SUPPLEMENTAL PROTEIN SOURCES FOR GRAZING BEEF CATTLE

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Introduction

Most cow-calf operations use forages to provide the major source of nutrients for their livestock. When working with grazing or forage-fed cattle, it is common to encounter situations where the nutrient quantity and/or balance is undesirable. This may be evident as the inability of the animal to maintain itself (i.e., maintain weight and/or condition) or as the inability of the animal to meet a producer's performance expectations. The lower the quality of forage consumed and the higher the level of performance expected, the more likely it is that the nutrient density or balance will be inadequate. Under such conditions, supplementation represents an opportunity to bridge the gap between nutrient supply and demand. However, if forage is serving as the main source of nutrients, it is important that the supplement deliver the designated nutrients without negatively impacting the nutrients that can be harvested from the forage. Ideally supplements should work in concert with forages to meet nutrient demands while concurrently maximizing the proportion of those nutrients actually derived from the forage. In order to achieve such an ideal approach to supplementation, it is critical that we understand the impact of specific supplement constituents on forage use. This paper will focus on importance of protein, particularly degradable intake protein (DIP), in supplements for cattle consuming low-quality forage.

Importance of Supplemental DIP

Common feedstuffs used in supplementation programs vary in their concentration of crude protein (CP) and in the relative proportion of CP that is likely to be ruminally degraded (i.e., the DIP) or to escape ruminal degradation (i.e., the undegradable intake protein; UIP). Because supplemental UIP cannot contribute directly to microbial production and forage digestion primarily occurs in the rumen, the degradable portion of the supplemental CP is that which should have greatest impact on forage use. Furthermore, even when significant quantities of forage carbohydrate are available, ruminally available N and(or) protein must be present to permit substantive microbial growth and fermentation. This too suggests the importance of DIP and implies that it may be the macronutrient that is most likely to be first-limiting for effective use of low-quality forage.

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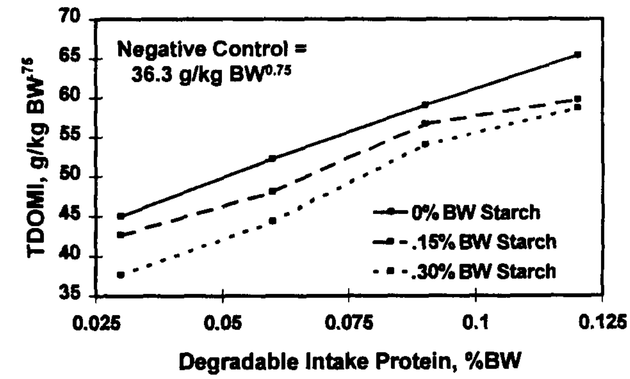
To clarify the potential impact of supplementing cattle fed low-quality forage with ruminally available protein versus ruminally available energy, we undertook a series of studies using discrete dietary ingredients. In each study, purified feedstuffs were chosen to represent the nutrients of interest and were administered directly into the rumen in the designated amounts. The short-term nature of these experiments coupled with the animals' previous diets and management (i.e., vitamin injections when deemed necessary) indicated that vitamin status was adequate. To prevent mineral deficiencies from inhibiting ruminal or host performance, macro and trace minerals were administered in each study in sufficient quantities to meet NRC (1984) guidelines. In the first of these studies, Olson et al. (1997) ruminally administered casein and corn starch (representing ruminally available protein and energy, respectively) to beef steers fed low-quality forage. Treatments consisted of a non-supplemented group (i.e., negative control) and 12 supplementation treatments composed of combinations of three levels of supplemental starch and four levels of supplemental DIP. The main response criteria was total digestible organic matter intake (TDOMI) which gives an estimate of the combined effects on intake and digestion as well as from both forage and supplement. In this study, Olson et al. (1997) observed that TDOMI was dramatically increased in response to supplemental DIP within the range of casein provided (Fig. 1). In fact, when DIP was fed alone and at the highest level, steers exhibited an increase in TDOMI of about 80% compared with the negative control. In contrast, response to the provision of ruminally available energy in the form of corn starch did not significantly increase TDOMI and generally appeared to have a negative effect. Taken together, this suggests that the deficiency in ruminally available nitrogen and/or protein was the principal limitation to effective forage utilization under the conditions of this study.

