped to its lowest point 4 h after feeding and returned to near pre-feeding levels by 8 h. The magnitude of differences varied by sampling day.

Diet × hour(run) interactions occurred ($P = 0.01$) for SUN (Figure 6) and serum NEFA (Figure 7). Like rumen ammonia concentrations, SUN concentration declined rapidly for all cows, regardless of diet. On sampling days immediately before and after the diet switch, CONTROL and 35% cows had lowest SUN concentrations at -1 h relative to feeding and peak SUN concentrations at 4 h post-feeding, with 8 h concentrations intermediate. On the other hand, 70% cows had peak SUN concentrations at 4 h, lowest at 8 h, and intermediate at -1 h. These differences were not observed in later sampling dates. Serum NEFA concentrations exhibited little diurnal variation for CONTROL and 35% cows, but 70% cows had much higher serum NEFA concentrations at -1 h than 4 or 8 h. These relationships persisted throughout the experiment.

Implications

Forage digestibility was depressed when heifers were fed a high-concentrate diet; however, this effect disappeared within 96 h of feeding an all-forage diet. Future research where in situ sampling hours are timed more immediately after the diet switch could target the precise timing of rumen adaptation. It appears that the rumen can adapt quickly when diets are switched from concentrate-containing to all-forage.

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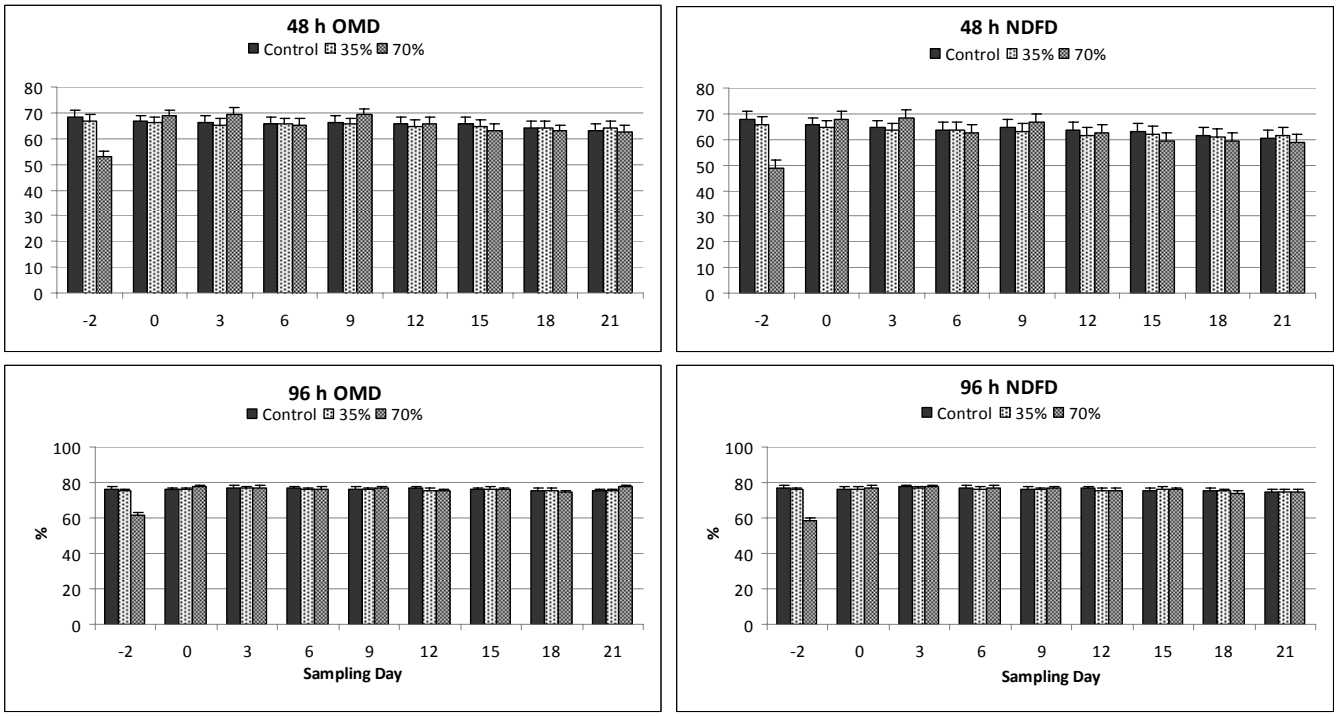


Figure 1. Diet × in situ run interaction ($P < 0.01$) for 48- and 96-hour in situ OM and NDF digestibilities. Cows were abruptly switched to an all-forage diet on day 0.

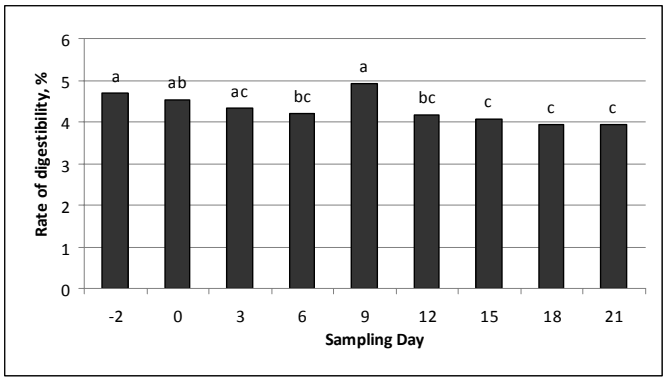


Figure 2: Influence of sampling day on rate of digestion, relative to switching from a concentrate-containing diet to a forage-only diet (P = 0.01; SE = 0.3 for day 9; for all other days, SE = 0.2).

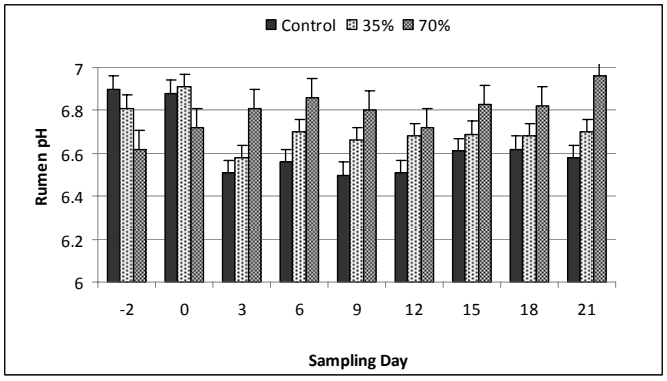


Figure 3. Diet × sampling day interaction for ruminal pH (P < 0.01; SE = 0.06, 0.06, and 0.09 for Control, 35%, and 70% respectively). Cows were abruptly switched to an all-forage diet on day 0.

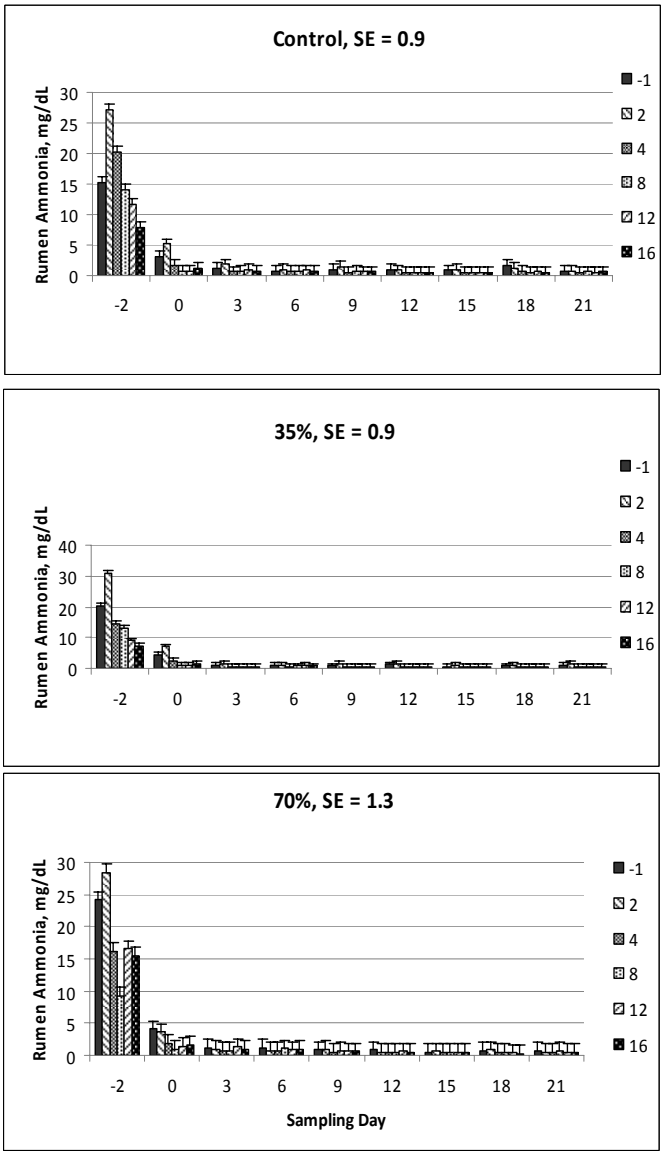


Figure 4. A diet × hour(sampling day) interaction occurred (P < 0.01) for ruminal ammonia. Cows were abruptly switched to an all-forage diet on day 0.

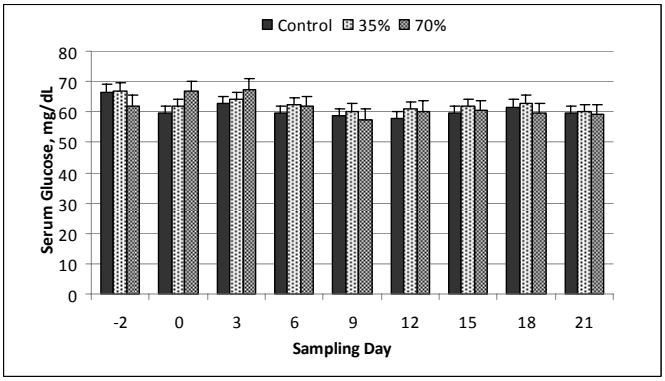
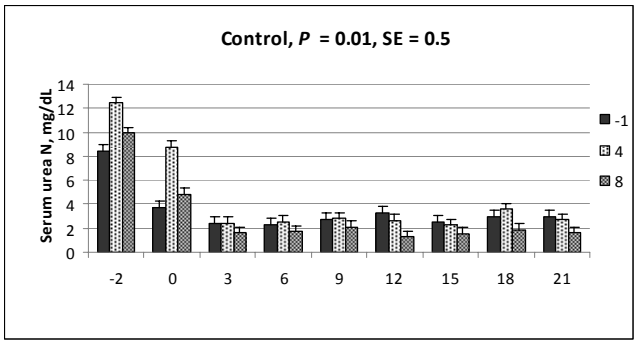
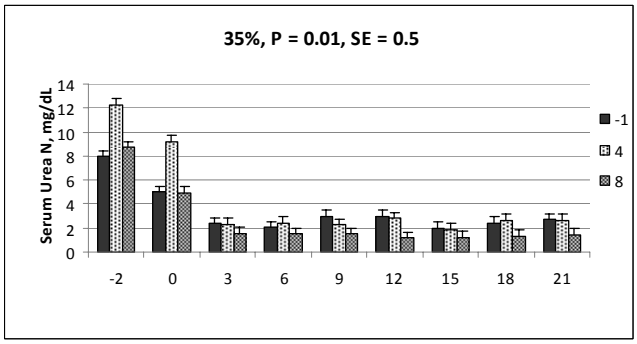


Figure 5. A diet × sampling day interaction occurred (P < 0.05; SE = 2.4, 2.4, and 3.4 for Control, 35, and 70 respectively) for serum glucose. Cows were abruptly switched to an all-forage diet on day 0.





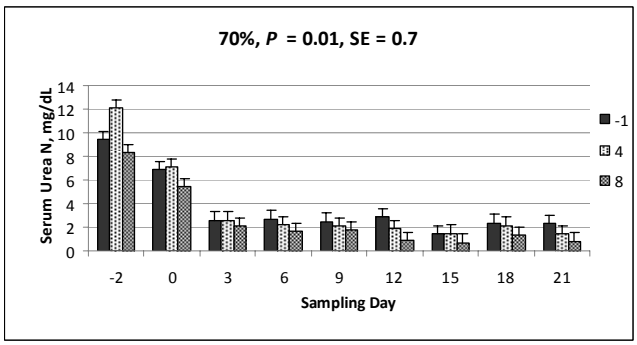
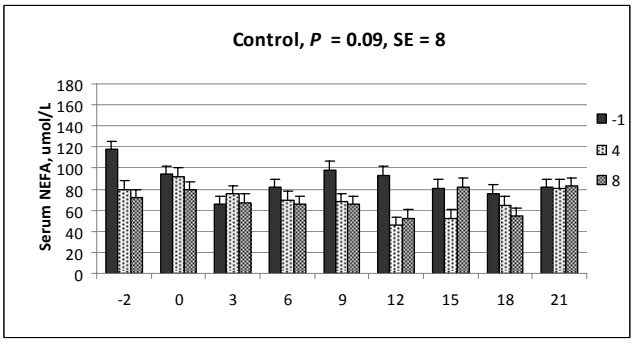
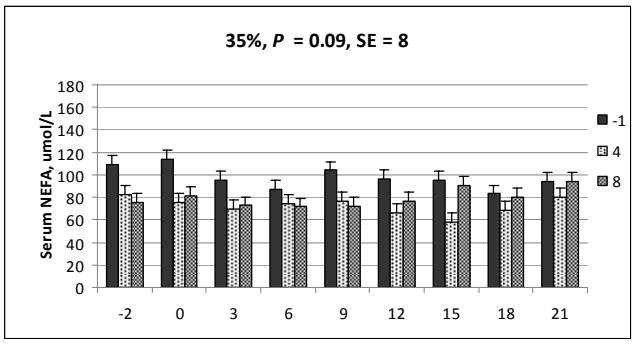


Figure 6. Diet × hour(run) interactions occurred for serum urea N. Cows were abruptly switched to an all-forage diet on day 0.





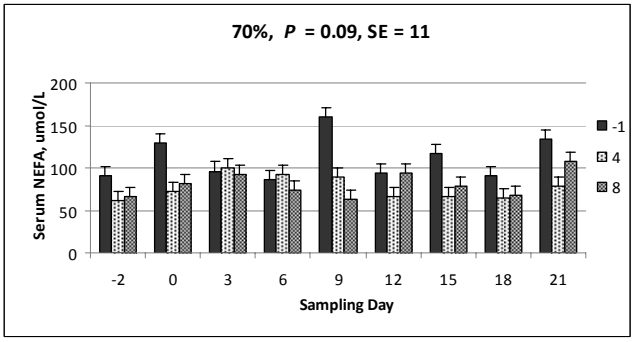


Figure 7. Diet × hour(run) interactions occurred for serum NEFA. Cows were abruptly switched to an all-forage diet on day 0.

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EFFECTS OF POLYUNSATURATED FATTY ACID SUPPLEMENTATION (PUFA) ON FORAGE INTAKE AND DIGESTIBILITY IN BEEF COWS

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ABSTRACT: The objective was to compare DMI and in situ forage digestibility in beef cows supplemented or not with a rumen-protected PUFA source. Three Angus x Hereford cows (724 ± 39 kg of BW) fitted with ruminal cannulas were allocated to a 3 x 3 Latin Square design containing 3 periods of 21 d each. Treatments consisted of grain-based supplements without (**CO**) or with the inclusion (10%; as-fed basis) of a PUFA source (**PF**; Megalac-R®, Church and Dwight, Princeton, NJ) or a SFA source (**SF**; Megalac®, Church and Dwight). Treatment intakes were formulated to be iso-caloric and iso-nitrogenous, and offered daily at a rate of 0.7 % of BW/cow/d. Within each experimental period, mixed alfalfa-grass hay was offered in amounts to ensure ad libitum access from d 1 to 13, and hay DMI was recorded daily. Data collected from d 8 to 13 were used to determine treatment effects on hay and total DMI. From d 14 to d 21, cows were restricted to receive 90 % of their voluntary hay DMI. Immediately before treatment feeding on d 16, polyester bags containing 4 g of hay (DM basis) were suspended within the rumen of each cow, and incubated in triplicates for 0, 4, 8, 12, 24, 36, 48, 72, and 96 h. After removal, bags were washed, dried for 96 h at 50°C in forced-air ovens and weighed. Triplicates were combined and analyzed for NDF content. Hay and total DMI were reduced ($P < 0.05$) in PF cows compared to SF and CO cows (2.19, 2.30, and 2.31 % of BW for forage DMI, SEM = 0.04; and 2.86, 2.98, and 3.05 % of BW for total DMI, SEM = 0.05). However, no treatment effects were detected ($P > 0.48$) for ruminal degradation rate of hay DM (6.81, 7.48, and 6.86 %/h for CO, PF, and SF; SEM = 0.40) and hay NDF (6.05, 6.43, and 6.17 %/h for CO, PF, and SF; SEM = 0.30). Similarly, no treatment effects were detected ($P > 0.63$) for effective ruminal degradability of hay DM (64.53, 64.93, and 64.94 % for CO, PF, and SF; SEM = 0.38) and hay NDF (71.24, 71.76, and 71.57 % for CO, PF, and SF; SEM = 0.36). In conclusion, PUFA supplementation did not impact forage digestibility, but decreased forage and total DMI in beef cows.

Introduction

Supplementation of rumen-protected PUFA to feeder cattle might be an alternative to alleviate the bovine acute-phase response stimulated by transportation and feedlot entry (Araujo et al., 2009). However, feeder calves supplemented with a rumen-protected PUFA source during preconditioning or feedlot receiving period experienced reduced ADG, feed intake (Araujo et al., 2008), and feed efficiency (Araujo et al., 2009) compared to cohorts offered iso-caloric and iso-nitrogenous control diets. It can be hypothesized that these outcomes were due to reduced dietary digestibility and consequent feed intake in PUFA-supplemented calves (Schauff and Clark, 1989). In these studies, however, total fat content of diets were less than 6% of the DM, the limit in which fat can be present in cattle diets without detrimental effects on ruminal digestibility (Hess et al., 2008).

Therefore, the objectives of the present study were to compare DMI and in situ forage digestibility in beef cows offered diets containing less that 6% of fat (DM basis), and enriched or not with a rumen-protected PUFA source.

Materials and Methods

This experiment was conducted at the Eastern Oregon Agricultural Research Center - Burns, in accordance with an approved Oregon State University Animal Care and Use Protocol.

