Effects of Previous Grazing Nutrition and Management on Feedlot Performance of Cattle[1]

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ABSTRACT: Management strategies designed to improve grazing animal performance can influence feedlot performance and carcass traits both positively and negatively. In spite of the economic relevance of potential interactions between grazing and finishing performance, controlled experiments evaluating integrated production systems are limited in number. Effects of grazing treatments can result from, or be overshadowed by, changes in gut fill, thus making it difficult to assign precise costs to different phases of production. Published reports have considered the effects of stocking rate, duration of grazing, forage characteristics, supplementation, and growth-promoting implants on subsequent finishing performance. Improvements in cattle performance attributed to changes in stocking rate generally have been neutral to positive with respect to effects on finishing performance. Comparisons among forages have led to the suggestion that forage species may contribute to differences in gastrointestinal fill of grazing cattle, thereby influencing gain and efficiency during the subsequent finishing phase. Creep-feeding suckling calves generally has increased preweaning performance but has had relatively little influence on performance during the subsequent finishing phase. Grain supplementation of stocker cattle during the grazing period has improved grazing performance, but effects on subsequent feedlot performance have been inconsistent. Potential carryover effects from protein and mineral supplementation also have been inconclusive. Lack of congruence among studies is puzzling but may be the consequence of highly varied production systems, differences in experimental procedures, and changes in gut fill or mass of internal organs. Based on the studies reviewed, the expression or absence of compensatory growth during the finishing phase appears to be related to the nutritional quality of forages utilized in the grazing period, with higher quality forages tending to yield greater compensatory effects. The bulk of evidence with suckling cattle and stocker implants suggests that effects on subsequent finishing performance are minimal. Attention is drawn to the noticeable lack of research pertaining to integrated production systems. A more thorough understanding of the interactions among grazing nutrition and management, finishing performance, and carcass traits is needed to facilitate greater economic exploitation of these relationships.

Key Words: Pastures, Supplements, Feedlots, Compensatory Growth, Implantation

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Introduction

Beef production historically has existed as a highly segmented industry, with the various segments being owned and operated independently of one another. These segments normally have represented distinct developmental phases of the beef animal. Profitability of one segment of the industry often has occurred at the expense of another, with little or no attention afforded to overall profitability of the entire production system. Vertical integration, networking, alliance development, joint ventures, and other forms of integration all are presumed to have the goal of increased overall efficiency of beef production and production of market-specific carcasses. Understanding interactions among various phases of beef production is key to identifying the means of fully exploiting these relationships. This review article emphasizes

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the carryover effects of nutrition and management factors employed during the grazing period(s) on performance during the subsequent finishing phase of production.

Compensatory Growth

Rate of growth generally is not constant from birth to slaughter. A multiphasic pattern of tissue accretion in cattle is more the norm, reflecting seasonal oscillations in nutrient supply. Beef production systems exploit these characteristic fluctuations in resource availability, deferring (or dramatically decreasing) growth until the necessary nutrient resources become available and(or) economical. Such is the case with traditional spring/summer grazing programs that follow wintering periods. Deferred growing systems also afford certain advantages in terms of altering phenotypes and(or) time of marketing in order to optimize market value.

Compensatory growth is the term coined by Bohman (1955) to describe the accelerated and(or) more efficient growth that commonly follows a period of growth restriction. Usually it is considered in the context of recovery from nutritional deprivation, though other environmental stressors that affect animal growth, such as extreme temperatures, disease, plant toxins, or parasite infestation, also could be involved. Effects of previous plane of nutrition on subsequent growth of domestic livestock have been documented extensively and are the subjects of several excellent reviews (Wilson and Osbourn, 1960; Allden, 1970; Moran and Holmes, 1978; O'Donovan, 1984).

The phenomenon of compensatory growth is of considerable practical significance to beef production. The segmented nature of the industry is such that ownership of an animal may change several times during its lifetime. Expression of compensatory growth frequently coincides with change of ownership. In other words, what is lost by one segment of the industry is captured by others. Ultimately, this results in little or no net change in value of the commodity; rather, it represents a redistribution of value. This redistribution is an important and common occurrence, often representing the margin of profit for certain segments of the beef industry.

Compensatory growth also can be capitalized on by allowing its expression to occur when input costs are greatest, thereby reducing overall cost of production. This commonly is the case with yearling finishing programs, in which performance may be compromised during portions of the grazing (low input) period and increased during the subsequent finishing (high input) phase. Changes in overall profitability are consistent with differences in production costs during each phase. In order to increase profitability under this scenario, improvements in efficiency realized during the high-input phase must be sufficient to offset higher costs associated with decreased productivity during the low-input phase. In traditional, multisegmented systems of production, market value of the animal at alternative end points must also be considered. Consequently, the impact of compensatory growth becomes relative. In the segmented system of production, the value of compensatory growth is based on differences in market value and growth efficiency of compensating vs noncompensating animals. In an integrated production system, actual input costs for each phase are considered. Extending the period of growth restriction decreases the likelihood of enhancing profitability in integrated systems because maintenance costs during the low-input phase become an increasing proportion of overall costs of production.

Patterns of growth can be altered in order to manipulate body weight at the point of slaughter. This is possible because cattle typically are slaughtered at weights substantially less than mature weight (Owens et al., 1995). Owens et al. (1993) suggested that mature weight of an animal could be defined as the weight at which fat content of the empty body reaches 34 to 37%. Presumably, body fat content of 28% (low Choice quality grade) could be attained by an infinite number of discontinuous patterns of growth.

Accumulation of body fat occurs in proportion to the excess energy provided beyond that required for maintenance, skeletal growth, and protein accretion. During periods of suboptimal nutrition, deposition of muscle and skeletal tissue proceeds at the expense of body fat, potentially leading to a lower percentage of body fat. When animals subsequently are provided access to additional nutrients, fat deposition resumes. Cattle producers exploit this mechanism to increase slaughter weights without substantially affecting the percentage body fat at slaughter. A wide range of genotypes thus can be used to arrive at a given phenotype.

Interpretation of Changes in Body Weight

Accurate assessment of the effects of nutrition on animal performance is contingent on the ability to obtain accurate, unbiased estimates of weight. This becomes particularly important when attempting to ascertain effects of treatments employed during one phase of production on performance during subsequent phases. Inaccurate or biased estimates of body weight can veil effects of treatments, leading to erroneous conclusions with potentially significant economic ramifications. Ruminants are predisposed to large variations in gut fill (Stock et al., 1983); consequently, live weight often may be an unreliable indicator of empty body mass. Changes in gut fill may be inherent with some dietary regimens or management strategies and may thereby bias estimates of body weight and, hence, interpretation of animal performance.

