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Strategies for Predicting the First Limiting Nutrient for Grazing Cattle

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Grazing cattle require two types of digestible protein. The first is a source of protein (or nonprotein nitrogen) that is degraded in the rumen and used by the microbes to produce microbial protein. The second is a protein that must escape rumen degradation and be digested in the small intestine. This is a source of metabolizable protein over and above that obtained from microbial protein. The escape protein can come from the forage or from the supplement. The degradable protein requirements for microbial growth logically should be met before a response to escape protein can be realized.

This last point needs to be emphasized--the concept of the First Limiting Nutrient. Our goal in optimizing the economics of producing cattle on grass can best be met if we identify the first limiting nutrient and supplement it first. Supplementation may not be economical but we likely will not get any response to supplementing a nutrient other than the first limiting nutrient. For example, if energy is the first limiting nutrient, we can supplement protein and we won't get any response. This cannot be economical! However, the converse may not be true...energy supplementation will not necessarily be economical even though a biological response will be obtained. That first limiting nutrient might be a mineral, energy or protein (rumen degradable or escape). I am going to discuss protein but I want to make it clear that this discussion is only meaningful when protein is limiting cattle performance. If energy is first limiting, it needs to be supplemented first if it can be done economically.

Beef cattle requirements for rumen degradable protein and escape protein are being better elucidated with time. The international literature (United States, Great Britain, France, Scandinavia and Germany) suggests the requirement for rumen degradable protein is 13% of TDN. On the average, the amount of microbial protein synthesized is 13% of the

TDN. Everyone agrees that rumen fermentable energy determines the amount of microbial growth if rumen degradable protein is adequate. A wide range of values for the conversion of energy to microbial protein have been reported and many factors affect the values obtained. These factors include rate of passage, type of energy being digested, rumen versus lower tract digestion, etc. Probably a bigger factor in the variation in calculated microbial growth is our ability to accurately measure it. Complex models will eventually better define these values but at present I feel we need to keep this concept as simple as possible--13% of TDN.

The need for escape protein is more difficult to determine in a given situation. Microbial protein alone is likely sufficient to meet the needs of cattle at or near maintenance. Young growing cattle and lactating cows need escape protein in addition to microbial protein to meet their metabolizable protein needs.

We have attempted to evaluate the rumen degradable and rumen escape protein needs of the gestating beef cow. These cows were fed mature prairie hay of 5.6% crude protein supplemented with increasing levels of corn steep liquor replacing molasses. Corn steep liquor is 40-45% crude protein and the protein is completely rumen degradable. Intake (dry matter) was kept equal at 1.7% of bodyweight. The hay contained 1.3% escape plus indigestible protein (% of dry matter). The rumen degradable protein, therefore, was 4.3% (5.6 - 1.3).

The rumen degradable protein requirement was met when the cattle consumed 6.3% rumen degradable protein (Figure 1). This is the sum of the rumen degradable protein in the hay and in the supplemental steep liquor. The crude protein level was 7.5% when the rumen degradable requirement was met because the crude protein includes the escape and indigestible proteins in the hay. The 7.5% crude protein is similar to generally accepted values. However, crude protein may not be sufficiently definitive because it doesn't account for escape protein, indigestible protein and TDN in the forage.

The TDN content of the diets fed to the cows was 51.3%. This included the hay and supplement. The rumen degradable protein requirement was then 12.3% of the TDN which is very close to the 13% value suggested previously.

An additional treatment was included in this cow experiment. Escape protein was fed above the highest level of rumen degradable protein. The cows gained only .08 lb/day more when fed the escape protein and this was not statistically significant. This suggests that the microbial protein and the small amount of escape protein in the hay met the metabolizable protein needs of the gestating cow.

A similar type of experiment was conducted with yearling steers grazing summer native range. The 700 lb steers were supplemented with graded levels of steep liquor and also escape protein sources above the highest level of steep liquor. Crude protein content of the animal selected diets dropped from 10.0% in June to 9.0% in September, 1989. Escape protein as a percent of organic matter, decreased slightly from 2.1 to 1.6 (Table 1). This was a dry year and the quality of the grass remained higher than in a normal year such as 1988 where crude protein fell to 7.1% in September.