Three Angus x Hereford cows (724 ± 39 kg of BW), housed in individual drylot pens and fitted with ruminal cannulas were allocated to a 3 x 3 Latin Square design containing 3 periods of 21 d each. Treatments consisted of corn and soybean meal-based supplement without (**CO**) or with the inclusion (10%; as-fed basis) of a PUFA source (**PF**; Megalac-R®, Church and Dwight, Princeton, NJ) or a SFA source (**SF**; Megalac®, Church and Dwight). Treatment intakes were formulated to be iso-caloric and iso-nitrogenous, and offered daily at a rate of 0.7 % of BW/cow/d (Table 1).

Within each experimental period, mixed alfalfa-grass hay was offered in amounts to ensure ad libitum access from d 1 to 13, and hay DMI was recorded daily by measuring refusals. Samples of the offered hay and treatment ingredients were collected weekly to determine nutrient composition (Dairy One Forage Laboratory, Ithaca, NY) and DM, whereas samples of refusals were collected daily to determine DM content only. Hay samples were dried for 96 h at 50°C in forced-air ovens. Data collected from d 8 to 13 were used to determine treatment effects on hay and total DMI. From d 14 to d 21, cows were restricted to receive 90 % of their voluntary hay DMI.

Immediately before treatment feeding on d 16, polyester bags (pore size 50-60 µm) containing 4 g (DM basis) of mixed alfalfa-grass hay were suspended within the rumen of each cow, and incubated in triplicates for 0, 4, 8, 12, 24, 36, 48, 72, and 96 h. Prior to incubation, all bags were soaked in warm water (37 °C) for 15 min. The 0-h

bags were not incubated in the rumen but were subjected to the same rinsing procedure used for the ruminally incubated bags. After removal, bags were washed repeatedly until the rinse water was colorless, dried for 96 h at 50°C in forced-air ovens, and weighed. Triplicates were combined and analyzed for NDF (Robertson and Van Soest, 1981) using procedures modified for use in an Ankom 200 Fiber Analyzer (Ankom Co., Fairport, NY).

Table 1. Nutrient profile of treatments.

	Treatments		
Item	CO [1]	SF [2]	PF [3]
NE_g, Mcal/kg [4]	0.75	0.80	0.81
NE_m, Mcal/kg [4]	1.41	1.48	1.49
TDN, %	59.0	60.0	61.0
CP, %	16.5	16.7	16.7
NDF, %	52.5	52.9	52.4
Ether extract, %	2.2	4.0	4.1
Ca, %	0.4	0.6	0.7
P, %	0.3	0.3	0.3

[1] CO = Corn and soybean meal-based supplement (90:10 ratio, respectively; as-fed basis), fed at 0.75% of BW, without supplemental fat.
[2] SF = Corn and soybean meal-based supplement with the addition of rumen-protected SFA (Megalac®; Church & Dwight, Princeton, NJ) source (75:15:10 ratio, respectively, as-fed basis) fed at 0.67% of BW.
[3] PF = Corn and soybean meal-based supplement with the addition of rumen-protected PUFA (Megalac-R®; Church & Dwight) source (75:15:10 ratio, respectively, as-fed basis) fed at 0.67% of BW.

Voluntary forage and total DMI were analyzed using the PROC MIXED procedure of SAS (SAS Inst., Inc., Cary, NC) and Satterthwaite approximation to determine the denominator df for the tests of fixed effects. The model statement contained the effects of treatment, day, and the interaction, in addition to period as independent variable. Data were analyzed using cow as the random variable. Kinetic parameters of hay DM and NDF disappearance were estimated using nonlinear regression procedures of SAS, as described by Vendramini et al. (2008). Treatment effects on ruminal degradation rate and effective ruminal degradability (Coblentz and Hoffman, 2009) were analyzed using the PROC MIXED procedure of SAS and Satterthwaite approximation to determine the denominator df for the tests of fixed effects. The model statement contained the effects of treatment and period as independent variables. Data were analyzed using cow as the random variable. Results are reported as least square means and were separated using PDIFF. Significance was set at $P \leq 0.05$, and tendencies were determined if $P > 0.05$ and ≤ 0.10. Results are reported according to treatment effects if no interactions were significant.

Results & Discussion

Cows receiving PF had decreased ($P < 0.05$) forage and total DMI compared to SF and CO cows, whereas no differences were detected between SF and CO cows (Figure 1). These results support previous efforts indicating that rumen-protected PUFA supplementation, more specifically as calcium soaps of fatty acids, reduced DMI in cattle (Araujo et al., 2008, Araujo et al., 2009). One could speculate that reduced feed intake in PF-fed calves was due to reduced dietary digestibility (Schauff and Clark, 1989).

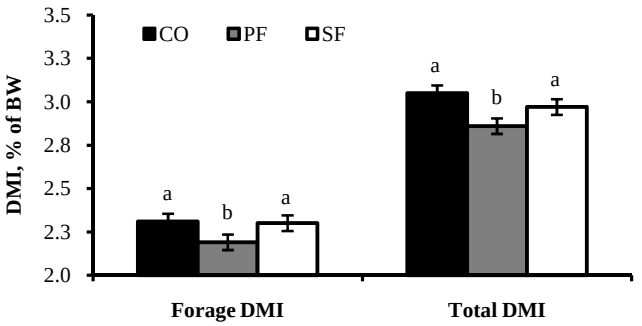

Figure 1. Forage and total DMI, as percentage of BW, of cows offered diets without (CO) or with the inclusion of a rumen-protected SFA or PUFA (PF) source. A treatment effect was detected ($P < 0.05$). Within variables, values bearing a different letter differ ($P < 0.05$).

However, in present study, total fat content of PF and SF was approximately 4% (DM basis; Table 1) based on feed intake and nutritional analysis. According to Hess et al. (2008), ruminal digestibility is not impaired if diets contain less than 6% (DM basis) of fat. Supporting this rationale, no treatment effects were detected ($P > 0.48$) on ruminal degradation rate (K_d) of hay DM and NDF (Table 2). Similarly, no treatment effects were detected ($P > 0.63$) for effective ruminal degradability of hay DM and NDF (Table 2).

Table 2. In situ disappearance kinetics of DM and NDF of mixed alfalfa-grass hay incubated in cows offered diets without (CO) or with the inclusion of a rumen-protected SFA or PUFA (PF) source.

Treatment	K_d, /h	Effective degradability, [1] %
DM analysis		
CO	0.069	64.53
SF	0.068	64.94
PF	0.075	64.93
SEM	0.004	0.38
P-value	0.48	0.71
NDF analysis		
CO	0.061	71.24
SF	0.062	71.57
PF	0.064	71.76
SEM	0.003	0.36
P-value	0.69	0.63

[1] Calculated as $A + B \times [(K_d + K_p)/K_d]$, where K_p was the ruminal passage rate, which was arbitrarily set at 0.025/h (Coblentz and Hoffman, 2009).

These results indicate that PUFA supplementation did not impact forage digestibility, but decreased forage and total DMI in beef cows. These negative outcomes cannot be attributed to the chemical composition of the PUFA source, given that the SFA source used in the present experimental was also based on calcium soaps of fatty acids. Therefore, additional research is needed to understand the mechanisms by which PUFA reduces feed intake in cattle, so strategies

to alleviate this effect can be developed, which will allow the inclusion of PUFA sources into preconditioning and receiving diets without major pitfalls.

Implications

Inclusion of a rumen-protected PUFA source into cattle diets reduced forage and DMI intake; however, forage digestibility parameters were not affected. Therefore, additional research is required to understand the negative effects of supplemental PUFA on feed intake in beef cattle.

Acknowledgements

We would like to thank Andy Covington and Elliot Block from Church and Dwight for the donation of the treatments offered in the present study. We also would like to thank Stephanie Falck for her assistance in this study.

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EFFECTS OF SUPPLEMENTAL VITAMIN E WITH DIFFERENT OIL SOURCES ON GROWTH, HEALTH, AND CARCASS PARAMETERS OF PRECONDITIONED BEEF CALVES

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ABSTRACT: This trial was designed to evaluate the impact of supplemental vitamin E with or without different oil sources during a 35-d preconditioning period. Sixty-four (224 ± 33 kg) Angus-cross calves were stratified by weight and sex then randomly allotted to one of four treatments: CON (corn-soybean meal (base) diet with no added vitamin E or oil), SE (base diet plus 150 IU supplemental vitamin E), ELA (SE diet plus 1.5% safflower oil) and ELNA (SE diet plus 1.5% linseed oil). Following preconditioning, calves were shipped to a feedlot where they received a modified live intranasal vaccine for Infectious Bovine Rhinotracheitis (IBR) and Parainfluenze-3 (PI_3) on d37 and d56 to stimulate immune activity. Blood samples were obtained after preconditioning (d35), post-transit to the feedlot (d36), post-initial vaccination (d42), and post-secondary vaccination (d63 and 70) to quantify glucose and antibody titers. Weights were collected throughout the study with carcass data collected at harvest. Gain and carcass data were evaluated as a randomized complete block design with sex as block, using the following preplanned contrasts: CON vs vitamin E (mean of SE, ELA, and ELNA), SE vs OIL (mean of ELA and ELNA), and ELA vs ELNA. No differences ($P>0.10$) were detected for ADG or body weights during the preconditioning and finishing periods. No differences ($P>0.10$) were detected for carcass measurements between treatment contrasts, with the exception of backfat tending ($P<0.10$) to be greater in SE calves versus OIL calves. Morbidity rates were less than 1% and consistent across treatments. Supplementation of vitamin E resulted in greater amounts of IBR titer at d35 and d36 ($P<0.05$). The SE calves had higher PI_3 titers ($P<0.05$) at d35 compared to OIL calves, but were similar ($P>0.10$) through the feedlot phase. No differences ($P>0.10$) were detected for PI_3 titers or glucose after the preconditioning period for any contrast. Supplementation of preconditioning diets with vitamin E with or without dietary essential fatty acids showed limited improvement in gain and immune response indicators in weaned calves.

Key words: vitamin E, preconditioning, cattle

Introduction

Both metabolic and respiratory illnesses in feedlot calves results in reduced gains, poorer feed conversions and negatively impacts carcass quality (Gardner et al., 1999; Wittum et al., 1996). As a result producers have been encouraged to precondition weaned calves for 30 to 45 days prior to feedlot arrival. Typically preconditioning programs focus on vaccination strategies, dehorning, and castration. These programs emphasize feeding "balanced" diets to improve nutrient intake while acclimating calves to feed bunks, but little research has been conducted on augmentation of preconditioning diets and their impact on subsequent feedlot health and gain performance. Vitamin E is intimately involved with the immune system, especially regarding oxidative stress and reducing free radicals that can damage cell membranes (Combs, 1998). This study was designed to evaluate the impact of feeding elevated levels of vitamin E with or without essential fatty acid sources, on the gain and health performance during both the preconditioning and feedlot periods and subsequent carcass quality.

Materials and Methods

Animals and Treatments. All procedures involving animals were approved by the Oregon State University Institute of Animal Care and Use Committee. Sixty-four Angus-cross calves (n = 36 steers, 28 heifers; 224 ± 33 kg) were stratified by weight and sex then randomly allotted to one of four 35-d preconditioning treatment groups (table 1). Preconditioning dietary treatments were: CON (base-diet with no supplemental vitamin E or oil), SE (base-diet plus 150 IU/kg (DM basis) of supplemental vitamin E), ELA (SE diet supplemented with 1.5% safflower oil) and ELNA (SE diet supplemented with 1.5% linseed oil). Concentrate mixes were limit-fed to 2.5 kg (AF basis) offered once daily in the afternoon. Eight pastures of similar size were used to house the calves during the pre-conditioning period of the trial (2 pastures per treatment). Each pasture contained a designated feeding area for the concentrate supplement and for free-choice grass hay (bluegrass hay), along with an open-access watering area. At the conclusion of the pre-conditioning period, all calves were transported (443 km) to a commercial feedlot for finishing. All calves received an intranasal application of IBR-PI_3 vaccine (TSV-2™, Pfizer Animal Health) 48-h post-arrival (d38) and again at 20d post-arrival (d56). This particular vaccine (and route of administration) was used in an attempt to stimulate an acute immune response to determine whether the preconditioning treatments altered the immune activity of the calves during the first 30d post-arrival. Calves were fed in a common pen and sent to slaughter when visual assessment indicated 1.0 cm of backfat cover, as determined by management. Carcass data was collected on all animals at time of harvest.

Blood collections. Blood samples were collected on a subsample of the population (n = 31) during the following times: trial commencement (d0), conclusion of the preconditioning period (d35), post-transit to the feedlot (d36), post-initial respiratory vaccination (d42), and post-secondary respiratory vaccination (d63 and 70). Blood samples were analyzed for glucose concentration (Stanbio Glucose Liqui-UV, Pro. 1060), Infectious Bovine Rhinotracheitis (IBR) antibody titer, and Parainfluenza-3 (PI_3) antibody titer. The IBR titers were determined via serum virus neutralization using a standard viral challenge, whereas PI_3 titers were determined via hemagglutination-inhibition using a standard viral challenge.

Statistical Analysis. All data were analyzed using the General Linear Model procedures of SAS (SAS Inst. Inc., Cary, NC) for a randomized complete block design with sex as block using the following preplanned contrasts: CON versus vitamin E (mean of SE, ELA, and ELNA), SE versus OIL (mean of ELA and ELNA), and ELA versus ELNA.

Results and Discussion

Table 2 summarizes the performance and carcass data for all treatments. Two calves were treated for sickness during the preconditioning period, but both were not common to a single dietary treatment group. No other animals were diagnosed as sick or treated during the remainder of the study. No differences ($P > 0.10$) were detected in daily gain (ADG) during either the preconditioning or finishing periods for any treatment contrasts. The only ADG differences ($P = 0.09$) tended to be between SE and OIL treatments during the receiving period. There were no differences ($P > 0.10$) in carcass characteristics for any treatment contrasts. Backfat accumulation tended ($P = 0.10$) to be greater in SE calves versus the OIL treatment calves. The performance and carcass data indicate that supplemental vitamin E with or without added linoleic or linolenic oil sources have minimal or no impact on animal gain performance or carcass merit.

Infectious Bovine Rhinotracheitis (IBR) antibody titers. Figure 1 illustrates the IBR antibody titer concentrations measured on d35, 36, 42, 63, and 70 of the study for each contrast. The only differences ($P < 0.05$) detected in antibody titer levels were at d35 and 36 with CON calves having greater levels versus calves receiving supplemental vitamin E. Upon initial evaluation of the IBR titer data one could state that titer levels responded to supplemental vitamin E (CON vs vitamin E) and supplemental vitamin E without added oil sources (SE vs OIL) during the receiving period in the feedlot. After detailed examination of the data and associated residual errors we concluded that the subset of calves sampled were too small and individual variation masked potential differences. The visual trends indicate that supplemental vitamin E (with or without oil) seemed to positively impact immune responses to IBR, but due to individual variation and the small number of calves sampled, those conclusions are not supported.

Parainfluenza-3 (PI_3) antibody titers. Figure 2 illustrates the PI_3 antibody titer concentration measured on d35, 36, 42, 63, and 70 of the study for each contrast. No differences ($P > 0.10$) were detected at any time period for any contrasting treatments. Similar to the IBR antibody titer data, PI_3 antibody titers were lowest at time of transport and increased after vaccinations. Also similar to the IBR antibody titer data, the large amount of individual animal variation and the small number of calves sampled probably masked any potential treatment differences in the current study.

Plasma glucose. Figure 3 illustrates the plasma glucose levels measured on d35, 36, 42, 63, and 70 of the study for each contrast. Regardless of preconditioning treatment plasma glucose levels were similar and responded in a similar manner during the feedlot receiving period across treatments. The increasing glucose levels after feedlot arrival would correspond with increased dry matter and starch intake. Since minimal numbers of calves became ill during the study and performance was similar (indicating similar DM intake, gain efficiency, or both) we would not expect significant differences in metabolic glucose pools.

Implications

Potentially due to the small number of sampled calves in this study (and thus higher levels of associated error), the findings do not support the use of elevated levels of vitamin E in preconditioning diets for beef calves. The use of different oil sources to improve vitamin E uptake by the calves were also not shown to be effective. Antibody titer levels would suggest that there are effects of vitamin E, but replication of the study would be necessary to clarify the results.

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Table 1. Dietary treatments fed to newly weaned beef calves during the 35d preconditioning period.

	Dietary treatments (DM basis)[a]			
Item	**CON**	**SE**	**ELA**[b]	**ELNA**[c]
Cracked corn, %	57.8	57.5	56.7	56.7
Soybean meal, %	38.0	37.8	37.2	37.2
Molasses, %	1.3	1.3	1.2	1.2
Limestone, %	2.2	2.2	2.2	2.2
TM salt[d], %	0.75	0.75	0.74	0.74
Premix[e], %	0.0	0.48	0.47	0.47
Oil source, %	0.0	0.0	1.5	1.5
Nutrient analysis[f]				
Crude protein, %	27.9	30.0	25.9	26.0
Vitamin E, IU/kg	8.3	284.7	548.2	396.0

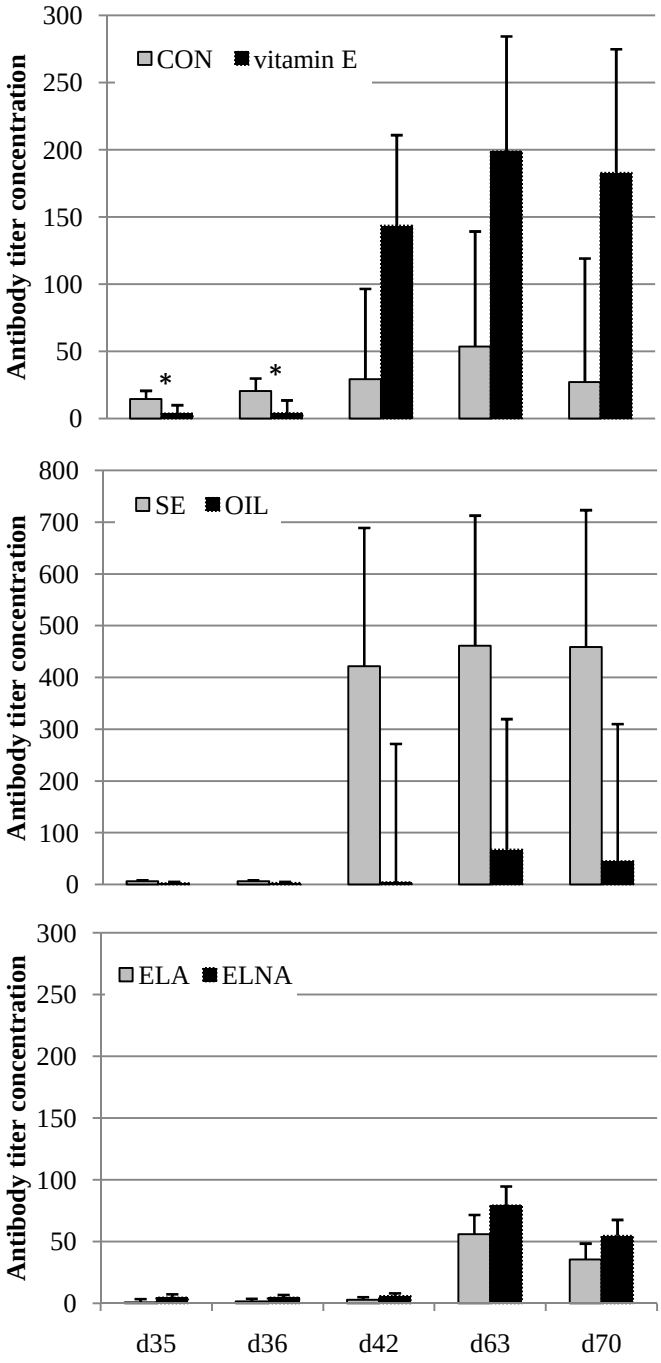
[a]Treatments were fed at 2.50 kg/day, with ad libitum bluegrass hay (6.75% CP)
[b]Oil source was safflower oil.
[c]Oil source was linseed oil.
[d]Trace mineralized salt
[e]Cracked corn carrier with predetermined levels of supplemental vitamin E.
[f]Based on laboratory analysis

Table 2. Summary of preconditioning and feedlot gain performance, and carcass characteristics of preconditioned beef calves with or without supplemental vitamin E.