Rohr and Daenicke (1984) reviewed the effects of various dietary factors on gut fill, citing a range in gut fill between 11 and 17.1% of live weight for cattle fed different types of diets. More recently, Johnson et al. (1998) measured seasonal changes in ruminal fill of steers grazing mixed-grass prairie. Ruminal contents ranged from a low of 9% of body weight in mid-June to a high of 16.5% in mid-December. Burns et al. (1997) evaluated digesta kinetics in steers fed switchgrass hays of varying maturity and determined that ruminal fill (dry basis) increased linearly with advancing maturity of the forage. In an earlier study, Burns et al. (1991) compared ruminal dry matter fill of steers grazing several grass species, noting only minimal differences. Ruminal fill values, when expressed on a dry basis, are of limited utility in interpreting changes in live weight because they do not consider the possibility that the moisture of ruminal contents can vary with diets.

Wet ruminal contents of cattle offered various forages were estimated by Reid et al. (1990) before and 6 h after feeding. The amounts of ruminal contents were different among cattle fed legumes and cool- and warm-season grasses. Just as important, the relative ranking changed between the 0-h and 6-h sampling times, reflecting differences in feed consumption patterns of the different forages. Waldo et al. (1990) measured gut fill of steers fed alfalfa and orchardgrass silages at two levels of intake within 10 to 14 h after feeding. At comparable intakes, gut contents were 28% lower for cattle fed legume compared with grass silage. Fill, expressed as a percentage of body weight, was somewhat lower at the higher levels of intake.

Tolley et al. (1988) provided evidence of the effects of diet switches on estimation of live weight. Switching from high- to low-energy diets resulted in significant losses of body weight during the 2-wk period immediately following the diet change, presumably because of changes in gastrointestinal tract fill. Löest et al. (1998) observed similar effects when switching cattle from ad libitum, mixed diets to limit-fed, high-concentrate diets. These short-term changes in gut fill can effectively obscure underlying effects of treatment.

Understanding changes in gut fill is prerequisite to discerning real treatment differences in nutrition experiments. Comparisons are obscured further by potential differences in the effects of growing regimens on mass of various body tissues. Ledger and Sayers (1977) restricted feed intake to maintain steers' constant live weights for 12 to 24 wk and observed that internal organ weights decreased, whereas carcass weight increased. Carstens et al. (1991) measured disproportionate increases in mass of internal organs relative to total empty body weight during compensatory growth. Mass of the internal organs is dynamic, reflecting fluctuations in nutrient availability and the necessity for “metabolic machinery” to process nutrients. Although superior to live weight estimates, empty body weights do not necessarily reflect changes in animal value, because they may or may not correlate with changes in mass of carcass tissues.

Accurate assessment of the interactions among various management strategies and phases of production is predicated on reliable estimates of animal performance during each phase. Therefore, valid estimation necessitates an underlying knowledge of the manner in which treatments interact with response criteria used to evaluate them. This can be likened to a statistical analysis using covariates; the analysis is inappropriate when values of the covariables are dependent on treatments. Attempts to standardize gut fill and weighing conditions are imperative.

Forage Systems and Their Effects on Subsequent Feedlot Performance

Substantial diversity exists among the major forage-producing areas in terms of plant species, annual precipitation, soil fertility, and other environmental factors. Consequently, a variety of management strategies have evolved to exploit these differences, including burning, rotational grazing, intensive stocking, fertilization, and supplementation. Substantial opportunity exists for interaction between forage resources, agronomic practices, animal management, animal performance, and the end product that is produced. Research pertaining to these interactions will be the subject of the following discussion.

Studies designed to assess various grazing strategies often are confounded with season of year, animal age, weight, and numerous other factors. Confounding of this sort is inevitable, thus precluding the ability to ascribe results to a particular factor, such as stocking density or length of grazing season. This poses a terrific dilemma when our objective is to define the precise biological or economic response in each phase of production. In the absence of accurate, unbiased estimates of performance during these distinct phases of production, our comparisons must be confined to one multiphasic system vs another. Perhaps this is best achieved by expressing total output as a function of total economic and(or) biological inputs during the combined phases of production.

Effects of Grazing Pressure and Duration of the Grazing Season. The effects of grazing pressure by cow-calf pairs on subsequent growing and finishing performance of calves was investigated by Phillips et al. (1991). Preweaning grazing pressure did not affect subsequent performance during the receiving, winter grazing, spring grazing, or finishing periods. However, feedlot gain and efficiency were greater for calves that grazed native tallgrass prairie pastures than for calves that grazed winter wheat. Data in this study were confounded by season of feeding, initial weight in the feedlot, average weight during finishing, and other factors, thus making it impossible to ascribe treatment differences solely to type of pasture. Gill et al. (1991) compared feedlot performance of stockers grazing single- or double-stocked summer pastures (153 and 84 d, respectively) and found no differences in gain, feed efficiency, or carcass traits. Similarly, Brethour (1985) noted no difference in finishing performance or carcass traits among steers that were stocked on native, mixed-grass prairie at rates of 1.37, 1.75, or 2.13 animals/ha. The absence of compensatory growth in some, but not all, experiments draws into question our ability to accurately determine body weight at the point when animals complete one phase of growth (grazing) and enter a subsequent phase (finishing). Data from these studies could be interpreted to suggest that differences in body weight acquired during grazing reflect actual differences in tissue deposition, rather than gut fill.

In a later study by Gill et al. (1992), heifers that grazed native, tallgrass prairie season long (single stocked) had poorer feedlot gains and efficiencies than heifers that were intensively stocked for an 81-d grazing season. Carcass characteristics were not different, however. Estimations of transit shrink led to the suggestion that differences in gut fill may have influenced initial feedlot weights of cattle from the two treatments; this is consistent with seasonal fluctuations in gut fill reported by Johnson et al. (1998). Consideration also must be given to the potential effects of the season during which cattle in each treatment were finished. In the study by Gill et al. (1992), short-season cattle were finished by mid-December, whereas full-season cattle were not slaughtered until mid-February. Brandt et al. (1995) attempted to minimize differences in gut fill by feeding designated amounts of a standardized diet prior to estimating weights at the beginning and end of the grazing season. During the subsequent feedlot phase, short-season (intensively stocked) steers gained more rapidly and more efficiently than steers grazing season long. Season-long grazing resulted in heavier (22 kg) carcass weights, but carcass finish and quality grades were not different between treatments.

