METABOLIZABLE PROTEIN REQUIREMENTS OF EARLY LACTATING BEEF COWS GRAZING DORMANT NATIVE RANGE

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Bachelor of Science

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1994

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
July, 1998

OKLAHOMA STATE UNIVERSITY

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ACKNOWLEDGEMENTS

I thank God for creating all animals and especially the ruminant animal as complex as He did. Unraveling the mysteries which lie hidden within it has been a constant challenge and source of happiness, excitement and also frustration for many men and women in the past, present, and no doubt, in years to come.

I would like to thank my advisor, Doctor D. L. Lalman, and my committee members, Doctors G. W. Horn and R. P. Wettemann, for the time and effort that they invested in me. I appreciate their advice throughout my program and review of this manuscript. Donna Perry, Carolyn Lunsford, LaRuth Mackey, David Cox, Mark Anderson, Randy Jones and Steve Welty were all invaluable in enabling me to complete this program.

Special appreciation goes to my parents, Marice and Yvonne Vermeulen, who through their example, taught me and my sisters, Sharon and Maryvonne, to live life to its fullest and to pursue all opportunities. Their continuous love and caring and the home they created for us are all things that we will strive to give to our children.

I dedicate this thesis to Philip Stander, who's constant love, support and reassurance has carried me for many miles. To Philip: I truly am a lucky woman!

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CHAPTER I

INTRODUCTION

One of the primary characteristics of the ruminant animal is the complexity of its digestive system. Because the protein requirements of ruminants are met by both microbial protein and dietary protein that escapes digestion in the rumen this complexity is especially true for protein digestion.

In the past, protein requirements of beef cattle were expressed in terms of crude protein. This system predicts animal protein requirement by accounting for nitrogen losses in the form of metabolic fecal nitrogen, urinary nitrogen and scurf as well as nitrogen required for growth, fetal growth during gestation and milk production (NRC, 1984). The crude protein system assumes that all feedstuffs have equal protein degradation in the rumen. In 1985 a new system for predicting protein requirement was introduced which included an estimate for bacterial protein supply to the animal (NRC, 1985). This system, known as the metabolizable protein system, accounts for protein degradation in the rumen and separately predicts protein requirements for the microorganisms in the rumen and the host animal (NRC, 1996). Metabolizable protein is defined as the true

protein which is absorbed by the intestine and supplied by both microbial protein and protein which escapes degradation in the rumen (NRC, 1996).

Postpartum beef cows have high protein and energy requirements due to lactation and postcalving tissue regeneration. A lactating cow producing 4 kg milk/d requires substantially more TDN (1.3 kg/d) than a steer gaining 1.5 kg/d (Owens et al., 1991). In addition, cold stress may further increase protein requirements of beef cows (NRC, 1996). In Oklahoma, spring calving cows often graze dormant native range and are subject to harsh weather conditions in the first few months after calving, a time which coincides with peak milk production. The nutritive value of dormant winter range in Oklahoma is typically low and crude protein may fall below 3% of DM (Waller et al., 1972). Low forage quality is directly related to low dry matter digestibility and indirectly to a decrease in dry matter intake, resulting in decreased animal performance. Dormant native range does not meet the lactating cows' protein and energy requirements and thus supplementation is necessitated. It is well documented that supplementation with ruminally available nitrogen may increase feed intake and performance due to an increased digestibility of the forage (Van Soest, 1982; Paterson et al., 1994; Köster et al., 1997).

Commercial range supplements are formulated on the basis of crude protein. In Oklahoma, a standard industry practice is to supplement lactating beef cows grazing dormant native range with approximately three pounds of a 40% crude protein supplement daily. Since the nutrient requirements of the

rumen microorganisms and the animal are not accounted for separately, this practice generally exceeds degradable intake protein (DIP) requirement while under providing undegradable intake protein (UIP). Consequently, the metabolizable protein requirement of the animals is not met.

The objective of this study was to determine the early lactation metabolizable protein requirement of spring calving beef cows grazing native winter range in Oklahoma.

CHAPTER II

LITERATURE REVIEW

Metabolizable Protein System

The metabolizable protein system makes use of two protein fractions to predict the protein requirement of animals: protein that is degraded in the rumen and utilized by the ruminal microorganisms for the synthesis of microbial protein, primarily bacterial crude protein (BCP) and that fraction of crude protein which escapes digestion in the rumen. Metabolizable protein is that which is available to the animal for maintenance, growth, fetal growth during gestation and milk production. Bacterial crude protein contains about 80% amino acids or bacterial true protein (BTP) since approximately 20% of BCP is present in the form of nucleic acids (Owens and Zinn, 1988). The digestibility of BTP is estimated to be about 80%, giving the conversion of BCP to metabolizable protein (MP) a coefficient of 0.64. Undegradable intake protein (UIP) is also assumed to be about 80% digestible, giving a coefficient of 0.80 for the conversion of UIP to MP. Metabolizable protein requirements can be expressed as estimated crude

protein (CP) requirements. These estimates are obtained by dividing the MP requirement by a value ranging between 0.64 and 0.80, depending on the extent to which the dietary protein is degraded within the rumen. The coefficient of 0.64 would be used when all of the dietary protein is DIP (NRC, 1996).

Depending on the amount of UIP supplied in the diet, 50-100% of the MP required by beef cattle can be supplied by BCP (NRC, 1985). Owens and Zinn (1988) suggested a greater range in which microbial nitrogen can comprise about 40-100% of the non-ammonia nitrogen entering the small intestine. For ruminants fed most diets, it was suggested that microbial protein generally makes up about 50% of the protein digested in the small intestine (Owens and Bergen, 1983).

In terms of meeting the protein requirements of beef cattle, it is economically important to optimize BCP synthesis. Because DIP requirements are directly related to BCP synthesis, it is important to accurately predict BCP synthesis.

Metabolizable Protein Requirements and Metabolizable Protein Efficiency

Metabolizable protein requirements for maintenance are based on metabolic body weight ($BW^{0.75}$). The value of 3.8 g MP/kg $BW^{0.75}$ is used as estimated by Wilkerson et al. (1993) based on the growth performance of 253 kg growing calves. The calves were fed diets high in roughage and it was assumed

that BCP synthesis was equal to 13% of TDN. This value of 3.8 g MP/kg $BW^{0.75}$ was supported by Susmel et al. (1993) from results based on nitrogen balance data.

Metabolizable protein requirements for growth, fetal growth and milk production are dependent on both the stage and the level of production as well as the efficiency with which the MP is converted to net protein (NP). This efficiency of MP use is in turn a function of the biological value (relative amino acid balance) of the MP and the efficiency with which an ideal combination of amino acids would be used (Oldham, 1987). Oldham (1987) suggested that the efficiency is constant for all physiological functions at 0.85. Biological values of proteins will vary depending on the source of UIP in the diet, and Oldham (1987) also indicated that biological values will vary for different production functions, being higher for pregnancy and lactation than for gain. Zinn and Owens (1983) reported the average biological value of absorbed amino acids to be 66%. The coefficient for the conversion of MP to NP is thus a multiple of these factors and assumed to be 0.65 for milk production and 0.50 for gain (NRC, 1985).

Because body compostion changes as body size increases, the efficiency of MP use for growth is not constant but will decrease as body weight increases. This is clearly illustrated by Anslie et al. (1993) and Wilkerson et al. (1993) where the efficiency in the case of a 150-kg calf is calculated to be 0.66 while it would be 0.49 for a 300-kg steer.

Microbial Protein Synthesis and Degradable Intake Protein Requirement

In 1974 it was suggested that BCP synthesis averages 13.05% of the total digestible nutrients (TDN) (Burroughs et al., 1974). This value was based on the evaluations that 52% of ration TDN undergoes digestion within the rumen and that 25% of the digested TDN is transformed into microbial crude protein. Therefore, at an 80% true digestibility for BCP (based on cattle and sheep metabolism trials), protein available for utilization by the animal will be 10.4% of TDN (Burroughs et al., 1974; Burroughs et al., 1975). In 1985 the National Research Council (NRC) developed an equation to predict BCP synthesis and calculated BCP synthesis to be 12.8% of TDN intake for diets containing more than 40% forage. Bacterial crude protein (g/d) was calculated to be equal to intake (kg/d) multiplied first by 26.12 TDN - 31.86 and then by the coefficient of 6.25 (NRC, 1985).

Since DIP requirements are generally expressed as a percentage of digestible OM or TDN, the amount of DIP required by an animal will depend on the level of intake and the digestibility of the diet. Digestible OM and TDN are considered to be roughly equivalent in feedstuffs and diets (NRC, 1996). The NRC (1996) also considers DIP requirement equal to BCP synthesis. Ruminal bacteria enzymatically fixate ammonia nitrogen to carbon with an efficiency of 1.0 to synthesize bacterial protein and therefore DIP requirement and BCP synthesized have a ratio of 1:1.