	Preconditioning treatments[a]					Pre-planned Contrasts		
Item	**CON**	**SE**	**ELA**	**ELNA**	SEM	CON vs Vit. E	SE vs OIL	ELA vs ELNA
Preconditioning and Feedlot Performance								
In weight, kg	224.8	223.5	222.4	224.7	8.7	NS	NS	NS
Preconditioning ADG, kg/d	0.60	0.52	0.67	0.53	0.17	NS	NS	NS
Shrink, %[b]	2.35	2.31	2.63	2.47	0.43	NS	NS	NS
Receiving ADG, kg/d[c]	0.85	0.96	0.87	0.83	0.11	NS	0.09	NS
Finish ADG, kg/d[d]	1.18	1.19	1.17	1.11	0.08	NS	NS	NS
Feedlot ADG, kg/d[e]	1.13	1.16	1.13	1.07	0.08	NS	NS	NS
Final BW, kgf	486.5	474.4	477.2	469.4	11.1	NS	NS	NS
Carcass characteristics								
Carcass weight, kg	301.7	294.2	295.9	291.1	15.2	NS	NS	NS
Backfat, cm	1.08	1.24	1.04	1.10	0.03	NS	0.10	NS
Ribeye area, cm^2	30.9	29.3	30.8	29.3	0.3	NS	NS	NS
KPH, %	2.12	2.19	2.06	2.32	0.12	NS	NS	NS
Marbling score[g]	476.3	488.5	461.7	506.0	24.1	NS	NS	NS
Yield grade[h]	2.62	2.93	2.54	2.79	0.11	NS	NS	NS
Retail Yield, %[i]	50.7	50.0	50.9	50.3	0.3	NS	NS	NS

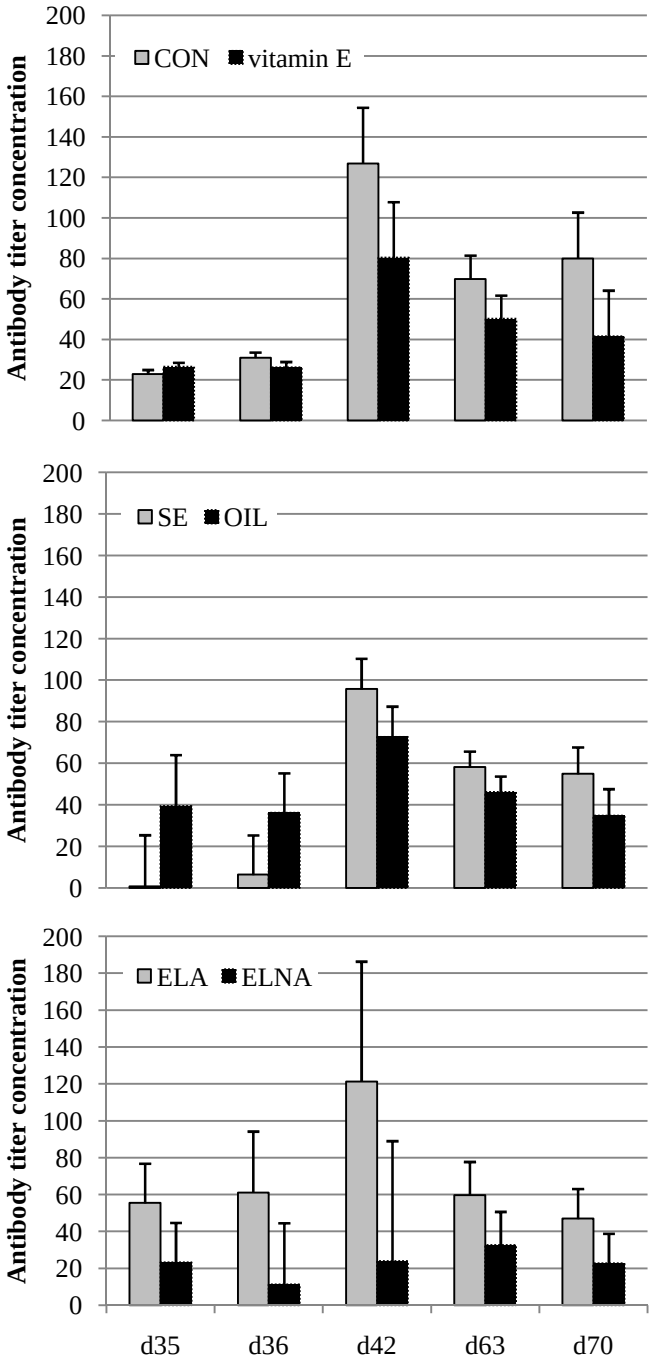
[a]CON = base diet with no supplemental vitamin E or oil, SE = base diet supplemented with 150 IU of vitamin E, ELA = SE diet supplemented with 1.5% safflower oil, ELNA = SE diet supplemented with 1.5% linseed oil.
[b]Calculated from individual weights collected after transport to feedlot (443 km).
[c]Based on initial 35 d in the feedlot.
[d]Calculated for the period following feedlot receiving until harvest.
[e]Calculated for the entire feedlot period (receiving and finishing phases).
[f]Calculated using carcass weights divided by dressing percentage (steers = 63%, heifers = 61%).
[g]300 = slight (Se), 400 = small (Ch^-), 500 = modest (Ch^0), 600 = moderate (Ch^+)
[h]Calculated as: yield grade = 2.5 + (2.5*backfat) + (0.0038*carcass weight) + (0.2*KPH) – (0.32*ribeye area)
[i]Calculated as: % retail yield = 51.34 – (5.78*backfat) – (0.0093*carcass weight) – (0.462*KPH) + (0.740*REA).

Figure 1. Infectious Bovine Rhinotracheitis (IBR) antibody titer concentrations in preconditioned[a] beef calves.



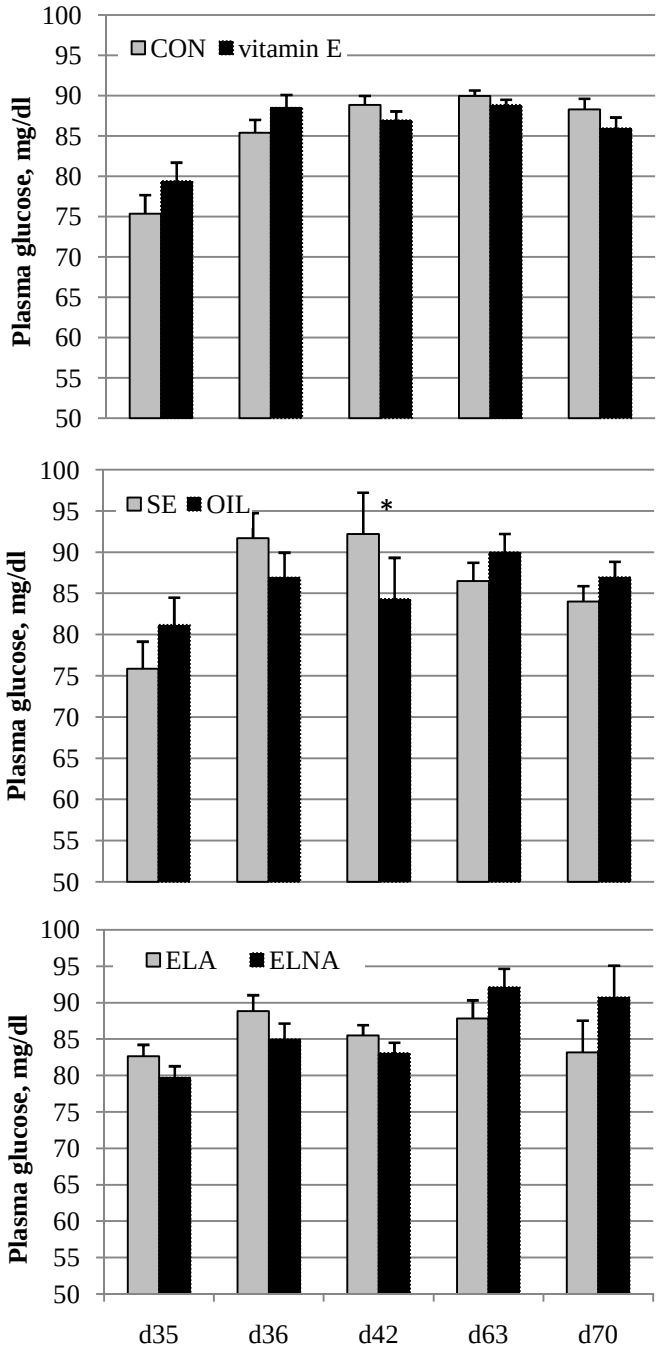
[a]CON = base diet with no supplemental vitamin E or oil,
SE = base diet supplemented with 150 IU of vitamin E,
ELA = SE diet supplemented with 1.5% safflower oil,
ELNA = SE diet supplemented with 1.5% linseed oil.
*P < 0.05

Figure 2. Parainfluenza-3 (PI_3) antibody titer concentrations in preconditioned[a] beef calves.



[a]CON = base diet with no supplemental vitamin E or oil,
SE = base diet supplemented with 150 IU of vitamin E,
ELA = SE diet supplemented with 1.5% safflower oil,
ELNA = SE diet supplemented with 1.5% linseed oil.
*P < 0.05

Figure 3. Plasma glucose concentrations in preconditioned[a] beef calves.



[a]CON = base diet with no supplemental vitamin E or oil, SE = base diet supplemented with 150 IU of vitamin E, ELA = SE diet supplemented with 1.5% safflower oil, ELNA = SE diet supplemented with 1.5% linseed oil.

*P < 0.05

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EFFECTS OF WET DISTILLERS GRAIN AND A DIRECT-FED MICROBIAL ON FINISHING PERFORMANCE AND CARCASS CHARACTERISTICS OF BEEF STEERS FED A SORGHUM-BASED FINISHING DIET

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ABSTRACT: Angus x calves (n = 406; initial BW = 441 ± 31 kg) were stratified by BW and ultrasonically-measured longissimus muscle characteristics and assigned randomly to 1 of 4 ration treatments (4 pen replicates per treatment). Ration treatments were: 1) soybean meal protein supplement (CON); 2) control plus direct-fed microbial (CON+DFM); 3) wet distiller's grain plus solubles (WDGS; 15% of diet DM); and 4) WDGS plus direct-fed microbial (WDGS+DFM). Steers were fed for 106 d before harvest. Longissimus muscle characteristics were measured ultrasonically on d 0 and 56 of the feeding period. Increase in backfat thickness was greater (P < 0.01) for steers receiving WDGS compared those receiving the control diet during the first 56 d on feed. In addition, increase in longissimus muscle depth was greater (P <0.01) for cattle receiving DFM compared those receiving no microbial treatment. Change in marbling score was similar (P = 0.44) among treatments. Steer ADG during the entire feeding period was greater (P < 0.01) for WDGS than for CON (1.66 and 1.43 ± 0.02 kg/d, respectively). Likewise, harvest BW was greater (P < 0.01) for steers receiving WDGS compared to steers receiving the control diet. Carcass weight was greater in steers fed WDGS+DFM compared to WDGS, but was lower in steers fed CON+DFM compared to CON (WDGS x DFM; P = 0.01). Dressing percent and LM area were similar (P > 0.30) between treatments. USDA yield grade (P = 0.41) and quality grade (P = 0.45) were also similar among treatments with 69.0% of steers grading choice or better. Under the conditions of our study, these data were interpreted to suggest that sorghum-based feeding diets containing WDGS and a direct-fed microbial may improve finishing performance and carcass merit compared to diets containing no distiller's grains. Further research is needed to elucidate optimal use conditions of direct-fed microbials in sorghum-based finishing diets.

Key W ords: Steers, Distillers Grains, Direct-fed Microbial

Introduction

A majority of the grain sorghum produced in the United States is currently utilized as livestock feed or in the production of ethanol (National Sorghum Producers, 2010). However, there is limited information regarding the effects of wet distiller's grains (**WDGS**) inclusion in sorghum-based rations on animal performance and carcass characteristics. Additionally, the recent fluctuations in commodity prices have stimulated interest in technologies, such as direct fed microbials (**DFM**) that may improve animal performance during the feeding period (Brown and Nagaraja, 2009).

Therefore, the objective of this study was to evaluate the effects of WDGS and DFM inclusion on feedlot performance and carcass quality attributes in steers fed sorghum-based finishing rations.

Materials and Methods

Animals, Facilities and Treatments. Procedures were approved by the Kansas State University Institutional Animal Care and Use Committee. Angus crossbred steers (n= 428; initial BW = 441 ± 31 kg) were used for this experiment. Steers originated from three livestock markets and were maintained in 1033 m^2 earth-floor pens (~27 hd/pen) for the duration of the study.

Steers were received and processed at the KSU Agricultural Research Center–Hays (KSU-ARCH) feedlot. At processing steers were weighed, implanted with a Synovex-Choice (Fort Dodge Animal Health, Overland Park, KS) implant and measured with ultrasound to determine 12th rib fat thickness, LM depth and marbling score. Steers were stratified by BW and ultrasonically-measured carcass characteristics, and assigned randomly to 1 of 4 ration treatments (4 pen replicates per treatment). Ration treatments were: 1) soybean meal protein supplement (CON); 2) control plus direct-fed microbial (CON+DFM; (NovaCell) Nova Microbial Technologies, Omaha, NE); 3) wet distiller's grain plus solubles (WDGS; 15% of diet DM);

and 4) WDGS plus direct-fed microbial (WDGS+DFM). The DFM was dissolved in 90°C water and top dressed to the ration immediately after feeding.

All cattle were fed a common receiving diet for 7 d and were then gradually adapted to the finishing diets (Table 1) and fed for 106 d until harvest. Cattle were fed using a slick-bunk method and feed calls were made each morning at 0630 prior to feed delivery. Cattle were evaluated daily by KSU-ARCH feedlot personnel for clinical signs of morbidity.

Table 1. Ingredient and nutrient composition of ground sorghum based finishing diets.

	Treatment	
Item,	Control	WDGS[1]
Ingredient, % DM		
Sorghum, Ground	71.5	65.7
Sorghum Sudan Hay	15.7	15.8
Wet Distiller's Grain	-	15.8
Soybean Meal	10.5	-
Calcium Carbonate	1.4	1.8
Ammonium Sulfate	0.2	0.2
Salt	0.2	0.2
Vitamin and Mineral Premix[2]	0.5	0.5
Nutrient concentration, % of diet DM		
CP	11.8	14.8
NEm, Mcal/kg	1.89	1.85
NEg, Mcal/kg	1.16	1.14
Ca, %	0.70	1.07
P, %	0.28	0.37
S, %	0.14	0.23

[1]Wet Distiller's Grains plus Solubles.
[2]Supplied 299.2 mg Rumensin per hd.

Data Collection. Steers were weighed approximately every 28 d during the finishing period and carcass characteristics (12th rib fat thickness, LM depth and marbling score) were determined by ultrasound using an Aloka 500V (Aloka Co., Ltd, Wallingford, CT) B-mode instrument equipped with a 3.5-MHz general purpose transducer array (UST 5021-125 mm window) on d 0 and 56 during the finishing period. Ultrasound images were collected with Cattle Performance Enhancement Company (**CPEC**, Oakley, KS) software. Backfat thickness, LM depth, and marbling score were estimated with procedures that incorporated image analysis software (Brethour, 1994) that are an integral component of the CPEC product. Harvest date was determined by the d 56 scan to meet an average carcass endpoint of 11 mm of fat depth over the 12th rib.

Cattle were transported approximately 3 h to a commercial abattoir (National Packing Company, Dodge City, KS) on the harvest date. Carcass characteristics were measured by camera and automated software and included 12th-rib fat thickness, 12th-rib longissimus muscle area, kidney-pelvic-heart fat, USDA maturity grade, USDA yield grade, USDA quality grade, and marbling score (USDA, 1997). Data were validated by a trained evaluator. Due to software error, actual data for 12th-rib fat thickness and marbling score were omitted.

Statistical Analysis. Data were subjected to ANOVA using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC). All steers that exhibited clinical signs of morbidity or expired during the course of the studied were removed from the analysis. Class variables included pen, treatment WDGS and DFM. The model included terms for WDGS and DFM and their interaction. F- tests were constructed using the type-3 error mean squares. Least Squares Means were considered to be different when $P \leq 0.05$ and trends occurred when $P \leq 0.10$.

Results and Discussion

During the course of the study 22 steers were removed due to morbidity or mortality. Steer ADG was only affected by DFM inclusion during period 2 when steers receiving the DFM had greater ($P < 0.01$) ADG compared to steers receiving no DFM (1.34 ± 0.04 vs. 1.51 ± 0.04 kg/d, respectively). This is in contrast to reviews of previous literature (Fox, 1988; Krehbiel et al., 2003) in which steers, across all weight classes, fed a DFM gained weight more rapidly. However, DFM has been reported to possibly be more beneficial in young or newly received high-stress cattle. The greatest improvement in performance or health due to DFM has generally occurred within the first 14 d of receiving (Crawford et al., 1980; Hutcheson et al., 1980). Perhaps feeding a common receiving ration for the first 7 d after receiving, before feeding diets containing DFM, masked some potential benefits in the present study. Steer ADG during the majority of the feeding periods of the finishing phase and for the entire feeding period was greater ($P < 0.01$) for WDGS than for CON (Table 2). As a result, harvest BW was greater ($P < 0.01$) for steers receiving WDGS compared to steers receiving the control diet (592 vs. 569 ± 3 kg, respectively).