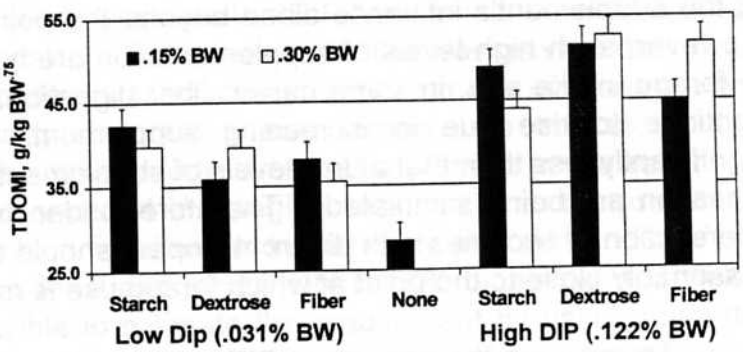
Figure 1. Effect of Level of Starch and Degradable Intake Protein on Total Digestible Organic Matter Intake



(Olson et al., 1997)

Because fiber rather than starch is the principal carbohydrate available to ruminal microorganisms with forage-based diets, it is reasonable to question whether the source of supplemental carbohydrate would impact the response to ruminally available protein versus energy. To answer this question, Heldt et al. (1997) ruminally administered high and low levels of DIP (as casein) and, within each DIP level, administered two levels of each of three sources of ruminally available carbohydrate. The carbohydrates were corn starch, dextrose, and digestible fiber. The digestible fiber was a commercially available product produced by treating oat fiber with alkaline hydrogen peroxide (which increases its potential digestibility). The response to DIP supplementation in this study was similar to that of Olson et al. (1997). That is, TDOMI was dramatically increased by the provision of supplemental DIP (Fig. 2). For the highest level of DIP supplementation this represented an increase of about 72% compared with the negative control and of about 27% compared with the lower level of DIP. Although treatments where only DIP was supplemented are not available for comparison in this study, the depression in TDOMI with increasing supplemental starch concurs with the observations of Olson et al. (1997). It is interesting to note that the other sources of carbohydrate appeared to behave a bit differently in their effect on TDOMI compared with corn starch. However, even in those situations where the proportional response to increasing carbohydrate appeared to be positive and maximal (e.g., fiber at high DIP), the relative effect on TDOMI was much less than that observed for supplemental DIP. This supports the contention that ruminally available nitrogen and(or) protein represents a greater limit to the effective use of low-quality forage than does ruminally available energy. The positive effects of supplemental DIP on TDOMI observed in the studies of Heldt et al. (1997) and Olson et al. (1997) were due to increases in both digestion and intake, although the proportional response for forage intake was typically larger. 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. However, there are situations where improvements in the efficiency of use of absorbed nutrients also appear to have been improved with protein supplementation (Lee et al., 1987). Köster et al. (1996a) also ruminally infused increasing amounts of casein to beef cows fed low-quality forage but measured changes in microbial activity and nutrient flow to the small intestine in addition to monitoring changes in intake and digestion. As noted in the studies reported above, they observed positive effects on forage intake and digestion in response to increasing supplemental DIP. However, they also observed significant impact on total VFA concentrations and in the amount of total and microbial protein arriving at the small intestine. Taken together, these studies illustrate the importance of supplemental DIP and confirm that this approach to supplementation can result in dramatic improvements in an animal's protein AND energy status.

Figure 2. Effect of Carbohydrate Source and DIP Level on Total Digestible Organic Matter Intake (TDOMI)



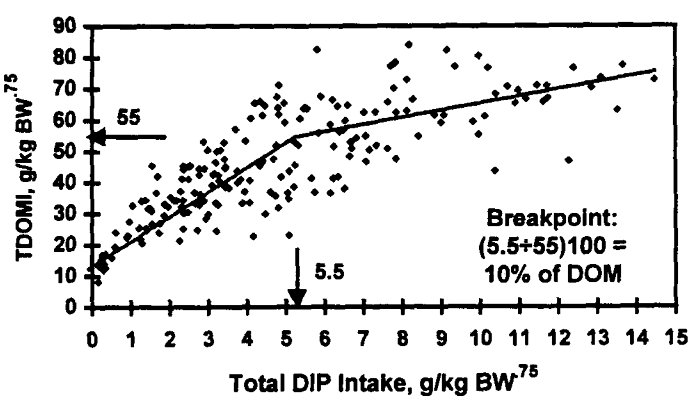
Heldt et al. (1997)

Amount of Supplemental DIP

While DIP supplementation can elicit positive effects on forage use, clearly there are limits to which the intake and(or) digestion of a given forage can be stimulated. In order to effectively plan the use of DIP in a supplementation program, it is desirable to know the amount of DIP required to achieve maximal forage use. Furthermore, it is desirable to know the rates at which intake and digestion decline when the amount of DIP consumed is less than optimal. This knowledge facilitates prediction of performance in situations where, by circumstance or conscious management decision, DIP consumption is suboptimal. In our studies we have used the combined effect on forage intake and digestion (i.e., TDOMI) to estimate the "requirement" for DIP. Clearly, this encompasses both direct effects on ruminal microbial activity as well as possible indirect effects on forage intake due to altered nutrient flow (particularly protein) to the small intestine. However, it is our belief that maximal TDOMI represents a definable reference point that should be consistent with the maximum nutrients harvestable from the forage per se. Thus, we have operated from the assumption that the DIP "requirement" can be reasonably estimated by the break point (i.e., the point at which TDOMI plateaus or exhibits a significant change in the slope of the response) in the regression of TDOMI on total DIP intake. The one complicating factor in this approach is that when TDOMI is measured in mixed diets, TDOMI may continue to increase due to the supplement's influence alone beyond the point at which forage use is maximal. However, such high levels of supplementation are typically accompanied by decreases in forage intake and, in some cases, fiber digestion. Thus, even though TDOMI may continue to rise due to increasing supplement, the rate of increase should be significantly less than that at low levels of supplementation (i.e., when forage intake and digestion are being stimulated). Therefore, under these conditions a break point (the intersection of two lines with different slopes) should still be discernible and it should be reasonably close to the point at which forage use is maximized.

