PROTEIN AND ENERGY SUPPLEMENTS IN RANGE BEEF PRODUCTION SYSTEMS

by

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DISSERTATION TITLE

Protein and Energy Supplements in Range

Beef Production Systems

BY

L. Aaron Stalker

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PROTEIN AND ENERGY SUPPLEMENTS IN RANGE

BEEF PRODUCTION SYSTEMS

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University of Nebraska, 2005

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Protein and energy supplements are often required to achieve optimal production efficiency in range beef production systems. A series of experiments evaluated the use of protein and energy supplements in multiple beef production systems.

Spring calving cows were used to evaluate the influence of supplemental protein prepartum and grazing sub-irrigated meadow postpartum on pregnancy rates and calf feedlot performance. Feeding supplement prepartum did not affect pregnancy rate but calves born to cows fed supplement were heavier at weaning. Allowing cows to graze subirrigated meadow improved body condition score pre-breeding and calf weaning weight but did not affect pregnancy rate. Feedlot performance and carcass weight were not affected by either prepartum or postpartum treatment.

Spring-calving, crossbred heifers were used to compare two wintering systems. The control treatment included native range, supplement and hay. The treatment system relied on grazing and dried distillers grains based supplement. Heifers in the treatment system were heavier, had greater BCS at end of supplementation and heavier calves at

birth and weaning but subsequent pregnancy rates were similar between systems. The treatment system cost $8.16/heifer less than the control.

Three experiments evaluated the influence of dried distillers grains supplementation frequency on forage digestibility and growth of yearlings. Diet digestibility decreased as dried distillers grains supplementation frequency decreased and heifers and steers fed dried distillers grains more frequently has greater average daily gain.

Two experiments evaluated supplemental degraded intake protein requirements when dried distillers grains were fed in excess of metabolizable protein requirements. Base diets were formulated to be greater than 100 g/d deficient in degradable intake protein. In both experiments, no response in performance was observed when degradable intake protein was added to the diet. Sufficient endogenously produced urea was probably recycled to correct the degradable intake protein deficiency. Adding urea is not necessary when dried distillers grains are fed in excess of the metabolizable protein requirement in forage based diets.

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LITERATURE REVIEW

Introduction

Beef production systems are comprised of a series of segments with potential complex interactions. Management changes in one segment may influence productivity of the entire system not just the segment in which the change occurs. Therefore, changes should be evaluated in the context of the entire system. Beef production in extensive, forage based settings presents unique challenges. Forage quality is dynamic and creates seasonal nutrient deficiencies during specific segments of the system that do not support optimal animal performance. Intervention, especially in the form of specific nutrient supplementation, may or may not enhance efficiency of that segment but its effects may carry over into other segments and influence the entire system.

The most profitable cow/calf operators are those with low per unit production costs not necessarily those with greatest product output. To be advisable an expense must return more than it costs. Since protein is typically the most expensive supplemental nutrient finding ways to reduce costs associated with protein supplementation can make significant improvements in economic efficiency. Greater understanding of cow protein requirements will facilitate greater precision in supplement feeding. To accomplish this, management strategies and recommendations applicable to extensive production systems need to be developed.

Objectives of this literature review are to 1) examine the relationship between body energy reserves and reproduction, 2) discuss appropriate supplements for forage-

based beef systems and their influence on productivity, and 3) evaluate the use of urinary purine derivatives as a marker for microbial protein production.

Body Condition Score

The nutritional status of an animal is reflected in body reserves available for basic metabolism, growth, reproduction, lactation or activity and can be evaluated by body condition score (BCS; Wright et al., 1987). Jefferies (1961) developed a method for subjectively assessing body condition of sheep with high correlation ($r^2 = 0.94$) to percentage of fat in fleece-free empty body. The BCS system most commonly used in the beef industry (NRC, 1996) was first used by Lowman et al. (1976) who adapted Jefferies' (1961) scoring system to use in cattle. Subsequent research by Wagner et al. (1988) demonstrated BCS assigned to beef cows by palpation and visual observation accounts for 85% of the variation in carcass energy content. Results of Houghton et al. (1990b) support the conclusion that body condition score accurately estimates body energy content.