Although the treatment diets were nearly iso-energetic (1.16 (CON) vs. 1.14 (WDGS) Mcal/kg of NEg) steers fed WDGS gained 0.23 kg/d more and were 23 kg heavier at harvest than steers fed the control diet. Additionally, steers fed WDGS also exhibited a greater increase in backfat deposition during the first 70 d on feed. These differences, in part, may be due to a conditioning effect of WDGS inclusion in the ground-sorghum based ration, which may have increased total DMI and subsequent energy intake.

The increase in backfat thickness was greater ($P = 0.005$) for steers receiving WDGS compared to those receiving the control diet during the first 70 d on feed (1.95 ± 0.11 vs. 1.54 ± 0.10 mm, respectively). In addition, during the first 70 d on feed the observed increase in backfat thickness tended ($P < 0.10$) to be greater for steers receiving DFM compared to those receiving no DFM (1.87 ± 0.11 vs. 1.62 ± 0.10 mm, respectively). Increase in LM depth was greater ($P < 0.001$) for cattle receiving DFM compared those receiving no microbial treatment (16.46 ± 0.34 vs. 13.85 ± 0.34 mm, respectively). Change in marbling score was similar ($P = 0.44$) among treatments.

Hot carcass weight was greater in steers fed WDGS+DFM compared to WDGS, but was lower in steers fed CON+DFM compared to CON (WDGS x DFM; $P = 0.01$; Table 3). Krehbiel and coworkers (2003) summarized data from 6 experiments and found that HCW was significantly greater for steers fed a DFM. The reason DFM fed in conjunction with a sorghum-based soybean ration resulted in a reduced HCW is unclear. However, the majority of these previous trials likely utilized corn-based rather than sorghum-based finishing rations. Dressing percent and LM area were similar ($P > 0.30$) between treatments (Table 3). USDA yield grade ($P = 0.41$) and quality grade ($P = 0.45$) were also similar among treatments (Table 3) with 69.0% of steers grading choice or better. A meta-analysis conducted by Klopfenstein et al. (2008) reported a linear increase in yield grade and fat thickness in response to increasing dietary concentrations of WDGS in dry-rolled and high-moisture corn-based diets. However, the lack of difference in yield and quality grade among steers fed CON and WDGS diets may be due to the relatively low inclusion (15.8% of diet DM) of WDGS in this study.

Implications

Use of WDGS in sorghum grain-based finishing rations resulted in an increase in ADG compared to sorghum grain rations containing soybean meal. This resulted in greater harvest weights for those steers fed WDGS. Addition of a DFM to the diets containing WDGS resulted in greater HCW compared to steers consuming only WDGS diets. Addition of a DFM to diets containing soybean meal or WDGS only improved average daily gain during an early period of the finishing phase. Use of a direct-fed microbial did increase longissimus muscle depth and tended to increase 12th-rib fat thickness during the first 70 d on feed. Further research is required to elucidate the optimal timing of use and potential economic benefits of feeding a DFM in combination with WDGS.

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Table 2. Average daily gain of steers fed finishing diets containing soybean meal (CON) or wet distiller's grain plus soluble (WDGS), with and without a direct-fed microbial (DFM).

	Treatment				
Item	CON	CON+DFM	WDGS	WDGS+DFM	SEM
Finishing period ADG, kg/d					
Days 0 – 35[1]	1.47[a]	1.51[a]	1.85[b]	1.81[b]	0.04
Days 36 – 56[1,2]	1.21[a]	1.38[a,b]	1.48[b,c]	1.64[c]	0.06
Days 57 – 84	2.01	1.96	2.11	2.00	0.06
Days 85 – 101[3]	0.71[d]	0.43[e]	0.67[d,e]	0.88[d]	0.08
Overall ADG, kg/d	1.44	1.42	1.65	1.67	0.03

[1]Main effect of wet distiller's gain plus solubles ($P < 0.001$).

[2]Main effect of direct-fed microbial ($P = 0.005$).

[3]Interaction of wet distiller's gain plus solubles and direct-fed microbial ($P = 0.002$).

[a,b,c] Within a row, means without a common superscript differ ($P < 0.01$).

[d,e] Within a row, means without a common superscript differ ($P \leq 0.05$).

Table 3. Carcass characteristics of beef steers following 106 d finishing period with diets containing soybean meal (CON) or wet distiller's grain plus soluble (WDGS), with and without a direct-fed microbial (DFM).

	Treatment				
Item	CON	CON+DFM	WDGS	WDGS+DFM	SEM
Hot carcass wt, kg	357.9[a]	348.5[a]	368.6[a,b]	376.2[b]	3.45
Dressing, %	62.6	64.7	62.6	63.3	1.35
Longissimus area, cm^2	85.5	86.7	87.3	88.6	1.22
USDA quality grade Choice, %	68.9	62.0	69.7	73.7	-
USDA yield grade	1.98	2.87	2.20	2.19	0.40

[a,b] Within a row, means without a common superscript differ ($P < 0.01$).

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Population Dynamics of Protozoa in Dairy Cows Fed with Rumensin200® and Tallow During Dry and Lactating Stages

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Addition of Rumensin200 and tallow in TMR for dairy cows on protozoan populations was explored in dry and early-lactating cows. Ionophores have been used in ruminants to decrease acidosis and to mitigate gaseous emissions in dairy operations, by inhibiting growth of microorganisms such as protozoa. Also, tallow as an energy alternative in TMR has shown changes in fiber digestibility and gases production, mainly due to the interaction of its unsaturated component with rumen microorganisms. For this experiment, 4 ruminally fistulated Holstein cows were fed rations based on a 90:10 (dry) and 40:60 (lactating) forage to concentrate ratios. Four treatments were randomly assigned in a 4X4 Latin Square experimental design as follows: TMR (T1), TMR + 3.3 g Rumensin200® (dry/lactating), (T2), TMR + 3,2% DM tallow (T3) and TMR + 3,3 g Rumensin200®+ 3,2% DM tallow (T4). Samples of ruminal content were taken at 0, 1, 2, 4, 8, 12, 18 and 24 hrs after feeding, filtered, preserved with an equal volume of 5% formalin and frozen. Thawed samples were treated with brilliant green and glycerol for direct protozoa count on a Neubauer chamber under a microscope at 40X. Oxidation-reduction potential (ORP) and pH were recorded in rumen during the same sampling times. Total number of protozoa at 24 hrs after feeding did not differ (P>0.001) among treatments in lactating cows, whereas the addition of Rumensin200® to TMR for dry cows caused a significant decrease (P>0.001) in population size (5.0 vs. 1.06E5, respectively). Also, protozoa were less diverse in lactating compared to dry cows; while the *Diplodiniinae* species were dominant (98%) in lactating cows with any treatment, dry cows fed T3 exhibited a more diverse community formed by 68% *Diplodiniinae* and 29% *Entodinium*. Monitoring of pH did not show significant differences (P>0.001) among treatments in both dry and lactating stages, while ORP values suggested a more reduced environment (-241 to –310 mV) in lactating than in dry cows (-234 to –294 mV). This experiment showed changes in protozoan community composition led by modification of the rumen environment.

Keywords: Ruminal protozoa, Rumensin200®, tallow, dairy cows.

Introduction

Ciliate protozoa are normally present in the rumen content of wild and domestic ruminants. Their diversity is determined greatly by animal diet as well as geographical areas (Göcmen *et al*., 2001). The presence of ciliate protozoa results in a more stable ruminal fermentation, as shown by studies with rumen dafaunation. Also, the large protozoa biomass in the rumen comprises from 40 to 80% of total microbial biomass (Harrison *et al*., 1979), and their ability to attack the major components of feeds (water-soluble carbohydrates) suggest that, eventhough not essential, they serve an important role in ruminal fermentation pattern (Ogimoto and Imai 1981). The concentration of ciliates protozoa in the rumen contents in healthy animals varies between 10^{-5} and 10^{-6} ml^{-1} depending upon conditions previously described (Dehority *et al*., 1986). Another crucial role is the recycling of microbial N in the rumen caused by bacteria predation by ciliates. *In vitro* studies suggest that the presence of protozoa and their engulfment and digestion of bacteria is the most important activity regulating the turnover of bacterial N in the rumen (Koening *et al.,* 2000). The impact of the presence or absence of ruminal ciliated protozoa on the host may depend on the diet and on the numbers and kinds of ciliates. For example, in animals fed low-protein diets, these organisms apparently have a negative effect on growth and performance (Nagaraja et al., 1992). However, in animals fed high-grain diets, ciliated protozoa may have a beneficial role, primarily because of their ability to influence starch and lactic acid metabolism (Veira 1986). The presence of protozoa in animals fed high grain diets is associated with decreased accumulation and increased fermentation of lactic acid. Because of their influence on ruminal lactate accumulation, it is hypothesized that ciliated protozoa play an important role in the moderation of ruminal fermentation in ruminants fed high-grain diets (Nagaraja et al., 1992). This study aims to compare shifts in protozoa populations in diets formulated for dry and lactating cows, supplemented with Rumensin200® and tallow.

Materials and Methods

Animals and diets

Four multiparous Holstein cows (average 650 kg BW) fitted with ruminal cannulae were used in the present study during dry and lactating stages (80 DIM). Cows were randomly assigned in a 4X4 Latin Square to individual stalls and fed a TMR formulated to contain a 90:10 and 40:60 F:C ratio, for dry and lactating stages, respectively (Table 1). The cows were fed after milking at 0800 and 1500 h during periods that consisted of twelve days of adaptation and three days of sampling.

Sampling and rumen parameters measurement

On day 13 of each period, ruminal content (RC) was collected through the canulae at 0, 1,2 4, 8, 12, 18 and 24 hours after feeding and strained through several layers of cheesecloth. An aliquot of 5 mL of ruminal liquid was preserved with an equal amount of 5% formalin. Meanwhile, pH and ORP were measured, directly *in rumen* using a Multiparameter Sensor (HANNA 9828) inserted directly in the ventral section and let to stabilize 10 minutes before recording the readings. The total number of protozoa was counted after staining with two drops of brilliant green dye, mixed and allowed to stand for 4 h. After the staining period, 4.5 ml of a 30% glycerol solution was added to 0.5 ml of sample (1:20 dilution) following a modification of the counting technique (Makkar and McSweeney, 2005) in a Neubauer chamber at a microscopical magnification of 40X. Classification of species was done following the scheme proposed by the same authors.

Results and Discussion

The average number of protozoa in dry cows was $4.45x10^5$ compared to $3.25x10^5$ cells ml^{-1} in lactating cows, over a 24 hrs period. However these numbers were not affected by sampling times. The only positive interaction of a treatment with the protozoa population was exhibited by the presence of tallow in the ration (T3) during the dry stage, which also showed a quadratic response that can be attributed to the input of fresh substrates immediately after feeding times. This effect has also been related to a higher forage proportion of the TMR (Figure 1). Previous studies (Nagaraja et al., 1992) have shown that diets high in water-soluble carbohydrates, such as those present in concentrates tend to decrease the number of protozoa during lactation stages (Figure 2). The addition of Rumensin200® the ciliate populations, especially during the dry stage, whereas supplementation with tallow in dry cows showed higher counts that can be related to a more stable ruminal pH.

In the latter study TMR formulated for lactating cows favored the dominance of species of one genus (*Diplodiniinae* 98%, *Entodinium* 2%) regardless of the treatment, while in dry cows the protozoan community was more diverse (68% *Diplodiniinae,* 29% *Entodinium,* 3% *Isotrichia*). Monitoring of pH did not show differences (P>0.001) among treatments in both dry and lactating stages, while ORP values suggested a more reduced environment (-241 to –310 mV) in lactating than in dry cows (-234 to –294 mV). This experiment showed changes in protozoan community composition led by modification of the rumen environment.

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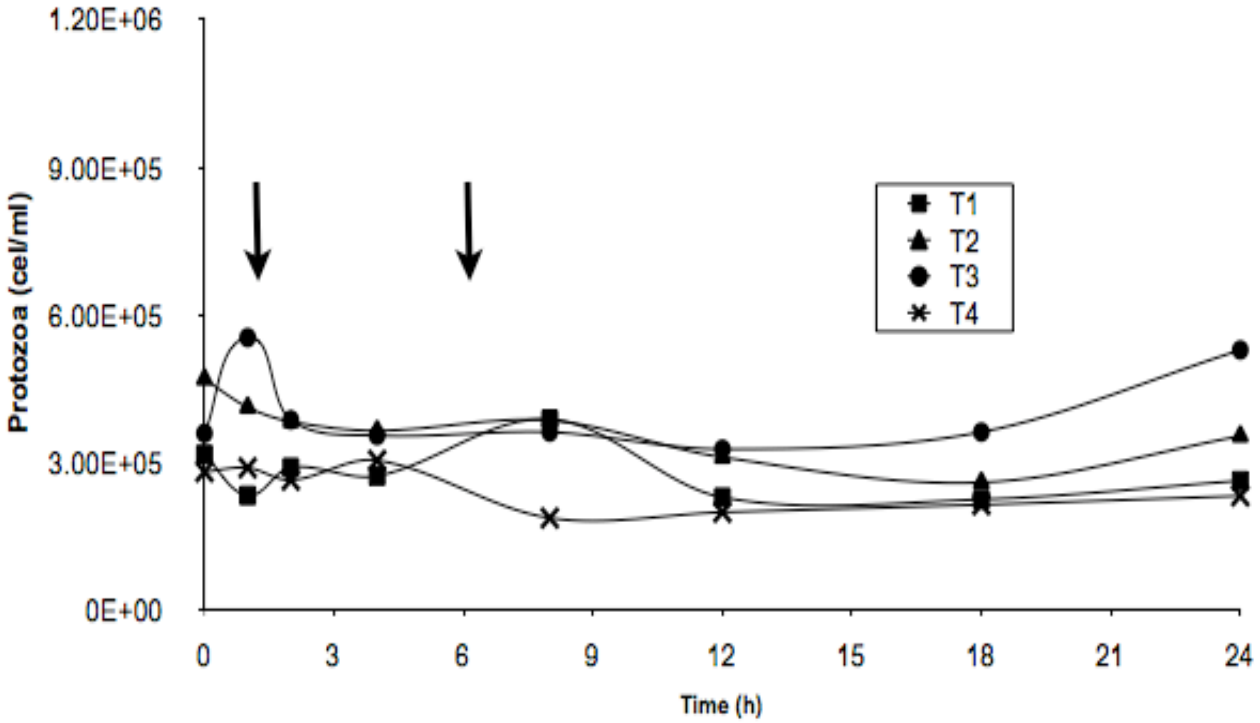

Figure 1. Hourly protozoan communities in lactating cows. X-axis shows time starting at 0800 h (0). Arrows indicate feeding times.

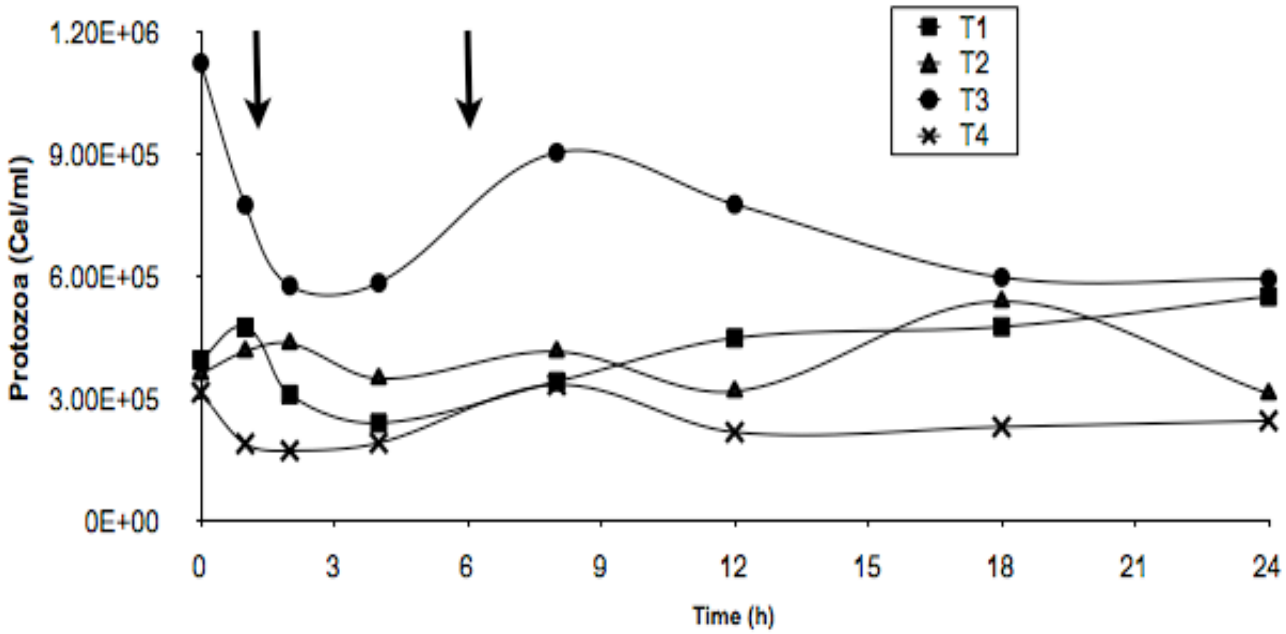

Figure 1. Hourly protozoan communities in dry cows. X-axis shows time starting at 0800 h (0). Arrows indicate feeding times.

Table 1. Composition of experimental total mixed rations

Total Mixed Rations (%DW)				
	Dry Cows		Lactating Cows	
	T1 and T2[a]	T3[b] and T4[c]	T1 and T2	T3 and T4
Corn Silage	63.49	63.93	25.63	26.53
Alfalfa Hay	27.01	27.19	17.53	18.18
Concentrate	9.51	8.88	56.84	55.32

[a]2/3.3 g of Rumensin for the dry and lactating cows, respectively, [b]3.2% of DM was included as tallow and [c]both Rumensin and tallow.