To estimate the amount of DIP required to maximize TDOMI in forage-fed cattle we have used two approaches. The first approach is very broad based and entailed compiling observations from supplementation trials reported in the literature where cattle received forage as the basal feedstuff. Data from specific trials were used only if intake and digestion were directly measured and reported and if the forage CP was reported. When information on forage or supplement DIP was unavailable, it was estimated using published literature values. The data collected represented 17 different forages (primarily grasses or straw) that ranged from approximately 1.9 to 17.4% CP and from 37 to 73% forage digestibility. Forage intake ranged from .5 to 2.9% of body weight. When we graphed the relationship between TDOMI and total DIP intake, it was clear that there was a positive relationship. However, it was also evident via break-point analysis that the increase in TDOMI was

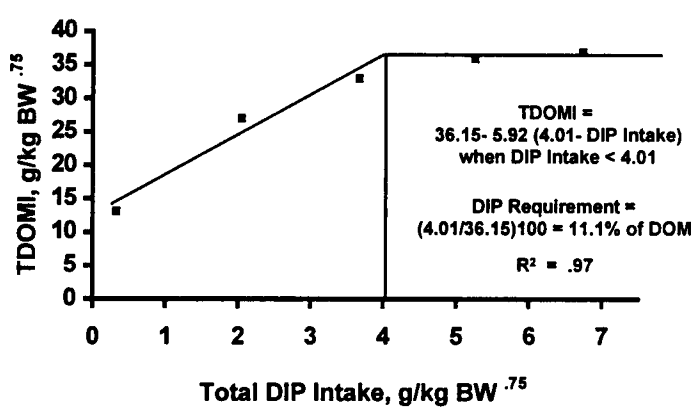
Figure 3. Relationship of Total DIP Intake to Total Digestible Organic Matter Intake (TDOMI)



slower when the amount of total DIP intake exceeded 5.5 g/kg $BW^{.75}$ (Fig. 3). By expressing the DIP intake as a percentage of the TDOMI at this breakpoint (55 g/kg $BW^{.75}$), it is estimated that DIP should compose approximately 10% of the digestible organic matter ([5.5/55] x 100 = 10%) in order to come close to maximizing TDOMI. The nature of this relationship suggests that the need for DIP supplementation will vary with diet intake, digestibility, and the amount of DIP in the forage to be supplemented. It also implies that TDOMI may increase above the break point in some cases. Because this literature data set included many different types of supplements fed at different levels, some of the increase beyond the break point may have been due to the supplement per se. Using the estimated requirement of 10%, a diet (forage + supplement) whose organic matter is 50% digestible would need to contain approximately 4.5% DIP on a dry matter basis in order to come close to approaching maximum TDOMI (assuming 10% ash in the diet; .50 x .90 x .10 x 100 = 4.5%). The amount of CP this would represent would depend on the degradability of CP in the diet.

The second approach we used to estimate the DIP "requirement" entailed direct experimentation. In this case, the data of Köster et al. (1996a) was used to determine the break point in TDOMI when casein was placed into the rumens of mature, non-pregnant beef cows fed low-quality, tallgrass prairie forage. In this study, the regression of TDOMI on total DIP intake clearly indicated a plateau in the response (Fig. 4). Furthermore, the plateau occurred in a region very similar to that observed with the large database. The estimated requirement in this study was about 11% of the TDOMI (~5% DIP in the dry matter for a diet whose OM is 50% digestible and which contains 10% ash). It is also possible to estimate the requirement by using quadratic (i.e., second order polynomial) regression. However, estimates of requirement using this method are typically larger compared with break-point analysis (Baker, 1986). This is largely due to the fact that when using the latter approach, one is attempting to predict the point at which response is maximal. Given the cost of supplemental nutrients and the potential for TDOMI to increase solely in response to increasing supplement once forage use is maximized, we believe the break-point approach is preferable. Using an approach based on an average microbial efficiency for a variety of diets, the NRC (1996) has proposed that the DIP requirement is approximately 13% of TDN (note: digestible organic matter is relatively similar to TDN for most non-fermented forage diets). This is similar to values recently proposed by the AFRC (1992) in the United Kingdom for ruminants at maintenance but is somewhat

Figure 4. Relationship of Total DIP Intake to Total Digestible Organic Matter Intake (TDOMI)



