The effects of degradable and metabolizable protein supply on the performance of first-calf heifers
by Leif Paul Anderson

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Animal Science
Montana State University

Abstract:
Trial 1 evaluated the effects of supplements containing varying amounts of degradable intake protein (DIP) and undegradable intake protein (UIP) to create deficient or adequate diets of DIP and(or) metabolizable protein (MP) on cow and calf weight gains, body condition score (BCS), milk production, and diet digestibility. Thirty-two individually fed first-calf heifers were allotted to a 2x2 factorial arrangement of treatments [main effects of DIP and MP] one day after calving, fed a basal diet of chopped crested wheatgrass hay (4.3% CP, 55% TDN, 67% DIP) ad libitum for 60 d.

The DIP and UIP were supplied by using differing ratios of soybean and protected soybean meal in a supplement. Cow weight change was greater (P<.01) when adequate DIP was supplied compared to cows deficient in DIP. BCS was improved (P<.01) with DIP but not with MP (P>.10). Levels of BUN were higher (P<.01) in cows receiving adequate DIP vs. MP. Milk production and calf daily gains were not changed (P>. 10) due to treatment. Digestibilities of OM, NDF and ADF were similar among treatments. Trial 2 also evaluated the effects of protein supplementation on changes of cow and calf weight gain, BCS and pregnancy rate when supplements contained varying amounts of DIP and UIP. Ninety first-calf heifers were allotted to a 2x2+1 factorial arrangement of treatments one day after calving, group fed grass hay (5% CP, 58% TDN, 53% DIP) ad libitum for 60 d and individually supplemented 3 d/wk. Degradable intake protein and MP were supplied using differing ratios of soybean, protected-soybean and corn gluten meals with fifth treatment included to assess replacing soybean meal with urea. Diets adequate in MP improved (P<.05) cow weight gain. Calves of dam’s supplemented with DIP were 5 kg heavier at 60 d than calves from dam’s deficient in DIP. BUN levels increased with both DIP (P<.01) and MP (P<.01) treatments. Urea substitution had no effect on cow and calf performance or overall BUN levels. Pregnancy rate was not affected (P=.90) due to supplementation. These data suggest DIP was the limiting protein fraction for Iactating first-calf heifers.

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APPROVAL

of a thesis submitted by

Leif Paul Anderson

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency and is ready for submission to the College of Graduate Studies.

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VITA

Leif Paul Anderson was born on March 12, 1973 to Donald and Oddlaug Anderson in Havre, Montana. Leif attended Devlin Elementary School and Havre Middle School before graduating from Havre High School in May of 1991. Upon graduation, Leif pursued his interest in agriculture receiving a Bachelor's of Science in Animal Science from the College of Agriculture at Montana State University-Bozeman in May of 1996. Leif then began his graduate studies at Washington State University before transferring to Montana State University to finish his graduate studies in Animal Science. Leif Paul Anderson was awarded his Master's of Science in Animal Science from Montana State University-Bozeman in December of 1998.

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ABSTRACT

Trial 1 evaluated the effects of supplements containing varying amounts of degradable intake protein (DIP) and undegradable intake protein (UIP) to create deficient or adequate diets of DIP and(or) metabolizable protein (MP) on cow and calf weight gains, body condition score (BCS), milk production, and diet digestibility. Thirty-two individually fed first-calf heifers were allotted to a 2x2 factorial arrangement of treatments [main effects of DIP and MP] one day after calving, fed a basal diet of chopped crested wheatgrass hay (4.3% CP, 55% TDN, 67% DIP) ad libitum for 60 d. The DIP and UIP were supplied by using differing ratios of soybean and protected soybean meal in a supplement. Cow weight change was greater (P<.01) when adequate DIP was supplied compared to cows deficient in DIP. BCS was improved (P<.01) with DIP but not with MP (P>.10). Levels of BUN were higher (P<.01) in cows receiving adequate DIP vs. MP. Milk production and calf daily gains were not changed (P>.10) due to treatment. Digestibilities of OM, NDF and ADF were similar among treatments. Trial 2 also evaluated the effects of protein supplementation on changes of cow and calf weight gain, BCS and pregnancy rate when supplements contained varying amounts of DIP and UIP. Ninety first-calf heifers were allotted to a 2x2+1 factorial arrangement of treatments one day after calving, group fed grass hay (5% CP, 58% TDN, 53% DIP) ad libitum for 60 d and individually supplemented 3 d/wk. Degradable intake protein and MP were supplied using differing ratios of soybean, protected-soybean and corn gluten meals with fifth treatment included to assess replacing soybean meal with urea. Diets adequate in MP improved (P<.05) cow weight gain. Calves of dam's supplemented with DIP were 5 kg heavier at 60 d than calves from dam's deficient in DIP. BUN levels increased with both DIP (P<.01) and MP (P<.01) treatments. Urea substitution had no effect on cow and calf performance or overall BUN levels. Pregnancy rate was not affected (P=.90) due to supplementation. These data suggest DIP was the limiting protein fraction for lactating first-calf heifers.

CHAPTER 1

INTRODUCTION

Beef cattle producers seek methods to continually optimize the economic efficiency of their enterprises. Forages, which are either grazed or fed, provide the base resource of nutrients for the beef cow. However, there are times throughout the year when forage may not provide adequate levels of protein and (or) energy because of limiting quality and (or) quantity. Often, the first limiting dietary nutrient is protein. The 1996 publication, "Nutrient Requirements of Beef Cattle" (NRC, 1996), describes the refined concept for meeting the protein requirements of beef cattle. With the release of this publication, the expression of the animal's requirement for protein has changed from a generalized crude protein (CP) requirement (nitrogen (N) x 6.25) to requirements for both the ruminal microbial population and the animal; the metabolizable protein (MP) system. Ruminal microbes require degradable intake protein (DIP) which is defined as that portion of consumed protein digested in the rumen and potentially available for microbial protein synthesis. Undegradable intake protein (UIP) is that portion of protein which resists rumen degradation and escapes into the small intestine where it may be absorbed to meet requirements for muscle growth, milk production, reproduction and other tissues. Microbial protein passing out of the rumen plus UIP combine to meet the animal's MP requirement.