Although BCP is generally assumed to be 13% of TDN, much variation exists. Hollingsworth-Jenkins et al. (1996) concluded that DIP was only required at 7.1% of the digestible organic matter (OM) to meet the needs of gestating beef cows grazing native winter Sandhills range. Karges (1990) found the DIP requirement of beef cows fed native range hay to be only 10.9% of TDN in order to maximize forage digestion and microbial protein synthesis. This value corresponds closely to the value observed by Köster et al. (1994) where DIP requirements were determined to be approximately 11% of TDN. Lardy et al. (1997a) determined the DIP requirements for summer calving cows grazing dormant native Sandhills range to be similar to those of spring calving cows at 9-10% of the digestible OM intake. From a database compiled by Cochran (1995) and which included numerous supplementation trials, it was calculated that DIP should compose approximately 10% of the total digestible material in the diet. Hoover and Stokes (1991) determined that the DIP requirement may have to be about 14% of dietary DM to optimize microbial protein synthesis. These differences reported in DIP requirement may be due to the type of diet consumed by the cattle in the various trials and/or to differences in response criteria used to determine when DIP was adequate (Paterson et al., 1996).

Efficiency of Microbial Protein Synthesis

The efficiency of BCP synthesis is decreased in the case of low quality forages since more energy is used for microbial maintenance in the rumen when the passage rate is decreased (NRC, 1985; Russel and Wallace, 1988; Russel et al., 1992). Russel et al. (1992) suggested that for every 1% decrease in forage effective neutral detergent fiber (eNDF) below 20% NDF, BCP synthesis is reduced by 2.5%. Microbial efficiency is therefore also reduced at intake levels which are low enough to reduce the rate of passage. When using an equation to predict BCP synthesis, the NRC (1996) suggests that BCP synthesis could be as low as 8% with low TDN (50-60%) diets and intakes at 1.9-2.1% of BW. Sniffen et al. (1992) indicated that the amount of nitrogen or carbohydrate that is digested in the rumen is determined by the relative rates of degradation and passage, and that ruminal passage rates in turn are a function of DM intake, particle size, bulk density and the type of feed that is consumed.

For high energy diets, BCP usually makes up a smaller percentage of TDN as lower pH values will also result in slower microbial turnover (NRC, 1996). For a 10% roughage diet BCP is predicted at 8% of TDN (NRC, 1985). Spicer et al. (1986) determined the ruminal and post-ruminal utilization of nitrogen and starch from sorghum grain-, corn- and barley-based diets and found BCP to be 10.8% of digestible OM. Furthermore, the efficiency of BCP synthesis can also be affected by the nature of the dietary protein since ruminal

amino acids and peptides could result in a greater rate and amount of BCP synthesized compared to ammonia (Russel et al., 1992). The ruminal bacterial population can broadly be divided into two groups: those that ferment structural carbohydrate (SC) and utilize primarily ammonia as a nitrogen source and those that ferment nonstructural carbohydrate (NSC) and can utilize either ammonia or peptides. Russel et al. (1992) found that the yield of NSC bacteria was increased by as much as 18.7% when proteins or peptides were available.

Forcherio (1994) also showed that when vegetative tall fescue (24% CP) was fed to lambs and supplemented with increasing quantities of UIP to alleviate a MP deficiency, ruminal digestion of OM was depressed but flows of microbial DM to the duodenum and microbial efficiencies were increased. Milton et al. (1997) reported that steers fed soybean meal had higher total tract starch digestion, duodenal microbial nitrogen flow and efficiency of microbial protein synthesis in the rumen compared with those fed urea-supplemented diets. Supplementation with soybean meal therefore increased MP supply and dietary energy utilization.

However, Rangngang et al. (1997) found that apparent bacterial efficiency and true bacterial efficiency were not affected by blood meal supplementation, but supplementation with blood meal did increase ruminal escape nitrogen and duodenal flows of total and most essential amino acids. In an in vitro study by Jones et al. (1998), it was found that even though the efficiency of conversion of peptide nitrogen to microbial CP increased with

increasing peptides, there was no change in grams of microbial nitrogen produced per kilogram of OM digested. It was thus suggested that in diets high in NSC, excessive peptides can depress protein digestion and ammonia concentrations, resulting in decreased OM digestibility, fiber digestion and total microbial CP production.

Ruminal Ammonia Concentrations, Nitrogen Recycling and Nitrogen Flow

Ruminal ammonia nitrogen stimulates the utilization of ingested fiber by cellulolytic bacteria (Van Soest, 1982). The ruminant has the ability to conserve nitrogen through continually recycling nitrogen to the rumen for re-utilization. This serves as a mechanism to conserve nitrogen which might otherwise be lost via the urine (Schmidt-Nielson, 1977). The NRC (1996) considers DIP requirement equal to BCP synthesis since a deficiency of ruminal ammonia will increase ammonia absorption through the rumen wall into the rumen and increase urea entering the rumen with saliva. In contrast, an excess of ruminal ammonia or low plasma urea concentrations will increase the absorption of ammonia through the rumen wall into the blood stream and increase ammonia flushing from the rumen to the duodenum. Low ruminal ammonia is associated with low nitrogen intake and/or slow protein degradation within the rumen. The ability of the ruminant to compensate for low ruminal ammonia levels is illustrated by Beaty et al. (1994) who reported similar weight and body condition

changes for gestating cows receiving four levels of protein supplementation either daily or only three times per week.

Nitrogen recycling to the rumen equals 10-15% of dietary nitrogen intake with typical diets (Owens and Zinn, 1988). Owens and Zinn also indicated that 23-92% of plasma urea is recycled to the digestive tract and that from 15% to 50% of the total urea recycled can follow the salivary route in the case of forage diets.

Estimates of ruminal ammonia nitrogen requirements are varied and values from as low as 2-5 mg/dl to as high as 23.5 mg/dl have been reported for maximized microbial protein synthesis, nonammonia nitrogen flow to the small intestine and/or rate of digestion (Hume, 1970; Satter and Slyter, 1974; Nikolic et al., 1975; Allen and Miller, 1976; Mehrez et al., 1977). However, Smith (1979) suggested that variation in cell numbers and permeability of cells to ammonia make it improbable that only one concentration of ammonia could maximize microbial growth under various dietary conditions.

Stokes et al. (1988) found that ruminal fluid concentrations of ammonia nitrogen, ruminal fluid dilution rate and particulate passage rate increased with an increase in soybean meal added to the diet. Köster et al. (1996) found similar results when cows consuming low-quality, tallgrass prairie forage were intraruminally infused with increasing levels of DIP in the form of sodium caseinate. Total ruminal ammonia and volatile fatty acid concentrations increased in response to treatment as did microbial nitrogen flow and efficiency,

ruminal fluid dilution rate and true ruminal OM and NDF digestion. Higher rumen ammonia levels were also observed in beef cows when their diets were supplemented with DIP and UIP although the rate of digestion was not affected by protein supplementation (Karges, 1990). Shain et al. (1998) also found a linear increase in nitrogen intake and ruminal ammonia nitrogen concentration with increasing levels of urea supplementation.

In a study in which DIP was replaced by UIP and forage intakes held constant (2.2%), there was no alteration in bacterial flow to the small intestine, forage utilization or rate of passage and no significant differences were observed between treatments concerning the performance of the cows (Peterson et al., 1985). Zinn and Owens (1993) found increased levels of UIP to increase the passage of nonammonia and amino acid nitrogen to the small intestine in feedlot calves but also concluded that excess UIP could possibly limit growth and performance by placing an additional demand on arginine for detoxification of ammonia.

Forage Intake and Forage Digestion

Since animal performance depends on the intake of digestible and metabolizable nutrients, both intake and digestibility are important factors to consider when endeavouring to meet the nutritional requirements of animals. Of the variation in digestible dry matter (DM) or digestible energy intake among

animals and feeds, 60-90% is related to differences in intake while only 10-40% is related to differences in digestibilty (Crampton et al., 1960; Reid, 1961). Intake generally accounts for twice as much variability in digestible DM intake as does digestibility (Milford, 1960; Ingalls et al., 1965). It was also observed that digestible DM intake is more closely correlated with DM intake than with any other feed or animal characteristic and that high correlations would therefore occur between DM intake and metabolizable or net energy intake and therefore also between DM intake and overall animal performance when forages are fed (Milford and Minson, 1966).

The positive correlation between the energy value and protein content of forages is ascribed to a DIP deficiency or adequacy experienced by the ruminal microbes digesting SC rather than an actual increase or decrease of the energy value of forages. Therefore, a protein deficiency decreases digestibility and subsequently also DM intake. This was clearly illustrated by Jones et al. (1995) that supplementing steers fed low quality tallgrass prairie hay (5% CP) with DIP resulted in an increase in digestible dry matter intake and dry matter digestibility while supplementing the same diet with energy in the form of ruminally available starch decreased forage intake and in some cases depressed forage digestion. These results are consistent with those of Olson et al. (1997) where beef steers were fed combinations of three levels of supplemental DIP (casein) and four levels of supplemental ruminally available energy (corn starch). Similar results were also reported by Heldt et al. (1997) who found that total digestible OM

intake was dramatically increased by the provision of supplemental DIP while increasing levels of supplemental starch depressed total digestible OM intake. Total digestible OM intake increased significantly in response to supplemental DIP. In contrast, response to the provision of ruminally available energy did not significantly increase total digestible OM and generally appeared to have a negative effect. When DIP is deficient, starch digesting microorganisms are generally better able to compete for limited DIP than are fiber digesting microorganisms.