Köster et al. (1996)

lower than the values they suggest for growing and(or) lactating ruminants. In the nutrient guidelines published prior to the most recent AFRC publication, the ruminally degradable N requirement was estimated as a function of the amount of microbial N that is produced per kg of organic matter apparently digested in the rumen (ARC, 1980). This approach is relatively similar to that currently suggested by the NRC (1996). In the latter case, the ARC (1980) proposed a mean value of 30 g microbial N/kg of organic matter apparently digested in the rumen. For the data used to derive these values, they reported that on the average 65% of the total organic matter digested was apparently digested in the rumen (ARC, 1980). Thus, by taking this into account, the estimate of the requirement is approximately 19.5. If this is expressed as units of microbial crude protein and then expressed per 100 g of digestible organic matter (i.e., % TDN), the estimate would translate to about 12.2% of digestible organic matter. Preliminary results from work currently underway at Kansas State with several different forages and with different combinations of DIP and ruminally available energy appear to fall in a similar range.

To calculate the amount of DIP needed to maximize TDOMI for a given situation requires some knowledge of the diet characteristics and intake. As an example of the calculation procedure, let's assume we are working with 1200 lb cows who are eating a low-quality forage. The forage consumed contains 4% CP of which 50% is ruminally degradable (i.e., 2% DIP in the forage dry matter) and has a potential intake of about 1.8% of body weight daily in dry matter. The organic matter digestibility for a forage-based diet of this quality when it is appropriately supplemented is estimated at about 55%. We also assume that the forage contains about 9% ash and that the DIP requirement is approximately 12% of TDOMI. By taking into account each of these components, we calculate that the 1200 lb cow will eat 21.6 lb of dry forage (.018 x 1200 = 21.6) of which approximately 19.6 lb is organic matter (21.6 x .91 = 19.6). Assuming that the forage will be supplemented with an appropriate amount of DIP, we can calculate that this amount of forage will contain 10.8 lb of digestible material (19.6 x .55 = 10.78) It is important to note that if the forage is not supplemented or is supplemented with a low-protein, high-starch feedstuff, the diet digestion would likely be different. Using an intermediate value for the estimate of DIP requirement (12%), one would need 1.3 lb of DIP to come close to maximizing digestible intake (10.8 x .12 = 1.3). Given the forage CP and degradability specified above, the amount of DIP provided by the forage would be .43 lb (21.6 x .04 x .5 = .43). Thus, the supplement would need to provide the remaining .87 lb of DIP (1.3 - .43 = .87). If you chose to meet this with 49% soybean meal (55% CP on a dry basis; 70% degradability of CP; 91% moisture), it would require approximately 2.5 lb on an as-fed basis (.87/.55 = 1.58; 1.58/.70 = 2.26; 2.26/.91 = 2.48). Once the approximate amount of supplement required is determined, one can "fine tune" the calculation by adding the supplement to the forage dry matter intake and repeating the calculation (making sure to use each feed's degradability when calculating the amount of DIP it contributes). However, one would not expect a great increase in accuracy by such "fine tuning" unless the amount of supplement fed is large. It is important to recognize that the accuracy of the above predictions is dependent on the accuracy of the associated assumptions (i.e., amount of forage consumed, digestibility, etc.). Thus, if factors independent of the forage or supplement per se (for example, physiological status or environmental conditions) impact intake or digestion, these in turn can impact the amount of supplement needed to meet the DIP requirement. For example, in a recent experiment at K-State (Olson et al., unpublished data) intake of low-quality forage by pregnant cows that were supplemented throughout pregnancy, increased from about 1.5% of body weight 14 weeks before calving to as much as 2.5% of body weight 5 weeks before calving. Thus, if we assumed that the cows' forage consumption was 2.25% of body weight in the preceding example, then the amount of soybean meal required to maximize TDOMI would be predicted to be 3.7 lb/day (after making the fine tuning adjustments mentioned earlier). This observation highlights the need for quantitative information regarding quality of diet selected and amounts of forage consumed in order to do a good job of developing a nutrition program for grazing cattle.

In the example presented above, the DIP needed to maximize TDOMI was provided via a common feedstuff (soybean meal). It is important to recognize that there is considerable variability among feeds in the concentration of CP they contain and in likelihood that the protein will escape degradation in the rumen (Table 1). Thus, while it is feasible to use many different feeds to deliver supplemental DIP, the nature of the protein present will affect the quantity of supplement required. Clearly, it will require less quantity of feed to provide a given amount of supplemental DIP from those feeds that contain high concentrations of protein and whose protein has a high likelihood of being degraded in the rumen. Because of the variation in protein characteristics, feeding the same total quantity of CP from different feeds (or feed mixtures) can elicit different

Table 1. Chemical Composition of Select Feeds

Feedstuff	TDN	% CP	% CP: % DIP	% CP: % UIP	DIP in DM / TDN
Soybean meal (49%)	87	55	70	30	44
Cottonseed Meal	76	47	59	41	36
Alfalfa, mid-bloom	58	17	78	22	23
Wheat Middlings	82	18	76	24	17
Corn Grain	88	10	45	55	5
Sorghum Grain	82	10	46	54	6
Corn Gluten Meal (60%)	89	67	40	60	30
Blood Meal	50	92	18	82	33