Supplements in winter feeding programs account for as much as 50% of the total "out of pocket" cost associated with maintaining cows. Therefore, it is important to understand the effect that supplementation programs have on the efficiency of nutrient usage by beef cows. Research show that supplementing low quality forage-based diets with protein may have more of a positive benefit for heifer productivity than supplementation with a starch-based energy supplement. It is generally believed this may be a response from stimulated forage consumption and enhanced digestion, which in turn provides more dietary energy.

The overall goal of this research project was to determine the necessary information to achieve optimal performance from first-calf lactating heifers by evaluating dietary DIP and UIP ratios. The specific objectives were to: 1) determine the influence of meeting the ruminal DIP and (or) animal's MP dietary requirements for lactating first-calf heifers by measuring changes in weight gain, body condition, diet intake and digestibility, milk production and pregnancy rates; and 2) to validate the 1996 NRC Beef Cattle Requirements computer model used to estimate the animal's requirements by comparing predicted vs. actual cow performance.

CHAPTER 2

LITERATURE REVIEW

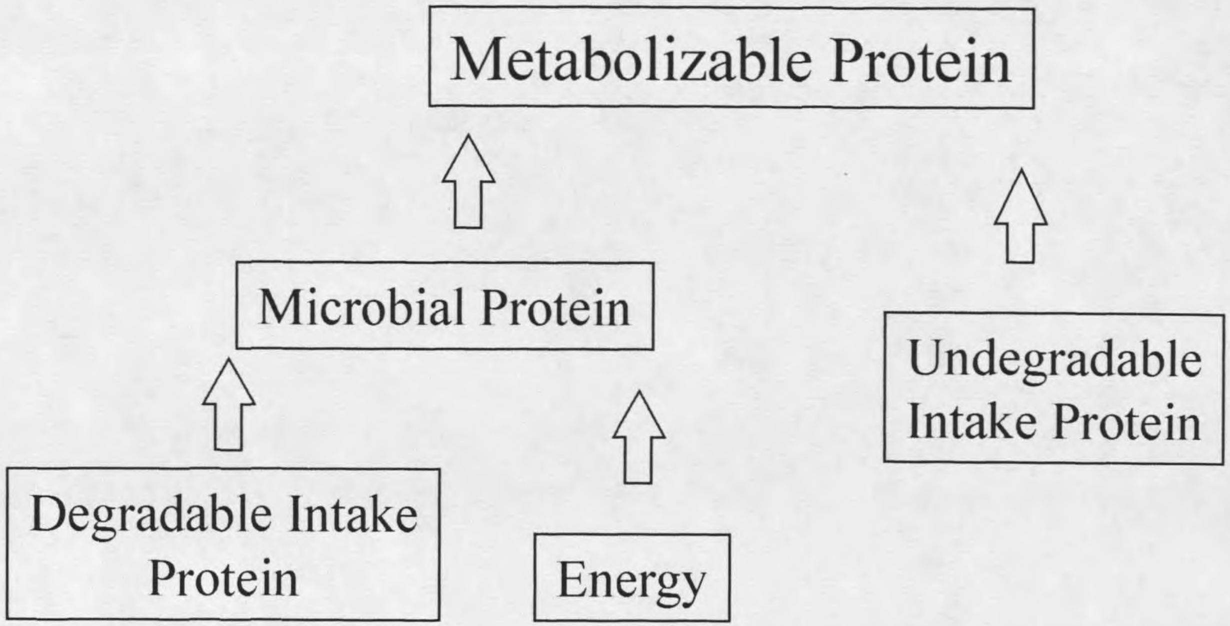
Today's cattle producer continually faces the challenge of producing a profitable product that meets the customer's (feedlot, packer, purveyor, consumer) expectations. In order to remain profitable and enhance efficiency, it is essential to understand how supplementation affects first-calf heifer productivity. The 1996 NRC publication, "Beef Cattle Requirements", attempts to partition the protein requirements accounting for both microbial and animal requirements to improve protein supply and subsequent use and production by first-calf heifers.

Metabolizable Protein System

The NRC (1996) Beef Cattle Requirements adapted the metabolizable protein system (Burroughs et al., 1974; NRC, 1985) for two reasons. First, using the MP system over the CP system provides more information. Two components of protein can be accounted for in the MP system; DIP which is required for microbial growth and production of bacterial crude protein (BCP), and UIP which escapes rumen degradation (Figure 1). The NRC (1996) model estimates the DIP requirement by multiplying TDN intake by microbial efficiency. Due to microbial yield impacting both the DIP requirement and MP supply, Lardy et al. (1998) suggests caution when using book values for DIP and UIP, due to lack of complete estimates for degradabilities of forages and energy values. The previous CP system (NRC, 1984) assumed ruminal protein

Figure 1

Metabolizable protein system



degradability to be equal among feedstuffs. However, due to changes in growing conditions, year, location and feed type, wide ranges in feedstuff protein degradability can occur. A highly degradable protein source such as urea can not be fairly compared to slowly degradable sources like blood meal or feather meal for animal utilization at similar dietary protein contents. Second, animal requirements for both DIP and MP vary due to stage of production and even forage quality. Standard CP requirements may not account for microbial and animal requirements.

Cochran et al. (1997) stated that even if significant quantities of forage carbohydrates are available, ruminally available protein and (or) N is needed to permit microbial growth and fermentation. Their research indicates that effective use of low-protein forages is often limited by dietary DIP. Requirements for DIP can be partially met by urea supplementation. Even though DIP can be supplied by urea, high urea levels may not improve overall utilization of low-quality forage. Koster et al. (1997) found OM intake unaffected, but digestible OM declined with increasing levels of urea supplementation (0-100%). Cochran et al. (1997) detailed two methods of estimating amounts of DIP needed to maximize total digestible OM intake in forage-fed cattle. The first approach was based upon compiling literature where cattle were fed a basal diet of forage. There was a large range in percentpercent CP, OM digestibility and intake of forage. It is estimated that DIP should comprise 10% of DOM. The second approach was estimation by direct experimentation. Results indicated a plateau in intake when digestible OM contained 11% DIP.

NRC Computer Model

The 1996 NRC computer model utilizes the metabolizable protein system to balance the animal's protein requirements. This system accounts for protein degradation in the rumen, for the protein needs of the microorganisms (DIP) and the needs of the animal (MP). The NRC (1996) Beef Cattle Requirements defines MP as the true protein absorbed by the small intestine, supplied from both microbial protein and UIP.