Relationship between Body Condition Score and Reproduction

Reproduction in beef cows is closely related to body energy reserves. Level of prepartum nutrition, as indicated by BCS at calving, is the most important determinant of length of postpartum interval and pregnancy rate in multiparous beef cows (Richards et al., 1986; Selk et al., 1988). Body condition score at parturition is negatively correlated with length of postpartum anestrous (Wright et al., 1987, 1992). Lamond (1970) was first to propose the concept of a target BCS at calving and Dzuik and Bellows (1983)

suggested a minimum BCS of five (1-9 scale) at parturition was the critical level affecting subsequent reproduction. This suggestion of a BCS of five has been substantiated (Richards et al., 1986; Morrison et al., 1999) and is consistent across multiple breeds (Tinker et al., 1989). If cows calve in BCS five, d to first estrus and ovulation are reduced (Wettemann et al., 2003) and is independent of previous nutritional plane.

Mature beef cows experiencing large changes (either increases or decreases) in body energy reserves during late gestation that result in a BCS of 5 at calving have pregnancy rates similar to cows maintained at a BCS of 5 from late gestation to calving (Morrison et al., 1999). Results of DeRouen et al. (1994) support the concept that prepartum changes in BW and/or BCS are of little consequence on pregnancy rates, provided target BCS is reached by parturition.

Level of nutrition during early lactation also influences subsequent reproduction (Randel, 1990). First-calf heifers fed to gain 0.9 kg/d postpartum have a shorter interval to first estrus and ovulation, a larger dominant follicle, and increased first service conception rates compared to heifers fed to gain only 0.45 kg/d postpartum (Spitzer et al., 1995; Ciccioli et al., 2003). Similar results have been observed in cows. Cows fed to gain BW postpartum have greater pulse frequency of LH, appearance rate of small and large follicles, shorter interval from parturition to ovulation and greater percentage of cows that ovulate by a fixed number of d after parturition (Perry et al., 1991). Improved reproduction in response to increased postpartum nutritional plane may be influenced by prepartum BCS. If cows were a BCS of five or greater at calving postpartum nutritional

plane did not improve productivity but increased postpartum nutritional plane did improve productivity of cows that calved in a BCS of 4 or less (Richards et al., 1986).

Notwithstanding the fact that BCS at calving is the most important determinate of subsequent pregnancy rate with traditional management (Richards et al., 1986), production systems that capitalize on improved reproduction resulting from high postpartum nutritional plane may be more economical. This concept has been termed weight cycling. Freetly et al. (2000) fed mature cows to 1) maintain a BCS from the second trimester of gestation until start of breeding, 2) lose BCS during the second trimester but regain BCS during the third trimester of gestation to calve at a BCS similar to cows that maintained BCS, or 3) lose BCS during the second trimester but regain BCS after the first 28 d of lactation to reach a similar BCS as the other treatments by the start of the breeding season. Pregnancy rates and calf weaning weights were not different among treatments but DMI was less for cows fed to lose and regain BCS during early lactation. A follow-up study using heifers and young cows yielded similar results (Freetly et al., 2005). These results suggest feed costs can be reduced without sacrificing performance by allowing cows to lose weight during gestation then regain before start of breeding.

Supplementation

Requirements

The metabolizable protein system (NRC, 1996) separates nitrogen requirements of ruminal microorganisms and host protein requirements. Dietary nitrogen degraded in

the rumen is termed degraded intake protein (DIP) and serves as the primary source of nitrogen from which ruminal microorganisms synthesize protein. Dietary protein not degraded in the rumen passes to the small intestine where it is subjected to enzymatic digestion and is termed undegraded intake protein (UIP). Microbial protein and undegraded intake protein absorbed by the intestine constitute metabolizable protein.

A discussion of beef cow metabolizable protein requirements must address both degraded and undegraded intake protein requirements. Degraded intake protein requirements are considered by the NRC (1996) equal to microbial crude protein production. Microbial crude protein production is a function of dietary fermentable energy content. Protein of microbial origin may be sufficient to meet metabolizable protein requirements under conditions of maintenance (NRC, 1985). However, under conditions of greater productivity, such as growth or lactation microbial protein may not be sufficient to meet requirements and addition of undegraded intake protein may be necessary (Klopfenstein, 1996; NRC, 2001).