Adapted from Preston, 1992

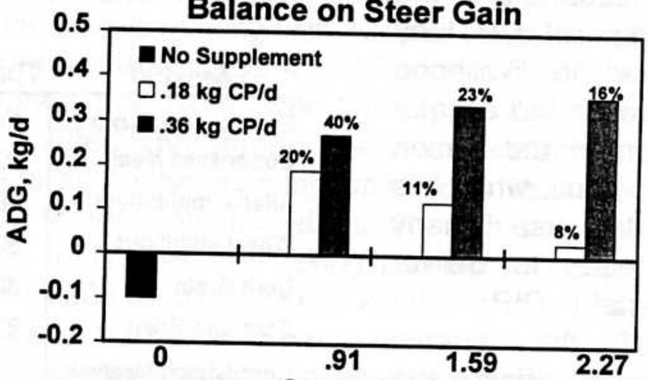
Table 2. Composition of Supplements

CP, % DM	Corn, % DM	SBM, % DM	TDN, % DM	DIP, % CP	DIP in DM / TDN
10 %	99.5	0.5	90	46	5.1
15 %	87	13	89	54	9.1
20 %	75	25	88	58	13.2
25 %	62	38	88	61	17.3
30 %	50	50	87	63	21.7
35 %	37	63	86	64	26.0
40 %	25	75	85	65	30.6

Corn (90% TDN, 9.8% CP, 45% DIP); SBM (84% TDN, 49.9% CP, 66% DIP) effects. For example, if one were to use corn and soybean meal to formulate supplements with CP concentrations from 10 to 40%, the degradability of the CP in the supplements would differ by as much as 19 percentage units at the extremes (Table 2). Thus, if one were to feed 1 lb of CP from a supplement with 10% CP vs 40% CP, the amount of DIP delivered would be .46 vs .65 lb, respectively. Obviously, delivering about 40% more DIP in this instance could have significant impact on forage use and performance.

In addition to the protein characteristics per se, the balance between the amount of DIP and digestible organic matter in a supplement can vary dramatically. For example, the 10% CP supplement in Table 2 has a DIP:TDN ratio of 5 compared to a ratio of about 30 for the 40% supplement. This too has the potential to elicit differences in the effect of a supplement on intake and digestion and, subsequently, on performance. This seems to be particularly true in those cases where small amounts of total protein are supplemented and the protein is fed in conjunction with large amounts of supplemental energy. As an example of the potential impact of such changes in supplement composition, Clanton (1980) reported that under conditions where non-supplemented cattle were losing weight, increased supply of supplemental energy depressed performance when limited supplemental CP was fed (Fig. 5). In contrast, when the supplemental CP was doubled, performance was slightly improved by supplemental energy. However, the magnitude of increase was much less than that due to increasing protein per se. Based on information reported in a companion paper (Rittenhouse et al., 1970), it appears that the supplements used in this study were formulated from corn and soybean meal. Thus, using this assumption in combination with the generalizations from Table 2, it appears that when the DIP:TDN ratio in a supplement is extremely low (for example, 5% of TDN as represented by a 10% CP supplement) the ability of the supplemental CP to positively impact forage use is compromised. Location of the specific breakpoint, as well as other mitigating factors influencing this relationship is not well established. In light of the limited information available at present, a reasonable guideline for supplementing low-quality forage appears to be use of a DIP:TDN ratio in the supplement that will be at least sufficient to effectively ferment the supplement without needing to draw from the forage DIP. Conceptually this implies that at low DIP:TDN, the amylolytic bacteria would use the DIP present in the supplement to ferment the supplemental carbohydrate and would

Figure 5. Effect of Protein:Energy Balance on Steer Gain



(Adapted from Clanton, 1980)

also effectively compete for use of some forage DIP in this process. The end result would be to exacerbate the deficiency of available N and(or) protein in the rumen and, thus, to negatively impact forage digestion and, potentially, intake. On the other hand, when the DIP:TDN ratio is high, adequate DIP would be available to ferment the supplemental carbohydrate plus to make additional DIP available to aid in forage fermentation. Using the estimates of DIP requirement discussed previously, it appears that supplements to be used with low-quality forage should have a minimum DIP:TDN of about 12 to 13%. For the supplement examples in Table 1, this would equate to a CP concentration of about 20%. In general, it seems that use of supplements with DIP:TDN ratios above this level would be desirable in order to ensure that adequate DIP was available to specifically target enhancement of fermentation of forage organic matter. Clearly, the higher the ratio of DIP to digestible organic matter the easier it will be to elevate the total diet's DIP to digestible organic matter ratio.