Microbial protein supplied is estimated from the BCP synthesized. However, in order to estimate BCP, an estimate of microbial efficiency must also be given in conjunction with TDN estimates of the feedstuff. Microbial efficiency is defined as grams BCP synthesized per 100 grams of TDN (NRC, 1996). Bacterial crude protein is an important source of meeting the animals MP requirement, making synthesis of BCP economically important to beef cattle production (NRC, 1996). Zinn et al. (1981) measured microbial efficiency in steer calves fed 60% chopped alfalfa hay and 40% concentrate and estimated BCP synthesized to be an average of 15.1%, with a range from 11% to 19%. This was closely related to intake of digestible organic matter and rate of passage of non-microbial OM from the rumen.

Estimates of protein content, protein degradability, TDN and overall digestibility of a particular feedstuff are essential for proper formulation of beef cattle rations. Lardy et al. (1998) stated that better estimates, including intake, are factors necessary to properly use the NRC model. At present for grazing animals, estimates of protein degradabilities are lacking, lending to reliance on generalized book values. Lardy et al. (1996) determined that of the total CP content found in the forage, DIP comprised the largest fraction and total variation of CP % throughout the year than did the UIP fraction (Figure 2). Because protein degradability can vary due to plant species, year, location or harvesting method, degradability information greatly limits the model's effectiveness when using book values. However, in a review of forage CP values by Lardy et al. (1996), CP ranged from approximately 1.9% to 17.4% CP with digestibilities ranging from 37% to 73%. Because intake is associated with digestibility (Galyean and Owens, 1991), difficulty arises in estimating appropriate DIP requirements as defined in the 1996 NRC computer model.

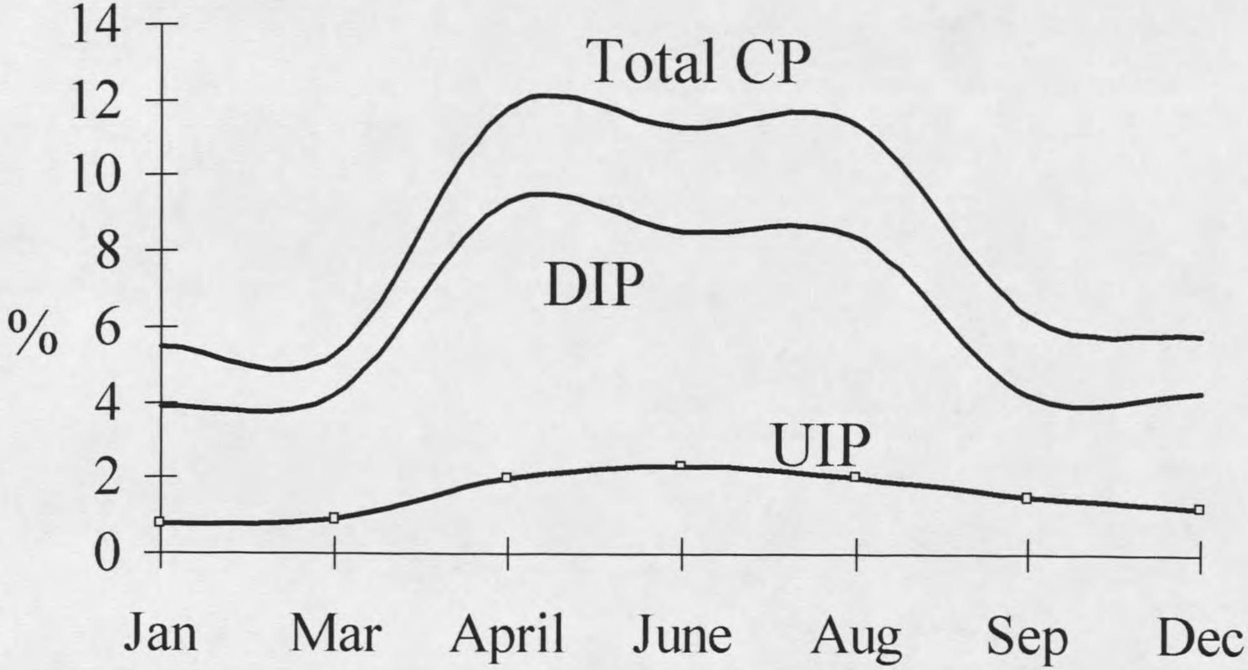
Lardy et al. (1998) noted that as microbial efficiency changed from 8 to 10%, DIP went from slightly deficient to highly deficient, while MP balance went from deficient to adequate in supply. They report microbial efficiency values for dormant native range to be approximately 7-10%. Higher microbial efficiency estimates will over predict DIP requirements and overestimate the MP supply.

Effect of Supplementation on Body Weight

Dietary protein intake has been cited as the primary limiting nutrient for cattle consuming forage or roughage based diets (Bowman et al., 1995; Cochran, 1995). A positive response to supplemental protein was measured for cow weight gain during both pre- and postpartum stages of production. Limited data show that supplementing protein to low quality forage based diets may have more of a positive benefit on heifer productivity than energy supplementation, based on increased weight gain and favorable protein supply (Wiley et al., 1991; Cochran, 1995). Moore et al. (1995) indicated that

Figure 2

Changes in protein fractions of native range (adapted from Lardy et al., 1996)



daily gains of cattle are generally increased with feeding of liquid protein supplements when CP concentrations were above 15% of OM. Appeddu et al. (1997a) found that two-year-old postpartum cows grazing winter range supplemented with protein lost less weight compared to unsupplemented cows (-20 kg vs. –33 kg). In a study supplementing lactating two-year-old heifers with a soybean meal (SBM) based supplement, Deutscher et al. (1997) found that heifers from the supplemented group were 8 kg heavier than heifers in the unsupplemented group at the end of the trial. Although diets were deficient in both protein and energy, weight loss was minimized with supplemental protein. Cochran et al. (1986) supplemented pregnant mature cows grazing fall-winter range with cubed alfalfa or cottonseed meal-barley cake, and found that supplemented cows gained more body weight than unsupplemented cows grazing only range. Huston et al. (1996) found that supplementation with a cottonseed meal or sorghum grain, regardless of feeding interval, reduced body weight loss of cows grazing native winter range. However, Kartchner and Carr (1978) indicated that there may be times during fall-winter grazing on native range, when snow cover is minimal, that supplementation with either energy or protein may not provide additional benefits in cow performance (cow weight change, body condition, reproduction) due to availability of forage.