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Influence of Rumensin200® and Tallow on the Rumen Parameters and Fiber Digestion on Dairy Cows

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ABSTRACT

The modification of rumen physical-chemical parameters such as pH and oxidation-reduction potential (ORP) by addition of Rumensin200® and tallow to the TMR of dry and lactating cows was investigated. For this experiment, 4 ruminally fistulated Holstein cows were fed rations based on a 90:10 (dry) and 40:60 (lactating) forage to concentrate ratios. Four treatments were randomly assigned in a 4X4 Latin Square experimental design as follows: TMR (T1), TMR + 2/3.3 g Rumensin 200 ® (dry/lactating), (T2), TMR + 3,2% DM tallow (T3) and TMR + 2/3.3 g Rumensin200® + 3.3% DM tallow (T4).. The cows were fed *ad libitum* (0800 and 1500 h) in individual stalls and milked twice daily (0400 and 1300 h). Each of 4 experimental periods had 12 days of conditioning, followed by sampling on days 13 and 15. Samples of ruminal content were taken at 0, 1, 2, 4, 8, 12, 18 and 24 hrs after morning feeding for DM and NDF digestibility evaluation with standard protocols. Oxidation-reduction potential and pH were measured in rumen with a multiparameter electrode. Statistic analysis of data was done using PROC mixed in SAS. Ruminal pH fluctuated considerably during day and showed a quadratic trend for all treatments ($P<0.05$), producing wide value ranges as follows: T1=6.22-7.02, T2=6.27-7.02, T3=6.22-6.93, and T4=6.03-6.95. However, there were not significant differences among treatments and between dry and lactating stages ($P>0.05$). The oxidation-reduction potential changed between physiological stages and over time ($P<0.05$), while exhibiting little variation among treatments. Dry matter digestibility and NDF were not different among treatments ($P>0.05$). This experiment suggested that the addition of Rumensin200 and tallow lowered the ORP to more negative values and showed a significant difference ($P>0.05$) of this parameter between dry and lactating stages.

Keywords: Rumensin200®, ORP, pH

INTRODUCTION

The pH is an important indicator of rumen fermentation conditions (Kebreab *et al*., 2009), that determines the optimal environment for bacterial growth (normal range, 6.0 to 6.9). A low pH may decrease fiber digestibility, microbial biomass production and milk production, which in turn can lead to higher feed costs (Allen, 1997). Rumen is normally anaerobic with negative redox potential (ORP) of approximately -350 mV. This parameter not only reflects the absence of dissolved oxygen, but also the presence of strong reducing agents (Kamra, 2005). Both pH and ORP parameters can be manipulated directly trough the feedstuff and supplementation additives, such as ionophores and tallow. In recent years these products have been used for several purposes, like the mitigation of methane emissions. Ionophores regulate ruminal pH due to inhibition of growth of Gram-positive bacteria, such as several species of lactate-producing bacteria. One important feature is that under optimal conditions they do not affect fiber fermentation (Nagaraja, *et al.,* 1982). One of the commercially available ionophores is Rumensin200® (Monensin) that has been used in numerous studies. On the other hand, tallow has also been widely studied, probably because it has effects in ruminal fermentation, increasing propionate production, decreasing CH_4 synthesis and it can de used as an energy-dense alternative total mixed rations. (Clary *et al*., 1993). This study aims to compare the effect of Rumensin200 and tallow on rumen parameters of dairy cows on two different physiological stages.

MATERIALS AND METHODS

Animals: Four multiparous Holstein cows (650 kg BW) fitted with ruminal cannulae were used in the present study during dry (32 DD) and lactating stages (30 DIM). The experiment was conducted at the Center for Research, Teaching and Technology Transfer at the Animal and Ecology

Sciences Department of the Universidad Autonoma de Chihuahua.

Treatments and sampling. Four treatments were randomly assigned in a 4X4 Latin Square experimental design as follows: T1 (TMR), T2 (TMR + 2/3.3 g Rumensin 200® (dry/lactating), T3 (TMR + 3,2% DM tallow and T4 (TMR + 2/3.3 g Rumensin200® + 3.3% DM tallow. The cows were fed *ad libitum* (0800 and 1500 h), milked twice daily (0400 and 1300 h) and had free access to fresh water all the time. The TMR for each physiological stage was based on a forage:concentrate ratio of 90:10 and 40:60 for dry and lactating cows, respectively (Table 1). Each treatment was offered in periods of 15 days on which the first 12 were for diet adaptation and days 13 thru 15 were for sampling and data collection.

Measurement of the rumen parameters. Rumen pH and ORP were measured *in rumen* using a multiparameter sensor (Hanna Instruments HI-9828) via canulae in the ventral sac at 0, 1, 2, 4, 8, 12, 18 y 24 post feeding hours The electrode was introduced into the rumen for at least 5 minutes to let it stabilize before collecting data.

Dry matter and detergent neutral fiber digestibility. On days 13, 14 and 15 of each period, feces were taken directly from the rectum, according to the following layout: On day 13 samples were taken at 0, 2, 4 and 6 h; on day 14 samples were taken at 8, 10, 12 and 14 h, while on day 15 the rest of the samples were taken at 16, 18, 20 and 22 h. These samples were dried for 48 h at 60°C in a forced-air oven and 20 g per sample were mixed obtaining a sample of 240g per cow per period, to measure dry mater and neutral detergent fiber. Dry mater and neutral detergent fiber digestibility were determined using the non-digestible acid detergent fiber as an internal marker (Penning and Johnson, 1983).
Feces and TMR components (alfalfa, corn silage, and concentrate samples (0.35 g (±0.05), in triplicate were transferred into Ankom F57 filter bags (Ankom Technology, Macedon, NY) and were incubated in a Daisy II (Ankom Technology, Macedon, NY) following modified directions from the manufacturer, in which the incubation period was extended for five days instead of two. Digestibility was calculated using the Schneider and Flatt, 1975 equations.

Statistical analysis: Data were analyzed using PROC MIXED in SAS (SAS Inst., Inc., Cary NC)

RESULTS AND DISCUSSION

Ruminal pH was not modified by the addition of Rumensin200® nor tallow in either dry or lactating cows ($P<0.05$). This effect was consistent with studies by Zinn *et al*., (1994) on feedlot cattle, although he reported a 1.4% numerical reduction on this parameter ($P< 0.1$).
Other authors (Ruppert, *et al*., 2003) found that ruminal pH was not affected by tallow supplementation at 0,2 y 4% DM content. However, we observed a quadratic trend ($P<0.05$ over time (Figure 1). This trend showed that pH decreased after the fifth sampling (1600 h) for all treatments in dry cows, while this same effect was observed during the sixth sampling (2000 h) in lactating cows. Similarly, ruminal ORP was not modified by Rumensin200® nor tallow in the ration among treatments. However this parameter was different among physiological stages ($P<0.05$), being higher in dry than in lactating cows (Figure 2). This parameter also showed a quadratic trend over time ($P<0.05$).
Dry mater and neutral detergent fiber digestibility were similar ($P>0.05$) in all treatments for dry and lactating cows (Table 2). Ruminal pH and ORP parameters change around the day, having a quadratic effect. This can be explained by the rumen as a dynamic microhabitat influenced by the addition of new substrates. Presence of Rumensin200® and tallow in TMR's for dry and lactating cows at levels used in his experiment, did not changed rumen parameters nor fiber digestibility.

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Table 1. Composition of experimental total mixed rations

Total Mixed Rations (%DW)				
	Dry Cows		Lactating Cows	
	T1 and T2[a]	T3[b] and T4[c]	T1 and T2	T3 and T4
Corn Silage	63.49	63.93	25.63	26.53
Alfalfa Hay	27.01	27.19	17.53	18.18
Concentrate	9.51	8.88	56.84	55.32

[a]2/3.3 g of Rumensin for the dry and lactating cows, respectively, [b]3.2% of DM was included as tallow and [c]both Rumensin and tallow.

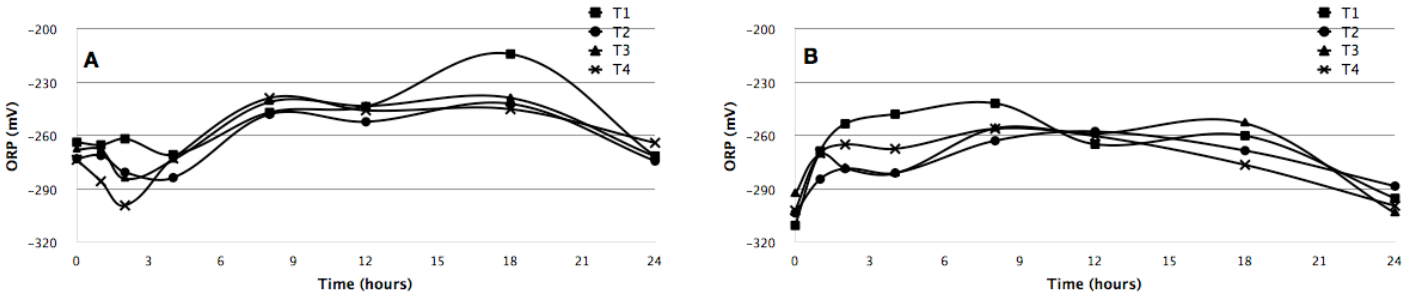

Figure 1. Oxidation-reduction potential (ORP) fluctuation in A) Dry and B) Lactating cows. The values are the mean of 4 independent observations taken over a 24 hr period.

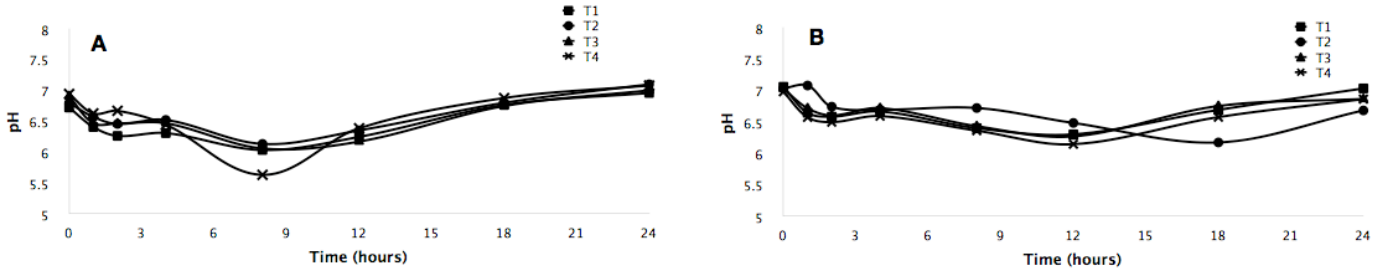

Figure 2. pH fluctuation in A) Dry and B) Lactating cows. The values are the mean of 4 independent observations taken over a 24 hr period.

Table 2. Total mixed rations dry matter and neutral detergent fiber digestibilities

Dry matter (DM) and Neutral Detergent Fiber (NDF) digestibility				
	Dry Cows		Lactating Cows	
	DMD (%)	NDFD (%)	DMD (%)	NDFD (%)
T1	48.54±2.73	33.33±4.53	71.07±2.24	30.49±3.7
T2[a]	47.41±2.24	35.09±3.7	69.79±2.24	37.62±3.7
T3[b]	43.96±2.24	27.87±3.7	66.46±2.24	38.82±3.7
T4[c]	52.08±2.74	37.74±4.53	72.04±2.24	38.94±3.7

[a]2/3.3 g of Rumensin for the dry and lactating cows, respectively, [b]3.2% of DM was included as tallow and [c]both Rumensin and tallow.

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USE OF WASTE PINTO BEAN GRAIN ON FINISHING HAIR LAMBS

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ABSTRACT: Feeds price increment has obliged sheep producers to look for new alternatives in animal feeding; one of them is waste pinto bean grain. The objective was to evaluate the effect of three waste pinto bean grain levels (in concentrate dry matter) on dry matter intake (DMI), average daily gain (ADG) and gain efficiency (GE) of finishing hair lambs. Treatments were: Control (C= 0%), low waste pinto bean (LWB= 12.5%) and high waste pinto bean (HWB= 25%). Seventy two crossbred hair lambs (Dorper X Pelibuey and Kathadyn X Pelibuey) were used (36 females and 36 males), all lambs being twins, with 18.69 ± 3.89 Kg initial body weight and 75 ± 6 d old. Lambs were fed *ad libitum* with isoenergetic and isonitrogenous (2.6 Mcal/Kg ME; 17.9 % CP) diets (80:20 concentrate:forage ratio) during 70 d, with an adaptation period of 18 d. Lambs were assigned to blocks by initial body weight (3 lambs per block, 4 female blocks and 4 male blocks by treatment) and then randomly assigned to the treatments (C, LWB and HWB; n= 24 per treatment) and were weighted every 14 d for ADG. In the last 5 d of each period DMI was measured for each block and then GE was estimated. Data for DMI, ADG and GE was analyzed with PROC MIXED in a completely random block arrangement where the treatment, gender and their interaction effects were evaluated, likewise a tendency analysis was made for each variable. For DMI (Kg) a quadratic effect was found ($P<0.05$), but treatments were not different ($P=0.0657$) (C= 1.22, LWB= 1.14 and HWB= 1.05). Data for ADG (Kg) showed a quadratic response for each treatment ($P<0.05$) (C=0.26, LWB=0.23 and HWB=0.21) during the test. Final body weight lsmeans (Kg) were C= 37.67, LWB= 34.22 and HWB= 33.27. For GE (Kg) a clear general tendency was not found, with no differences between treatments ($P=0.6001$) during the test (C= 6.53, LWB= 6.94 y HWB= 6.94). Gender and its interaction treatment by gender effect were not found ($P>0.05$) for any variable. The best productive performance of treatments in this research was found for C, so that the waste pinto bean grain use on finishing hair lambs is not a recommendable alternative for this productive stage.

Key words: Hair Lambs, Waste Pinto Bean Grain, Feedlot Lambs

Introduction

Feeds price increment has obliged sheep producers to look for new alternatives in animal feeding; one of them is waste pinto bean grain (*Phaseouls vulgaris L*). Dixon and Hosking (1992) said that one of the strategies used to alleviate the effect of under nutrition is supplementation with grain legumes. In 2007 Mexico produced 1, 102,963.66 tons. of bean (INEGI, 2007); grain that does not meet the quality standards for human consumption is used in animal feeding. It represents a good source of protein, some vitamins and minerals, and complex carbohydrates, however, these nutritional components, also contain some antinutritional factors such as protease inhibitors, polyphenols, lectins and phytic acid, among others (Mejia *et al.,* 2003). Mexico has 7, 306,600 ovines (INEGI, 2007) and their main product is finishing lambs for national consumption. Studies conducted with lambs receiving high concentrate diets have shown improved ADG, GE and carcass traits (Borton *et al.,* 2005); however, this is not a common practice in Chihuahua sheep units (Villalobos *et al.,*2006). The waste pinto bean grain use on feeding sheep has increased in Mexico; nevertheless, its effect on finishing hair lambs productive performance is unknown.

The objective was to evaluate the effect of three waste pinto bean grain levels (concentrate dry matter) on productive performance of finishing hair lambs.

Materials and Methods

This study was conducted in the Facultad de Zootecnia y Ecología of the Universidad Autónoma de Chihuahua. Seventy two crossbred hair lambs (Dorper X Pelibuey and Kathadyn X Pelibuey) were used (36 females and 36 males) all lambs being twins with 18.69 ± 3.89 Kg initial body weight and 75 ± 6 d old. At the start of the experiment a Brucella diagnosis test was done, all the animals were identified received ADE vitamins, 3 way clostridial vaccine and topical parasiticide, and received an adaptation period of 18d. The lambs were fed *ad libitum* with isoenergetic and isoproteic diets (Table 1) with 5 -10% adjusted refusals and had *ad libitum* clean and fresh drinking water. Animals were assigned to blocks by initial body weight (three animals per block; four female blocks and four male blocks per treatment) and randomly assigned to the treatments (n=24 per treatment). Treatments were: Control (**C** = 0%), Low Waste Pinto Bean Grain (**LWB** = 12.5% of concentrate DM) and High Waste Pinto Bean Grain (**HWB** = 25% of concentrate DM). Two animals from LWB and one from C were retired from the test because they presented respiratory disease during the first period of test, so their ADG and DMI was reduced and altered. The lambs were weighed every 14 d to obtain ADG. The DMI for each block was evaluated in the last five days of each period and GE was calculated. Data for ADG, DMI and GE was analyzed by PROC MIXED (SAS Inst., Inc. Cary, NC) in a complete random block arrangement, considering the pen as experimental unit; treatment, gender and their interaction effects were evaluated; by the way a tendency analysis was done for each treatment.

Results and Discussion

Gender and its interaction treatment*gender effect were not found (P>0.05) for any variable.

For DMI (Kg) a cuadratic effect was found (P<0.05) this result was because the rain presence on periods two and three reduced DMI in all treatments, there were no differences (P=0.0657) among them; numerically, the best DMI was for C= 1.22, followed by both waste pinto bean grain treatments LWB= 1.14 and HWB= 1.05 (Figure 1). DMI was higher for C in all periods and lowest was for HWB, it is assumed that this tendency was because the lower digestibility of HWB. Haddad and Obeidat (2007) had similar results (1.36 Kg DMI) with 80% concentrate diets, compared with C in this experiment,

Results for ADG (Kg) showed a cuadratic response for each treatment (P<0.05) (C=0.26, LWB=0.23 and HWB=0.21) during the test. Haddad and Obeidat (2007) reported an ADG of .235 Kg with a similar diet, that is lower than C but equal to LWB. The lsmeans for final body weight (Kg) were (P< 0.05): C= 37.67, LWB= 34.22 and HWB= 33.27 (Figure 2), and showed a better performance for C. Singh *et al.* (2006) supplemented with cowpea grain at 23 and 47% of the concentrate and they found a better ADG for the group receiving more grain legume (46 and 58.1 gr., respectively), nonetheless, these values are lower compared to the results obtained with waste pinto bean grain in this study. They concluded that including cowpea grain in the concentrate had a positive associative effect on roughage intake, rumen environment and growth performance of lambs; their results are different to the findings in this experiment where the best ADG was for C.

In the case of GE (Kg) a clear general tendency was not found (Figure 3), with no differences among treatments (P=0.6001) during the test (C= 6.53, LWB= 6.94 and HWB= 6.94), the best treatment was C. These results showed that the use of waste pinto bean grain have a detrimental effect on animal performance, Díaz-Batalla *et al.,* (2006) said that like other legume seeds the common bean seed (*Phaseolus vulgaris L*) contains a number of bioactive substances that have been considered as antinutritional factors due to their effect on diet quality, that play metabolic roles in humans or animals that frequently consume these foods. Even though the cost per Kg. of feed is cheaper for HWB, the use of waste pinto bean grain is not a good alternative for finishing hair lambs.