Source of DIP in a Supplement

Many of the studies discussed earlier clearly demonstrate that ruminally available nitrogen and(or) protein represents a greater limit to the effective use of low-quality forage than does ruminally available energy. However, these studies do not delineate how much of the response is simply due to the provision of ruminally available nitrogen versus the provision of amino acids, peptides, and(or) protein per se. Certainly this is an important question in that proteinaceous feedstuffs are commonly one of the more expensive components in diets for ruminants. To address this question, Köster et al. (1997) administered different combinations of ruminally available N (urea) and(or) protein (casein) to steers fed low-quality forage. Based on previous work with similar forage (Köster et al., 1996a), the amount of DIP equivalent consumed was estimated to be sufficient to maximize TDOMI. To minimize potential health risks with the high-urea dosings, all nitrogen/protein doses were administered with some corn starch. The amount of corn starch was such that each of the supplements contained 40% CP. Although a slight numerical decline was evident, Köster et al. (1997) reported that they were unable to detect a significant effect of increasing proportion of supplemental urea on forage intake (Table 3). In contrast, diet organic matter (OM) digestion, neutral detergent fiber (NDF) digestion, and TDOMI all exhibited significant negative responses

Table 3. Effect of Urea Level and Supplementation Frequency on Digestion and Intake

Item	% Supplemental N from Urea					
	0%	25%	50%	75%	100%	SE
Forage Intake, $g/kg^{.75}$	54.6	53.9	51.5	51.6	50.8	2.8
OM Digestion, %	49.6	48.4	52.6	48.8	43.9	1.3
NDF Digestion, %	47.5	43.9	47.9	42.1	35.7	1.9
TDOMI, $g/kg^{.75}$	31.5	30.7	31.8	30.0	26.6	1.3

Adapted from Koster et al., 1997

to increasing urea. In each case the response tended to be quadratic in nature. That is, there was a greater relative decline in these traits at higher levels of urea substitution. In particular, it appeared that when the amount of urea exceeded 75% of the supplemental DIP equivalent, all three of these criteria were substantially depressed. Although it did appear that NDF digestion and TDOMI exhibited some depression, relative to lower levels, once the urea substitution exceeded 50%.

At least two principles can be drawn from these observations with regard to supplementation of low-quality forage. First, a substantial proportion of the effect of supplemental DIP on intake and digestion appears to be achievable via ruminally available nitrogen per se. For example, comparison of TDOMI at the extremes (0 vs 100% urea) indicates that supplementation with urea alone resulted in achievement of close to 85% of the response achieved by using all true protein. This concurs with other observations in the literature regarding the impact of NPN substitution on forage use. Minson (1990), in reviewing a large number of supplementation studies, noted that both natural protein and NPN are capable of stimulating forage intake (Table 4). Although, in the data sets he evaluated, the relative response to urea appeared to be somewhat less than for true protein. Similarly, Raleigh and Wallace (1963) evaluated the impact of urea substitution in supplements for a low-quality hay. The effects on diet digestion were fairly consistent across the levels fed and averaged about 1.5 percentage units lower for cattle receiving supplements that contained NPN. The second principle that can be drawn from the work of Köster et al. (1997) is that, even when considering forage intake and digestion alone, supplements based on NPN will be more effective in achieving maximal forage utilization if some of the DIP equivalents are from true protein. At least two methods by which true protein might elicit potential benefits would be provision of precursors of other microbial nutrients (e.g., branched-chain VFA) and improvement in overall microbial efficiency via direct incorporation of amino acids and(or) peptides into microbial cells. Based on the data presented above, one would estimate 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 (assuming the total DIP requirement is met).

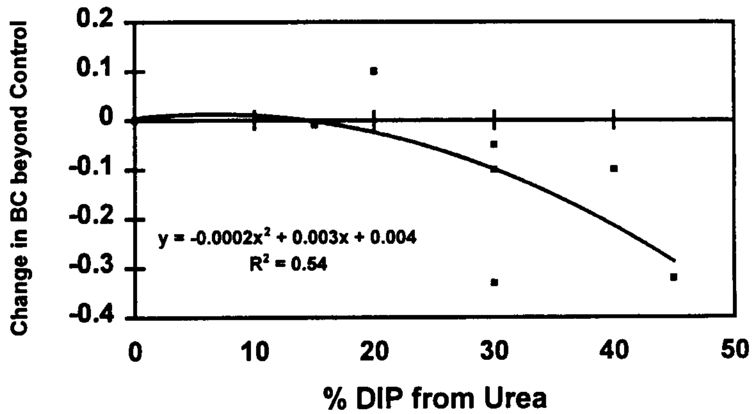
Table 4. Effect of Urea or Natural Protein Supplements on Forage Intake

Item	Supplements: Urea	Supplements: Natural
Number of Studies	**19**	**17**
Mean Forage CP, %	**3.7**	**4.5**
Mean Increase in Intake, %	**34**	**45**
Range in Response	**8 - 104**	**14 - 77**