Although protein supplementation may prove beneficial, optimal levels of DIP and UIP may increase response to supplementation. Dhuyvetter et al. (1993) found that early calving cows consuming winter range and fed a supplement containing 50% UIP lost 39 kg less body weight than cows provided a 75% UIP supplement. These results are in contrast with Forcherio et al. (1992), who found no difference in weight change for supplemented vs. unsupplemented cows, consuming summer pasture, with increasing amounts of UIP in the supplement (SBM:bloodmeal). However, Hibberd et al. (1988) found that supplementing lactating cows with 322 g/d UIP did decrease cow weight loss during late winter than supplementing with only 182 g/d UIP. Wiley et al. (1991) subjected to sub-maintenance or maintenance diets prior to calving and then supplemented with either CGM or SBM/wheat mill run supplements post-calving. The greatest postpartum weight gain was observed for cows on a low plane of nutrition supplemented with corn gluten meal (CGM) to provide additional UIP.

Mathis et al. (1998) determined the optimal amount (kg/d) of SBM to be fed to cows grazing low quality, tallgrass native range to maintain body weight (BW) and body condition score (BCS). Under their research conditions, a 0.45 kg/d decrease in intake of SBM could account for a 22 kg decrease in cow weight with a subsequent 0.4 decrease in BCS. Patterson et al. (1997) found that cow ADG during the lactation phase was unaffected by supplemental protein source. Supplemental protein sources were based on cull beans, sunflower meal or canola meal to provide high (182 g) or low (91 g) levels of CP $hd^{-1}d^{-1}$. Weder et al. (1996) measured increases in BW and BCS for cows grazing low-quality stockpiled meadow grass forage or fed meadow grass hay supplemented with high quality alfalfa hay (18% CP). Cattle consuming only the low-quality feed gained the least weight and lost body condition.

Effect of Supplementation on Body Condition

Protein supplementation can improve cow body condition during both gestation and lactation phases of production. With BCS at calving and breeding being important factors in reproductive performance, improving cow response by increasing body condition could be critical to rebreeding productivity.

To determine the necessary input to improve BCS by a 1 unit change, Lalman et al. (1997) varied diets prior to calving to create thin first-calf heifers (BCS = 4). After calving, heifers were allotted to one of four diets differing in energy content to provide different ending BCS and rates of gain. Increasing the dietary energy concentration increased weight and body condition by 90 d postpartum. As a result, they were able to classify a 1-unit loss in BCS with a 33 kg loss in cow body weight.

In a trial to compare supplemental DIP, UIP and fat, Appeddu et al. (1996) found that cows grazing winter range receiving UIP in the supplements (feathermeal; meat, blood and bone meal), regardless of additional fat for energy, had greater increases in body condition than cattle receiving only control or a combination DIP and fat. It was suggested that UIP has the potential to repartition nutrients towards body condition earlier in the postpartum period. However, Hibberd et al. (1988) found that supplementation with blood meal to provide UIP did not improve body condition of lactating beef cows. It was found that a combination of DIP and UIP (SBM and blood meal) in the supplements helped to improve cow performance by stimulating microbial fermentation and providing additional ruminal escape protein, thereby improving overall protein status of the cow.

Mathis et al. (1998) reduced BCS loss for spring-calving cows from December through May, the beginning of the breeding season, by increasing the level of supplemental SBM. However, supplementing beyond the animal's requirement for protein (> 1.75 kg/d of SBM) reached a response plateau for cow performance. Appeddu et al. (1997a) found that body condition loss tended to be less for two-year-old lactating cows grazing winter native range when supplemented with a protein cube based on CSM compared to cattle receiving no supplement. Appeddu et al. (1997b) also found that adding UIP to supplements equal in DIP content provided for a decreased body condition loss over cows not receiving any supplemental protein. Huston et al. (1996) measured reduced body condition loss when cattle where supplemented with CSM when grazing winter native range compared to cattle not receiving supplement. Weder et al. (1996) improved body condition of lactating crossbred cows by five percent when supplementing with high quality alfalfa hay compared to cattle consuming only low quality harvested forage. Triplett et al. (1995) observed no differences in body condition score for lactating cows fed supplements with increasing levels of UIP (38%, 56% or 75%). Reed et al. (1997) measured no difference in body condition change of first-calf heifers when diets were changed from a high forage to concentrate ratio (80:20) to a moderate forage based diet (50:50). Patterson et al. (1997) found that during lactation, daily body condition change was unaffected by protein source (cull beans, sunflower meal, canola meal) when cows grazed Eastern Colorado winter range.

Supplementation to provide additional sources of DIP or UIP has met variable success. Stage of production and basal diet quality appear to greatly influence source of protein required to balance for deficiencies.

Milk Production and Effects on Calf Performance

Improving body weight and body condition is important in preparing the cow for the breeding season, but pounds of calf produced at weaning can significantly impact profitability. Early et al. (1998) reported that increased weaning weight could offset the costs of a liquid protein supplement. Milk production data collected after 120 d of lactation measured 27% greater calf ADG in the supplemented groups than unsupplemented groups. Calves consumed the protein supplement with supplementation increasing both the calf's and cow's ADG.

Ansotegui et al. (1991) related calf gain during the first 60 d of lactation with total milk intake. However, as lactation progressed, milk intake and ADG were no longer significantly correlated. Gleddie and Berg (1968) suggested one test milking was a good estimate of milk yield compared to multiple milking throughout one day or over multiple days. Milk yield was highly related to calf ADG from birth to weaning when estimated during any month of lactation. Milk production and consumption early in the calf's development can benefit the productivity (ADG) through to weaning.