Influence of Supplementation on Forage Intake and Digestibility

Protein supplementation: Nutrient content of grazed forage often does not support desired production. Supplements containing energy and protein are often fed to grazing animals to correct dietary nutrient deficiencies and enhance performance (Allison, 1985; Caton and Dhuyvetter, 1997). Examples of increased performance of beef cattle grazing low quality forage in response to protein supplementation abound in the literature (DelCurto et al., 2000). Low quality forage does not supply sufficient nitrogen to support optimal microbial growth in the rumen. Positive associative effects result from

supplementing poor quality diets with degradable intake protein, thus promoting microbial growth, fermentation and passage rates, and intake (Kartchner, 1980; McCollum and Galyean, 1985; Caton et al., 1988; DelCurto et al., 1990b; Köster et al., 1996; Allen, 2000). There has been considerable interest in using NPN as a source of degraded intake protein because it is the least expensive source of crude protein (DelCurto et al., 2000). Numerous research studies have evaluated the incorporation of urea into beef cattle diets since it was first used in the 1940's (Kellems and Church, 2002). In general, NPN sources are not as effective as natural proteins when fed to cattle consuming low-quality diets (Williams et al., 1969; Oltjen et al., 1974; Rush and Totusek, 1976). Köster et al. (1997) substituted urea for sodium caseinate on an equal N basis and observed decreased ruminal and total tract OM and NDF digestibility of tallgrass prairie forage. The efficacy of NPN as a degraded intake protein source may depend on its level of inclusion. Farmer et al. (2004b) concluded comparable cow performance can be achieved when urea comprises less than 30% of supplemental degraded intake protein but greater levels may result in reduced performance. Various theories exist to explain less than expected performance when non-protein nitrogen is supplemented (DelCurto et al., 2000). Reduced performance may be related to the lack of carbon skeletons (preformed AA, branched chain VFA), sulfur and other nutrients supplied by natural protein sources but not NPN (Chalupa, 1968; Russell et al., 1992). With the exception of NPN, most protein supplements also contain other nutrients, especially energy.

Energy supplementation: Energy supplements containing non-structural carbohydrates, such as cereal grains, may exert a negative associative effect on forage

intake and digestibility (Chase and Hibberd, 1987, Sanson et al., 1990; Pordomingo et al., 1991; Olson et al., 1999; Bodine and Purvis, 2003). Reasons for decreased forage intake and digestibility when non-structural carbohydrates fed in forage-based diets include: low ruminal pH, increased lag time, and competition between cellulolytic and amylolytic microorganisms.

A major reason fiber digestion is depressed when non-structural carbohydrates are supplemented is because starch digestion lowers rumen pH. Products (volatile fatty acids and lactic acid) of starch fermentation reduce rumen pH to levels that inhibit fibrolytic microorganism (Mould and Ørskov, 1983; Mould et al., 1983). Caton and Dhuyvetter (1997) suggested depressed ruminal pH can not fully explain all instances of reduced intake and digestibility often observed when forage-fed beef cattle are supplemented with grain. Depressed fiber digestion is often observed when low-protein, high-starch supplements are fed to cattle consuming low quality forage. In this situation, ruminal microorganisms capable of fermenting starch may out compete fiber fermenting microorganisms for limited degraded intake protein (Chase and Hibberd 1987; Paterson et al., 1996). Additionally, fibrolytic bacteria may preferentially utilize nutrients supplied by non-structural carbohydrates in favor of less accessible nutrients supplied by structural carbohydrates, thus creating a lag in fiber digestion (Mertens and Loften, 1980; Hoover, 1986). Ensuring microbial protein requirements are met by balancing the diet for degraded intake protein may improve animal performance when supplements contain non-structural carbohydrates (Bodine and Purvis, 2003; Bowman et al., 2004).

It is important to point out forage intake and digestibility are not always depressed when non-structural carbohydrates are fed (Caton and Dhuyvetter, 1997; Bodine and

Purvis, 2003; Bowman et al., 2004). Furthermore, decreased forage intake and digestibility may be desirable under circumstances of limited forage quantity or when non-structural carbohydrates are a less expensive source of energy than forage (Bowman and Sanson, 1996). Total digestible organic matter intake may increase with low levels of non-structural carbohydrate supplementation (Goetsch et al., 1991; Pordomigo et al., 1991) and may therefore represent a viable management alternative in forage-based beef production.

In contrast to non-structural carbohydrates, energy supplements containing highly digestible structural carbohydrates, such as soybean hulls, beet pulp, wheat midds, and corn milling co-products, do not depress forage intake and digestibility to the same extent as supplements containing non-structural carbohydrates (Bowman and Sanson, 1996; Caton and Dhuyvetter, 1997). Supplements containing these feedstuffs may be more appropriate when maximal use of forage resources is desired (Kunkle et al., 2000).