As shown in the studies of Jones et al. (1995), Heldt et al. (1997) and Olson et al. (1997), positive responses of supplemental DIP (as apposed to increased supplemental starch) are often due to an increase in both digestion and intake with the proportional response typically being larger for forage intake compared to digestion. This concurs with the observation of Owens et al. (1991) that most of the positive effects of protein supplementation can be attributed to effects on intake and/or digestion. Protein supplementation has in some instances appeared to improve the efficiency of use of absorbed nutrients (Lee et al., 1987). Ruminally available nitrogen and/or protein therefore represents a greater limit to the effective use of low quality forage than does ruminally available energy (Cochran et al., 1998). If DIP supplementation is required, the amount will depend on forage intake, forage digestibility and forage DIP concentration.

When cattle on most low quality forage diets receive sufficient DIP to aproach maximum intake levels, digestibility is approximately 50-60% (Hannah et al., 1991; Beaty et al., 1994; Köster et al., 1994, 1995; Jones et al., 1995). However, in the case of some roughages such as straw and corn residue, digestibility will be lower at about 38-45%.

Protein Intake and Forage Utilization

From a data base compiled from various supplementation trials, Cochran (1995) determined that when forage CP was less than 6.3% the rate of forage intake declined and forage digestion also declined when forage CP levels were inadequate (<7% CP). These data represent 17 different forages (primarily grasses or straw) that ranged from approximately 1.9-17.4% CP and about 37-73% digestibility. Forage intake ranged from about 0.5-2.9% of BW. From the same database it was determined that the rate of digestible forage intake decreased when the amount of DIP intake exceeded 5.5 g/kg of metabolic body weight ($BW^{0.75}$) or 10% of digestible OM. Therefore, to approach maximum total digestible OM intake, a diet with a 50% OM digestibility and a 10% ash content would need to contain 4.5% DIP on a DM basis.

In a study in which cows consuming low-quality, tallgrass-prairie forage were intraruminally infused with increasing levels of DIP in the form of sodium caseinate, digestible OM intake reached a maximum when DIP reached 540 g/d

(4.01 g DIP/kg $BW^{0.75}$ or DIP intake equal to about 11% of digestible OM). In this case a diet with a 50% OM digestibility and a 10% ash content would need to contain about 5% DIP on a DM basis if maximum total digestible OM intakes were to be obtained (Köster et al., 1994; Köster et al., 1996). Cochran (1995) also summarized results of several studies conducted at Kansas State University and found that forage intake increased by an average of 49% and neutral detergent fiber digestion by an average of 22% when the CP concentration in supplements was increased from below 15% to 22-28%.

From another data base compiled from the results of various studies, it was estimated that when forage CP content reached approximately 6% the increase in forage intake plateaued (Bowman et al., 1995). Moore et al. (1995) developed a data base from 30 publications which included results from 58 dried grasses or straws fed alone and with supplements and found that when forage CP was less than 7%, voluntary intake was low and positively related to CP, but when forage CP was above 7%, there was little relationship between intake and CP. When the ratio of digestible OM to CP was greater than 7 (indicating a deficiency of protein relative to digestible energy), it was found that there was a negative relationship between intake and the ratio. For a ratio less than 7 (indicating a balance between protein and digestible energy), it was found that intake was not related to the ratio of digestible OM to CP.

Meeting the nutritional requirements of cattle on native range depends on both supplementation and the quantity and the quality of the forage available as

well as associative effects of nutrients consumed and how these factors interact to affect intake and forage use. Supplementing low quality forage with CP generally increases performance. The response to protein supplementation may be due to one or more of the following factors: increased intake of digestible DM directly from the supplement, increased intake of digestible forage DM in response to increased rate and/or extent of digestion, increased gut fill or increased rate of passage, or increased efficiency of nutrient use (Owens et al., 1991). Peterson (1987) and Paterson et al. (1994) also reported that supplementing protein when forage protein is inadequate increased forage intake or forage digestibility.

For diets deficient in DIP the addition of urea may be beneficial. Shain et al. (1998) included urea in the diets of steers fed dry-rolled corn and found an increase in efficiency of 5.4% and weight gain of 6.6% compared with steers receiving no urea. However, based on the studies of Raleigh and Wallace (1963), Minson (1990) and Köster et al. (1997) in which supplemental protein in the form of urea and/or natural protein was given to animals, Cochran et al. (1998) estimated that a minimum of 25% of the supplemental DIP equivalent should be provided as true protein to come close to maximizing forage intake and digestion.

For forages containing a high level of DIP, supplementation is beneficial in some cases. Phillips et al. (1995) fed wether lambs freshly harvested wheat forage daily and evaluated the effects of supplemental energy and protein on

forage intake, diet digestibility and nitrogen retention. Obtained results suggested that digestible DM intake was increased when supplemental energy or protein was provided. Wheeler et al. (1995) also found that DIP fed to Holstein cows consuming wheat or sorghum silage tended to increase DM intake.

Forage Quality

In order to determine the protein status of ruminants consuming forages it is necessary to know the DIP values and the potential digestibility of the UIP. The challenge to accurately predict required protein supplementation for grazing cows and calves is increased due to the continuous changes in forage composition throughout the year. In general, warm-season grasses have higher levels of UIP than cool-season grasses when expressed as a percentage of total CP. It has been estimated that UIP values for forages range from essentially zero to 3% of DM while the DIP values range from 2-20% of DM (Paterson et al., 1996).

Expressed as a percentage of CP, good quality tallgrass prairie hay has approximately 60% DIP (40% UIP) while winter pasture tallgrass prairie has about 50% DIP (50% UIP) (Cochran, 1995). In estimating the relationship of total DIP intake to digestible OM intake, Köster et al. (1994) also found low forage DIP values at 53% of CP. In contrast to these values, it has been found

by Lardy et al. (1996) and Lardy et al. (1998) that DIP makes up a much larger percentage of total CP throughout the year compared to UIP. Summer Sandhills native range had CP values of 12.5±2.4% of OM and DIP values of 82.3±2.5% of CP while winter Sandhills native range had CP values of 6.2±0.5% of OM and DIP values of 84.7±2.4% of CP (Lardy et al., 1998). However, it was also found by Lardy et al. (1997a) that meadow and range diets increased in digestibility, CP and UIP (as a percentage of CP and DM) during active periods of growth. Differences among these studies may be due to the natural variation of plant species between different locations.

Lardy et al. (1996) predicted the deficiencies of MP and DIP in the diets of spring calving cows grazing native range and found that while MP was only deficient in one month of the year (September), DIP was deficient in three months (September, December and January) by 200g/day. Lardy et al. (1997c) also determined that gestating summer calving cows grazing dormant native Sandhills range require between 91 g/d and 181 g/d DIP supplementation during late winter to meet their daily DIP requirements of 454-590 g. The MP system predicts a DIP deficiency of about 200 g/d for gestating cows grazing dormant winter range. Therefore, when supplementing protein to cattle grazing native range, DIP and MP deficiencies should be addressed individually by supplementing either DIP or UIP or a specific proportion of both while at the same time taking into consideration the amount and proportion of DIP and UIP supplied by the forage.

The complexity of providing supplemental DIP and/or UIP lies not only in the fact that these protein fractions continuously vary throughout the year but also that there is year to year variation in these fractions. Karges et al. (1992) showed that native range met the DIP requirements throughout the 1989 growing season but during the previous year it was deficient in DIP during August. Degradable intake protein had a range of about 11-16% of digestible OM in the 1988 season but only about 12.3-13.5% in the 1989 season.

Undegradable Intake Protein

Since the amount of DIP that can be utilized by the microbial population in the rumen for the production of BCP is limited, the animal's MP requirements must further be met by the inclusion of UIP in the diet. For spring calving cows, the MP system generally predicts DIP to be more deficient than MP during gestation. These predictions were confirmed by Karges (1990) when gestating cows fed native range hay and/or poor quality prairie hay were shown to be limiting in DIP but not in MP. However, due to the large protein requirements during lactation, both DIP and MP are predicted to be deficient for lactating cows grazing dormant native range (NRC, 1996). Lardy et al. (1997b) substantiated the NRC predictions and found both DIP and UIP to be limiting for summer calving cows during the breeding season and during late lactation and it was recommended that the needs of the animals would best be met by supplying a

supplemental protein source that contained both DIP and UIP in equal proportions at 272 g total protein per day.