We used the 12.3% value determined with the cows to estimate the need for rumen degradable protein (Figure 2). From these calculations, we would predict that the cattle would not respond to rumen degradable protein in 1989. In a more normal year such as 1988, a response would have been expected beginning in August.

The yearlings did not respond to degradable protein in 1989 (Figure 3). The response was not statistically significant and the decrease at the higher levels of degradable protein can be explained by a decrease in energy for the microbes. The steep liquor supplement replaced a cornstarch control supplement and this reduced the energy. This is consistent with our prediction.

The cattle responded to escape protein (Figure 4) which shows that their requirement for metabolizable protein was higher than the supply from microbial protein and escape protein in the grass. This supplementation may not be economical even though there is a biological response.

Ionophores have been shown to increase gains of yearlings on pasture. Much of the cost of supplementation of either an ionophore or protein is the cost of delivery of the nutrient or compound through the supplement. If we combine these two items in a supplement as the feed industry does, it can improve the economics of supplementing cattle on pasture.

Yearling cattle grazing smooth brome responded to both escape protein (corn gluten meal and blood meal) and an ionophore (tetronasin, uncleared) (Figure 5). The responses were additive and totaled over .6 lb/day.

The metabolizable protein requirements for lactating beef cows is similar to that of yearling cattle--although the requirement is primarily for lactation rather than growth. Experiments were conducted with lactating cows grazing both smooth brome grass and big bluestem to determine if their metabolizable protein needs were being met.

There was a significant response to escape protein (corn gluten meal and blood meal) both in milk production and calf gains when the cows grazed smooth brome grass (Figure 6). There was no response to escape protein when the cows grazed big bluestem (Figure 7). Response to rumen degradable protein was not tested and it is possible that the rumen degradable protein content of the grass fell below the requirement. These data are generally in agreement with those from the yearling cattle. The escape protein in the big bluestem is somewhat higher than in the smooth brome grass so the cows responded to escape protein when grazing smooth brome grass but not when grazing big bluestem.

How do we put these observations into practice? Let's first discuss what we know.

The rumen degradable protein requirement is about 13% of TDN. Gestating cows need little or no supplemental escape protein. Lactating cows and growing cattle will likely respond to escape protein supplements but the response may not be economical.

What are the unknowns? The largest unknown is the composition of the protein in the grass. It is important to remember that we are speaking of the grass that is consumed, not the standing forage. The cattle generally select a diet higher in quality than the average standing forage. We must know the escape protein, the degradable protein and the indigestible protein in the diet. Acid detergent insoluble nitrogen (ADIN) is a reasonable measure of the indigestible protein. This is fairly constant and ranges from .9 to 1.3% of the dry matter in protein units (ADIN × 6.25). The escape protein is more variable and more difficult to determine. The dacron bag procedure is most widely used but most of the reported results are not corrected for microbes attached to the fiber of the forage residue. Escape values range from essentially zero to 3% of the dry matter. This range seems small but makes a critical difference in the supplies of rumen degradable protein and metabolizable protein to the animal. In general, warm-season grasses have more escape protein than cool-season grasses but there are important differences among both cool and warm season species.

Rumen degradable protein is crude protein minus escape and indigestible protein (ADIN × 6.25). This degradable protein value can range from 2 to 20% of the dry matter.

It is obvious that our greatest need is for more information on the forage protein fractions. Until we have that information, we cannot make use of the information we have on animal performance.

I have made a very general calculation which may be of value when warm-season grass is being grazed (Table 2). If a clipped sample is available and crude protein and TDN values are determined, then the calculations in Table 2 can be made. I assume the cattle select 10% higher TDN than the clipped sample. This value depends on forage type and availability. The crude protein required is calculated using the conversion to microbial protein (13%) and indigestible and escape protein estimates. The escape estimate is just that--an estimate and may not be correct for a given warm-season species. Finally, I have assumed a 30% increase in diet crude protein due to animal selectivity. If the TDN of the forage increased, the degradable protein required for optimal microbial efficiency would increase by .13 percentage units for each percentage unit increase in TDN. The indigestible and escape protein values would likely not change.