Conclusions

The best productive performance of treatments in this research was found for C, so that the waste pinto bean grain use on finishing hair lambs is not a recommendable alternative for this productive stage. Nevertheless, the use of this product at 25% of the concentrate (DM basis) can help reduce feeding costs in the farm. Further research is necessary in order to understand the effect of waste pinto bean grain on ruminal factors that affect performance in finishing lambs.

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Table 1. Ingredients and chemical composition of the diets.

Igredients	Treatments		
	C	LWB	HWB
Alfalfa %	20.3	20.1	20.1
Sorghum %	47.5	47.3	42.2
Waste pinto bean grain %	0.00	10.0	20.0
Cotton seed meal %	18.9	11.8	11.5
Corn distiller grain %	10.1	7.7	3.1
Animal fat%	2.0	1.9	1.9
Minerals %	0.5	0.5	0.5
Sodium chloride %	0.5	0.5	0.5
Calcium carbonate	0.2	0.2	0.2
Chemical composition			
Nutrient	C	LWB	HWB
CP %	17.9	17.9	17.9
ME Mcal/Kg	2.6	2.6	2.6
NDF %	14.9	13.8	11.8
Lignin %	2.5	2.4	2.2
CA %	0.6	0.5	0.5
P %	0.5	0.4	0.4

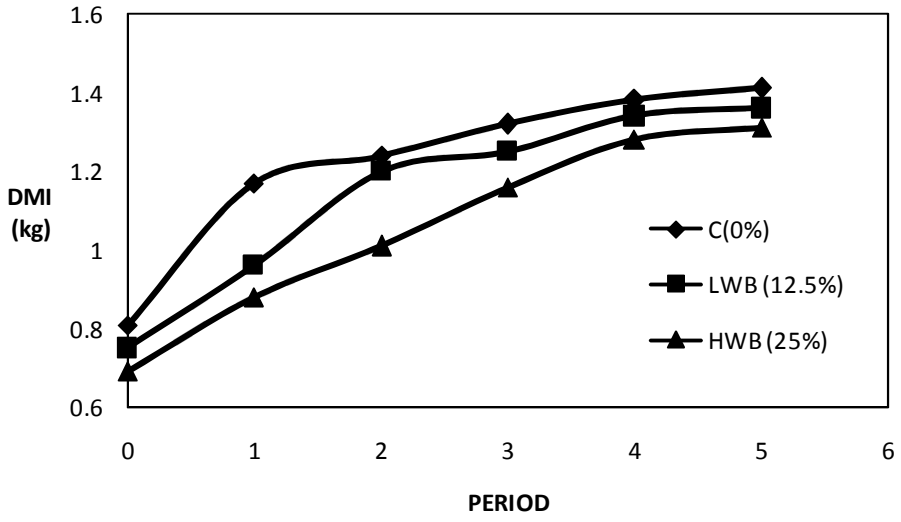

Figure 1. DMI per treatment and period for finishing hair lambs receiving different levels of waste pinto bean grain (% concentrate DM).

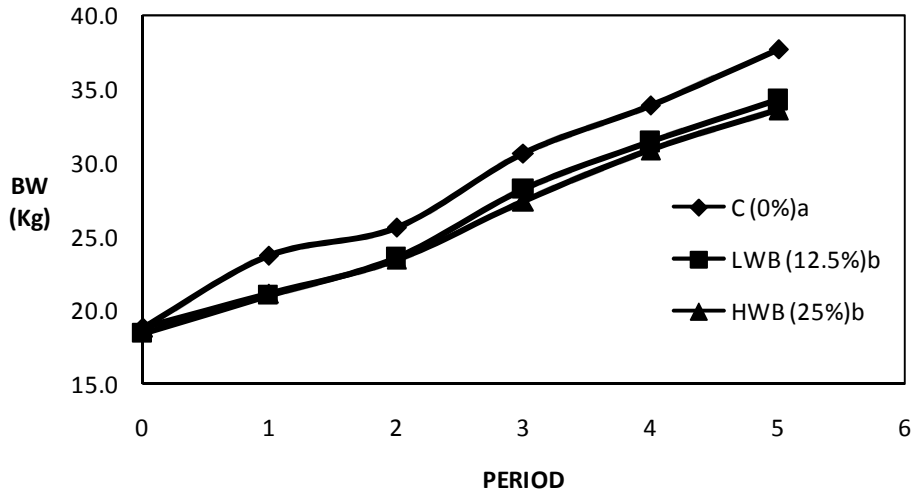

Figure 2. Change of BW per treatment and period for finishing hair lambs receiving different levels of waste pinto bean grain. Means whitin different literals differ (P<0.05).

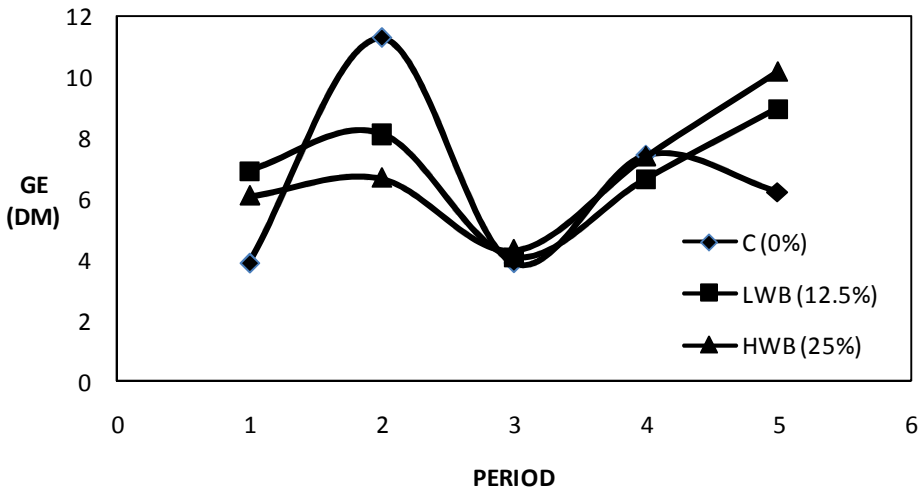

Figure 3. GE per treatment and period for finishing hair lambs receiving different levels of waste pinto bean grain (% concentrate DM).

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Use of zeranol and reimplantation on performance of finishing hair lambs.

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ABSTRACT: Use of zeranol has improved daily gain and gain efficiency of lambs, leading to a higher profitability in sheep industry. This study evaluated the effect of using different zeranol levels and its reimplantation on dry matter intake, body weight, average daily gain and gain efficiency of finishing hair lambs. Thirty two weaned intact male lambs (21.2 ± 1.58 kg and 60 d old) crosses of Dorper X Pelibuey and Kathadin X Pelibuey were blocked by initial body weight and randomly assigned to four treatments (n=10, 5 pens and 2 lambs per pen): Z0 (control); Z12 (12 mg of zeranol, Ralgro), Z24 (24 mg of zeranol in a single application), and Z12-12 (12 mg of zeranol given twice). Lambs were implanted 12 d before starting the experiment, and animals of Z12-12 were reimplanted 28 d after starting the study. Lambs were fed ad libitum a 80:20 concentrate:forage diet (% DM) containing 2.7 Mcal ME/kg DM and 18.2 % CP. Dry matter intake (DMI) was determined daily, while body weight, average daily gain (ADG) and gain efficiency (GE) were recorded every 14 d during the 56 d trial. Data were analyzed as a complete random design with repeated mesarurements on time, using the PROC MIXED. Implanted animals had similar DMI vs. non implanted (1.42 vs. 1.47 kg). Final body weight of implanted animals was not improved vs. non implanted (40.0 vs. 36.9 kg), and was similar among implanted treatments. The ADG of implanted lambs was 12.4% higher vs. non implanted (0.326 vs. 0.290 kg/d; P<0.05), and it was 6.2% enhanced in lambs of Z24 compared to lambs of Z12 (0.340 vs. 0.320 kg/d; P<0.05), and was similar between Z24 and Z12-12 treatments. Implanted lambs had 17% higher GE (4.4 vs. 5.3; P<0.05), and it was 8.7% superior in Z24 vs. Z12 (4.2 vs. 4.6), and was similar between Z24 and Z12-12 treatments. Implanting finishing lambs with 24 mg of zeranol in a single dosis showed the best animal performance.

Keywords: Implants,Finishing,lambs,Zeranol

Introduction

The huge demands of lamb in the central region of Mexico and the high price per kilogram of finished lamb are the main reasons that maintain the sheep industry as a profitable activity. The profitability of this activity increases as production costs decline,as well as animal perform better. Zeranol is an anabolic agent that has improved animal performance in ruminants (Schneider, et al., 2007; Lupton, 2008). In the last 37 years results of research trials has reported increments about 14% and 11% for ADG and feed efficiency, respectively, in lambs implanted with Zeranol on different feeding systems, ages and sexual conditions (Nsahlai, et al., 2002; Sluite, et al., 2007; Salisbury, et al., 2007).However, data from the effect of zeranol level and reimplantation on lamb performance fed high concentrate diets is scarce.

Materials and Methods

This study was conducted at the ruminant metabolic facilities of Facultad de Zootecnia y Ecologia of Universidad Autónoma de Chihuahua, Chihuahua, Mexico. Thirty two weaned intact hair lambs (21.3 ± 1.53 kg initial BW and 60 d old) were randomly assigned to one of four treatments (n=10 lambs, 5 pens and 2 lambs per pen) arranged as a randomized complete block design. Treatments were: **Z0** (control); **Z12** (12 mg of zeranol, Ralgro®, Intervet Schering-Plough Animal Health); **Z24** (24 mg of zeranol in a single application), and **Z12-12** (12 mg of zeranol given twice). Lambs were implanted 12 d before starting the experiment, and animals of Z12-12 were reimplanted 28 d after starting the experiment. Twelve days before the experiment started lambs received an application of A, D, E vitamins, three way clostridium vaccine, and were dewormed, against internal and external parasites. Then animals were placed in 2x2m individual pens. During the 15 d of adaptation period, lambs were slowly adapted to a 20:80 forage:concentrate diet (Table 1).

Table 1 . Ingredients and chemical composition of the diet.

Ingredients	
Alfalfa %	20.3
Sorghum %	47.5
Cotton seed meal %	18.9
Corn distiller grain %	10.1
Animal fat%	2.0
Minerals %	0.5
Sodium chloride %	0.5
Calcium carbonate	0.2
	Chemical composition
Nutrient	
CP %	17.9
ME Mcal/kg	2.6
NDF %	14.9
Lignin %	2.5
Ca %	0.6
P %	0.5

Lambs were fed ad libitum during the whole experiment of 56 d. Animals were weighed every 14 days with a 12 h fasting. Data were analyzed as a complete

random design with repeated measurements on time, using PROC MIXED of SAS. The model included treatment effect, weight date, and their interaction as fixed effects and animal as random effect.

Results and Discussion

Implanted animals had similar DMI (Table 2) vs. non implanted (1.42 vs. 1.47 kg; P>0.05). Feed intake across the feeding period (Table 3) was not affected by treatments. Literature related with the effect of zeranol use in lambs on feed intake is scarce. In contrast to the results of this experiment, feed intake has been increased by 4.0% (P<0.05) in implanted vs. non implanted lambs fed a high concentrate diet (1.55 vs. 1.49 kg; Villalobos et al., 2009), and by 8.2 % (P<0.05) when fed implanted lambs with a high forage diet (2.38 vs. 2.20 kg; Olivares and Hallford, 1990).

Final body weight (Table 2) of implanted lambs was not improved vs. non implanted lambs (40.0 vs. 36.9 kg). This is in agreement with most of literature results (Nold et al., 1992; Field et al., 1993; Villalobos et al., 2009). However, Olivares and Hallford (1990) reported a higher (4.7%; P<0.05) body weight in lambs implanted with 12 mg of zeranol vs. non implanted.

The ADG (Table 2) of implanted lambs was 12.4% higher vs. non implanted (0.326 vs. 0.290 kg/d; P<0.05), 6.2% enhanced in lambs of Z24 vs. lambs of Z12 (0.340 vs. 0.320 kg/d; P<0.05), and was similar (P>0.05) between Z24 and Z12-12 treatments. Across the experiment (Table 4), the ADG was not affected by treatments (P>0.05) from the 1 to 14 and 29 to 42 d of feeding period, and averaged 0.340 and 0.336 kg, respectively. However, ADG of Z24 lambs was 24.0 and 35.6 % superior than Z0 lambs from 15 to 28 d, and from 43 to 56 d of trial, and it was 28.4% higher than Z12 lambs from 43 to 56 d of experiment. The positive effect of zeranol on ADG in lambs is well established, and has been partially attributed to the better nitrogen balance, since zeranol allows for a higher nitrogen retention (Hufstedler and Greene, 1995). Villalobos et al. (2009) and Hufstedler et al. (1996), reported an improvement of 8.0 and 12.4% (P<0.05) on ADG in implanted lambs with 12 mg of zeranol vs. non implanted (0.320 vs. 0.296, and 0.217 vs. 0.193 kg, respectively). Lambs reimplanted (12 mg of zeranol twice), showed an outstanding increase of 24% on ADG than non implanted (0.319 vs. 0.250 kg; Field et al., 1993). Few experiments (Nold et al., 1992; Field et al., 1993) showed no improvements on ADG of implanted lambs.

Implanted lambs had 17% higher GE (4.4 vs. 5.3; P<0.05), and it was 8.7% superior in Z24 vs. Z12 (4.2 vs. 4.6), and was similar between Z24 and Z12-12 treatments. Table 5, presents the gain efficiency during the feeding period. GE was not affected by treatments from 1 to 14 and 29 to 43 d of experiment, and averaged 3.47 and 4.55, respectively. GE of Z24 lambs was 28.3 and 24.2 % better than Z0 lambs from 15 to 28 and from 43 to 56 d of trial. Gain efficiency of implanted lambs is improved in most trials, since zeranol commonly increased ADG, with low or null effect on DMI. Nold et al. (1992), Hufstedler et al. (1996), Field et al. (1993) reported that GE of zeranol implanted lambs was 4.7, 8.3, and 17.0% superior than non implanted lambs. However, Villalobos et al. (2009) found similar GE between implanted and non implanted lambs fed a high concentrate diet (4.84 vs. 4.97).

Implications

Implanting finishing lambs with 24 mg of zeranol in a single dosis showed the best animal performance. Therefore, further research is warranted to evaluate its impact on carcass characteristics.

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Table 2. Effects of zeranol and reimplantation on performance of finishing hair lambs.

	TREATMENT			
Item	Z0	Z12	Z24	Z12-12
Initial BW (kg)	20.8	20.9	21.8	21.5
Final BW (kg)	36.9	39.7	40.7	39.6
DMI (kg)	1.47[a]	1.46[a]	1.44[a]	1.38[a]
ADG (kg)	0.29[c]	0.32[b]	0.34[a]	0.32[ab]
GE	5.3[c]	4.6[b]	4.2[a]	4.3[ab]

[abc] Means within a row with different superscripts are different ($P < 0.05$).
Z0: Control; Z12: 12 mg of Zeranol; Z24: 24 mg of Zeranol in a single dosis; Z12-12: 12 mg of Zeranol given twice.

Table 3. Effects of zeranol and reimplantation on dry matter intake (kg) of finishing hair lambs across the feeding period.

	TREATMENT				
days	Z0	Z12	Z24	Z12-12	EE
14	1.24[a]	1.12[a]	1.18[a]	1.12[a]	0.07
28	1.55[a]	1.57[a]	1.39[a]	1.42[a]	0.07
42	1.54 [a]	1.56[a]	1.58[a]	1.42[a]	0.07
56	1.53[a]	1.46[a]	1.59[a]	1.56[a]	0.07

[abc] Means within a row with different superscripts are different ($P < 0.05$).
Z0: Control; Z12: 12 mg of Zeranol; Z24: 24 mg of Zeranol in a single dosis; Z12-12: 12 mg of Zeranol given twice.

Table 4. Effect of zeranol and reimplantation on average daily gain (kg) of finishing hair lambs across the feeding period.

	TREATMENT				
days	Z0	Z12	Z24	Z12-12	EE
14	0.326[a]	0.353[a]	0.339[a]	0.344[a]	0.01
28	0.259[b]	0.304[ab]	0.321[a]	0.286[ab]	0.01
42	0.308[a]	0.353[a]	0.353[a]	0.330[a]	0.01
56	0.250[b]	0.264[b]	0.339[a]	0.335[a]	0.01

[abc] Means within a row with different superscripts are different ($P < 0.05$).
Z0: Control; Z12: 12 mg of Zeranol; Z24: 24 mg of Zeranol in a single dosis; Z12-12: 12 mg of Zeranol given twice.

Table 5. Effect of zeranol and reimplantation on gain efficiency of finishing hair lambs across the feeding period.

	TREATMENT				
Item	Z0	Z12	Z24	Z12-12	EE
14	3.9[a]	3.2$_a$	3.5[a]	3.3[a]	0.25
28	6.0[a]	5.2[ab]	4.3[b]	5.0[ab]	0.25
42	5.0[a]	4.4[a]	4.5[a]	4.3[a]	0.25
56	6.2[a]	5.6[b]	4.7[b]	4.7[b]	0.25

[abc] Means within a row with different superscripts are different ($P < 0.05$).
Z0: Control; Z12: 12 mg of Zeranol; Z24: 24 mg of Zeranol in a single dosis; Z12-12: 12 mg of Zeranol given twice.

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Fiber digestibility of a finishing lamb diet supplemented with Fibrozyme

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ABSTRACT. Fibrolytic enzymes can enhance rumen microbial enzyme activity under low ruminal pH conditions improving fiber digestion. This study evaluated the effect of Fibrozyme addition on fiber digestion of a finishing lamb diet. Six crossbreed lambs (Charolais X Pelibuey; 30 ± 6.1 kg) fitted with ruminal cannula were individually housed and randomly assigned to three levels of Fibrozyme ® (Alltech Inc.): 0.0 (T-0.0), 0.1 (T-0.1) y 0.2 g/kg of body weight (T-0.2) added to concentrate. The experimental design was a replicated 3X3 latin square. Lambs were fed *ad libitum* with a diet containing 2.9 Mcal ME/kg DM and 15.9% CP, based on 20% alfalfa hay and 80% concentrate (% DM). Each experimental period last 17 d, with an adaptation phase of 7 d. Dry matter intake (DMI) was determined daily and individually from 8th to 12th d. Ruminal pH was determined on 13th d at 0, 1, 2, 4, 8, 12, 18 and 24 h after morning feeding. Fecal samples were taken on 15th to 17th d, to determine fiber digestibility using indigestible ADF. Content of NDF and ADF were sequentially determined in period composite samples of forage, concentrate, and fecal grabs. Dry matter intake and digestibility data were analyzed with PROC GLM, while ruminal pH data were analyzed as repeated measurements on time using PROC MIXED. DMI was similar among treatments (1.44, 1.48 and 1.48 kg, respectively; P>0.05). Rumen pH for all treatments was lower than 6.0 during 14 h (from 4th to 18th h after feeding). Dry matter digestibility was not affected by treatments (76.6, 75.1, and 77.6%, respectively; P>0.05). However, NDF and ADF digestibility was higher for T-0.2 vs. T-0.0 and T-0.1 (15.0 vs. 12.7 and 8.9%; and 17.3 vs. 11.2 and 13.3%, respectively; P<0.05). Hemicellulose digestibility was similar among treatments (14.4, 8.8 and 14.7%, respectively; P>0.05). Adding Fibrozyme at 0.2 g/kg of body weight to finishing lambs diet improved fiber digestibility.