Ridenour et al. (1982) evaluated growing and finishing performance of steers that grazed irrigated wheat pasture for 133 or 201 d, followed by finishing periods of 156 or 101 d, respectively. Comparing systems as a whole, daily gains or carcass characteristics were not different. Feedlot average daily gains and efficiencies of cattle grazing for 133 d were superior to those of cattle grazing for the longer interval, thus compensating for lower gains during the grazing period. Again, length of the grazing season was confounded with other factors, such as placement weights and season of feeding.

Multiphasic Systems. Beef cattle growing systems frequently employ multiple forage resources, such as native grass, improved pastures, summer annuals, crop residues, winter annuals, and harvested forages, depending on seasonal availability and geographical location. Wintering programs often are characterized by relatively high feed costs, prompting considerable interest in the effects of low nutritional inputs during wintering periods on performance during subsequent grazing and finishing periods. This subject has defined the scope of numerous research trials over the past five decades. Interpretation of results is subject to limitations in estimation of weight, as previously discussed.

Early studies by Connell et al. (1948) and Heinemann and Van Keuren (1956) assessed the effects of different levels of gain during the winter feeding period on performance during subsequent grazing and finishing periods. In both instances, cattle held at low rates of gain during the winter period gained more rapidly during the subsequent grazing period. Compensation was less than complete, however; calves maintained at low rates of winter gain recovered only 58 to 66% of their weight deficit during the subsequent grazing period. Finishing performance was not influenced by winter gain. White et al. (1987)

conducted a similar study and determined that differences in rate of gain during the summer grazing season accounted for only about 24% of the differences in winter gain among treatment groups. The degree of restriction during the winter period was fairly severe, ranging from –.23 to .16 kg/d for 98 d. In a more recent study by Lewis et al. (1990), the degree of compensation was estimated at 81% for cattle grazing summer pastures following various degrees of winter growth restriction. Again, finishing performance was not influenced by winter gain.

Effects of Forage Type. The prevalence of endophytic fungus (*Acremonium coenophialum*) in tall fescue grazing regions of the United States has prompted concern over its potentially deleterious effects on long-term cattle performance. Several studies have compared growing and finishing performance of cattle that grazed various monocultures or mixtures of different forage types.

Holloway and Butts (1983) monitored postweaning growth of calves after cow-calf pairs grazed pastures containing fescue or fescue-legume mixtures. Calves raised on fescue pastures were nearly 22 kg lighter at weaning but exhibited more rapid growth during the subsequent fall, winter, and spring growing periods. Feedlot gain and most carcass traits were unaffected by preweaning treatment. Carcass weights were 11 kg greater for calves that previously grazed fescue-legume mixtures, indicating that compensatory growth during the growing period was far from complete. Beconi et al. (1995) reported that finishing gain and efficiency were related inversely to pasture gain of cattle previously exposed to endophyte-infected and endophyte-free forages (grazed and harvested). Likewise, Cole et al. (1987) concluded that the poor grazing performance associated with high endophyte infestation was offset partially by improved performance in the feedlot phase. Lusby et al. (1990) compared feedlot performance of steers that grazed fescue or fescue-clover mixtures. Cattle previously exposed to higher endophyte levels exhibited compensatory growth during the feedlot phase, but carcass weights still were substantially less at slaughter. Coffey et al. (1990) conducted a similar experiment and likewise observed that poor grazing performance was partially offset by expression of compensatory growth during the feedlot phase. A significant portion of the compensation appeared to occur early in the finishing period, suggesting the possibility that treatments differed in terms of gut fill at the end of the grazing period. The study of Lusby et al. (1990) provided further evidence of rapid changes in gut fill following removal from infected fescue pastures. The report by Hedrick et al. (1983) provided a rare glimpse of comparative slaughter data from cattle backgrounded on different forage systems preceding feedlot finishing. Cattle that grazed fescue pastures had lighter carcasses (11 kg less) than their counterparts that grazed fescue-legume mixtures. By the end of the 123-d finishing period, the difference in carcass weight had diminished to less than 6 kg.

Burton et al. (1994) performed an economic analysis of fescue grazing using production data from the study of Coffey et al. (1990). This work is intriguing in that it represents one of the few detailed comparisons of grazing-finishing production systems. Cattle grazing on endophyte-infected pastures yielded the poorest returns on pasture and the greatest returns during the finishing phase compared with cattle that grazed fescue-clover mixtures or endophyte-free fescue. However, cattle grazing a mixture of infected fescue interseeded with clover consistently yielded the greatest overall profitability.

In general, grazing forages infested with endophyte reduced stocker gains relative to grazing nonendophyte varieties or grass-legume mixtures. These cattle also exhibited compensatory growth during the finishing phase, particularly early in the postgrazing period. Compensatory growth did not appear to be driven by increases in feed intake during the finishing phase. Carcass traits reported in these studies generally were unaffected by previous grazing regimen.

Effects on Sensory Attributes of Beef. Sensory characteristics of beef from cattle that previously grazed fescue, fescue-red clover, or fescue-birdsfoot trefoil were evaluated by Hedrick et al. (1983) after 123 d of high-concentrate feeding. No differences were apparent among the forages. Larick et al. (1987) determined sensory traits for beef derived from cattle backgrounded on different forages and subsequently fed high-grain diets for 0 to 112 d. Meat tenderness was not influenced by pasture treatment, but differences in concentrations of several volatile compounds associated with grassy flavor of beef were evident. In a later study, Larick and Turner (1990) evaluated flavor of beef after backgrounding the cattle on different forages and subsequently finishing them for 0 to 82 d. Beef from cattle that previously grazed a fescue-clover mixture had less “sweet, gamey aftertaste” than that from cattle grazed on pearl millet or sorghum-sudangrass. Sensory characteristics normally associated with grass feeding dissipated after only 54 d on feed. Linolenic (C18:3) acid was key in distinguishing flavors associated with forage feeding. Concentrations of linolenic acid were decreased substantially after 54 d of grain feeding, but levels in beef from the different forage types were not markedly different. Apparently, minimal differences occur among forages with respect to their influence over sensory attributes of beef, providing that cattle are permitted sufficient time on high-concentrate diets.