The crude protein required in a cool-season grass is compared to a warm-season grass in Figure 8. The grasses each have 60% TDN so the need for rumen degradable protein is the same (7.8%). However, because of more ADIN and escape protein estimated to be in the switchgrass, more crude protein is required to meet the rumen degradable protein needs of the rumen microorganisms. This demonstrates that crude protein alone is useful but may not be an accurate indicator of the first limiting nutrient.

In conclusion, we can make some estimates of the first limiting nutrients in grazed forages. However, much needs to be done with forage analysis to be able to "fine tune" the nutrient needs. This research and the application of this research is important to the economical production of beef on grazed forages.

References

Karges, K. K., T. J. Klopfenstein, W. A. Wilkerson and D. C. Clanton. 1992. Effects of ruminally degradable and escape protein supplements on steers grazing summer native range. J. Anim. Sci. 70:1957.

Drouillard, J. and T. Klopfenstein. 1989. Protein sparing effects of tetronasin in grazing steers. Nebraska Beef Cattle Report MP 54:27.

Blasi, D. A., J. K. Ward, T. J. Klopfenstein and R. A. Britton. 1991. Escape protein for beef cows: III. Performance of lactating beef cows grazing smooth brome or big bluestem. J. Anim. Sci. 69:2294.

Karges, K. K., T. Klopfenstein and V. Wilkerson. 1991. Protein requirements of beef cows fed native range hay. Nebraska Beef Cattle Report MP 56:32.

Table 1. Analyses of Extrusa Samples From Summer Native Range for 1988 and 1989[a]

	1988[b]				1989[b]				
Item	June	July	Aug.	Sept.	June	July	Aug.	Sept.	SE
CP, %[c]	14.1	11.6	10.4	7.1	10.0	9.4	9.1	9.0	.89
Escape protein									
% of OM[d]	3	2.3	2.9	1.3	2.1	2.1	1.7	1.6	.28
% of CP	21.1	20.9	27.9	17.8	20.7	22.1	18.7	18.3	3
ADIN, %	.17	.13	.15	.17	.16	.15	.19	.14	.02
ADF, %[e]	40.5	41.8	39	45.7	44.6	44.7	45.2	45.7	1.9
NDF, %	68.2	74.9	66.2	71	73.7	77.1	73.7	74.1	2.9
IVOMD, %[f]	68.9	62.6	57.8	51.8	60.5	57	53.1	55.2	1.5

[a]OM basis.
[b]1988 n = 3; 1989 n = 2.
[c]CP; year effect, $P<.03$; month effect, $P<.01$; year × month interaction, $P<.02$.
[d]Escape protein as a percentage of OM; month effect, $P<.01$; year effect, $P<.01$; year × month interaction, $P<.05$.
[e]ADF; year effect, $P<.03$.
[f]In vitro OM digestibility; year, month, and year × month interaction effects, $P<.01$.

Table 2. Example Calculations for a Warm-Season Grass

50% TDN in clipped sample.
55% TDN in diet--10% increase due to selectivity.
7.15% Degradable protein required (13% of 55).
9.65% crude protein required in diet (1.0% indigestible plus 1.5% escape protein).
7.42% crude protein required in clipped sample (assumes 30% increase due to selectivity).