Although supplementation can affect milk composition, Rutledge et al. (1971) reported that milk quantity was a more important factor for influencing 205 d weaning weight than milk quality. Appeddu et al. (1997a) measured a greater milk yield in two-year-old cows fed supplements high in additional UIP, supplied by feather, meat, bone and blood meals, compared to cows receiving a supplement containing SBM. The high UIP treatment cows tended to wean heavier calves, however, low or no additional UIP treatment cows responded with no difference in milk production or calf weaning weight. Hibberd et al. (1988) were able to increase milk production by supplementing blood meal to cows grazing dormant native grass during the winter. Calves suckling cows fed blood meal gained more weight than calves suckling cows fed a SBM supplement. Triplett et al. (1995) measured greater milk production in heifers fed a medium UIP (56%, provided by fishmeal and SBM) supplement than heifers receiving a high level of UIP (75%, provided by fishmeal) in the supplement. Also, calves from dams fed medium levels of UIP had a greater ADG than calves of dam's receiving either low (38%, SBM) or high UIP diets. Appeddu et al. (1997b) suggested that increased levels of UIP fed to young postpartum cows resulted in improved acetate utilization and an increased supply of glucogenic amino acids, which spared the cow's body reserves.

Blasi et al. (1991) found a cubic response for milk production and calf gain in cows grazing smooth brome during active growth periods. By replacing corn starch and molasses with CGM and blood meal, UIP content increased from 0 to .34 kg/d of UIP/animal. Due to the low quantity of UIP in the smooth brome, it was suggested the moderate UIP supplements helped to meet the MP requirements. ∅rskov et al. (1981) used lactating Friesian cows fed a low quality diet and supplemented fishmeal at 1 kg/d as a source of UIP and found it stimulated greater milk yield compared to cows supplemented with barley fed at the same level. However, a greater loss of calculated body reserves and live-weight was also observed compared to a supplement of groundnut meal providing additional DIP. Forcherio et al. (1992) measured increased milk production for cows grazing endophyte-infected tall fescue during 70 and 150 d of lactation when supplemented with either cracked corn or soyhulls. Cows consuming lower levels of UIP in the supplement produced more milk and greater calf gains than cattle offered the high UIP supplement. Hess et al. (1998) measured greater milk yield for cattle fed supplemental protein with protected amino acids (methionine and lysine) compared to cattle fed a control protein supplement (corn/SBM). However, no difference in calf growth performance was associated with the dam's dietary treatment. Wiley et al. (1991) measured no difference in milk production for first-calf heifers fed supplements containing either UIP or DIP. Supplementation consisted of either a combination of blood meal and CGM to provide UIP in supplements or SBM and wheat mill run for the DIP supplements. No difference in calf weight was measured due to differences from feeding either supplement to postpartum dams. Holloway et al. (1979) compared performance of lactating beef cows grazing high or low quality pastures. Milk production was unaffected between forage treatments; however, calf gain was greater for calves on high quality pastures. These researchers suggested that this appeared to be due to increased consumption of nutrients from the forage and not the level of milk ingested.

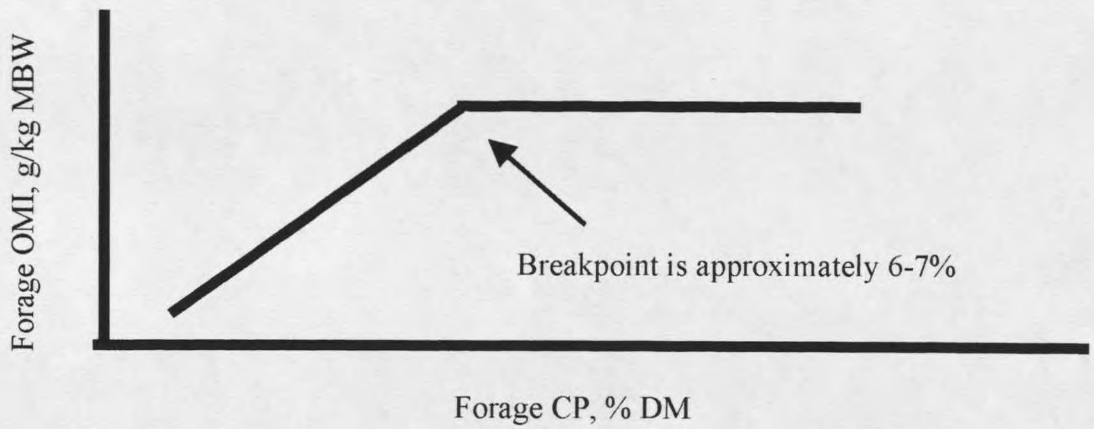
Effect of Supplementation on Forage Intake and Digestibility

Diets deficient in MP may benefit from supplementation of additional UIP. However, this UIP source needs to be balanced with a degradable protein source to provide adequate protein for proper ruminal fermentation. Cochran et al. (1997) suggested that intake and digestion of low quality forage can be stimulated by supplementation with a degradable protein source, however, there is apparently an upper limit to which total digestible organic matter intake could be maximized. Moore et al. (1995) found that when DOM:CP ratios were greater than 12, all types and levels of supplements increased forage intake, however, DOM:CP ratios between 7 and 12 had variable effects, both increasing and decreasing forage intake. Hollingsworth-Jenkins et al. (1996) researched the effect of level of supplemental DIP supplied to gestating beef cows grazing native winter range on intake and digestibility. No difference in forage intake was measured by increasing levels of steep liquor to increase DIP supplied, however, there was a tendency to linearly increase digestibility with increased levels of DIP.

In a review by Paterson et al. (1996), it was suggested that an increased intake of forage digestible DM due to protein supplementation could be measured by an enhancement of performance. Owens et al. (1991) suggested enhanced cattle performance in response to protein supplementation may be due to: 1) increased intake of digestible DM from the supplement directly; 2) increased intake of digestible forage DM in response to increased rate and (or) extent of digestion; 3) increased gut fill; 4) or increased rate of passage or increased efficiency of nutrient use. Bowman et al. (1995) and Cochran (1995) suggested voluntary forage intake was increased by protein supplemetation until forage CP was between 6-7%, after which intake levels were not further stimulated by supplemental protein (Figure 3). Hess et al. (1998) found that

Figure 3

Relationship between forage CP and OM intake (adapted from Bowman et al. 1995, Cochran, 1995)



complementing SBM as a DIP source with ruminally protected amino acids improved overall cow productivity (maintained body weight, increased milk production). It was suggested that although DIP and energy may stimulate fermentation, microbial protein synthesis was still limiting total MP supply. The protected amino acids augmented this deficiency by allowing amino acids escape to the small intestine for absorption by the cow, thereby improving overall protein status.