Adapted from Minson, 1990

Given the nature of the forage intake and digestion response when urea is substituted as a part of the supplemental DIP equivalent, one might expect that the impact on performance would be small at low levels of urea inclusion but more negative at higher levels. This appears to be the case. However, in some cases it appears that the point at which negative effects on performance are evident occurs at lower levels of NPN inclusion than is the case for intake and digestion. This implies that substituting supplemental NPN for true protein has impacts on animal performance (for example, metabolic effects) beyond those of intake and digestion per se. Recent research reported by Köster et al. (1996b) and Woods et al. (1997) with beef cows grazing low-quality winter range, as well as an unpublished study recently completed at Kansas State, illustrate this point. In these studies, cows were fed "dry" supplements that had an increasing proportion of the DIP replaced by urea (all supplements contained 30% CP and were fed to meet the calculated DIP requirement). By expressing the changes observed in body condition for those groups receiving urea relative to that observed in the groups not receiving urea, a quadratic response was observed as urea level increased (Figure 6). From these data it appeared that when urea was included up to approximately 20 to 25% of the DIP, the difference in performance was negligible when compared with those supplements without urea. However, when urea was substituted at higher levels, a decline of approximately .12 units of body condition (scored on a 1 to 9 scale) was observed for each 10% increase in the proportion of DIP from urea. The supplements in these trials were fed from the beginning of the winter supplementation programs (which were initiated at the beginning of December) until each cow calved (average calving dates were in mid-March). Thus, if cows were in good body condition entering the winter, substitution at even the highest levels reported (45% of DIP equivalent) would not be excessively negative. Acceptability of reduced performance will depend on the potential impacts on traits of large economic importance, notably subsequent pregnancy rate, and potential savings in supplement cost. Substitution at rates of up to 20 - 25% of the DIP equivalent would likely have little substantive impact on weight or condition change. This amount can be calculated from the supplement's CP concentration, CP degradability, and the desired NPN inclusion level. For example, if one was feeding a supplement with 40% CP and 65% degradability, then the DIP as a percentage of the supplement DM would be 26% (40 x .65 = 26). Assuming that one was targeting an NPN inclusion level of 25% of the DIP equivalent, then 6.5 percentage units of total CP equivalent in the supplement could come from NPN (26 x .25 = 6.5). Higher levels of substitution (beyond 45% of the DIP equivalent) were attempted in

Figure 6. Additional Loss of Body Condition (BC) for Supplements with Urea vs No Urea



Adapted from Koster et al. (1996b) and Woods et al. (1997)

some of the studies discussed, but unwillingness of all cattle to consume those supplements was evident at the higher levels. Thus, such treatments were discontinued. Similar reports of unwillingness to fully consume targeted allotments of "dry" supplements that contained significant amounts of urea has been reported elsewhere (Table 5). Clearly, supplement acceptability and its potential to impact delivery of targeted amounts of certain nutrients is an important issue. Potential impacts on supplement palatability must be carefully considered if one incorporates urea at high levels in supplements for forage-fed cattle.

It is important to note that the studies discussed above were conducted with prepartum cows that were fed sufficient DIP to come close to maximizing TDOMI. Potential differences in response during the prepartum versus postpartum phase are not well defined. In the studies of Köster et al. (1996b) and Woods et al. (1997) the results were variable, but when taken together appear to indicate that prepartum use of supplements with low levels of urea did not have a large carryover effect on pregnancy rate. Similarly, Thompson et al. (1973) suggested that ruminants fed high-roughage diets can be supplemented with urea without significant, negative impacts on reproductive performance. However, there are some studies in which reproductive performance has been quite poor in groups receiving supplements with significant amounts of NPN. For example, in the study of Forero et al. (1980; Table 5) pregnancy rate was depressed in all groups fed supplements that contained NPN compared with the positive control (i.e., the group that received the 40% supplement without NPN). However, reproductive performance was also unusually poor in this study for those cattle in the negative control group (i.e., those fed the 15% supplement without urea). Clearly, there are multiple factors (e.g., reduced supplement intake, physiological state, and differences in the amount of supplemental DIP/UIP provided) that could have affected performance in this instance. Clarification of the impact on reproduction of prepartum versus postpartum supplementation with urea-based supplements, particularly at high levels of NPN inclusion, would be helpful in establishing the optimal use of such supplements for cows consuming low-quality forage.

Table 5. Effect of NPN on Supplement Palatability, Gain, and Pregnancy Rate

Item	Natural		Slow-Release Urea	Urea	
CP Level, %	15	40	40	40	20
Offered, kg/d	1.22	1.22	1.22	1.22	2.44
Eaten, kg/d	1.22	1.22	1.22	.72	1.54
% Difference	0	0	0	-41	-37
ADG, kg/d	-.98	-.39	-.74	-.85	-.85
% Pregnant	44	94	50	76	53

(Data for fall-calving cows grazing winter range; 45-d breeding season)
Adapted from Forero et al. (1980)

Conclusions

For cattle fed low-quality forage, provision of supplemental degradable intake protein has greater potential to enhance forage use and improve performance than does the provision of ruminally available carbohydrate. Results from research with cattle fed forage-based diets appears to indicate that degradable intake protein would need to comprise between 10 and 13% of the total digestible organic matter consumed in order for total digestible organic matter intake to be close to maximal. Although supplemental degradable intake protein should contain some true protein, non-protein nitrogen compounds, such as urea, can replace significant quantities of true protein without greatly affecting forage intake and digestion. However, reduced performance from substituting urea for true protein in supplements appears to occur at lower levels of inclusion than is the case for forage use. If low levels of urea substitution are used (i.e., about 20 to 25% of the DIP) weight and body condition change in prepartum cows should be relatively similar to cows fed a similar supplement without urea.