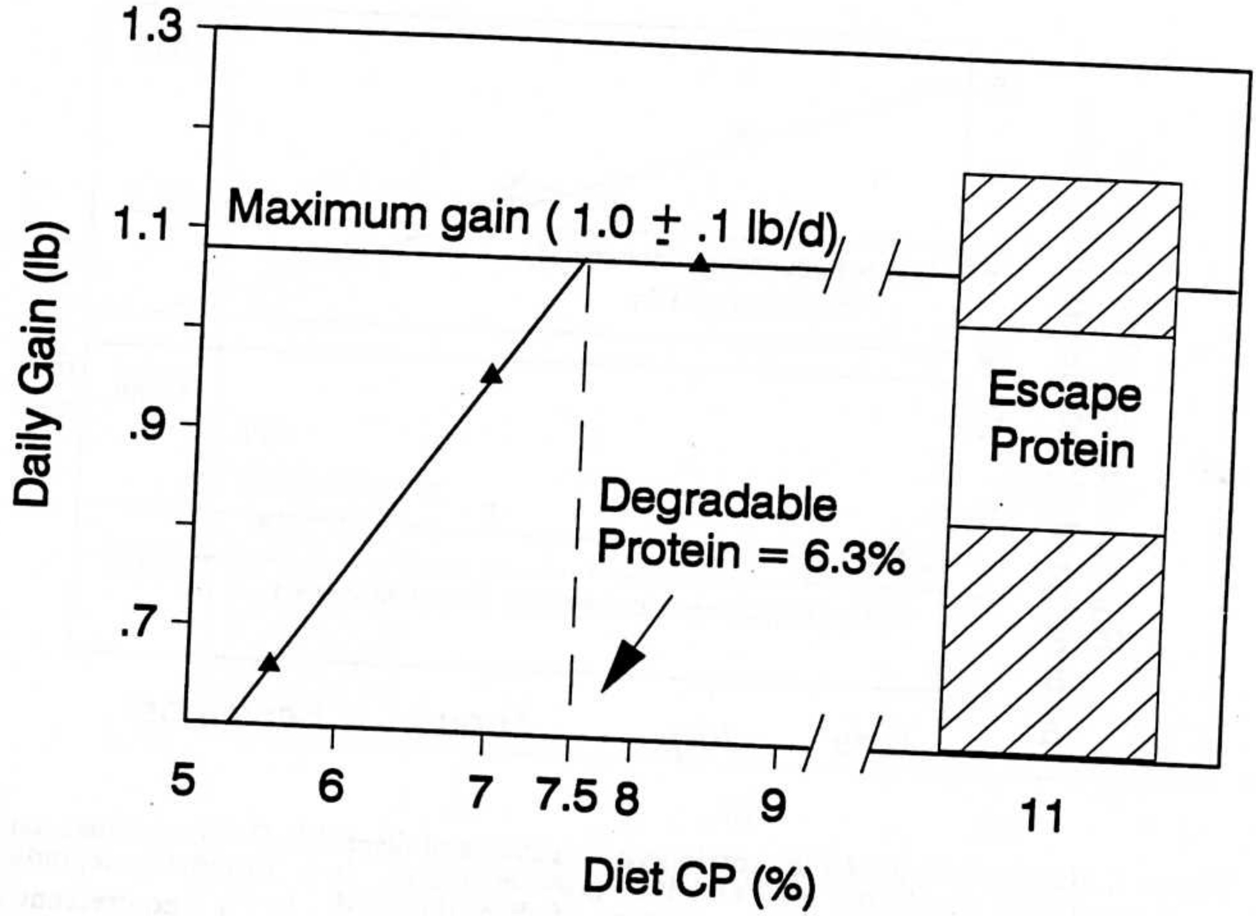

Figure 1. Cow weight gain response to degradable and(or) escape protein supplements fed native range and(or) prairie hay. Significant linear response to degradable protein P<.01; quadratic response to degradable protein P=.5; high level of degradable protein versus escape protein P=.5 (Karges et al., 1991).

Corn steep liquor was CP source (no NPN).