Deutscher et al. (1997) investigated the effect of a SBM/wheat pellet supplement on low quality meadow hay by measuring digestibility of the hay. No differences were measured in hay intake or digestibilities for lactating two-year-old heifers. Forcherio et al. (1992) varied the level of UIP in supplements fed to cow-calf pairs grazing growing tall fescue. No differences in forage intake were measured due to supplementation with SBM (low UIP) compared to blood meal (high UIP). Gaylean and Owens (1991) reported that changing ruminal degradability of supplemental protein for cattle consuming low-quality roughages had little effect on ruminal OM and fiber digestion. Serrato-Corona et al. (1997) compared varying ratios of DIP:UIP in a supplement for two-year-old lactating cattle fed sudan grass hay. Dry matter and NDF digestibilities of diets were similar among treatments. However, with increasing N content of the supplements, apparent N digestibility was increased compared to control (no supplement) and low level protein supplemented groups. Guthrie and Wagner (1988) evaluated the effects of a low (0.36 kg/d of 32% CP) or high-level (0.67 kg/d of 34% CP) protein supplement or a grain-based supplement compared with supplementation with only a vitamin-mineral premix for steers fed harvested prairie hay. Supplementation with either protein- or grain-based supplements improved hay DM intake and digestibilities of DM, OM, CP, ADF and cellulose compared to steers receiving only a mineral-vitamin mix. High levels of protein in the supplement provided additional increases in DM OM, CP, ADF and cellulose digestibilities over low levels of protein in the supplement. They found that adding SBM consistently increased observed diet digestibilities above calculated digestibilities. Heldt et al. (1998) compared wheat middlings to SBM and corn-SBM as supplements for cows grazing winter range. High levels of wheat middlings (0.68 kg/d CP) resulted in lower total digestible DMI than low levels of wheat middlings (0.34 kg/d CP). Corn-SBM supplemented cattle had higher digestible DMI than cattle supplemented with high levels of wheat middlings. Kartchner and Carr (1978) compared protein supplements for gestating cows grazing winter native range forage. Supplementation with either protein or energy fed to be isocaloric provided no benefit over control animals receiving no supplement when forage intake and digestibility were evaluated. It was suggested, however, the short-term nature of the experiment did not allow for any significant effects, even though grain supplementation tended to decrease digestibility of the low quality forage.

Martin and Hibberd (1990) determined the intake and digestibility of low quality grass hay when cows were supplemented with differing levels of soybean hulls (1, 2 or 3 kg/d). Digestibility of NDF was unaffected by supplementation, however, ADF digestibility was increased with increasing level of soybean hull supplementation. Total OM digestibility also increased, but was due to greater digestibility of soybean hulls compared to the hay. Only a slight reduction in forage intake (0.64 kg/d) was measured when 3 kg/d of soybean hulls was fed. Petersen et al. (1985) conducted metabolism trials to determine the influence of protein degradability in range supplements fed to yearling steers consuming mature native forage. Supplements contained 40% CP and consisted of combinations of corn, soybean meal, blood meal and urea. Increases in DM, CP and NDF digestibilities for supplemented diets and increased ADF digestibility for diets supplemented with SBM were measured compared to unsupplemented diets. Nitrogen retention was greater for cattle fed SBM and blood meal-urea compared to SBM-urea or no supplement. Westendorf and Gordan (1998) measured the responses of lambs fed increasing levels of UIP for N digestibility and retention. Growing lambs fed diets low in protein had greater N retention and lower urinary N excretion when fed fishmeal compared with SBM. Reed et al. (1997) compared digestive characteristics in beef heifers fed high- (80:20) and medium-forage (50:50) to concentrate ratio diets. Digestibility of DM was greater for the moderate-forage diet; however, NDF digestibility was not different between treatments. Less dry matter and NDF were digested for the moderate-forage diet due to the restriction of intake to provide equal amounts of metabolizable energy.

Effect of Supplementation on Reproduction

Supplementing SBM to provide DIP enhances ruminal fermentation and can potentially improve intake, weight gains and body condition. Improving protein and energy status then allows for redirection of available nutrients to non-maintenance functions. Dzuik and Bellows (1983) indicated that reproductive efficiency is a major factor affecting cow profitability. Recently, questions have arisen with DIP and UIP supplementation as to whether increased reproductive performance was due to positive effects on cow body condition, body weight, and digestion or may be due to catalytic activity on hormonal and metabolic pathways in response to protein supplementation (Wiley et al., 1991).

Whitman et al. (1975) determined that a significant portion of variation in return to estrus in the period 60 to 90 d postpartum was due to cow body condition score at calving. Richards et al. (1986) found that the interval to estrus and interval to pregnancy were reduced for cattle with body condition scores greater than five compared to cattle with body condition scores less than four. Lalman et al. (1997) measured decreases in postpartum interval as dietary energy density increased from 198 to 305 kcal of ME kg^{-1} $BW^{.75\ -1}$ postpartum. Condition score at calving accounted for greater variation in postpartum interval than did change in condition score or body weight 90 d postpartum.

Appeddu et al. (1997a) fed two-year-old cows either high- (+ 256 g/d) or low-levels (+52 g/d) of supplemental UIP or no supplement during the postpartum period. The high-level UIP supplement consisted of cottonseed meal and animal byproducts while the low-level UIP supplement was composed of wheat midds, SBM and cottonseed meal. Protein supplementation decreased days to rebreeding and numerically increased the percentage of cows pregnant during the first 25 d of the breeding season. While overall pregnancy was unaffected, earlier conception and increased calf gains were accomplished without delaying time to rebreeding. No differences were attributed to UIP content. Appeddu et al. (1996) evaluated feeding postpartum two-year-old range cows supplements containing combinations of DIP, UIP, and fat; or a commercial energy cube. Protein supplements were based on cottonseed meal and fat or animal byproducts for additional UIP. Fat supplementation decreased cows cycling by the breeding season and increased milk production. They suggest feeding fat repartitioned nutrients away from needed reproductive processes while feeding UIP stimulated earlier conception. Deutscher et al. (1997) supplemented SBM to two-year-old lactating beef heifers fed low quality meadow hay. Supplementation increased rebreeding performance, with cows calving nine days earlier with their second calf than non-supplemented cows. Dhuyvetter et al. (1993) in a calving study found cows that received supplements containing 25% UIP returned to estrus faster than cattle offered a 50% UIP supplement. Dunn et al. (1969) compared various levels of energy intake on pregnancy rate. By 80 days post-calving, 54% of cattle on the high energy diet were pregnant compared to 42% on a moderate and 33% on a low energy diet. Because all other nutrients were fed according to NRC requirements, energy was considered to be the only limiting nutrient. Mathis et al. (1998) provided increasing levels of SBM as a supplemental source of DIP to Hereford x Angus cows grazing low quality, tallgrass-prairie forage. Although increasing SBM supplementation did minimize body weight and body condition score loss, pregnancy rate was not influenced by the additional DIP.