KEYWORDS: fibrozyme, fiber digestibility, hair lambs

Introduction

Finishing diets for lambs include high levels of concentrate to achieve an outstanding animal growth. This conditions decrease ruminal pH, affecting fiber digestibility and structural carbohydrate–fermenting microbes (Hoover, 1986), possibly due to anion toxicity (Russell and Wilson, 1996). Enzymes have been utilized to increase nutrient digestibility of diets (Bedford y Schulze, 1998). Improvement in DM and ADF digestibility has been reported by Beauchemin *et al*. (2000; 1995), respectively. However, Avellaneda *et al.* (2009) and Pinos-Rodríguez *et al.* (2008) did not find a benefit on DM and NDF digestibility, when used fibrolytic enzymes in animals fed 100:00 and 40:60 diets, respectively. Improving nutrient digestibility could enhance energy availability, leading potentially to a higher animal performance (Beauchemin *et al.,* 1999; Titi, 2003). So, research conducted with fibrolytic enzymes in high concentrate diets is limited, and dose levels of these additives are not well defined.

The objective was to evaluate the effect of three levels of Fibrozyme® added to a finishing lamb diet on DMI and fiber digestibility.

Materials and Methods

This study was conducted in the facilities of Facultad de Zootecnia y Ecología of Universidad Autónoma de Chihuahua, México. Six crossbred male lambs (Charolais X Pelibuey; 30 ± 6.1 kg body weight) fitted with ruminal cannula were individually housed and randomly assigned to three levels of Fibrozyme® (Alltech Inc., Nicholasville, KY), added to concentrate: 0.0 (T-0.0), 0.1 (T-0.1) and 0.2 gr/kg body weight (T-0.2). The experimental design was a replicated 3X3 latin square, where each experimental period last 17 d, using the first 7 d for adaptation. Prior to the experiment lambs were treated for internal and external parasites and vitamins A, D and E were applied, allowing for 15 d of adaptation period to reach 20:80 forage:concentrate diet. Animals were fed *ad libitum* once daily at 08:00 (Table 1) allowing for 10% of feed refusal.

The amounts of feed offered and refused were weighed daily for each lamb and were utilized to determine DMI from 8th to 12th d of each period.

Ruminal fluid was obtained at 0, 1, 2, 4, 8, 12, 18 and 24 h after feeding on d 13th of each period, with the help of a vacuum pump and pH was immediately determined on strained samples using a portable pH meter (Combo, HANNA instruments® Inc.,Woonsocket, RI).

Daily samples of the forage and concentrate were taken to obtain period composites. Samples were dried in a 60°C forced air oven during 48 h to determine DM content (AOAC, 1990), and then ground with a Wiley mill (1 mm screen; Arthur H. Thomas Philadelphia, PA). The absolute DM content was determined on the ground samples by drying them in a 105°C forced air oven during 8 h for purposes of expressing nutrient digestibility on a DM basis.

Samples were analyzed for NDF and ADF content (Van Soest *et al.,* 1991), determined sequentially in the ANKOM^{200} Fiber Analyzer (Ankom Technology, Fairport, NY), using the Ankom® F57 filter bags with a porosity of 30 microns. Analysis of NDF was done using both sodium sulfite (Na_2SO_3) and α-amylase to remove nitrogenous matter and starch, respectively.

A total of 12 fecal samples (4 per d) by period were taken directly from the rectum of the animal on d 15th to 17th

to determine nutrient digestibility. Fecal composites were dried, ground and analyzed for NDF and ADF content as described above.

Digestibility was determined using indigestible ADF (IADF) as an internal marker (Penning and Johnson, 1983). Quadruplicated period composites samples of forage, concentrate and feces were weighed (0.35 ± 0.05 g) into Ankom® F57 filter bags. Blanks were also run in quadruplicated. One bag of every quadruplicate was placed on every jar of DAISY^{II} incubator (Ankom Technology, Macedon, NY) and was run according to assay procedure of *In vitro* true digestibility. After incubation, bags were removed and hand washed with top water until the rinse water was clear. Finally, ADF content of the bag residue was determined, and digestibility was calculated by the formula:

$$\text{DM digestibility (\%)} = 100 - \left(100 \times \frac{\text{\% FDAI in feed}}{\text{\% FDAI in feces}}\right)$$

$$\text{Nutrient digestibility (\%)} = 100 - \left(100 \times \frac{\text{\% FDAI in feed} \times \text{\% nutrient in feces}}{\text{\% FDAI in feces} \quad \text{\% nutrient in feed}}\right)$$

Dry matter intake and digestibility data were analyzed using the PROC GLM, while ruminal pH data were analyzed as repeated measurements on time using PROC MIXED of SAS (SAS, 2005).

Table 1. Experimental diet composition.

Item	DM (%)
Ingredients	
Alfalfa hay	20.0
Corn ground	58.5
Cottonseed meal	14.7
Molasses	3.6
Corn gluten	2.0
Mineral and vitamin premix	0.5
Calcium carbonate	0.3
Salt	0.4
Chemical composition	
DM	88.4
CP	16.0
NDF	6.2
ADF	2.1
ME (Mcal/kg DM)	2.9

Results and Discussion

Dry matter intake was similar among treatments (P>0.05; Table 2). The overall DMI during the whole experiment was 1.47 ± 0.07 kg/a/d. Pinos-Rodríguez *et al.* (2008) also reported no difference in DMI for lambs fed a 60:40, 50:50 and 40:60 forage:concentrate diets supplemented with Fibrozyme®. In contrast, Pinos-Rodríguez *et al.* (2002) reported an increase on DMI in forages treated with 5.0 and 0.0 g of Fibrozyme®/ a/d (1.486 vs. 1.349 kg, respectively).

The average rumen pH through the whole day for all treatments was 5.9 ± 0.005. However, rumen pH was lower than 6.0 during 14 h from 4th to 18th h sampling (5.8, 5.5, 5.3 and 5.6, respectively; Figure 1). Chemical constraints that may be responsible for the decrease in fiber digestion include like a major factor the rumen pH, so moderate depression in pH, to approximately 6.0, results in a small decrease in fiber digestion, and further decreases to 5.5 or 5.0 result in decreased structural carbohydrate–fermenting microbes and fiber digestion may be completely inhibited (Hoover, 1986).

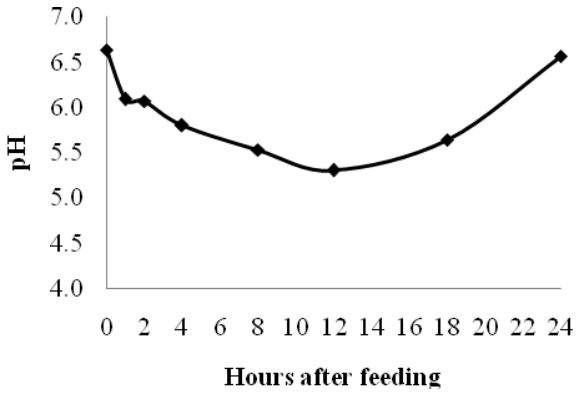

Figure 1. Performance of ruminal pH after feeding (h 0).

Dry matter digestibility was not affected (P> 0.05) by the inclusion of fibrolytic enzyme (Table 2). The overall DM digestibility was 76.4 ± 0.8 %. Pinos-Rodríguez *et al.* (2008) and Avellaneda *et al.* (2009) reported no differences on DM digestibility (70.2 vs. 69 % and 60.4 vs. 60.4 %, respectively) in lambs fed a diet added with Fibrozyme®. Use of fibrolytic enzymes (Pinos-Rodríguez *et al.,* 2002) in lambs fed a forage based diet (alfalfa or ryegrass) did not improve DM digestibility (59.4 vs. 60.3 %, respectively).

However, Beauchemin *et al.,* (2000) using Natugrain 33-L (1.22 and 0.0 lt/ DM ton of TMR) reported a higher DM digestibility (67.3 vs. 64.7 and 64.7, respectively).

Tous (2007) reported an improvement on DM digestibility by adding Biocellulace^{A-20} (56.0 %), and Promote^{NET} (54.3 %) compared to control (50.1 %).

Digestibility of NDF and ADF were increased (P< 0.05) by T-0.2 compared to T.0.0 and T-0.1 (15 ± 0.9 vs. 12.7 ± 0.7 and 8.9 ± 0.9; and 17.3 ± 1.9 vs. 11.2 ± 1.5 and 13.3 ± 1.9, respectively; Table 2). However, hemicellulose digestibility was not affected by treatments T-0.0, T-0.1 and T-0.2 (14.4 ± 1.4, 8.8 ± 2.8 and 14.7 ± 1.8, respectively).

Tous (2007) reported higher NDF and ADF digestibility (54.1 vs. 47.9, and 53.6 vs. 48.1 %, respectively) by feeding Biocellulace^{A-20}.

These results are in contrast with Pinos-Rodríguez *et al.* (2008) which did not found effect of adding fibrolytic enzyme to diets with different forage:concentrate ratios (60:40, 50:50 and 40:60) on NDF digestibility (overall mean of 43.2 %). Neither Avellaneda *et al.* (2009) nor Pinos-Rodríguez *et al.* (2002) found differences in a forage based diet (100%) on NDF digestibility (72.4 vs. 72.5 %, and 66.5 vs. 63.9 %, respectively) and ADF digestibility (66.6 vs. 66.9 %, and 58.7 vs. 57.9 %, respectively) by adding 0.0 and 5 g/a/d of Fibrozyme® , respectively.

The depression in fiber digestibility at higher inclusion rates of concentrate can most likely be explained by the rapid degradation of non-structural carbohydrate (Varga and

Kolver, 1997). This can reduce the rumen pH as the forage:concentrate ratio decreases (Pinos-Rodríguez *et al.,* 2008). The low forage:concentrate (20:80) ratio utilized in this study could affect digestibility of fiber since it was found a low NDF and ADF digestibility (mean = 12.2 and 13.9 %, respectively). Digestibility was of 8.1 % when the pH was 5.8 using a 35:65 forage:concentrate rate (Shriver *et al.,* 1985).

Implications

Adding Fibrozyme® (0.2g/kg body weight) to high concentrate finishing lamb diet improved NDF and ADF digestibility. In spite of increasing fiber digestibility, total DM digestibility was not affected because the low fiber concentration on the diet.

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Table 2. Effect of Fibrozyme® on DMI, and DM, NDF, ADF and Hemicellulose digestibility.

	TREATMENT		
	T-0.0	T-0.1	T-0.2
DMI kg/a/d (± EE)	1.44 ± 0.07	1.48 ± 0.07	1.49 ± 0.07
Aparent digestibility % (± EE)			
DM	76.6 ± 0.8	75.1 ± 0.8	77.6 ± 0.8
NDF	12.7 ± 0.7[a]	8.9 ± 0.9[a]	15 ± 0.9[b]
ADF	11.2 ± 1.5[a]	13.3 ± 1.9[a]	17.3 ± 1.9[b]
Hemicellulose	14.4 ± 1.4	8.8 ± 2.8	14.7 ± 1.8

T-0.0= Control; T-0.1= 0.1 g and T-0.2= 0.2 g of Fibrozyme®/kg body weight
Means in rows with different superscripts are different (P< 0.05).

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EFFECT OF VARIETY AND MATURITY STAGE OF OAT HAY ON PERFORMANCE OF EWE LAMBS

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ABSTRACT: Oat hay is an important forage source in the sheep industry of Chihuahua, México. This study evaluated the effect of genotype and maturity stage on nutritional value of oat hay and their effect on performance of ewe lambs. Karma (K), Cevamex (C) and Bachiniva (B) oat varieties were cultivated under non irrigated conditions and harvested at soft-dough (SDS) and hard grain stage (HGS). Ninety hair ewe lambs of commercial crosses with an initial average weight of 30.2 ± 2.5 kg were randomly assigned to six treatments (n=15, 5 pens and 3 lambs per pen) in a 3X2 factorial design. Animals were fed *ad libitum* a 80:20 forage:concentrate diet (% DM) containing 2.4 Mcal ME/kg DM and 16.0% CP. Production of DM per hectare (DM/ha), and content of CP, NDF, ADF, and ADL were determined for oat varieties. Dry matter intake (DMI) was determined daily per pen, while body weight, average daily gain (ADG) and gain efficiency (GE) were recorded individually every 14 d, and apparent digestibility of DM, CP and NDF at the final of the study. Data was analyzed as a complete random blocking design in a factorial arrangement, using PROC MIXED. There was no effect of oat variety on DM/ha, but it was higher for HGS (5,211 vs. 4,293 kg/ha; $P < 0.05$). Genotype and maturity stage did not affect chemical composition. Content of CP, NDF, ADF and ADL for SDS and HGS were: 11.5 and 10.2; 51.8 and 51.1; 28.4 and 27.7; and 2.75 and 2.90%, respectively. DMI, final body weight, ADG and GE were not affected by treatments, average for SDS and HGS were: 1.29 and 1.22; 36.4 and 35.5; 0.116 and 0.110 kg; and 14.2 and 14.3, respectively. Dry matter and NDF digestibility was higher ($P < 0.05$) for C-SDS (67.6 and 59.5%), while CP digestibility was similar among treatments. Harvesting and feeding oat hay at SDS showed small benefit on nutritive value of forage, but did not improve animal performance.

Keywords: oat variety, maturity stage, ewe lambs.

Introduction

In the state of Chihuahua, Mexico, 200,000 ha of oat (*Avena sativa* L.) fodder are grown annually under rainfed conditions, making hay at physiological maturity stage. Oat hay is the main source of forage for livestock industry, accounting for 33% of the source of fodder used for feeding sheep (Esqueda et al., 2008).

Production and nutritional quality of oat hay is highly variable, attributed to the effect of genotype and rainfall (Salmeron et al., 2003), and stage of maturity (Collar et al., 2004; Dominguez et al., 2008a).

However, rainfall limitations and high temperatures can accelerate maturity of forages leading to similar yield and quality of oat genotypes harvested at soft-dough and hard grain stage (Dominguez et al., 2008a), as a result, animal response could not be improved by feeding oat hay harvested early.

The objective was to determine the effect of genotype and stage of maturity on nutritional value of oat hay and their effect on performance of ewe lambs.

Materials and Methods

Establishment and Forage Harvest. In August of 2007, in the facilities of INIFAP at Research Center of Sierra de Chihuahua, Mexico, oat varieties Karma (K), Cevamex (C) and Bachiniva (B) were cultivated under rainfed conditions and harvested at soft-dough (SDS) and hard grain stage (HGS) at 74 ± 2 and 81 ± 3 d after sowing, respectively. At harvest time oat forage samples were obtained to estimate dry matter production (DM/ha), by drying them at 55℃ during 48 h. Oat forage harvested was baled and then ground at 2.5 cm of theoretical length of cut.

Animals, Facilities, and Diets. In July 2008, in the Sheep Production Unit of University of Chihuahua, ninety crossbred ewe lambs of commercial (30.2 ± 2.5 kg initial BW) were blocked by weight and randomly placed in groups of three per pen. Lambs had free access to fresh water and were fed *ad libitum* once daily at 0730 h an oat hay based diet (Table 1).

Treatments Arrangement. The experiment was a complete random block design in a factorial arrangement, and lasted 59 d, allowing the initial 10 d as adaptation to diets, and the last 3 d for fecal collection. Animals were randomly assigned to six treatments (n=15, 5 pens and 3 lambs/pen/treatment) in a 3 x 2 factorial design. Lambs were individually weighted every 14 d, and DMI was determined daily by pen.

Sample Collection. Forages and concentrate samples were taken weekly and stored in plastic bags. Fecal samples were taken four times daily during three consecutive days from 30 lambs (5 lambs per treatment), stored in plastic

Table 1. Composition of experimental diets.

	SDS			HGS			Average	
Item	K	C	B	K	C	B	SDS	HGS
Ingredient	---------- % of DM ----------							
Oat hay	79.7	79.7	79.7	79.8	79.8	79.8	79.7	79.8
Cottonseed meal	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7
Corn gluten meal	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Molasses	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Soybean oil	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Calcium	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Premix	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Salt	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Nutrient	---------- Chemical Composition (%) ----------							
DM	91.9	91.9	92.0	92.1	92.0	92.2	91.9	92.1
CP	19.2	19.5	18.9	18.2	18.8	17.0	19.2	18.0
EE	4.31	4.31	4.31	4.32	4.31	4.32	4.3	4.3
NDF	52.0	53.7	54.9	52.2	55.2	51.5	53.6	53.0
ADF	29.4	29.6	30.7	29.1	30.2	28.7	29.9	29.3
ADL	3.87	3.62	4.12	3.93	4.05	4.06	3.9	4.0
ME, Mcal/kg DM	2.34	2.34	2.34	2.35	2.35	2.35	2.3	2.3
Ca	0.39	0.39	0.39	0.39	0.39	0.39	0.4	0.4
P	0.41	0.41	0.41	0.41	0.41	0.41	0.40	0.40
Ash	8.65	8.91	8.33	8.37	8.40	7.84	8.6	8.2

K= Karma, C= Cevamex, and B= Bachíniva oat genotypes
SDS= soft-dough stage and HGS= hard grain stage

bags and frozen at -4ºC for subsequent analysis.

Sample Analysis. Forages, diets, and fecal samples were dried at 55ºC in a forced air oven, and ground to pass a 1-mm screen. Samples were analyzed for absolute DM (105ºC for 24 h), OM (600ºC for 4 h) and CP (AOAC, 1995) and NDF, ADF (Goering and Van Soest, 1970) and ADL (Van Soest et al., 1991) sequentially using the ANKOM^{200} fiber analyzer. Dry matter digestibility of oat forages was estimated using the equation of Moore and Undersander (2002).