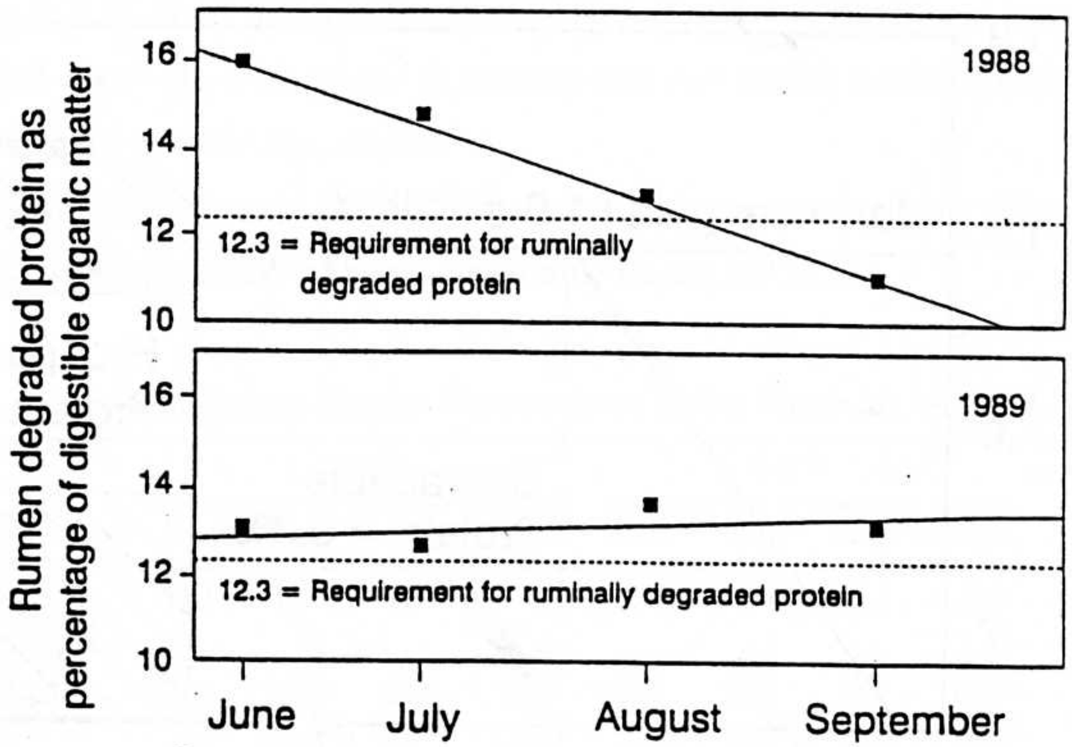

Figure 2. Ruminally degradable protein as a percentage of digestible OM in summer native range forage during the 1988 and 1989 growing season. (–) Ruminally degradable protein in native range as a percentage of digestible OM. (-----) Requirement for ruminally degradable protein for maximum microbial protein synthesis (Karges et al., 1991).