When supplementing UIP to meet the MP requirements of animals, it is important to consider the UIP contribution from the supplements which are moderate to high in DIP. Although increasing levels of UIP (from corn gluten meal and blood meal) were fed to gestating cows grazing dormant, tallgrass-prairie forage, weight changes were observed to be similar for the different treatments (Jones et al., 1994). It is possible that the UIP present in the principle DIP source (soybean meal), which was not accounted for, may have contributed significantly to the total UIP intake by the treatments fed lower UIP levels. Consequently, MP requirements were likely met by those treatments receiving the lower levels of additional UIP. Sindt et al. (1993) fed either urea or a combination of urea, blood meal and feather meal to finishing calves consuming dry-rolled corn and dry-rolled grain sorghum diets. Feeding the combination supplement improved feed efficiency when MP was limiting but not when MP was adequate.

The presence of a protein source high in UIP improves nitrogen metabolism and reduces the amount of nitrogen excreted. Westendorf and Gordon (1998) fed growing lambs low protein diets (10% CP) containing either soybean meal or fish meal or a 17% CP soybean meal control diet. Nitrogen retention was greater together with lower urinary nitrogen excretion for lambs receiving the fish meal compared with those receiving the soybean meal diets.

This is consistent with increased nitrogen balance and a reduction in nitrogen excretion when proteins high in UIP were fed (Pell, 1992).

Increasing levels of UIP in an attempt to meet MP requirements of an animal will not necessarily meet all amino acid requirements. Klemesrud (1998) reported that the protein efficiency of meat and bone meal can be enhanced by the addition of ruminal escape methionine which was the first limiting amino acid for steers fed a basal diet of sorghum silage and corncobs. Campbell et al. (1997) found that gains were greater for soybean meal supplemented steers than those receiving urea and intermediate for steers supplemented with free amino acids. Cattle fed soybean meal or amino acids tended to be fatter and have better marbling scores and quality grades but amino acid supplementation did not greatly alter ruminal fermentation or cattle performance.

Although many studies in the past have involved feeding increasing amounts of UIP to cattle, the metabolizable protein requirements of beef cattle are not yet well established and to date limited research has been conducted in this field.

CHAPTER III

METABOLIZABLE PROTEIN REQUIREMENTS OF EARLY LACTATING BEEF COWS GRAZING DORMANT NATIVE RANGE

Abstract

Sixty-three Angus x Hereford cows, 3-7 years of age were used to determine the metabolizable protein (MP) requirements of early lactating spring calving beef cows grazing dormant native range. The MP requirements of lactating beef cows (499 kg) with a peak milk production of 6.4 kg/d is predicted at 734 g/d (NRC, 1996). When feeding an industry standard supplement (40% CP) at 1.36 kg/d, the MP system predicts a MP deficiency of 152 g/d. Control cows were fed the industry standard supplement and three treatment groups were fed with incremental increases in undegradable intake protein (UIP) by varying amounts of blood meal and corn gluten meal which was added at a constant ratio of 36:64. The MP balance for the control and treatments receiving additional UIP was calculated to be -152, -95, -39 and 18 g/d respectively. Eight cows from each treatment were used to determine forage DM intake. Four

heifers were used to collect forage masticate samples. Protein degradability of the forage and the supplements were determined to calculate the actual MP intake and MP balance of the cows. Cow weight and body condition score changes and calf weight changes were used to determine the response to treatment. Ten cows from each treatment were used to determine milk production at 30 and 45 days postpartum using the weigh-suckle-weigh technique. Blood samples were collected postpartum and analyzed for progesterone to determine the initiation of ovarian function.

Based on the observed CP content and protein degradability of the forage and supplements, and forage DM intakes, the MP balance for treatments was calculated to be -129, -90, -94 and -58 g/d. The cows in this study (487±14 kg; 5.56±0.04 BCS) had higher MP requirements (807±8 g/d) due to greater milk production (7.9±0.2 kg/d) and consequently the MP requirements were not met for any of the treatments.

Treatment did not influence forage DM intake, cow weight and BCS change, milk production, calf weight change or number of days from calving until the first normal luteal function. For all cows, weight loss from calving to weaning was 27±6 kg and the interval from calving to ovarian function was 54.4±3.3 d. Lack of response to treatment could be due to the fact that the range in MP balance among treatments was smaller than originally calculated. The duration of treatment between calving and the first availability of high quality spring forage was limited (37 d) and possibly the cows did not have sufficient time to

respond to treatment. The high production and reproduction responses of cows on all treatments indicates that the cows were probably not deficient in MP and MP requirements of the cows may have been over predicted.

Materials and Methods

Sixty-three Angus x Hereford cows, 3-7 years of age were used to determine the MP requirements of early lactating spring-calving beef cows grazing dormant native range. Prior to initiating the study, the Beef NRC (1996) was used to predict MP requirements and MP supply from range forage and a standard high protein supplement fed at the rate of 1.36 kg per cow daily. Animal, forage and supplement characteristics used in the initial evaluation are shown in Table 1. The model (NRC, 1996) predicted a MP deficiency of 152 g per day (Table 2). Using this value, three experimental supplements were formulated to provide incremental levels of UIP, with the industry standard supplement serving as the control. The calculated MP balance provided by the supplements ranged from -152 to 18 g/d (Table 3).

Supplemental UIP for the treatments was increased in titration fashion by adding 63 g/d (C+63), 126 g/d (C+126) and 189 g/d (C+189) additional UIP in the form of a fixed combination of blood meal (36%) and corn gluten meal (64%). The main supplement components were soybean meal (54% CP, 65% DIP), soybean hulls (12% CP, 75% DIP), blood meal (94% CP, 25% DIP) and corn

TABLE 1. VALUES USED TO PREDICT METABOLIZABLE PROTEIN BALANCE FOR BEEF COWS GRAZING DORMANT NATIVE RANGE DURING EARLY LACTATION

Body weight, kg	499
Milk production, kg/d	6.4
Forage intake, % of BW	2.2
Forage CP, %	4
Forage DIP, % of CP	77
[a]Supplement CP, %	41
Supplement DIP, % of CP	65
Forage TDN, %	49
Microbial efficiency, %	10

[a]Supplement was formulated to supply DIP and UIP according to industry standard supplementation practices.

TABLE 2. PREDICTED METABOLIZABLE PROTEIN BALANCE FOR BEEF COWS GRAZING DORMANT NATIVE RANGE DURING EARLY LACTATION AND FED AN INDUSTRY STANDARD SUPPLEMENT

Body weight, kg	499
Forage intake, % of BW	2.2
Forage digestibility, % of DM	49
DIP required, g/d	538
Forage DIP supplied, g/d	338
[a]Supplement DIP supplied, g/d	327
DIP balance, g/d	127
[b]MP required, g/d	734
Microbial MP supplied, g/d	345
MP supplied from forage UIP, g/d	81
[a]Supplement MP supplied, g/d	158
MP balance, g/d	-152

[a]Supplement composition shown in Table 10.
[b]Calculated from NRC (1996).

TABLE 3. EXPERIMENTAL SUPPLEMENT COMPOSITION AND PREDICTED METABOLIZABLE PROTEIN BALANCE (DM BASIS)

	Treatment			
	Control	C+63	C+126	C+189
Soybean meal, %	81.93	72.76	62.77	52.77
Soybean hulls, %	9.40	5.65	2.62	1.27
Blood meal, %	-	4.55	9.15	13.18
Corn gluten meal, %	-	8.08	16.27	23.44
Dicalcium phosphate, %	2.02	1.99	1.97	1.91
Potassium chloride, %	3.69	3.99	4.26	4.45
Molasses, %	2.89	2.92	2.89	2.92
Vitamin A (30 000 IU), %	0.07	0.07	0.07	0.06
Amount fed, g/d	1360	1360	1360	1360
DIP supplied, g/d	396	396	396	396
UIP supplied, g/d	211	274	337	400
NEm, Mcal/d	2.59	2.59	2.59	2.61
MP from supplement base, g/d	190	247	303	360
Additional MP supplied, g/d	0	57	113	170
Predicted MP balance, g/d	-152	-95	-39	18

gluten meal (66% CP, 41% DIP). The supplements were calculated to supply equal DIP (396 g/d) and energy (2.59 Mcal NEm/d) while supplying 211 g/d (Control), 274 g/d (C+63), 337 g/d (C+126) and 400 g/d (C+189) UIP.

Prior to calving the cows were individually supplemented daily with the control supplement to acquaint them with the supplementation barn. Body condition was individually determined by two trained technicians and the average value used. Cows were also weighed prior to calving and then at 14 d intervals until the end of supplementation. Cows were penned the evening prior to weighing and 16 hour shrunk weights were used consistently. Calves were individually identified and weighed within 48 hours of calving. Post calving (early February through late March) the cows were allotted to one of the four treatments based on calving date, body condition score (BCS) and age and individually supplemented an equal amount of 1.59 kg/d, six days per week. Supplementation continued until the forage started greening (mid April).