Supplementation on Pasture and Its Effects on Subsequent Finishing Performance

Creep Feeding. Provision of self-fed, creep supplements to beef calves is employed commonly as a means of increasing weaning weights and, hence, potential profitability of cow-calf operations. Creep feeding could potentially influence postweaning growth both positively and negatively. Given their previous exposure to concentrates, creep-fed calves might be less disposed to digestive problems during the transition from pasture to concentrate-based finishing diets. Creep feeding of animals that otherwise would be nutrient deficient, such as calves nursing dams with poor milk production, might influence satellite cell proliferation during critical periods of development, thereby altering future growth potential. Permanent effects of early postnatal nutrition on growth and metabolism, referred to as *nutritional programming*, have been demonstrated in primates, rodents, ruminants, and other species (Desai and Hales, 1997). Early postnatal growth restriction can retard future growth potential (Everitt and Jury, 1977) as well as the expression of compensatory growth (Wardrop, 1966; Drennan and Harte, 1979; Robelin and Chilliard, 1989). Alternatively, growth restrictions imposed several months after birth may have no permanent detrimental effects, in which case the animals could exhibit compensatory growth, thus ameliorating the benefits of creep feeding.

Finishing performance of creep-fed beef calves has been the subject of several studies. Myers et al. (1997) evaluated the effects of creep feeding during the final 8 wk of suckling on finishing performance of several biological types of cattle. Creep feeding increased preweaning gains in both years of the experiment. During the finishing phase, gains and efficiencies of supplemented calves were equal or superior to those of calves that did not receive creep. Fluharty et al. (1996) evaluated creep feeding the last 105 d of suckling and obtained only marginal, nonsignificant improvements in preweaning performance. Likewise, performance and carcass traits during the subsequent finishing period were unaffected by creep feeding.

Faulkner et al. (1994) evaluated the use of corn and soybean hulls as creep feeds for suckling calves. Relative to unsupplemented controls, creep feeding decreased forage intake but had no effect on milk consumption. Calves in the supplemented groups were heavier at weaning and retained their advantage throughout the subsequent growing and finishing periods. Preweaning supplementation did not impact growing or finishing performance but resulted in higher quality grades. Differences in quality grade could be attributed to differences in overall fatness, as carcasses of creep-fed cattle tended to have more subcutaneous fat and higher yield grades.

Tarr et al. (1994) conducted a 2-yr study to evaluate the effects of creep feeding for the final 0, 28, 56, or 84 d before weaning. Gain during the preweaning period increased linearly as days of creep feeding increased. Creep feeding appeared to have no substantial effects on performance during the finishing phase and had no effect on carcass quality or degree of fatness.

In general, increases in body weight acquired through creep feeding are retained throughout the subsequent finishing phase. Creep feeding appears to have no dramatic effects on finishing growth or carcass characteristics. Berge (1991) similarly concluded that preweaning treatments, in the form of milk allowance or concentrate level, do not substantially influence subsequent finishing performance. Consequently, the efficacy of preweaning supplementation regimens can be evaluated predominantly on the basis of benefits achieved during the period of supplementation.

Mineral Supplementation. Relatively few studies have been conducted to ascertain the effects of mineral status during the grazing period on performance during the ensuing finishing period. Greene (1998) hypothesized that copper, zinc, and selenium are of greatest practical significance in terms of potential carryover effects because of their role in immune function. Deficiencies during the grazing phase could potentially be manifested as immune failure when cattle are subjected to the stresses of weaning, transportation, and introduction to the feedyard. Stabel et al. (1993) demonstrated the relationship between dietary copper status and immunocompetence using a disease challenge model in young dairy calves (30 d old). Addition of supplemental copper to semipurified, copper-deficient diets increased immunological responses in calves.

Sankoh and Boila (1987) observed no change in grazing performance when calves received injectable copper at the start of a 113-d grazing trial. During the subsequent feedlot phase, daily gain and carcass weight of the supplemented calves were less than those of controls. Coffey et al. (1992) compared grazing and subsequent finishing performance of yearling steers on fescue-legume pastures with and without supplemental copper in the form of copper oxide needles. Although concentrations of copper and ceruloplasmin increased with copper supplementation, performance was not improved during the grazing or finishing periods, indicating that basal copper levels were not limiting for growth or immunocompetence of the yearling cattle.

Although little doubt remains that serum constituents can be altered as a result of mineral consumption, evidence is lacking with respect to the beneficial or deleterious effects on grazing and subsequent finishing performance. Defining these effects seems an almost insurmountable task, given the broad range of soil types, climatic conditions, fertilization practices, plant species, maturation processes, grazing systems, animal requirements, supplementation practices, and countless other variables that are likely to interact.

Energy and Protein Supplementation. Stocker programs frequently are complemented by the strategic use of energy and protein supplements. Immature forages often contain an excess of degradable intake protein and presumably could be complemented by supplementation with readily available forms of energy or undegraded intake protein. As forages mature, protein may become limiting, particularly protein that is readily degradable. Consequently, supplements containing appreciable quantities of degradable protein can stimulate microbial digestion and forage utilization. Supplementation of grazing cattle has been the subject of thousands of research studies worldwide. In spite of the enormous emphasis on supplementation, only a few studies have investigated carryover effects in the feedlot.

Owensby et al. (1995) conducted a study with yearlings grazing native, bluestem range to assess the effects of grain supplementation on performance during grazing and the ensuing finishing period. Performance during the pasture phase increased linearly with grain supplementation but did not affect gain or efficiency during the finishing period. Carcass weight and dressing percentage increased linearly as a result of increasing grain consumption on pasture, indicating that little or no compensatory growth occurred in the feedlot. Brethour (1985) observed similar increases in grazing performance while supplementing ground milo and monensin on native, mixed-grass prairie. Subsequent feedlot gains actually were marginally higher for cattle supplemented with the grain/ionophore mixture.

Lake et al. (1974) fed grain-based supplements to cattle on irrigated grass-legume pastures and noted that grazing gain increased in proportion to the amount of supplement fed. Cattle fed grain on pasture required fewer days in the feedlot than unsupplemented cattle. Feedlot gains, efficiencies, and carcass traits were unaffected by previous supplementation. Coleman et al. (1976) reported that increases in performance attributable to protein-energy supplementation of cattle grazing St. Augustinegrass had no significant effects on subsequent finishing performance or carcass traits. This is in agreement with the work of Elizalde et al. (1998), in which cattle grazed infected fescue.