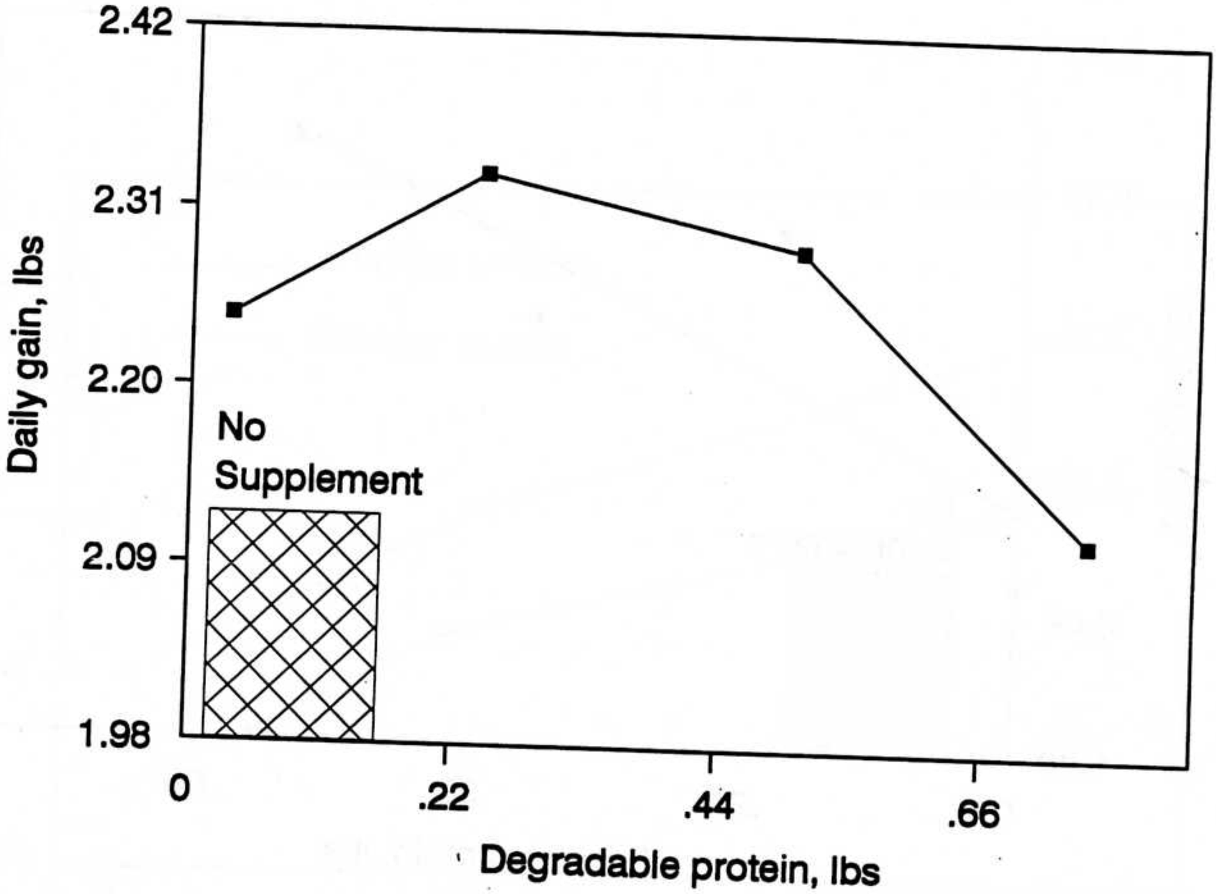

Figure 3. Yearling steer response to degradable protein supplementation on native range. No supplement vs energy control P=.20; energy control (first point nearest to y-axis) vs three levels of degradable protein, quadratic effect P=.15; SE=.05 (Karges et al., 1992).