Fat supplementation: Supplements containing high levels of fat inhibit fermentation of structural carbohydrates in the rumen (Moore et al., 1986; Keele et al., 1989). This is thought to occur by multiple mechanisms (Jenkins, 1993). One theory posits direct antimicrobial effects of lipids. Addition of fatty acid to pure cultures of ruminal bacteria decreases growth and metabolic rates (Maczulak, et al., 1981). A second theory explaining effects of fat supplementation on fermentation of structural carbohydrates is coating of feed particles. Fatty acids are known to become associated with feed particles (Harfoot et al., 1974) forming a lipid layer that supposedly prevents the requisite close contact of microbes or their enzymes with feed particles.

Degree to which supplemental fat inhibits structural carbohydrate fermentation depends on fat content of basal diet, source of supplemental fat (NRC, 2001), and level of supplementation. Unsaturated fatty acids restrict fermentation more than saturated fatty acids (Palmquist and Jenkins, 1980) and free fatty acids inhibit fermentation to a greater degree than do lipids without a free carboxyl group, such as, Ca salts of long chain fatty acids, fatty alcohols, fatty acyl amides, and triglycerides (Jenkins, 1993). Amount of supplemental fat is also important. Diets containing more than 6% ruminally active fat typically depress fiber digestion (Allen, 2000).

Forage quality dynamics: Amount of supplemental nutrient required to improve forage intake and digestibility of grazing cattle in extensive production situations is a function of forage nutrient supply. Forage energy and protein content decline as the grazing season progresses (Powell et al., 1982; Yates et al., 1982; McCollum et al., 1985; Adams et al., 1987). In addition to energy and crude protein, Lardy et al. (2004) provided estimates of forage DIP and UIP content dynamics and highlighted the importance of understanding these changes when formulating supplements to meet nutrient requirements of cows grazing native rangelands.

Supplementation frequency: Supplemental feeds represent a significant portion of variable costs of beef production. In the Northern Great Plains, purchased feeds comprise 33% of the annual operating costs (USDA, 2001). One way to reduce cost associated with supplementation is to reduce the frequency supplements are provided.

Infrequent feeding of non-structural carbohydrates frequently results in decreased performance relative to daily feeding. Kartchner and Adams (1982) fed corn to cows grazing dormant range either daily or every-other-d. Cows supplemented daily gained 65

kg while cows supplemented every-other-d gained only 31 kg during the 10-wk supplementation period. Beaty et al. (1994) reported cow BW and BCS loss were modestly increased when corn- and sorghum-based supplements were fed three times per wk compared to daily feeding.

In contrast to non-structural carbohydrates, numerous studies show infrequent feeding of protein supplements is as effective as daily feeding. Feeding supplements as infrequently as 1d/wk was as effective at maintaining steer growth performance (McIlvain, and Shoop, 1962) and cow BW and BCS (Huston et al., 1999; Bohnert et al., 2002b) as was daily feeding. Infrequent feeding of supplements containing moderate amounts of non-protein nitrogen results in similar cow performance and rumen function (Currier et al., 2004a, b) but performance can be negatively impacted when non-protein nitrogen comprises a large percentage of infrequently fed supplemental CP (Farmer et al., 2004b). Studies have shown undegraded intake protein concentration of a supplement does not effect how often it may be fed (Bohnert et al., 2002a, c). While infrequent feeding of protein supplements generally results in similar performance, some studies have demonstrated marginally reduced BW and BSC in cows fed protein supplements infrequently while grazing range (Beaty et al., 1994; Farmer et al., 2001). Recycling of nitrogen to the rumen is likely the mechanisms whereby equivalent performance is maintained when supplementation frequency is reduced.

Nitrogen recycling: Except some proteins and nitrogen associated with acid detergent fiber, all sources of dietary and endogenous nitrogen are subjected to degradation in the rumen (NRC, 1985). Many cellulolytic bacteria prefer or require nitrogen in the form of ammonia and have the requisite enzymatic machinery for

conversion of dietary nitrogen to ammonia (Russell et al., 1992). It is estimated 50 % of nitrogen intake passes through the ammonia pool (Parker et al., 1995) and 40 to 68 % of microbial protein is derived from ammonia, depending upon dietary protein source (Hristov and Broderick, 1994).