Data from the previously mentioned studies are in contrast to observations made by Horn et al. (1995) with supplementation of cattle on wheat pasture. As in previous experiments, stocker performance was improved with supplementation on pasture (two separate studies). However, effects on subsequent feedlot performance were not consistent between studies. In one instance, feedlot gain was unaffected by previous supplementation regimen. In the other case, cattle that received no supplemental energy during the grazing period gained more rapidly in the feedlot phase and had larger carcasses. Feed efficiency and carcass quality were not influenced by previous supplementation. Additional evidence of the potential negative effects of pasture supplementation on subsequent finishing performance was presented by Perry et al. (1971). A concentrate mixture (grain plus protein supplement) was fed at levels ranging from 0 to 6.7 kg/d to cattle grazing legume-grass pastures. Daily gain during the grazing period increased linearly with supplement intake and decreased linearly during the following feedlot phase. However, the degree of compensation was far from complete. Supplements fed at 0 and 2.2 kg/d during the grazing period compare reasonably well with treatments in the studies discussed previously. In this comparison, compensation by the unsupplemented animals was limited to approximately 20%. A subsequent series of experiments (Perry et al., 1972) later confirmed these observations. Denham (1977) evaluated the impact of supplementing grain to cattle grazing annual ryegrass followed by grazing on fall blue grama and western wheatgrass and later monitored performance in the feedlot phase. Previously unsupplemented cattle compensated during the finishing period, regaining about 80% of the weight deficit that existed at the end of the grazing period. Additionally, the compensating cattle were more efficient.

McCann et al. (1991) fed supplements of various protein contents to cattle grazing winter annuals and observed significant increases in pasture gain with supplementation. When cattle subsequently were finished, compensation was virtually complete. Denham (1977) evaluated protein supplementation of cattle grazing fall native pastures. Gain during the grazing period increased with protein supplementation in 2 out of 3 yr. Gains during the following feedlot phase were not altered by previous protein supplementation.

Considerable lack of consistency exists among studies evaluating carryover effects of grazing supplements on subsequent feedlot performance. However, studies showing no effect of previous supplementation on feedlot performance do appear to have the common feature of poorer quality forages during the grazing season. Conversely, studies characterized by a compensatory growth response during the feedlot phase seem to have in common the use of higher quality roughages. Initially, this seems contrary to the concept of compensatory growth, which by definition requires a period of growth restriction. Cattle in the studies characterized by compensatory growth were not restricted severely, even when not supplemented during the growing period. This may imply that supplementation has a greater influence over changes in gut fill with higher quality forages.

Implanting Pasture Cattle and Subsequent Effects on Finishing Performance

Recent reviews have characterized the benefits and potential positive and negative carryover effects of administering various growth-promoting implants to suckling calves (Mader, 1997) and grazing stockers (Kuhl, 1998). Although dozens of studies have documented the growth-enhancing capabilities of implants during the suckling, growing, and finishing phases of production, relatively few have evaluated carryover or lifetime effects. Laudert et al. (1981) showed that implanting suckling calves had no effect on growing and finishing gains, but implanting during the growing phase reduced feedlot gain. Conversely, Mader et al. (1985) reported that implants administered preweaning had no influence on growing performance but reduced finishing gain. In a large 3-yr study, Simms et al. (1988) found that finishing steer performance was not affected by implants used during the suckling or growing periods. In a pooled summary of the three aforementioned studies, all using Ralgro implants (Ralgro, Pitman-Moore, Terre Haute, IN), Mader (1997) concluded that implants used during the preweaning phase improved weaning weights slightly, positively influenced growing performance, and tended to reduce finishing and overall postweaning growth and feed efficiency.

In subsequent steer and heifer studies, Mader et al. (1994) explored the use of low-, moderate-, and high-potency implants during successive phases of production. This strategy using Synovex-C and -S or -H (Synovex-S; Fort Dodge Animal Health, Fort Dodge, IA) during suckling and growing phases, followed by Synovex and Finaplex (Finaplex, Hoechst-Roussel, Somerville, NJ) in the feedlot phase, increased lifetime weight gain by 50 kg. Additionally, gain and efficiency during the finishing phase were comparable to those of control cattle. Other studies of sequential doses of estrogenic implants have produced similar results (Mader, 1997). Suckling implants generally have had little influence on carcass characteristics.

Effects of implants administered during the grazing season on growing and finishing performance have been summarized by Kuhl (1998). New Mexico (Grigsby et al., 1988) and Nebraska (Rush et al., 1989) researchers, using estrogenic products in both production phases, found no carryover effects of summer grazing implants on feedlot performance or carcass traits. Grazing gains and overall (grazing plus finishing) gains were improved by pasture implants. Similarly, Hutcheson and Rouquette (1986) achieved greater steer and heifer gains with a Ralgro reimplantation program over a 180-d rye/ryegrass grazing period, but observed no effect on ensuing feedlot performance. However, pasture-implanted cattle tended to have higher quality grades at slaughter. Likewise, McCann et al. (1991) reported that Ralgro-implanted stockers gained 10 kg more weight over 73 d on wheat/ryegrass pasture, but implanting had no influence on finishing performance even though steers were not implanted during the 76-d feedlot phase. Similarly, Compudose-implanted (Compudose, Elanco Animal Health, Indianapolis, IN) calves gained 14% faster than controls on fescue pastures but showed no advantages in subsequent growing and finishing gains in drylot without reimplantation (Beconi et al., 1995). Coffey et al. (1992) also boosted stocker performance on fescue pasture with two successive Synovex-S implants. However, in the subsequent finishing period, during which all cattle received two additional Synovex-S implants, pasture-implanted steers gained 6% slower.

Researchers have also evaluated the potential carryover effects of various grazing implants in cattle receiving estrogen/trenbolone acetate implants in the feedlot. In a 2-yr study, Brandt et al. (1995) demonstrated that implanting stockers with Synovex-S had no effect on subsequent Synovex/Finaplix-influenced feedlot performance or carcass traits. Overall, pasture implants increased final slaughter and carcass weights about 9 and 5.4 kg, respectively. More recently, Fankhauser et al. (1997) compared performance of 480 stockers given either no implant, Ralgro, or Synovex-S on native range, followed by either Synovex Plus or a Ralgro/Synovex Plus reimplantation program in the 132-d feedlot phase. Feedlot performance was maximized with the reimplantation program. Finishing gains and feed intakes were similar for all stocker-phase treatments. However, pasture-implanted steers tended to be less efficient than controls during finishing, especially when the feedlot reimplantation program was not used. Carcass characteristics were not influenced by pasture treatments.