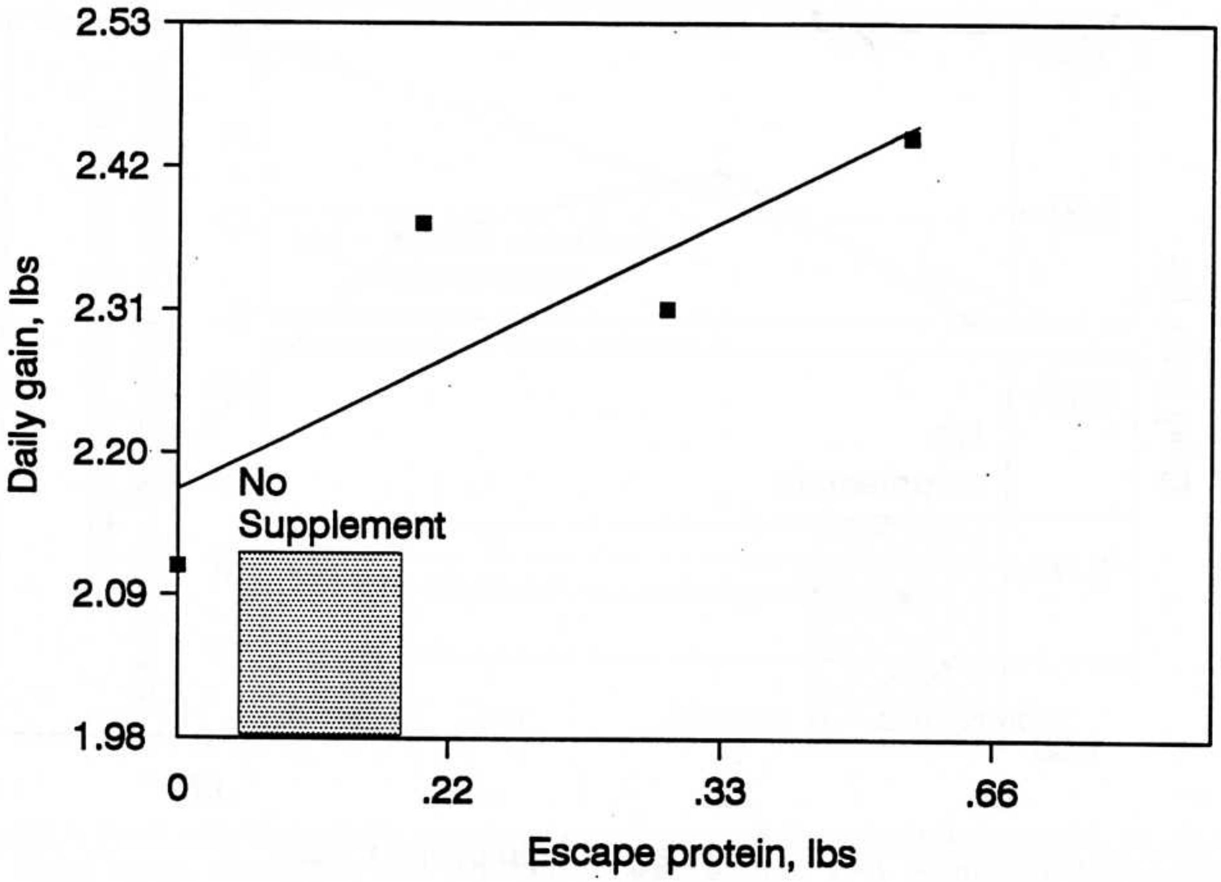

Figure 4. Yearling steer response to escape protein supplementation on native range. Point on the y-axis is zero level of escape protein. Linear effect of escape protein, $P<.03$; $SE=.05$ (Karges et al., 1992).