At the end of supplementation, cows weight and BCS and calf weight were recorded. At weaning (early October), cows and calves were once again weighed and BCS determined. Body condition score was based on a nine-point scale (Spitzer, 1986; Wagner et al., 1988) and determined by the same two trained technicians.

Forage intake was determined at the end of March using eight cows from each of the four treatments. Slow release chromic oxide boluses (Captec Chrome for Cattle, Captec (NZ) Ltd., Auckland, New Zealand) were used and

boluses were lubricated with mineral oil before administering. A five-day adaptation period was followed by a five day fecal collection period. Fecal grab samples were obtained daily during supplementation. For validation of marker release, total fecal collections were conducted using four steers equipped with fecal collection bags. Total fecal collections coincided with the time that fecal samples were collected from the cows to determine forage intake and the steers were bolused at the same time at which the cows were bolused. The bags were strapped on the steers the evening before the first grab samples were taken from the cows and then weighed and emptied at 12 hour intervals until after the last samples had been taken from the cows. Steers were housed in a pen and fed prairie hay. They were adapted to the diet and acquainted with the bags for one week prior to the fecal collection period. All fecal samples were dried at 60 °C in a forced air oven and then ground through a 2 mm Wiley mill screen. Chromium analysis was conducted using atomic absorption (4000 Atomic Absorption Spectrophotometer, Perkin-Elmer, Norwalk, CT).

Within the time of supplementation, milk production at 30 d and 45 d postpartum (late March and mid April) was determined using the weigh-suckle-weigh technique (Totusek et al., 1973) with ten cows and their calves from each of the four treatments. Twenty-four hour milk production was estimated by conducting three consecutive weigh-suckle-weighs at eight-hour intervals. The total of the three measurements was used to obtain daily milk production per cow.

A 10 ml blood sample was collected from each cow within one week after calving and thereafter at the same time weekly until the end of supplementation. Vacutainer tubes with EDTA were used to collect these samples (Becton Dickinson and Company, Franklin Lakes, NJ). Following collection, the blood samples were cetrifuged at 2500 rpm for 15 minutes. The blood plasma was then discanted and stored at -25 °C until analyzed. Samples were analyzed for plasma progesterone concentration as an indication of the first normal luteal phase to determine the time from calving until the initiation of cyclicity. Two consecutive weeks of plasma progesterone concentrations >1 ng/ml were used to indicate that ovulation had occurred and that a functional corpus luteum was present on the ovary (Vizcarra et al., 1997). Plasma samples were assayed for progesterone via RIA (COBRA^{TM}II, Auto Gamma, Packard Instrument Company, Downers Grove, IL) using coated tube methodology (Coat-A-Count^{TM}, Diagnostic Products Corporation, Los Angeles, CA).

Four oesophageally cannulated heifers were used to collect masticate samples of the grazed forage. Samples were collected late February, mid March, mid April and early May using masticate collection bags. The heifers received no supplementation and were held in drylot for three hours prior to sample collection to ensure a sizeable sample. Samples were squeezed to remove excess saliva (Hart, 1983) and then immediately stored at -30 °C. At a later stage the samples were lyophilized (without defrosting) at -50 °C and then ground through a 2 mm Wiley mill screen.

Masticate samples and supplement samples (also ground through a 2 mm Wiley mill screen) were incubated in situ to determine protein degradability. The in situ neutral detergent fiber nitrogen (NDFN) procedure was used (Mass et al., 1997; Mass et al., 1998; Bodine et al., 1998). This procedure estimates the amount of UIP of feeds by determining the amount and rate of disappearance of fiber-bound nitrogen (NDFN). The estimates of UIP are calculated based on initial NDFN, rates of disappearance and average retention time in the rumen.

The in situ study was conducted and replicated in two consecutive weeks using two ruminally cannulated steers each week. The steers were fed prairie hay (4.8% CP) and a soybean meal supplement (1.36 kg/d; 46.7% CP) to ensure that they were not DIP deficient and were adapted to the diet a week prior to incubating the samples. For each of the masticate and supplement samples duplicate 10 x 20 cm dacron bags (53±10 microns pore size) (Ankom, Fairport, NY) each containing 5±0.001 g of sample, were suspended in the rumen of each animal for 2, 12 and 96 hours. The bags were placed in an oven for 24 hours at 100 °C and then weighed before weighing out the sample. For each time, the dacron bags were placed together in a polyester mesh bag. Prior to incubation, the bags were all soaked in 39 °C water for 20 minutes. After removal from the rumen, the bags were rinsed in a top-load washing machine in cold water on the delicate cycle for 2 minutes and then spun for 1 minute on the same cycle. This was repeated ten times. The bags were then dried in a forced air oven for 48 hours at 50 °C and reweighed. The residue was then sub-sampled (0.5±0.001

g) and NDF determined for each sample (ANKOM^{200} Fiber Analyzer, Ankom, Fairport, NY). The bags used for NDF analyses were placed in an oven for 24 hours at 100 °C and then weighed before weighing out the sub-sample. After the NDF analyses the bags were again placed in an oven for 24 hours at 100 °C and reweighed. The post NDF residue was then analyzed for nitrogen using the combustion method (LECO-NS2000, Leco Corporation, St. Joseph, MI).

Rate of digestion was calculated from the slope of the regression of the natural logarithm of mg NDFN/g sample over time. The 2 and 12 hour mg NDFN/g sample values were used for the regression after being corrected for the 96 hour mg NDFN/g sample value (the ruminally undegraded NDFN). Vanzant et al. (1996) found that using the double-point approach overcame differences in rates of protein degradation and sizes of protein fractions that occurred when comparing protein degradation in animals fed different diets using a single-point value. However, Abdelgadier et al. (1997) found single time-point estimates of UIP to give similar values to those of in vivo values when alfalfa and prairie hay were incubated in vitro.

The exponential value of the Y-intercept value depicts the original pool (0 hours) of mg NDFN/g sample corrected for 96 hours (the fiber-bound nitrogen in the original sample less that which is not degraded within the rumen). There was no need to correct for microbial contamination of the in situ residue as bacterial crude protein is solublized in the neutral detergent solution.

Estimated passage rates of 2%/h were used for the forage samples and 4%/h for the supplement samples. Estimates of ruminal passage rate for many protein supplements and most feeds fall between 3% and 7% per hour (Stern and Satter, 1982; Ganev, 1979). Mass et al. (1997) suggested values of 2-2.5%/h for dormant forages and 4-5%/h for vegetative forages. The level of feed intake may impact the extent of ruminal protein degradation by influencing passage rate. Higher producing ruminants consuming larger quantities of feed are more likely to have a smaller fraction of feed protein digested within the rumen than those consuming low to moderate amounts of feed. This has been illustrated in studies where increased feed intake in steers (Zinn and Owens, 1983) and dairy cattle (Tamminga et al., 1979) decreased the quantity of feed protein degraded within the rumen. However, the effect of feed intake on ruminal retention time has also been found to be insignificant and may not necessarily alter the extent of ruminal degradation of protein (McAllan and Smith, 1983).

The masticate and supplement samples were also analyzed for dry matter (DM), ash, NDF and acid detergent fiber (ADF) (ANKOM^{200} Fiber Analyzer, Ankom, Fairport, NY) and nitrogen (LECO-NS2000, Leco Corporation, St. Joseph, MI). The ADF content of the samples was used to predict in vivo DM digestibility: %DMD = 88.9 - 0.779 (%ADF) (NRC, 1984). In a study in which various forage components were used to predict digestibility and intake and compared to in vivo values, ADF had a -0.75 correlation and in vitro digestibility

had a 0.80 correlation with in vivo digestibility (Van Soest, 1982). The study included 187 forages of diverse species. Clancy and Wilson (1966) also found that the correlation between ADF and digestibility was higher when fewer types of forage were included in a population.

Statistical analyses. The effect of the supplemention treatments on all the dependent variables were analyzed using the GLM procedure of SAS (1989) for a completely random design with individual animals as the experimental unit. The statistical model for intake and days to cyclicity included treatment. The model for milk production included treatment and stage in lactation curve. For analyzing the effect of treatment on cow weight change and BCS change, the model included treatment and time on treatment. The model for change in calf weight included treatment, calf age and calf sex.

Linear, quadratic and cubic contrasts were also tested in each case.

Results and Discussion

Metabolizable Protein Balance

Nitrogen analyses on the masticate samples collected with oesophageally cannulated heifers revealed that the CP content of the native range was higher than expected in 1997 and averaged 7.8%, 5.4%, 14.0% and 13.2% in February,

March, April and May, respectively (Figure 1). From the in situ trials it was also found that the UIP fraction of the protein was higher than anticipated at 30%, 28%, 47% and 46% (% of CP). Expressed as a percentage of DM, UIP values of 2.3%, 1.5%, 6.6% and 6.1% were determined for the respective months (Figure 2). Consequently, when predicting the MP balance of the cows during the trial period, primarily February and March, forage CP was underestimated (4% CP) while DIP was overestimated (77% DIP). Expressed as a percentage of CP, the values in this study are similar to those reported by Köster et al. (1994) were forage UIP was determined at 47%. Cochran (1995) also reported that winter pasture tallgrass prairie has about 50 % UIP (as a percentage of CP).