In a study with 480 stockers receiving either no implant, Revalor-G, Ralgro, or Synovex-S before grass, followed by Revalor-S or Synovex-S during the finishing phase, Kuhl et al. (1997) concluded that pasture feedlot carryover effects were nonexistent. On average, implanted stockers gained 9.1 kg more on grass and produced 8.2-kg heavier carcasses, but had no significant improvements in quality or yield grades. Similarly, Paisley et al. (1998) evaluated 300 calves dry-wintered on native tallgrass range with either no implant or Synovex-C, -S, or Revalor-G. Subsequently, all calves were implanted with Ralgro during the grazing period and with Revalor in the feedlot. Winter treatments had no effect on performance during the summer grazing period or in the finishing phase. Steers implanted in the winter averaged 14.1 kg heavier at slaughter (9.1-kg greater carcass weight). Unexpectedly, winter-implanted stockers had slightly higher yield grades and increased skeletal maturities. Collectively, these pasture/feedlot studies demonstrate that benefits achieved with grazing implants generally are retained through finishing when adequate, but not excessive, exogenous hormonal stimulation is provided throughout production phases.

Implications

Frequent bias in the estimation of animal weight severely limits the ability to ascribe true value to various phases of production in integrated systems. Management strategies can be used to effect changes in growth of grazing cattle without detrimental effects on subsequent finishing performance or carcass traits. Further characterization of the relative responses to pasture supplementation and effects on subsequent performance in the feedlot may prove useful for identification of alternative more profitable beef production systems.

Literature Cited

Allden, W. G. 1970. The effects of nutritional deprivation on the subsequent productivity of sheep and cattle. Nutr. Abstr. Rev. 40:1167–1184.

Beconi, M. G., M. D. Howard, T.D.A. Forbes, R. B. Muntifering, N. W. Bradley, and M. J. Ford. 1995. Growth and subsequent feedlot performance of estradiol-implanted vs nonimplanted steers grazing fall-accumulated endophyte-infested or low-endophyte tall fescue. J. Anim. Sci. 73:1576–1584.

Berge, P. 1991. Long-term effects of feeding during calfhood on subsequent performance in beef cattle (a review). Livest. Prod. Sci. 28:179–201.

Bohman, V. R. 1955. Compensatory growth of beef cattle: The effect of hay maturity. J. Anim. Sci. 14:249–255.

Brandt, R. T., Jr., C. E. Owensby, and C. T. Milton. 1995. Effects of grazing system and use of a pasture implant on grazing and finishing performance of steers. In: Proc. KSU Range Field Day, Kansas State University, Manhattan. pp 81–85.

Brethour, J. 1985. Intensive grazing of native, shortgrass pastures. In: 1985 Roundup. Rep. Prog. 475, Kans. Agric. Exp. Stn., Manhattan. pp 14–15.

Burns, J. C., K. R. Pond, and D. S. Fisher. 1991. Effects of grass species on grazing steers: II. Dry matter intake and digesta kinetics. J. Anim. Sci. 69:1199–1204.

Burns, J. C., K. R. Pond, D. S. Fisher, and J.-M. Luginbuhl. 1997. Changes in forage quality, ingestive mastication, and digesta kinetics resulting from switchgrass maturity. J. Anim. Sci. 75: 1368–1379.

Burton, R. O., Jr., P. T. Berends, J. L. Moyer, K. P. Coffey, and L. W. Lomas. 1994. Economic analysis of grazing and subsequent feeding of steers from three fescue pasture alternatives. J. Prod. Agric. 7:482–489.

Carstens, G. E., D. E. Johnson, M. A. Ellenberger, and J. D. Tatum. 1991. Physical and chemical components of the empty body during compensatory growth in beef steers. J. Anim. Sci. 69: 3251–3264.

Coffey, K. P., L. W. Lomas, and J. L. Moyer. 1990. Grazing and subsequent feedlot performance by steers that grazed different types of fescue pasture. J. Prod. Agric. 3:415–420.

Coffey, K. P., J. L. Moyer, L. W. Lomas, J. E. Smith, D. C. La Rue, and F. K. Brazle. 1992. Implant and copper oxide needles for steers grazing *Acremonium coenophialum*-infected tall fescue pasture: Effects on grazing and subsequent feedlot performance and serum constituents. J. Anim. Sci. 70:3203–3214.

Cole, N. A., J. A. Stuedemann, C. W. Purdy, and D. P. Hutcheson. 1987. Influence of endophyte in tall fescue pastures on the feedlot performance of feeder steers. J. Anim. Sci. 65(Suppl. 1): 331.

Coleman, S. W., F. M. Pate, and D. W. Beardsley. 1976. Effect of level of supplemental energy fed grazing steers on performance during the pasture and subsequent drylot period. J. Anim. Sci. 42:27–35.

Connell, W. E., S. S. Wheeler, and R. C. Tom. 1948. The effect of winter supplementation on subsequent gains of beef steers on grass and in the fattening lot. J. Anim. Sci. 7:430–433.

Denham, A. H. 1977. Influence of energy and protein supplements on grazing and feedlot performance of steers. J. Anim. Sci. 45: 1–7.

Desai, M., and C. N. Hales. 1997. Role of fetal and infant growth in programming metabolism in later life. Biol. Rev. 72:329–348.

Drennan, M. J., and F. J. Harte. 1979. Compensatory growth in cattle. Ir. J. Agric. Res. 18:145.

Elizalde, J. C., J. D. Cremin, Jr., D. B. Faulkner, and N. R. Merchen. 1998. Performance and digestion by steers grazing tall fescue and supplemented with energy and protein. J. Anim. Sci. 76: 1691–1701.

Everitt, G. C., and K. E. Jury. 1977. Growth of cattle in relation to nutrition in early life. N. Z. J. Agric. Res. 20:129.

Fankhauser, T. R., G. L. Kuhl, J. S. Drouillard, D. D. Simms, G. L. Stokka, and D. A. Blasi. 1997. Influence of implanting grazing steers with Ralgro® or Synovex®-S followed by Synovex® Plus™ or a Ralgro®/Synovex® Plus™ reimplant program in the feedlot on pasture/finishing performance and carcass merit. In: Cattlemen's Day Rep. Prog. 783, Kansas Agric. Exp. Sta., Manhattan. pp 38–42.