Test of Digestibility. Apparent digestibility of DM, CP and NDF was determined using indigestible ADF (IADF) as an internal marker (Penning and Johnson, 1983). The marker was determined weighing 0.35 ± 0.05 g of fecal, concentrate, and oat forage samples placed in Ankom® bags F57 and incubated in the ventral ruminal sac of two ruminal fistulated heifers during 12 d (Huhtanen et al., 1994). After this period bags were washed first on iced water and then on top water, then ADF analysis was conducted.

Statistics. Data collected from animal performance were analyzed with PROC MIXED of SAS using a complete random block design with a factorial 3 x 2 arrangement, considering as fixed effects animal, oat variety and maturity stage, and random effects block and period. Chemical composition of forages and digestibility were analyzed with the PROC GLM of SAS using a 3 x 2 factorial design.

Results and Discussion

Dry Matter Production. Production of DM/ha was not affected by genotype ($P > 0.05$): 4,036, 4,383, 4,462, and 6,426, 4,320, and 4,887 kg ha^{-1} for K, C and B in SDS and HGS, respectively, and was higher ($P < 0.05$) for HGS than SDS (5,211 vs. 4,292 kg ha^{-1}). Oat yield under non irrigated conditions is variable across years, since it is strongly affected by level and distribution of rainfall. Higher (Domínguez et al. 2009) and lower (Domínguez et al. 2008a) oat yield has been reported (5,960 vs. 5,740 and 4,775 vs. 3,120 kg of DM/ha for HGS and SDS, respectively).

Lack of response in DM yield of oat varieties by stage of maturity, was due to climatic reasons. Forages were harvested early in HGS at 81 d, when cycle normally reaches this maturity stage at 92 d on average (Salmeron et al., 2003). The interval between days of the SDS and HGS is normally 15 d on average, and the oat hay production increases linearly through the maturity stages (Dominguez et al., 2008a). The early harvest, did not allow the material to show its productive potential. Nevertheless, in this trial yield of 5,211 kg of DM is a good yield for this area (Dominguez et al., 2008b)

Chemical Composition of Oat Hays. Nutritive value was not affected by oat varieties ($P > 0.05$), maturity stage ($P > 0.05$) and variety x maturity stage interaction (Table 2). However, a trend was observed in lower CP and cell wall components concentration in HGS. This response is in agreement with the results of Dominguez et al. (2008a and 2008b) and Dominguez et al. (2009) and has been related to the higher grain content and its filling with starch at HGS stage.

The similar content in cell wall constituents between SDS and HGS, was a result to low grain:leaf and stem ratio in oat plants, consequence of the narrow range in days between SDS and HGS for harvest. Nevertheless, it was found that when oat hay is harvested at the proper stage of maturity of SDS or HGS, the content of NDF and ADF was 52.0 and 47.4%, and 28.8 and 26.0%, respectively, as a result of increased content and grain filling with starch in HGS (Dominguez et al., 2008a). Also, is important to note that CP content at HGS in this trial was not largely provided by the grain fraction as in the study of Dominguez et al. (2008a and 2008b), since the grain:foliage ratio observed in this experiment averaged 29.3:70.7% for HGS, much lower than that obtained by Dominguez et al. (2008a) of 51.3:48.7% at the same stage of maturity.

Apparent Digestibility. Table 3 shows data for digestibility of DM, CP, and NDF. C-SDS treatment shows the higher DM (67.6%) and NDF (59.5%) digestibility, but CP digestibility was similar ($P > 0.05$) among treatments. Overall, the higher nutrient digestibility was observed in soft-dough maturity stage. This response has been attributed to the lower fiber and lignin content of foliage fraction of oat plant at this maturity stage (Kamstra et al., 1958).

Ewe Lambs Performance. There was not effect of oat genotype ($P > 0.05$), maturity stage ($P > 0.05$) and their interaction ($P > 0.05$) on final BW, DMI (kg and % BW), and GE of ewe lambs (Table 4). Overall, means for SDS and HGS treatment were 36.4 kg, 1.29, 3.7%, 0.116 kg, 14.2 and 35.5 kg, 1.22, 3.6%, 0.110 kg and 14.3 kg of DM, respectively.

Lack of performance of ewe lambs fed oat hay harvested at SDS, could be related to the similar chemical composition of oat forages. Although, nutrient digestibility was higher in animals fed oat hay genotypes at SDS, this

was not enough to perform better vs. ewe lambs fed HGS treatments.

Implications

Harvesting oat hay at soft-dough stage decreased dry matter yield and did not improve nutritive value, although, nutrient digestibility was enhanced. This benefit did not allow for better animal response.

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Table 2. Chemical composition of oat forages.

	SDS			HGS			SEM[2]	Average	
Item	K	C	B	K	C	B	var*mat	SDS	HGS
Total DM, %	92.1	92.0	92.2	92.3	92.2	92.4	0.2	92.1 ± 0.1	92.3 ± 0.1
	---------- % of DM ----------								
CP	11.5	11.8	11.3	10.4	11.1	9.1	0.3	11.5 ± 0.2	10.2 ± 0.2
NDF	50.2	52.0	53.2	50.2	53.6	49.4	0.6	51.8 ± 0.3	51.1 ± 0.3
ADF	27.9	28.1	29.3	27.5	28.7	27.0	0.3	28.4 ± 0.2	27.7 ± 0.2
ADL	2.74	2.48	3.02	2.81	2.94	2.94	0.1	2.75 ± 0.0	2.90 ± 0.0
Hemicellulose	23.3	24.9	25.0	23.7	25.8	23.4	0.4	24.4 ± 0.2	24.3 ± 0.2
Cellulose	25.5	25.9	26.5	25.0	26.0	24.3	0.3	25.9 ± 0.2	25.1 ± 0.2
DMD[1], %	67.2	67.0	66.1	67.5	66.5	67.9	0.3	66.8 ± 0.1	67.3 ± 0.1
Ash, %	7.9	8.1	7.5	7.6	7.6	7.0	0.2	7.8 ± 0.1	7.4 ± 0.1

K= Karma, C= Cevamex, and B= Bachíniva oat genotypes
SDS= soft-dough stage and HGS= hard grain stage
[2]standar error of the mean. var*mat = variety and maturity stage interaction.

Table 3. Apparent digestibility of treatments.

	SDS			HGS			SEM[Ŧ]	Average	
Item	K	C	B	K	C	B	var*mat	SDS	HGS
DM; %	61.3[b]	67.6[a]	57.9[bc]	56.9[c]	56.5[c]	56.0[c]	0.9	62.3 ± .5[a]	56.5 ± .5[b]
CP; % DM	74.1	73.4	69.8	67.8	66.1	67.6	1.2	72.4 ± .7[a]	67.2 ± .7[b]
NDF, % DM	48.8[b]	59.5[a]	44.6[bc]	40.9[c]	46.5[b]	34.6[d]	1.0	51.0 ± .6[a]	40.7 ± .6[b]

K= Karma, C= Cevamex, and B= Bachíniva oat genotypes
SDS= soft-dough stage and HGS= hard grain stage
[Ŧ]standar error of the mean. var*mat = variety and maturity stage interaction.
Within a row, means without a common superscript differ ($P < 0.05$).

Table 4. Performance of ewe lambs fed oat hay varieties harvested at soft-dough and hard grain stage.

	SDS			HGS			SEM[†]	Average	
Item	K	C	B	K	C	B	var*mat	SDS	HGS
Initial BW, kg	30.2	30.7	30.2	30.5	29.3	30.5		30.3 ± 2.7	30.1 ± 2.5
Final BW, kg	36.4	36.9	35.9	35.5	34.6	36.4	1.3	36.4 ± 1.2	35.5 ± 1.2
ADG, kg	0.117	0.121	0.110	0.101	0.098	0.132	0.01	0.116 ± 0.0	0.110 ± 0.0
DMI, kg	1.30	1.30	1.26	1.23	1.20	1.25	0.1	1.29 ± 0.1	1.22 ± 0.1
DMI, % of BW	3.8	3.7	3.7	3.6	3.6	3.6	0.1	3.7 ± 0.1	3.6 ± 0.1
GE	13.4	12.7	16.5	13.0	17.0	13.0	2.4	14.2 ± 1.4	14.3 ± 1.4

K= Karma, C= Cevamex, and B= Bachíniva oat genotypes
SDS= soft-dough stage and HGS= hard grain stage
[†]standar error of the mean. var*mat = variety and maturity stage interaction.

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INFLUENCE OF SUBSTITUTION OF ALFALFA HAY FOR UNFERMENTED DRIED GRAPE POMACE ON PERFORMANCE AND CARCASS CHARACTERISTICS OF GROWING SHEEP

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ABSTRACT: The comparative feeding value of unfermented dried grape pomace (DGP; 1.09 Mcal/kg of ED, 12 % CP) was evaluated in an 84-d feeding trial involving 16 individually fed ewe lambs (17.2 kg initial wt). In the experimental diets DGP replaced (DM basis) 0, 10, 20 or 30% of full bloom alfalfa hay. Lambs were allowed ad libitum access to feed and water. Feed intake and orts were recorded daily. Initial and final shrunk weights were obtained following a 12-hour withdrawal of feed. The trial was analyzed as a randomized block design experiment. Substitution of DGP for alfalfa hay did not affect (P > .10) ADG, DMI/ADG, hot and cold carcass wts, dressing %, carcass length, and backfat thickness, however DMI was slightly higher with T2 (10 %) and T4 (8 %) than T1, and ribeye muscle area was 11 % greater with T4 than with T1 (P < .05). We conclude that unfermented DGP can replace up to 30 % of full bloom alfalfa hay in diets for lambs without adversely affecting animal growth and carcass characteristics.

Key word s: Dried grape pomace, sheep, carcass characteristic, growth, fibrous feeds

Introduction

Rural winery is an important industry in the northwest of Mexico, and a large proportion of their organic by-products are fresh grape pomace, and grape stalks (Bustamante et al., 2008). Generally these by-products are not industrialized; instead they are collected and eventually used as soil improvers. It seems that a better option for the fresh grape pomace, which contains a fair amount of sugars, would be that once dried (DGP), it could be used as a feedstuff for the animal industry of this region, which is also important. Some studies on the use of DGP as an ingredient for ruminant rations reported poor results in animal performance, these have been associated to the use of the type of DGP that was a by-product of the alcoholic fermentation, and therefore was of a very low energy value (Manterola et al., 1997). The objective this trial was to determine the comparative feeding value of unfermented DGP in substitution of full bloom alfalfa hay for growing ewe lambs.

Experimental procedures

The trial was initiated on May 2008. 16 individually fed crossbred growing ewe lambs (approximately 50 % Dorper, 50 % Pelibuey) with an average initial weight of 17.2 kg, were used in a feeding trial to evaluate the influence of the substitution of DGP for alfalfa hay on performance and carcass characteristics. Ewe lambs were blocked by weight and four treatments randomly assigned to weight groups. Animals were individually allocated in to pens. Pens were of 4 m^2 with roof and walls of 1.5 m height made of wood strips of 10 cm wide, separated 5 cm so the lambs could see each other and avoid loneliness stress. The trial lasted 84 days with 10 initial days for adaptation. Before the start of the experiment all animals were treated for internal parasites (Ivermectin, Vetoquinol, México). They also received injections of vitamins A, D, E (Synt-ADE, Fort Dodge, Animal Health, México), and were identified with ear tags. Four dietary treatments were compared where DGP replaced (DM basis) 0, 10, 20, or 30 % of late bloom alfalfa hay (Table 1). Diets were prepared before the initiation of the trial and stored in bags. Feed intakes and orts were recorded daily. Lambs were allowed ad libitum access to experimental diets (110 % of daily registered intake) and water. Fresh fed was provided twice daily at 0800 and 1400 in a level of 30 and 70 % of the recorded intake respectively. For calculating lamb performance, initial and final full weights were reduced 4 % to account for digestive tract fill, following a 12 h withdrawal of feed. Pens were used as experimental units. Hot carcass weights were obtained from all lambs during the slaughter. After the carcass were chilled for 48 h, the following measurements were obtained: 1) cold carcass wt; 2) longissimus muscle area (ribeye area), taken by direct grid reading of the eye muscle at the twelfth rib (Savell and Smith, 1993); 3) subcutaneous fat over the eye muscle at the twelfth rib taken at a location ¾ the lateral length from the chine bone end, (Donald and Boggs, 1993); 4) carcass length taken from the thirteenth rib. The trial was analyzed as a randomized block design experiment (Hicks, 1973). On significant (P < .05) differences between treatments, multiple mean comparisons were made using the LSD method.

Result and Discussion

The analized chemical composition of the unfermented dried grape pomace was 91.81 % DM, 12.47 % CP, 8.67 % Ash, 5.38 % EE; 48.82 % NDF, and 24.66 % N free extract (DM basis, except for DM).

Treatments effects on lamb performance and carcass characteristics are shown in Table 2. Substitution of DGP for alfalfa hay did not affect ($P > .10$) ADG, DMI/ADG, hot and cold carcass weight, dressing percentage, carcass length and back fat thickness, however DMI was slightly higher with 10 % DGP (10 %) and with 30 % DGP (8 %) than the control group without DGP.

The DGP used in this experiment was not fermented for alcohol production and therefore contained a fair amount of sugar which could have made the product palatable and could explain these slightly greater DM intakes. Rumsey and Lindahl (1982) fed gestating ewes with apple pomace (6.8 % CP, DM basis), plus protein concentrates and found that DM intakes, gains and lambing performace only were normal when 50 % or less of the diet DM was from supplemented apple pomace.

Rihani et al. (1993) using similar lambs to those used in this experiment studied the influence of N enrichment of a dried citrus pulp basalt diet through amoniation vs urea on its feeding value. They found that daily gain of urea fed lambs were higher (182 g; $P < .05$) than that of amoniated citrus pulp either with urea or ammonium hydroxide (138 g), feed efficiency and dietary NE values were similar ($P > .10$) amoung diets containing NPN, and concluded that growth performance seemed to be wore directly affected by intake, rather than N economy and that the ultimate response to N enrichment may be seen only of N is truly limiting performance. Both of the above mentioned by-products are low in CP, ie apple pomace 6.8 % and citrus pulp 6.2 % (DM basis), when they are compared to the animal requirements, in general that is why they are enriched or supplemented wiht N, however the DGP used in this experiment was higher in CP (12.6 %; DM basis), and the overal mean of ADG (106 g) obtained here were just slighthly lower than those reported by Rihani et al. (160 g; 1993) and by Rumsey and Lindahl (156 g, 1982).

Similar to the ones obtained in the present study in the Mexicali Valley there has been reports of lamb weight gains from 123 to 152 g/d, of cross breeds of Romanov and Pelibuey lambs, fed mixtures of alfalfa, sorghum and sudangrass hays (Alvarez, et al. 2001). In contrast to our results, Manterola et al., (1997) using 15 % fermented DGP in beef cattle diets based on alfalfa hay, wheat straw and wheat bran obtained lower ADG (57 %) and lower DMI/ADG, than without the fermented DGP. This negative effect was to be expected, due to the fact that the fermented DGP had a lower energy value than the other ingredients used in the trial.

In relation to carcass characteristics, although there were no statistical differences ($P > .10$) between treatments in hot carcass weight and in dressing % obtained in this work, there was a numerical difference in favor of DGP treatments (14 %) for both of this measures. A cross treatments Rihani et al.(1993) had slightly lower (17 %) dressing % than the one obtained here with DGP. Manterola et al (1997) also found lower dressing % with fermented DGP than without them. In this work a surprise was that unfermented DGP at 30 % in the diet produced a ribeye muscle 11 % greater ($P < .05$) than alfalfa hay alone.

Implications

Compared fermented and unfermented DGP, the later showed to have a fair content of sugars and proteins. Results obtained in this study proved unfermented DGP could be used as a feedstuff to substitute full bloom alfalfa hay in sheep diets withouth adversely affecting animal growth and carcass characteristics.

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Table 1. Composition of experimental diets used in the trial fed to lambs

Item	Treatment, % of grape pomace			
	T1, 0	**T2, 10**	**T3, 20**	**T4, 30**
Ingredient, % (DM basis)				
Alfalfa hay	90.00	80.00	70.00	60.00
Dryed grape pomace	0.00	10.00	20.00	30.00
Ground corn	6.00	6.00	6.00	6.00
Cane molasses	3.70	3.70	3.70	3.70
Trace minera salt[a]	0.30	0.30	0.30	0.30
Nutrient composition (DM basis)[b]				
Crude protein, %	14.37	14.27	14.17	14.07
NDF, %	45.80	45.60	45.40	45.21
ADF, %	33.70	34.22	34.76	35.24
Calcium, %	1.21	1.08	0.95	0.83
Phosphorus, %	0.26	0.24	0.22	0.19
ME, Mcal/kg	2.08	2.10	2.13	2.15
NE, Mcal/kg				
Maintenance	1.22	1.25	1.27	1.30
Gain	0.66	0.68	0.70	0.72

[a] Trace mineral salt composition: $CoSO_4$, 0.068%;$CuSO_4$, 1.04%; $FeSO_4$, 3.57%; ZnO, 1.24%; $MnSO_4$, 1.07; Kl, 0.052% y NaCl 92.96%.

[b]Based on tabular values for feed ingredients; nutritional values typical of unfermented dried grape pomace without stems and of full bloom alfalfa were: ME 2.22 Mcal/kg, CP 14 % and 1.99 Mcal/kg ME with 15 % of CP respectively (ARIES, 1997).

Table 2. Effect of the substitution of alfalfa hay by unfermented grape pomace without steam on growing sheep performance and carcass characteristics.

	Level of grape pomace in diet %				
Item	0	10	20	30	SEM[a]
No. of lambs	16	16	16	16	
Days on feed	84	84	84	84	
Live weight, kg[b]					
Initial	17.16	17.16	17.6	17.28	0.75
Final	26.16	26.40	25.32	26.28	0.94
ADG, g/d	107.80	110.70	97.70	107.80	0.01
DM, kg/d	1.15[c]	1.27[d]	1.12[c]	1.24[d]	0.03
DMI/ADG	10.85	11.66	11.63	11.62	0.55
Hot carcass weight, kg	11.50	13.50	12.50	13.25	0.74
Cold carcass wt, kg	10.50	12.10	11.43	11.90	0.70
Dressing percentage	44.17	51.49	49.35	50.75	3.07
Carcass lengh, cm	46.25	44.50	40.50	49.75	3.17
Backfat thickness, cm	0.20	0.35	0.20	0.23	0.07
Ribeye muscle area, cm^2	4.09[c]	3.78[c]	3.84[c]	4.53[d]	0.19

[a] Standard error of means.
[b] Initial and final live weights reduced 4 % to account for gut fill.
[cd] Means in the same row that do not have a common superscript differ (P<.05).

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