Nitrogen analyses of the supplements fed to the four treatment groups showed that the actual CP percentage was less (36%, 40%, 44% and 48% CP) than the calculated CP values (41%, 45%, 49% and 53% CP). Protein degradability determined in situ further revealed the DIP fraction of the actual supplements was greater (72%, 66%, 63% and 59% DIP) than that of the calculated values (65%, 59%, 54% and 50% DIP) as shown in Table 4.

Forage NDF declined in the treatment period from 69.9% in February to 61.9% in April while forage ADF declined from 43.0% in February to 40.0% in April. Calculated DMD increased from 55.4% to 57.7% in that same period (Table 5). These values for NDF, ADF and digestibility were very similar to those recorded by Hollingsworth-Jenkins et al. (1996) for native winter Sandhills range.

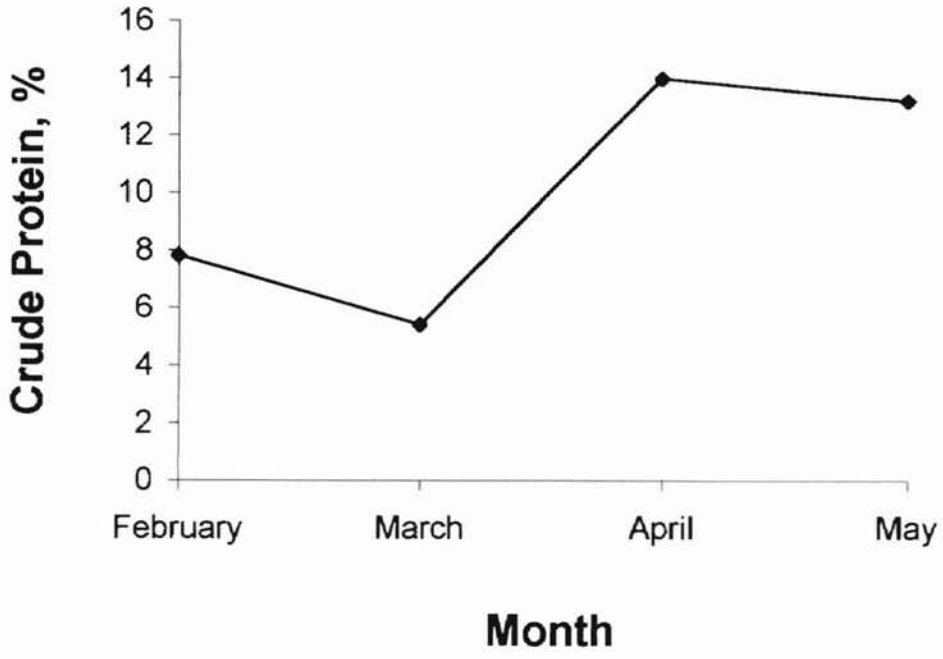

Figure 1. Crude protein content of Oklahoma native range in 1997 (% of DM).

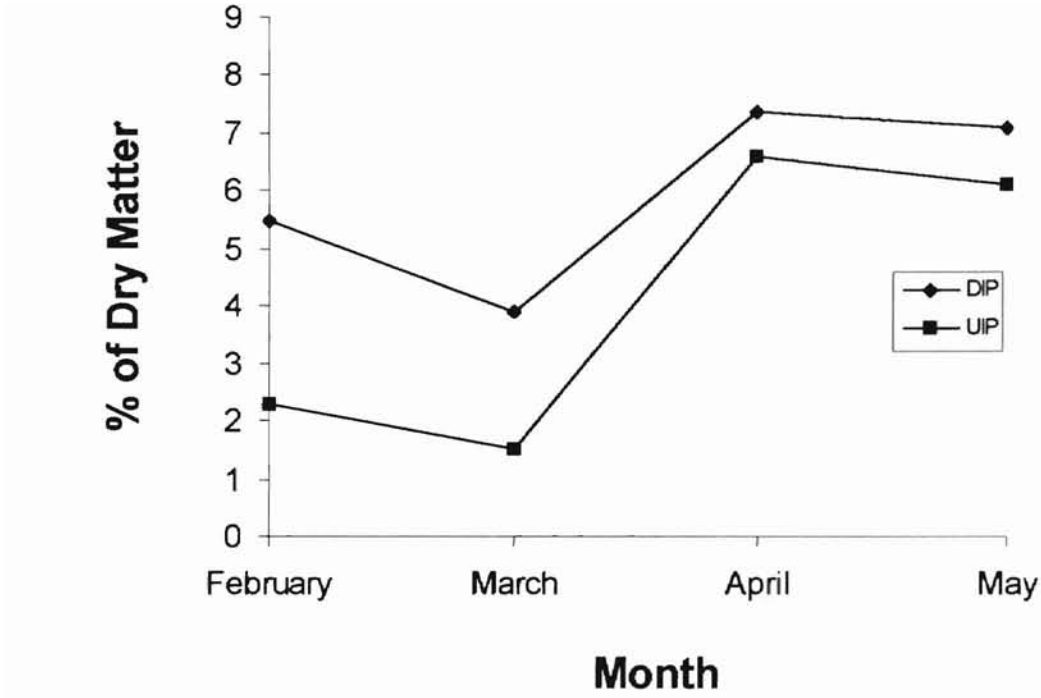

Figure 2. Degradable intake protein and undegradable intake protein content (% of DM) of native range in 1997.

TABLE 4. A COMPARISON OF CALCULATED AND OBSERVED VALUES OF INCREMENTAL UIP PROTEIN SUPPLEMENTS FED AT 1.36 KG DAILY TO EARLY LACTATING COWS GRAZING DORMANT NATIVE RANGE

	Calculated		Observed	
Supplement	CP (% of DM)	DIP (% of CP)	CP (% of DM)	DIP (% of CP)
Control	41	65	36	72
C+63	45	59	40	66
C+126	49	54	44	63
C+189	53	50	48	59

TABLE 5. MEANS OF ASH, CRUDE PROTEIN, PROTEIN DEGRADABILITY, NEUTRAL DETERGENT FIBER, ACID DETERGENT FIBER AND IN VIVO DRY MATTER DIGESTIBILITY OF OKLAHOMA NATIVE RANGE (% of DM)

Month	ASH	CP	DIP	UIP	NDF	ADF	[a]DMD
February	16.2	7.8	5.5	2.3	69.9	43.0	55.4
March	13.9	5.4	3.9	1.5	68.4	44.7	54.0
April	12.7	14.0	7.4	6.6	61.9	40.0	57.7
May	13.9	13.2	7.1	6.1	49.5	29.4	65.9
Control	11.0	36.3	26.1	10.2	12.3	6.8	83.6
C+63	13.5	40.4	26.7	13.7	11.1	5.1	84.9
C+126	11.5	44.1	27.8	16.3	10.5	4.4	85.5
C+189	11.3	48.4	28.6	19.8	8.9	3.6	86.1

[a]Acid detergent fiber content was used to predict in vivo DM digestibility: %DMD = 88.9 - 0.779 (%ADF) (NRC, 1984).

Based on the actual weights of the cows (487±14 kg) and the measurements for milk production (7.9±0.2 kg/d) the MP requirements for the cows were greater than initially calculated (807±8 g MP/d versus 734 g MP/d). The estimated average BW of the cows prior to the start of the experiment was 499 kg and the estimated average milk production 6.4 kg/d. The initial body condition scores of the cows in the study were 5.56±0.04.

The actual DIP and MP balance of the cows within each treatment was calculated based on measured values for BW, milk production, forage intake, forage CP, forage DIP and UIP, supplement CP and supplement DIP and UIP. From these values it was determined that all the cows had a positive DIP balance (341±15 g DIP/d) during the supplementation period but even the C+189 supplement did not meet MP requirements. The actual calculated MP balance of the four treatments was -129, -90, -94 and -58 g MP/d as compared with predicted values of -152, -95, -39 and 18 g MP/g (Table 6).

Forage Dry Matter Intake

The actual chromic oxide release rate from the boluses used to determine intake was 1.47±0.56 g/d. The chromic oxide boluses had a predetermined release rate of 1.49 g/d.