Faulkner, D. B., D. F. Hummel, D. D. Buskirk, L. L. Berger, D. F. Parrett, and G. F. Cmarik. 1994. Performance and nutrient metabolism by nursing calves supplemented with limited or unlimited corn or soyhulls. J. Anim. Sci. 72:470–477.

Fluharty, F. L., T. B. Turner, S. J. Moeller, and G. D. Lowe. 1996. Effects of age at weaning and diet on growth of calves. Spec. Circ. No. 156. Ohio Agric. Res. Dev. Center, Wooster. pp 29–35.

Gill, D. R., F. T. McCollum, C. A. Strasia, J. J. Martin, and R. L. Ball. 1991. Effects of growing diets and grazing regimen on feedlot performance and carcass traits. Rep. MP134, Okla. Agric. Exp. Stn., Stillwater. pp 114–121.

Gill, D. R., F. T. McCollum, C. A. Strasia, J. J. Martin, R. L. Ball, and H. G. Dolezal. 1992. Effects of winter feeding and summer grazing programs on feedlot performance and carcass merit of heifers. Rep. MP136, Okla. Agric. Exp. Stn., Stillwater. pp 223–229.

Greene, L. W. 1998. Mineral nutrition during the stocker/backgrounding phase and potential influences on feedlot performance. In: Proc. Plains Nutr. Conf. Publ. No. 98-24, Texas A&M Res. Ext. Ctr., Lubbock. pp 35–43.

Grigsby, M., G. P. Lofgreen, D. R. Garcia, M. Shafer, and M. Branine. 1988. Effects of different implants on performance of steers during summer grazing and in the feedlot. Prog. Rep. 56, New Mexico Clayton Livestock Res. Ctr., Clayton.

Hedrick, H. B., J. A. Paterson, A. G. Matches, J. D. Thomas, R. E. Morrow, W. C. Stringer, and R. J. Lipsey. 1983. Carcass and palatability characteristics of beef produced on pasture, corn silage, and corn grain. J. Anim. Sci. 57:791–801.

Heinemann, W. W., and R. W. Van Keuren. 1956. The effect of wintering plane of nutrition on subsequent gains of beef yearling steers on irrigated pastures. J. Anim. Sci. 15: 1097–1102.

Holloway, J. W., and W. T. Butts, Jr. 1983. Influence of preweaning nutrition on growth of Angus calves provided a postweaning nutritional system resulting in discontinuous growth. J. Anim. Sci. 56:1407–1415.

Horn, G. W., M. D. Cravey, F. T. McCollum, C. A. Strasia, E. G. Krenzer, Jr., and P. L. Claypool. 1995. Influence of high-starch and high-fiber energy supplements on performance of stocker cattle grazing wheat pasture and subsequent feedlot performance. J. Anim. Sci. 73:45–54.

Hutcheson, D. P., and F. M. Rouquette, Jr. 1986. Influence of pasture implant status on feedlot performance of Senepol-cross steers and heifers. Res. Rep. PR-4485, Texas Agric. Exp. Stn., College Station. pp. 55–57.

Johnson, J. A., J. S. Caton, W. Poland, D. R. Kirby, and D. V. Dhuyvetter. 1998. Influence of season on dietary composition, intake, and digestion by beef steers grazing mixed-grass prairie in the northern Great Plains. J. Anim. Sci. 76:1682–1690.

Kuhl, G. L. 1998. Implanting stocker cattle: Impact on growing and finishing performance, and carcass merit. Proc. Plains Nutr. Council Conf., Publ. No. AREC 98-24, pp 1–17. Texas A&M Res. Ext. Ctr., Amarillo.

Kuhl, G. L., C. T. Milton, G. L. Stokka, and R. T. Brandt, Jr. 1997. Comparative performance of grazing steers implanted with Revalor-G®, Ralgro®, and Synovex-S®, and subsequent finishing performance and carcass merit. J. Anim. Sci. 75(Suppl.1): 233.

Lake, R. P., R. L. Hildebrand, D. C. Clanton, and L. E. Jones. 1974. Limited energy supplementation of yearling steers grazing irrigated pasture and subsequent feedlot performance. J. Anim. Sci. 39:827–833.

Larick, D. K., H. B. Hedrick, M. E. Baily, J. E. Williams, D. L. Hancock, G. B. Garner, and R. E. Morrow. 1987. Flavor constituents of beef as influenced by forage- and grain feeding. J. Food Sci. 52:245–251.

Larick, D. K., and B. E. Turner. 1990. Flavor characteristics of forage- and grain-fed beef as influenced by phospholipid and fatty acid compositional differences. J. Food Sci. 55:312–317.

Laudert, S. B., J. K. Matsushima, and M. W. Wray. 1981. Effect of Ralgro implants on suckling, growing, and finishing cattle. Colorado Beef Nutrition Research GS-999, Colorado Agric. Exp. Sta., Fort Collins.

Ledger, H. P., and A. R. Sayers. 1977. The utilization of dietary energy by steers during periods of restricted food intake and subsequent realimentation: I. The effect of time on the maintenance requirements of steers held at constant live weights. J. Agric. Sci. (Camb.) 88:11–26.

Lewis, J. M., T. J. Klopfenstein, and R. A. Stock. 1990. Effects of rate of gain during winter on subsequent grazing and finishing performance. J. Anim. Sci. 68:2525–2529.

Löest, C. L., E. C. Titgemeyer, J. S. Drouillard, D. A. Blasi, and D. J. Bindel. 1998. Soybean hulls as a roughage-free diet for limit-fed growing cattle. J. Anim. Sci. 76(Suppl 1):304.

Lusby, K. S., W. E. McMurphy, C. A. Strasia, S. C. Smith, and S. H. Muntz. 1990. Effects of fescue endophyte and interseeded clovers on subsequent finishing performance of steers. J. Prod. Agric. 3:103–105.

Mader, T. L. 1997. Carryover and lifetime effects of growth promoting implants. Symposium: Impact of implants on performance and carcass value of beef cattle. P-957, Okla. Agric. Exp. Stn., Stillwater. pp 88–94.

Mader, T. L., D. C. Clanton, J. K. Ward, D. E. Pankaskie, and G. H. Deutscher. 1985. Effect of pre- and postweaning zeranol implant on steer calf performance. J. Anim. Sci. 61:546–551.