Reed et al. (1997) compared shifts in energy supply from forage to concentrate in primiparous beef heifers. Although the maximum size of the ovulatory follicle was greater for cattle on a high forage diet, overall reproduction (postpartum interval, first service, and conception rates) was not different among treatments. Randel (1990) in a review of literature correlated dietary protein intake to reproduction. Lactating beef cows and heifers receiving protein deficient diets during gestation had uniformly lower pregnancy rates than cows fed adequate protein diets. Inadequate protein during the postpartum period depressed pregnancy rate compared to cows receiving diets adequate in protein. Sasser et al. (1988) evaluated the effect of a protein restricted diet on return to estrus and conception of first-calf beef cows. Cows with reduced protein intake had an increased postpartum interval to first estrus, to first service and to conception. Overall pregnancy rates were 32% for protein restricted heifers compared to 74% for protein adequate heifers. Estrus was also reduced from 89% to 63% for animals receiving a protein restricted diet. Triplett et al. (1995) reported improved first-service conception rates and tended to improve pregnancy rates when cattle were supplemented with medium levels of UIP postpartum (56% UIP from fishmeal and SBM). Wiley et al. (1991) increased the percentage of heifers bred during the first estrus cycle of the breeding season by feeding supplemental UIP. Although more cattle were bred earlier in the season, overall pregnancy rate was not affected by level of DIP or UIP in the supplement. Albertini et al. (1996) examined the effects of supplements containing UIP on the postpartum interval of Hereford x Angus heifers. Under their study conditions, UIP was not effective in altering resumption of ovarian activity in postpartum cattle. Possibly a potential response to UIP supplementation was overshadowed by limited forage quantity or quality providing low energy intakes.

Supplementing to only correct for a protein deficiency may not be adequate to achieve the desired response from cattle (weight gain, body condition, rebreeding).

Although protein supply meets animal requirements, high energy deficiencies may offset gains anticipated by supplementation. Understanding forage supply, digestibilities, stage of production and application of resources is essential in maintaining beef cattle productivity. Research has provided continued building blocks to solutions while posing many new questions.

CHAPTER 3

THE EFFECTS OF DIP AND MP SUPPLY OF FIRST-CALF HEIFERS ON DIET UTILIZATION, WEIGHT GAIN, MILK PRODUCTION, AND CALF GAIN

Summary

The effects of protein supplementation on cow and calf weight gains, body condition score (BCS), milk production, and diet digestibility were evaluated when supplements contained varying amounts of DIP and UIP to provide deficient DIP and(or) MP to adequate DIP and(or) MP. Thirty-two individually fed first-calf heifers (avg. 395 kg) were allotted to a 2x2 factorial arrangement of treatments [main effects of DIP and MP] one day after calving, based on cow weight and sex of calf. Cows were fed a basal diet of chopped, crested wheatgrass hay (4.3% CP, 55% TDN, 67% DIP) ad libitum for 60 d through Calan-Broadbent gates. The DIP and UIP were supplied by using differing ratios of soybean and protected soybean meal in a supplement. Average N degradabilities for the soybean meal and protected soybean meal were 75 and 30%, respectively. All diets were formulated to provide equal amounts of energy. Cows were weighed and BCS measured on d 0, 30, 60. Milk production was determined by weigh-suckle-weigh at d 45 of the experiment. Calf weights were recorded on d 0, 45, and 60. Blood urea nitrogen (BUN) levels were determined for the cows at d 60. Cow weight change was greater ($P<.01$) when adequate DIP was supplied compared to cows deficient in DIP (avg. 39.0 vs. 2.2 kg). There was no response ($P>.10$) in cow weight change to altering MP. BCS was improved ($P<.01$) with DIP compared with MP ($P>.10$)

supplementation (0.5 vs. 0). Levels of BUN were higher (P<.01) in cows given supplemental DIP vs. MP (avg. 16.5 vs. 6.6 mg/dL). Milk production and calf daily gains were not changed (P>.10) due to DIP or MP treatment (8.1 vs. 8.4 kg/d; 0.60 vs. 0.56 kg/d, respectively). Digestibilities of OM, NDF and ADF were similar among treatments. Digestibility of N was higher (P<.01) when DIP was adequate (73.8%) compared to deficient DIP (59.3%). This research suggests that providing DIP in early lactation results in increased N digestibility compared to providing supplemental UIP. Providing DIP in early lactation resulted in faster weight gains and increased BCS, with no change in intake compared to providing supplemental UIP to first-calf heifers fed a basal diet of low-quality hay.

Introduction

Limited research indicate that supplementing protein to low quality forage-based diets may have more of a positive benefit for heifer productivity than energy supplementation due to improved protein status and positive influences on intake (Cochran, 1995; Wiley et al., 1991). This may be a response to increased forage consumption which provides more dietary energy (Jones et al.,1995). Research has also indicated that protein supplementation of thin cattle receiving protein restricted diets will improve N retention and NDF digestibility (Sawyer et al., 1998). Protein supplementation can also affect production factors other than intake and digestibility. Hibberd et al. (1988) increased cow milk production by supplementing blood meal to cattle grazing dormant native grass in the winter. Meek et al. (1998) reported that increasing weaning weight by 1% or decreasing the sale of dry cows could lead to a $3.36 to $6.51 increase of value per cow in the herd.

It has been hypothesized that determining the optimal balance of DIP and UIP in the diet of the first-calf heifer will have a positive effect on the postpartum performance. Appeddu et al. (1997b) suggested that increased levels of UIP fed to young postpartum cows could result in improved acetate utilization and an increased supply of glucogenic amino acids, sparing the cow's body reserves. A study in which lactating two-year-old heifers were supplemented with a soybean meal (SBM) based supplement, Deutscher et al. (1997) found that supplemented heifers were heavier than non-supplemented heifers at the end of the trial. The objective of this research was to determine the implications of altering the DIP and(or) MP supply in the diet of lactating first calf heifers in terms of forage intake, diet digestibility, milk production and weight gain during the first 60 d of lactation.