No significant differences ($P > 0.22$) were determined for amount of forage intake between treatments. The treatments, Control, C+63, C+126 and

TABLE 6. METABOLIZABLE PROTEIN BALANCE OF EARLY LACTATING COWS GRAZING DORMANT NATIVE RANGE AND FED INCREASING AMOUNTS OF UNDEGRADABLE INTAKE PROTEIN

	Treatment				
	Control	C+63	C+126	C+189	SE
Body weight, kg	500	476	473	481	18
Body condition	5.58	5.56	5.59	5.63	0.18
Milk production, kg/d	7.74	7.90	7.90	8.10	0.65
Forage intake, % of BW	2.38	2.47	2.33	2.35	0.13
DIP required, g/d	583	576	540	555	
Forage DIP supplied, g/d	591	584	548	563	
Supplement DIP supplied, g/d	318	324	340	347	
DIP balance, g/d	326	332	348	355	
MP required, g/d	807	800	799	814	
Microbial MP supplied, g/d	373	369	346	355	
MP supplied from forage UIP, g/d	193	191	179	184	
Supplement MP supplied, g/d	111	150	180	217	
MP balance, g/d	-129	-90	-94	-58	

C+189, had respective average daily forage DM intakes of 11.90, 11.75, 11.03 and 11.32 kg. As a percentage of body weight, respective treatments had forage DM intakes of 2.38%, 2.47%, 2.33% and 2.35% (Table 7). These values are similar to those guidelines presented by Hibberd (1993) where it was estimated that lactating cows consuming low quality forage together with a protein supplement had forage DM intakes of 2.2% of BW while those consuming average quality forage together with a protein supplement had forage DM intakes of 2.5% of BW.

An increase in forage DM intake increases animal DIP requirement. If DIP requirement is met, bacterial MP supplied will increase and MP requirement from supplemention UIP will consequently decrease. This is clearly illustrated in this study by the C+63 and C+126 treatments. Treatments had equal MP requirements (799.5±.05 g/d), but forage DM intakes were higher for the C+63 treatment (2.47% of BW) than for the C+126 treatment (2.33% of BW). Degradable intake protein requirements for the treatments were 576 g/d and 540 g/d respectively. Metabolizable protein balance for the C+126 treatment was more negative (-94 g/d) than for the C+63 treatment (-90 g/d), despite having received 63 g additional UIP per day.

Cows grazing dormant forage in the late fall and winter are protein deficient. In a study by Menges and Huston (1994) results were obtained indicating that cows receiving no supplement consumed less forage and lost more BW and body condition than those receiving a protein supplement. A

TABLE 7. DAILY FORAGE DRY MATTER INTAKES OF EARLY LACTATING COWS GRAZING DORMANT NATIVE RANGE AND FED INCREASING AMOUNTS OF UNDEGRADABLE INTAKE PROTEIN

	Treatment				
	Control	C+63	C+126	C+189	SE
Forage intake, kg/d	11.90	11.75	11.03	11.32	0.63
Forage intake, % of BW	2.38	2.47	2.33	2.35	0.13

trend was also observed indicating an increase in cow performance with increased level of protein in the supplement and protein supplements higher in UIP tended to further increase cow performance.

In another trial in which cattle had ad libitum access to ammoniated wheat straw, treatments receiving higher levels of protein supplementation had increased levels of digestible DM intake and also tended to have higher levels of digestible NDF intake (Fike et al., 1995). Stokes et al. (1988) also found that cows consuming prairie hay had increased DM intake and true ruminal digestibilities of organic matter, NDF and nitrogen when fed increasing levels of soybean meal. However, increases in DM intake were large relative to those of ruminal digestion and it was therefore concluded that metabolic regulation was most likely modifying intake of low-quality forage.

Weight and Body Condition Score

Weight losses were recorded for all cows from calving to the end of treatment (33±2 kg) and for the entire period from calving to weaning (27±6 kg). These weight losses for all the treatments could possibly be ascribed to the fact that the MP requirements were not met for any of the treatments. No treatment differences were found for the treatment period ($P > 0.67$) and for the period from calving to weaning ($P > 0.23$). From the end of supplementation until weaning there was a linear decrease in weight gain as supplementation UIP

increased ($P < 0.11$). Cow weight gains in the post supplementation period were 6±7 kg, with the C+189 treatment losing weight (Table 8).

Body condition losses were also recorded for all cows from calving to the end of treatment (0.7±0.1) and for the entire period from calving to weaning (0.7±0.1). No BCS changes were observed in the post supplementation period (Table 8). Treatment did not influence BCS during the supplementation period ($P > 0.30$), the period after supplementation until weaning ($P > 0.76$) or for the entire period from calving until weaning ($P > 0.26$)

Tripplett et al. (1995) also reported that Brahman first-calf heifers and mature cows showed no response concerning weight and BCS to increased levels of supplemental UIP.

DelCurto et al. (1990) conducted a study with beef cows grazing winter range in which treatment groups received the same quantity of supplement but with increasing levels of CP concentration (13, 25 and 39% CP). Cows fed the 13% CP supplement lost more weight (-87.5 kg) and body condition score (BCS) than did the cows that were fed the 39% CP supplement (-44.0 kg). The results of Vogel et al. (1989) showed that the performance of stocker cattle grazing wheat pasture (20-24% CP) was improved when a source of supplemental UIP was provided, suggesting that wheat pasture provided sufficient DIP but not UIP to meet MP requirements. Steers grazed only wheat pasture or received supplemental corn, meat meal or cottonseed meal and daily gains were 0.81 kg, 0.88 kg, 0.90 kg, and 0.93 kg, respectively. Steers grazing a non-irrigated corn

TABLE 8. WEIGHT CHANGES OF BEEF COWS AND THEIR CALVES AND BODY CONDITION SCORE CHANGES OF COWS GRAZING NATIVE RANGE AND FED INCREASING AMOUNTS OF UNDEGRADABLE INTAKE PROTEIN

	Treatment				
	Control	C+63	C+126	C+189	SE
Initial body weight, kg	500	476	473	481	18
Cow weight changes, kg					
Calving to end treatment, 37d	-33	-35	-31	-32	5
[a]End treatment to weaning, 173d	12	5	9	-1	7
Calving to weaning, 211d	-21	-30	-23	-33	7
Initial body condition score	5.58	5.56	5.59	5.63	0.18
Cow BCS changes					
Calving to end treatment, 37d	-0.66	-0.64	-0.83	-0.77	0.16
End treatment to weaning, 173d	0.04	-0.14	0.03	-0.08	0.18
Calving to weaning, 211d	-0.62	-0.78	-0.80	-0.85	0.19
Calf birth weight, kg	43	41	42	42	1
Calf weight changes, kg					
[b]Calving to end treatment, 37d	31	35	34	36	3
End treatment to weaning, 173d	144	137	138	138	6
Calving to weaning, 211d	176	172	172	174	8

[a]There was a linear effect ($P < 0.11$) post treatment to weaning with the cows fed the least amounts of undegradable intake protein gaining the most weight.
[b]There was a linear effect ($P < 0.11$) in the treatment period with calves gaining more weight when cows were fed undegradable intake protein.

residue field had higher daily gains (401 g) when supplemented with alfalfa hay and UIP compared with those supplemented with alfalfa hay together with an energy supplement (260 g) (Gutierrez-Ornelas and Klopfenstein, 1994). Gutierrez-Ornelas and Klopfenstein (1991) also found that when steers grazing corn residues were supplemented with UIP, UIP affected daily gains and resulted in an increased average daily gain/g of UIP (Gutierrez-Ornelas and Klopfenstein, 1991). Similar results were observed by Tomlinson et al. (1997) where increasing the percentage of UIP in the diet of Holstein heifers resulted in increased BW gain and feed efficiency. Dhuyvetter et al. (1993) also reported that when adequate CP was provided in the diet for optimal rumen function, additional UIP decreased weight loss of mature, postpartum beef cows grazing native range.

Supplemental UIP also increased live weight gains of steers consuming ensiled forage diets due to the low UIP contents of silages and barley and limited microbial synthesis (Nelson, 1997). Hoaglund et al. (1992) conducted two trials with pregnant ewes fed supplements containing either urea (90% DIP), soybean meal (66% DIP) or a combination of soybean meal and blood meal (54% DIP). Results showed that BCS change and weight change was more favorable for ewes fed the combination of soybean meal and blood meal than those fed urea or soybean meal. Adequate DIP would have been supplied by either urea or soybean meal but the combination supplement increased the DIP as well as the MP supplied to the animals.

Miner et al. (1990) supplemented gestating cows grazing winter native range with soybean meal or a combination of soybean meal and blood meal, thus providing equal amounts of DIP (200 g/d) to all supplemented animals but different amounts of UIP. In the first trial, cows that received no supplement had less favorable BCS changes (-1.5) and weight changes (-1.9 kg) than those receiving either soybean meal (-1.2; 32 kg) or a combination of soybean meal and blood meal (-0.8; 38 kg). In the second trial, MP requirements were best met by animals receiving both soybean meal and blood meal as was reflected by BCS change (-0.46) and weight change (-2 kg) compared to those receiving only soybean meal (-0.93; -20 kg) or no supplement (-0.95; -47 kg).