Ammonia not incorporated into microbial cells diffuses across the digestive tract and percentage of nitrogen intake absorbed as ammonia ranges from 16 to 73% (Huntington and Archibeque, 2000). Ammonia is highly toxic and removed from the blood by the liver (Reynolds, 1992). The most common route of ammonia detoxification is ureagenesis. The liver has a large capacity to produce urea with amounts as great as 386 g/d being reported in the literature (de Visser et al., 1997). The liver releases urea into the blood where it has two fates. Urea is either excreted in urine or is recycled to the digestive tract by two methods: diffusion into saliva or across the gastrointestinal wall (Huntington and Archibeque, 2000).

In ruminants, urea production, recycling and excretion depend on diet, level of intake and physiological status of the animal. According to Huntington and Archibeque (2000) 19 to 96 % of endogenous urea production is recycled to the gastrointestinal tract while 25 to 60 % is excreted in the urine. Increasing dietary nitrogen and ruminal ammonia concentrations decreases rate of urea recycling while increasing diet energy content, saliva production and plasma urea concentration increases rate of recycling to the rumen (Kennedy and Milligan, 1980). Saliva tends to be the most important route of urea recycling to the rumen when dietary nitrogen concentration is high (Huntington, 1989).

Bacteria associated with the ruminal epithelium express urease activity and rapidly convert urea to ammonia which then enters the ruminal ammonia pool. Between 0 and over 80% of the ammonia resulting from urea hydrolysis is incorporated into bacterial nitrogen, depending on dietary energy and nitrogen concentrations (Bunting et al., 1989). Recycling of endogenously produced urea represents a constant source of nitrogen to support microbial growth (Huntington and Archibeque, 2000) and has been implicated as a reason for successful reduction in protein supplementation frequency (NRC, 1996; Farmer et al., 2004a).

Dried distillers grains as a supplement in forage-based beef systems: Dried distillers grains (DDG) is a co-product of fuel ethanol production and its nutritive profile makes DDG an attractive supplement in forage-based production systems. Dried distillers grains is an excellent source of protein, energy, and phosphorous (Stock et al., 2000). Non-structural carbohydrates in cereal grains, most commonly corn and sorghum in the United States, are converted to ethanol and carbon dioxide during fermentation. As a result of starch removal, nutrient concentrations are approximately three times greater in dried distillers grains than in the original grain (Spiehs et al., 2002). Dried distillers grain's high energy content is attributed to highly digestible fiber and fat. Loy (2003) found the energy value of DDG in forage diets to be approximately 125% the value of corn. Additionally, DDG contain approximately 30% CP, about 65% of which is UIP. Undegraded intake protein is of value to growing cattle consuming forage based diets (Klopfenstein, 1996; Patterson et al., 2003). As a further asset, DDG contain approximately 0.6% phosphorous, a nutrient commonly deficient in forage diets

(McDowell, 1996). When one considers the nutrient profile in light of the ever increasing supply, DDG is an ideal supplement for growing cattle consuming forage based diets.

Influence of Supplementation on Subsequent Productivity

Calf growth: Protein supplements improve the nutritional status of cows as indicated by increased body condition score. Several studies have shown reduced BW and BCS loss as a result of feeding a protein supplement to pregnant cows grazing dormant range (DelCurto et al., 1990a, Hollingworth-Jenkins et al., 1996; Mathis et al., 1999). This increased nutritional status of the cow may impact postpartum growth of the calf. Beaty et al. (1994) demonstrated increased calf weaning weight as amount of CP fed during gestation increased. Feeding energy deficient diets, beginning 100 d prepartum, to heifers and 2 yr old cows resulted in lighter weight and fewer live calves at weaning (Corah et al., 1975).

Postpartum nutritional plane can also influence weaning weight of the calf. Increased weaning weight of calves nursing heifers on a high plane of nutrition postpartum was observed by Spitzer et al. (1995). Richards et al. (1986) found lighter weaning weights of calves that nursed cows fed low energy levels postpartum. Increasing the amount of degraded and undegraded protein in the postpartum diet increased calf weaning weight in a study conducted by Rusche et al. (1993).

Several studies have examined the interaction between nutritional plane pre- and postpartum and calf growth. Houghton et al. (1990a) documented greater weight 105 d postpartum in calves born to cows fed to maintain weight prepartum and of calves born to