Literature Cited

Agricultural and Food Research Council. 1992. Nutritive requirements of ruminant animals: Protein. Nutr. Abs. Rev. (Series B) 62:787-835.

Agricultural Research Council. 1980. The Nutrient Requirements of Ruminant Livestock. C.A.B. International, Wallingford, U.K.

Baker, D. H. 1986. Critical review: Problems and pitfalls in animal experiments designed to establish dietary requirements for essential nutrients. J. Nutr. 116:2339.

Clanton, D. C. 1980. Crude protein system in range supplements. In: F. N. Owens (Ed.) Protein Requirements for Cattle: Symposium. MP-109, Oklahoma State Univ., Stillwater.

Forero, O., F. N. Owens, and K. S. Lusby. 1980. Evaluation of slow-release urea for winter supplementation of lactating range cows. J. Anim. Sci. 50:532.

Heldt, J. S., R. C. Cochran, C. P. Mathis, B. C. Woods, K. C. Olson, E. C. Titgemeyer, G. L. Stokka, and T. G. Nagaraja. 1997. Evaluation of the effects of carbohydrate source and level of degradable intake protein on the intake and digestion of tallgrass-prairie hay by beef steers. Ag. Exp. Sta. Rep. of Progress 783, Kansas State Univ., Manhattan. pp 59 - 61.

Köster, H.H., R.C. Cochran, E.C. Titgemeyer, E.S. Vanzant, I. Abdelgadir, and G. St-Jean. 1996a. Effect of increasing degradable intake protein on intake and digestion of low-quality, tallgrass-prairie forage by beef cows. J. Anim. Sci. 74:2473.

Köster, H.H., R.C. Cochran, K. C. Olson, T. J. Jones, E.S. Vanzant, and E.C. Titgemeyer. 1996b. Effect of increasing urea level in protein supplements on performance by beef cows consuming low-quality tallgrass-prairie forage. Ag. Exp. Sta. Rep. of Progress 756, Kansas State Univ., Manhattan. pp 46-48.

Köster, H.H., R.C. Cochran, E.C. Titgemeyer, E.S. Vanzant, T.G. Nagaraja, K.K. Kreikemeier, and G. St-Jean. 1997. Effect of increasing proportion of supplemental nitrogen from urea on intake and utilization of low-quality, tallgrass-prairie forage by beef steers. J. Anim. Sci. 74:1393.

Lee, G. J., D. W. Hennessy, J. V. Nolan, and R. A. Leng. 1987. Responses to nitrogen and maize supplements by young cattle offered a low-quality pasture hay. Aust. J. Agric. Res. 38:195.

Minson, D. J. 1990. Forage in Ruminant Nutrition. Academic Press. San Diego, CA.

Olson, K.C., R.C. Cochran, T.J. Jones, E.S. Vanzant, and E.C. Titgemeyer. 1997. Effects of various supplemental starch and protein levels on ruminal fermentation and liquid passage of beef steers fed tallgrass-prairie hay. Ag. Exp. Sta. Rep. of Progress 783, Kansas State Univ., Manhattan. pp 52-54.

National Research Council. 1984. Nutrient Requirements of Beef Cattle. 6th Ed. National Academy Press, Washington, D. C.

National Research Council. 1996. Nutrient Requirements of Beef Cattle. 7th Ed. National Academy Press, Washington, D. C.

Owens, F.N., J. Garza, and P. Dubeski. 1991. Advances in amino acid and N nutrition in grazing ruminants. pp 109-137. In: Proceedings, 2nd Grazing Livestock Nutrition Conference, MP-133, Oklahoma State Univ., Stillwater.

Raleigh, R. J. and J. D. Wallace. 1963. Effect of urea at different nitrogen levels on digestibility and on performance of growing steers fed low quality flood meadow roughage. J. Anim. Sci. 22:330.

Rittenhouse, L. R., D. C. Clanton, and C. L. Streeter. 1970. Intake and digestibility of winter-range forage by cattle with and without supplements. J. Anim. Sci. 31:1215.

Thompson, L. H., L. Goode, R. W. Harvey, R. M. Myers, and A. C. Linnerud. 1973. Effects of dietary urea on reproduction in ruminants. J. Anim. Sci. 37:399.

Woods, B. C., R. C. Cochran, C. P. Mathis, J. S. Heldt, K. C. Olson, E. C. Titgemeyer, and D. M. Grieger. 1997. Effect of urea level in protein supplements on performance by beef cows consuming low-quality, tallgrass-prairie forage. Ag. Exp. Sta. Rep. of Progress 783, Kansas State Univ., Manhattan. pp 66-68.