Materials and Methods

Animals. This experiment was conducted at the Montana State University Teaching and Research Facility (MSU), Bozeman, Montana from March 10, 1997 to June 20, 1997. Animal care was conducted according to the guidelines established by the Montana State University Animal Care and Use Committee. Thirty-two, Angus-cross 2-yr-old primiparous cows selected randomly from the Montana State Prison herd at Deerlodge, Montana were transported to MSU 14 d prior to calving. Cows were trained to use the Calan-Broadbent gates for 7 d to adapt to the pens and feeding troughs.

Average initial BW and BCS of all cows were 395 kg and 4.1 (BCS scale 1-9), respectively.

Treatments. One day after calving, cows were allotted to a 2x2 factorial arrangement of dietary treatments based on cow calving weight and sex of calf to insure equal distribution throughout the treatments. Diets were formulated to be deficient in both DIP and MP (DEF, -345 g/d DIP, -123 g/d MP), deficient in DIP but adequate in MP (MPS, -306 g/d DIP, 0 g/d MP), adequate in DIP but deficient in MP (DPS, 18 g/d DIP, -54 g/d MP), or adequate in both DIP and MP (ADEQ, 15 g/d DIP, 36 g/d MP) according to NRC (1996) based on a microbial efficiency value of 10%. Supplements containing protected soybean meal (heat treated) consisting of 70% UIP of total protein were fed to supply diets adequate in MP. Soybean meal containing 25% UIP of total protein was fed as a ruminal degradable source of protein to supply DIP requirements. Soyhulls were fed as a fiber based source of energy to create isocaloric diets (-1.5 Mcals/d; NRC, 1996; Table 1).

A basal diet of chopped (5-10 cm chop) crested wheatgrass hay (CW; 4.3% CP, 55% TDN, 67% DIP) was fed by use of Calan-Broadbent gates. Heifers were individually fed supplements and CW once daily at approximately 1400. The basal CW ration was fed ad libitum maintaining a 20% refusal rate. Supplements were fed 15 min prior to feeding CW. Within 7 d of application of treatment, cows were consuming supplement at designated amounts. Diets were fed for 60 d.

Table 1. Composition of diets fed to first-calf heifers to determine the effects of supplying adequate degradable (DIP) and(or) metabolizable (MP) protein.

Item	DEF[a]	MPS[b]	DPS[c]	ADEQ[d]
	------------------- kg of DM/day	-------------------		
Crested wheatgrass hay	9.50	9.50	9.50	9.50
Protected SBM[e]		0.59		0.45
Soybean meal			1.25	1.13
Soybean hulls	1.93	1.29	0.68	0.34
Molasses	0.09	0.09	0.09	0.09
Mineral[f]	0.11	0.11	0.11	0.11
Calculated Analysis, 10% microbial efficiency				
Supplement, CP%	11	20	32	38
DIP balance, g	-345	-306	18	15
MP balance, g	-123	0	-54	36
NEm balance, Mcal	-1.51	-1.56	-1.53	-1.54

[a]Deficient DIP, Deficient MP

[b]Deficient DIP, Adequate MP

[c]Adequate DIP, Deficient MP

[d]Adequate DIP, Adequate MP

[e]Amino Gain provided by Consolidated Nutrition, L.C.

[f]12% Ca, 12% P, 1250 ppm Cu, 450 ppm Zn

Three cows were removed from the trial due to losses of calves from viral infection. Data from these cows was removed creating unequal numbers within treatments at the end of the trial.

Measurements. Individual feed intakes were measured daily during the 60 d trial. Cow weight was measured on d 0, 30, and 60. Cow BCS was also measured on d 0, 30, and 60 to determine body condition change due to supplementation. Calf weight was measured on d 0, 45 and 60.

On d 45, milk production was estimated using a modification of the weigh-suckle-weigh technique described by Williams et al. (1979). At 0600, calves were allowed to suckle. Following suckling, calves were removed from their dams at 0630 and separated for 6 h. Calves were weighed at 1230, paired back with their dams, allowed to suckle until completion and reweighed. Milk production for 6 h was then determined and adjusted to 24 h production.

On d 60 (trial termination) a blood sample was collected from cows by jugular venipuncture 4 h after feeding for determination of BUN (Dade, 1997). Blood urea N was analyzed to verify N status of animals.

Daily feed intake was measured with diet samplescollected every 14 d and fecal samples collected at d 60 to determine diet digestibility.

Laboratory Analyses. Fecal samples were dried in a forced air oven at 60°C for 48 h. Samples were ground through a Wiley mill to pass a 1mm screen. Analyses of diet and fecal samples included DM, OM, and Kjeldahl N as described by AOAC (1997).

Neutral detergent fiber and ADF were determined by the procedure of Van Soest et al. (1991).

Digestibilities were calculated by using acid insoluble ash (AIA) as an internal digestibility marker (Van Keulan and Young, 1977). Samples (3 g fecal, 9 g feed) were digested in 100 ml of 4 M HCl for 30 min. Samples were filtered through oven dried, pre-weighed sintered glass crucibles, and rinsed with boiling deionized water. Crucibles were then dried and ashed at 500°C overnight, brought to room temperature and weighed. Dry matter fecal output estimated from AIA was used to determine apparent dry matter digestibility of DM, OM, ADF, NDF and N by use of the following equations:

DM Fecal Output = Marker consumed (g/d) ÷ Marker concentration in feces (g/g)

DMD = [(DM intake of constituent (g/d) – Fecal DM output of constituent (g/d)) ÷ DM intake of constituent (g/d)] x 100

N degradabilities were determined on supplement and hay samples by use of a modified *Streptomyces griseus* protease (SGP; P-5147, Sigma Chemical, St. Louis, MO) in vitro method described in Abdelgadir et al. (1997). Samples containing 15 mg of N were weighed into Erlenmeyer flasks, 40 ml of borate-phosphate buffer (BP, pH 8.0) added, incubated for 1 h at 39°C and then 10 mL of a solution containing .33 units of SGP/mL was added. Using the single time-point method, samples were incubated at 39°C for 48 h with an additional set of samples placed for 8 h incubation to test initial degradability. Following incubation, samples were washed through Whatman No. 541