Moloney et al. (1997) evaluated the MP system and determined the performance response to an increase in MP supply above the estimated requirement. Finishing heifers were fed grass silage (18.3% CP, 2.46 Mcal ME/kg DM) ad libitum and 3 kg of a low (26 g/kg DM) or high (164 g/kg DM) isocaloric (3.20 Mcal ME/kg DM) CP concentrate per animal daily. Metabolizable protein supplied was calculated from the degradation characteristics of the feedstuffs when incubated in situ. Daily intakes of effective DIP were 584 g and 739 g and of MP were 750 g and 1053 g per animal for the treatments, respectively. Body weight gains predicted from ME intake for the two treatments were 858 g/d and 861 g/d while the actual daily body weight gains observed from growth were 677 g and 711 g. It was thus concluded that body weight gains on both diets was less than those predicted from calculated

MP and ME intake. However, an increase in carcass weight gain in response to an increase in MP supply above requirement was observed (404 g/d versus 473 g/d). This was not predicted by the MP system.

Milk Production and Calf Weight

Milk production at 30 days postpartum was 8.65±0.30 kg/d and at 45 days postpartum 7.16±0.03 kg/d (Table 9). Treatment did not influence milk production at 30 ($P > 0.55$) and 45 days postpartum ($P > 0.60$).

Calf weight gain in the treatment period was 33±3 kg and 140±4 kg in the post treatment period. Calves gained 174±2 kg from calving until weaning (Table 8). In the treatment period there was a linear increase in calf weight gain as supplementation UIP increased ($P < 0.11$). No treatment differences were observed for calf weight gains for the period from supplementation until weaning ($P > 0.35$) and for the entire period from calving until weaning ($P > 0.84$)

Lardy et al. (1997b) conducted a study and found that lactating cows grazing native range produced higher levels of milk when they received supplemental UIP. Subsequently, the calves of these cows also had increased weight gains. Other studies have also shown that increasing the level of supplemental UIP increased milk production of dairy cows (Orskov, 1982) and cows grazing dormant range (Hibberd et al., 1988). In the case of Hibberd et al. (1988), a subsequent increase in calf weight gains was also reported. Similarly,

TABLE 9. MILK PRODUCTION AND NUMBER OF DAYS FROM CALVING UNTIL THE FIRST NORMAL LUTEAL PHASE OF BEEF COWS GRAZING DORMANT NATIVE RANGE AND FED INCREASING AMOUNTS OF UIP

	Treatment				
	Control	C+63	C+126	C+189	SE
Milk production					
30 days postpartum, kg/d	8.40	8.35	8.94	8.76	0.87
45 days postpartum, kg/d	7.08	7.45	6.98	7.45	0.71
Average, kg/d	7.74	7.90	7.90	8.10	0.65
Days to cyclicity, d	57.7	55.4	51.1	53.4	4.3

Lee et al. (1985) found that higher levels of supplemental UIP resulted in increased hay intake and milk production.

Forcherio (1994) fed supplements of either 100 or 200 g of UIP to beef cows consuming vegetative tall fescue pastures. Supplements were fed daily from late May until late July. Calves nursing cows supplemented with 100 g/d UIP gained more BW because of an increased milk consumption and a slightly greater forage intake compared with calves nursing cows supplemented with 200 g/d UIP. Beef cows fed supplements containing a greater proportion of DIP had greater milk production that resulted in faster gains by their calves than did cows receiving a greater proportion of UIP.

Tripplett et al. (1995) studied level of UIP supplementation for postpartum first-calf Brahman heifers and mature Brahman cows. The animals grazed rye-ryegrass overseeded Coastal bermudagrass pastures with access to Coastal bermudagrass hay and were fed supplements of either 38.1%, 56.3% or 75.6% UIP. The heifers receiving 56.3% UIP produced more milk (1.18 ± 0.07 kg/4 h) than those receiving 75.6% UIP (0.94 ± 0.07 kg/4 h) but milk production in the mature cows was not influenced by diet.

Henson et al. (1997) evaluated the effect of different proportions of DIP and UIP and of vegetable protein and a combination of vegetable and animal protein on milk production and milk composition of lactating Holstein cows. However, no differences were observed between the various treatments. In a study conducted with goats an increased proportion of UIP in the diet had no

effect on level of milk production and protein and gross energy efficiency for milk production (Mishra and Rai, 1996). Wheeler et al. (1995) found that DIP fed to Holstein cows consuming wheat or sorghum silage increased milk protein, lactose and solids-non-fat and thus concluded that DIP supplementation was a necessity for early lactation cows fed diets containing sorghum or wheat silage.

Reproductive Performance

Treatment did not influence the number of days from calving until the first normal luteal function ($P > 0.21$). The average number of days was 54.4±3.3 (Table 9). This relatively short postpartum interval for all treatments indicates that although the MP balance for all the treatments was negative, the cows were not very MP deficient and it is possible that the MP requirements were over predicted.

Tripplett et al. (1995) found that first-calf heifers and cows receiving a low UIP supplement (38.1% of their supplemental protein as UIP) had lower first-service conception rates (29.2%) than those fed a medium UIP supplement (57.6%) and also tended to have lower first-service conception rates than those fed a high UIP supplement (54.6%). Overall, pregnancy rates tended to be greater in the medium (61.5%) and high (56.4%) UIP groups compared with those in the low (43.2%) UIP group. Therefore, supplementing the heifers and cows in this study at the medium UIP level (56.3% UIP) improved first-service

conception rates and tended to improve pregnancy rates but supplementation with high UIP (75.6% UIP) did not improve reproductive function over those fed medium UIP.

Wiley et al. (1988) found that UIP supplementation reduced cow postpartum interval when MP was deficient. Wiley et al. (1991) also reported that postpartum cows supplemented with UIP added to a 70% DIP supplement responded with a shorter interval to cyclicity, regardless of prepartum nutrition. Deutscher et al. (1997) found that supplementing the diet of heifers consuming meadow hay with protein, thereby increasing their MP supply, resulted in the heifers conceiving and calving earlier than those which did not receive additional protein.

In a study by Dhuyvetter et al. (1993), beef cows grazing native winter and spring rangeland were fed supplements (54% CP) containing different quantities of UIP (25% or 50% UIP) from calving until breeding. The percentage of cows serviced in the first 21 days of breeding and pregnancy rates did not differ regardless of postpartum protein supplement.

CHAPTER IV

SUMMARY AND CONCLUSIONS

The cows used in this study had higher MP requirements than expected due to greater milk production. According to calculations for the MP intake of the actual treatments, the MP requirements were not met for any of the treatment groups and the range in MP balance among treatments was smaller than anticipated. Some trends were observed for incremental levels of supplementary UIP but no treatment differences were found for forage intake, cow weight and BCS change, milk production, calf weight change and number of days from calving until the first normal luteal function.

The high production and reproduction responses of all the treatments indicate that although according to the MP sytem the MP requirements were not met for any of the treatments, the cows were probably not MP deficient and MP requirements may have been over predicted. Lack of response to treatment could also be due to the fact that the actual MP range across treatments was smaller than originally calculated and/or that the duration of the treatment from

calving until the first availability of high quality spring forage was very limited and possibly the cows did not have sufficient time to respond to treatment.

Due to the natural variation of the CP content and the DIP and UIP fractions in forages and in supplements, accurately feeding a specific amount of supplemental UIP and/or DIP is difficult. To compound matters, supplements are calculated and mixed based on previous data prior to the season in which they are fed and thus may or may not accurately compliment the DIP and UIP values of the forages and native range which is available and utilized in the time that the supplement is fed.

To date there is still limited data available for the evaluation of the MP system. Many production responses to feeding additional DIP and UIP are varying or contradictory and therefore reasons for production responses to supplemental DIP and UIP need further research. It was noted by Galyean (1996) that in the case of beef cattle finishing diets, improvements in performance noted in recent research seemed to be more consistent when supplemental CP was derived from DIP rather than UIP sources.

Despite its sensitivity, the MP system has merit in predicting and meeting the protein requirements of beef cattle. For cattle which are deficient in DIP and/or UIP the use of the MP system should allow producers to more accurately predict the type and amount of supplements necessary to achieve and maintain predetermined performance standards. By feeding the correct amount and type

of supplement at specific times, overall cost of supplementation could be reduced.

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APPENDIX

TABLE 10. ESTIMATED VALUES OF COMPONENTS OF PROTEIN SUPPLEMENTS FED TO EARLY LACTATING BEEF COWS GRAZING DORMANT NATIVE RANGE

Item	DM %	CP %	DIP %	UIP %	NEm Mcal/kg	Ca %	P %	K %
Soybean meal	90	54	65	35	2.15	0.29	0.71	2.42
Soybean hulls	90	12	75	25	1.86	0.53	0.18	1.29
Blood meal	91	94	25	75	1.51	0.40	0.32	0.31
Corn gluten meal	88	66	41	59	2.20	0.07	0.61	0.48
Molasses	76	6	100	0	1.70	0.15	0.03	6.06
Dicalcium phosphate	97	0	0	0	0	22	19.3	0
Potassium chloride	100	0	0	0	0	0	0	50.54

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