Mader, T. L., J. M. Dahlquist, M. H. Sindt, R. A. Stock, and T. J. Klopfenstein. 1994. Effect of sequential implanting with Synovex on steer and heifer performance. J. Anim. Sci. 72: 1095–1100.

McCann, M. A, R. S. Donaldson, H. E. Amos, and C. S. Hoveland. 1991. Ruminal escape protein supplementation and zeranol implantation effects on performance of steers grazing winter annuals. J. Anim. Sci. 69:3112–3117.

Moran, J. B., and W. Holmes. 1978. The application of compensatory growth in grass/cereal beef production systems in the United Kingdom. World Rev. Anim. Prod. 14:65–73.

Myers, S. E., D. B. Faulkner, F. A. Ireland, and D. F. Parrett. 1997. Beef production systems comparing early weaning to normal weaning with or without creep feeding for beef steers. Beef Res. Rep. 24, Illinois Agric. Exp. Sta., Urbana. pp 55–66.

O'Donovan, P. B. 1984. Compensatory gain in cattle and sheep. Nutr. Abstr. Rev. 54:389.

Owens, F. N., P. Dubeski, and C. F. Hanson. 1993. Factors that alter the growth and development of ruminants. J. Anim. Sci. 71: 3138–3150.

Owens, F. N., D. R. Gill, D. S. Secrist, and S. W. Coleman. 1995. Review of some aspects of growth and development of feedlot cattle. J. Anim. Sci. 73:3152–3172.

Owensby, C. E., R. C. Cochran, R. T. Brandt, Jr., E. S. VanZant, L. M. Auen, and E. M. Clary. 1995. Grain supplementation on bluestem range for intensive-early stocked steers. J. Range Manage. 48:246–250.

Paisley, S. I., G. W. Horn, C. J. Ackerman, B. A. Gardner, and D. S. Secrist. 1998. Effects of implants on daily gains of steers dry-wintered on native tallgrass prairie, subsequent performance, and carcass characteristics. J. Anim. Sci. (In Review).

Perry, T. W., D. A. Huber, G. O. Mott, C. L. Rhykerd, and R. W. Taylor. 1971. Effect of level of pasture supplementation on pasture, drylot and total performance of beef cattle. I Spring pasture. J. Anim. Sci. 32:744–748.

Perry, T. W., D. A. Huber, G. O. Mott, C. L. Rhykerd, and R. W. Taylor. 1972. Effect of level of pasture supplementation on pasture, drylot and total performance of beef cattle. II. Spring plus summer pasture. J. Anim. Sci. 34:647–652.

Phillips, W. A., J. W. Holloway, and S. W. Coleman. 1991. Effect of pre- and postweaning management system on the performance on Brahman crossbred feeder calves. J. Anim. Sci. 69: 3102–3111.

Reid, R. L., G. A. Jung, J. M. Cox-Ganser, B. F. Rybeck, and E. C. Townsend. 1990. Comparative utilization of warm- and cool-season forages by cattle, sheep and goats. J. Anim. Sci. 68: 2986–2994.

Ridenour, K. W., H. E. Kiesling, G. P. Lofgreen, and D. M. Stiffler. 1982. Feedlot performance and carcass characteristics of beef steers grown and finished under different nutrition and management programs. J. Anim. Sci. 54:1115–1119.

Robelin, J., and Y. Chilliard. 1989. Short-term and long-term effects of early nutritional deprivation on adipose tissue growth and metabolism in calves. J. Dairy Sci. 72:505–513.

Rohr, K., and R. Daenicke. 1984. Nutritional effects on the distribution of live weight as gastrointestinal tract fill and tissue components in growing cattle. J. Anim. Sci. 58:753–765.

Rush, I., B. Weichenthal, and B. Van Pelt. 1989. Implants for grazing yearling steers and their effect on feedlot performance. Nebraska Beef Cattle Rep. MP54, Nebraska Agric. Exp. Sta., Lincoln. pp 33–34.

Sankoh, F.A.-R., and R. J. Boila. 1987. Injectable copper and zinc for grazing yearling steers. Can. J. Anim. Sci. 67:1033–1041.

Simms, D. D., T. B. Goehring, R. T. Brandt, Jr., G. L. Kuhl, J. J. Higgins, S. B. Laudert, and R. W. Lee. 1988. Effect of sequential implanting with zeranol on steer lifetime performance. J. Anim. Sci. 66:2736–2741.

Stabel, J. R., J. W. Spears, and T. T. Brown, Jr. 1993. Effect of copper deficiency on tissue, blood characteristics, and immune function of calves challenged with infectious bovine rhinotracheitis virus and *Pasteurella hemolytica*. J. Anim. Sci. 71:1247–1255.

Stock, R., T. Klopfenstein, D. Brink, S. Lowry, D. Rock, and S. Abrams. 1983. Impact of weighing procedures and variation in protein degradation rate on measured performance of growing lambs and cattle. J. Anim. Sci. 57:1276–1285.

Tarr, S. L., D. B. Faulkner, D. D. Buskirk, F. A. Ireland, D. F. Parrett, and L. L. Berger. 1994. The value of creep feeding during the last 84, 56, or 28 days prior to weaning on growth performance of nursing calves grazing endophyte-infected tall fescue. J. Anim. Sci. 72:1084–1094.

Tolley, E. A., M. W. Tess, T. Johnson, and K. R. Pond. 1988. Effects of switching diets on growth and digesta kinetics of cattle. J. Anim. Sci. 66:2551–2567.

Waldo, D. R., G. A. Varga, G. B. Huntington, B. P. Glenn, and H. F. Tyrrell. 1990. Energy components of growth in Holstein steers fed formaldehyde- and formic acid-treated alfalfa or orchard-grass silages at equalized intakes of dry matter. J. Anim. Sci. 68:3792–3804.

Wardrop, I. D. 1966. The effects of plane of nutrition in early post-natal life on the subsequent growth and development of cattle. Aust. J. Agric. Res. 17:375.

White, T. W., F. G. Hembry, P. E. Humes, and A. M. Saxton. 1987. Influence of wintering weight change on subsequent pasture and feedlot performance by steers. J. Anim. Sci. 64:32–35.

Wilson, P. N., and D. F. Osbourn. 1960. Compensatory growth after undernutrition in mammals and birds. Biol. Rev. 35:324–363.