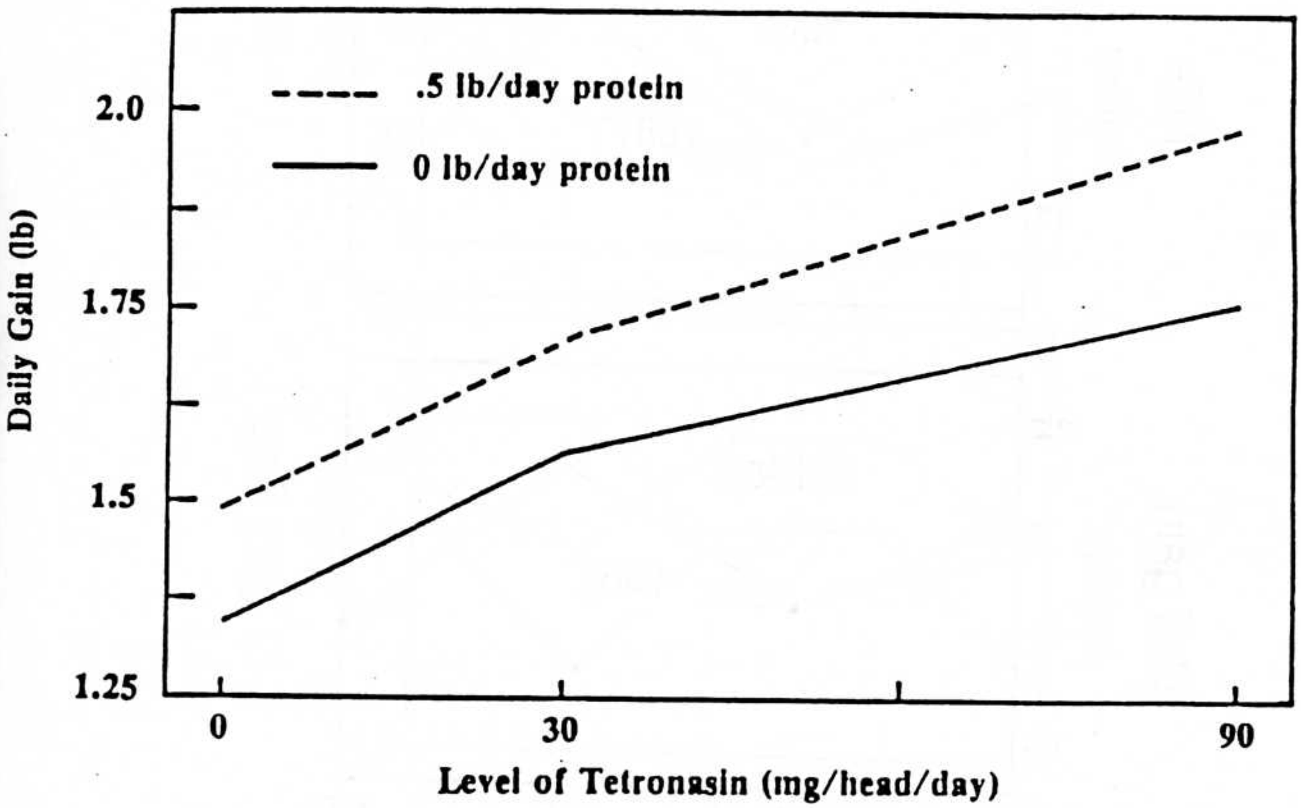

Figure 5. Relationship between daily gain, level of escape protein and level of tetronasin (Drouillard et al., 1989).

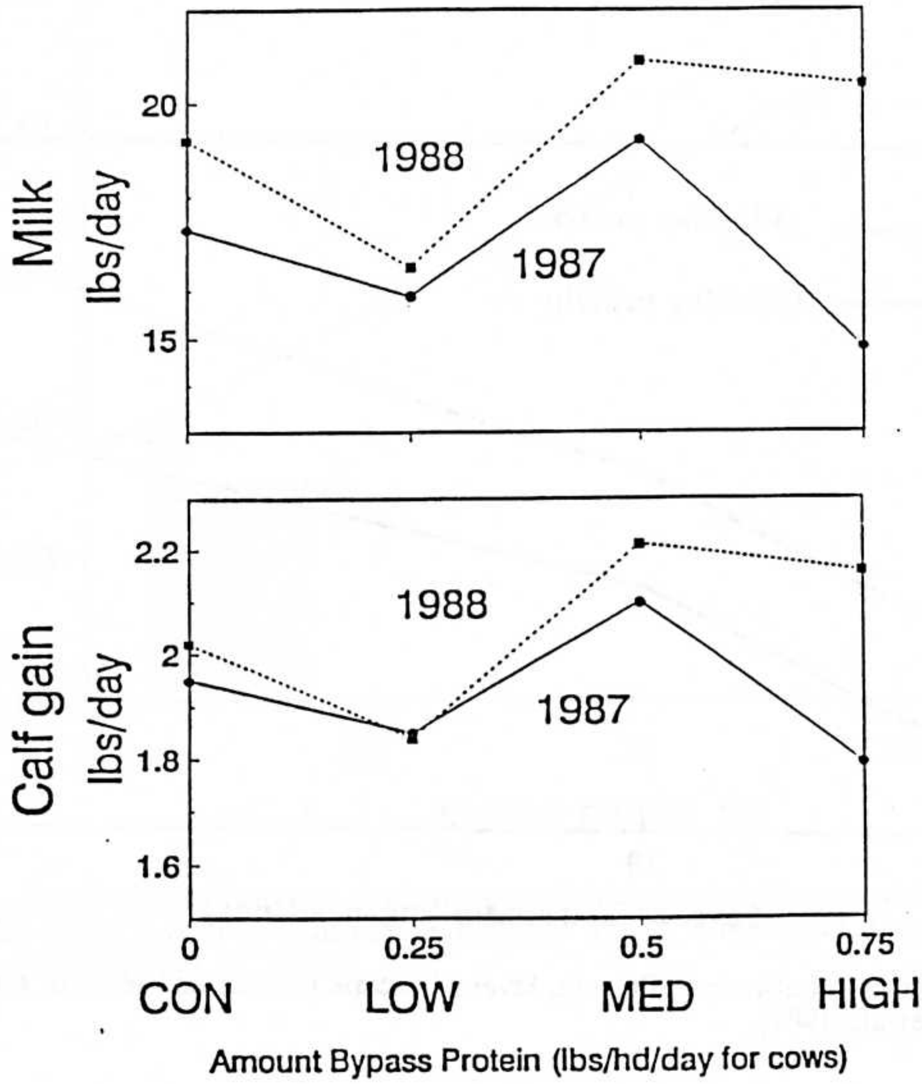

Figure 6. Response to bypass protein for bromegrass (Blasi et al., 1991).

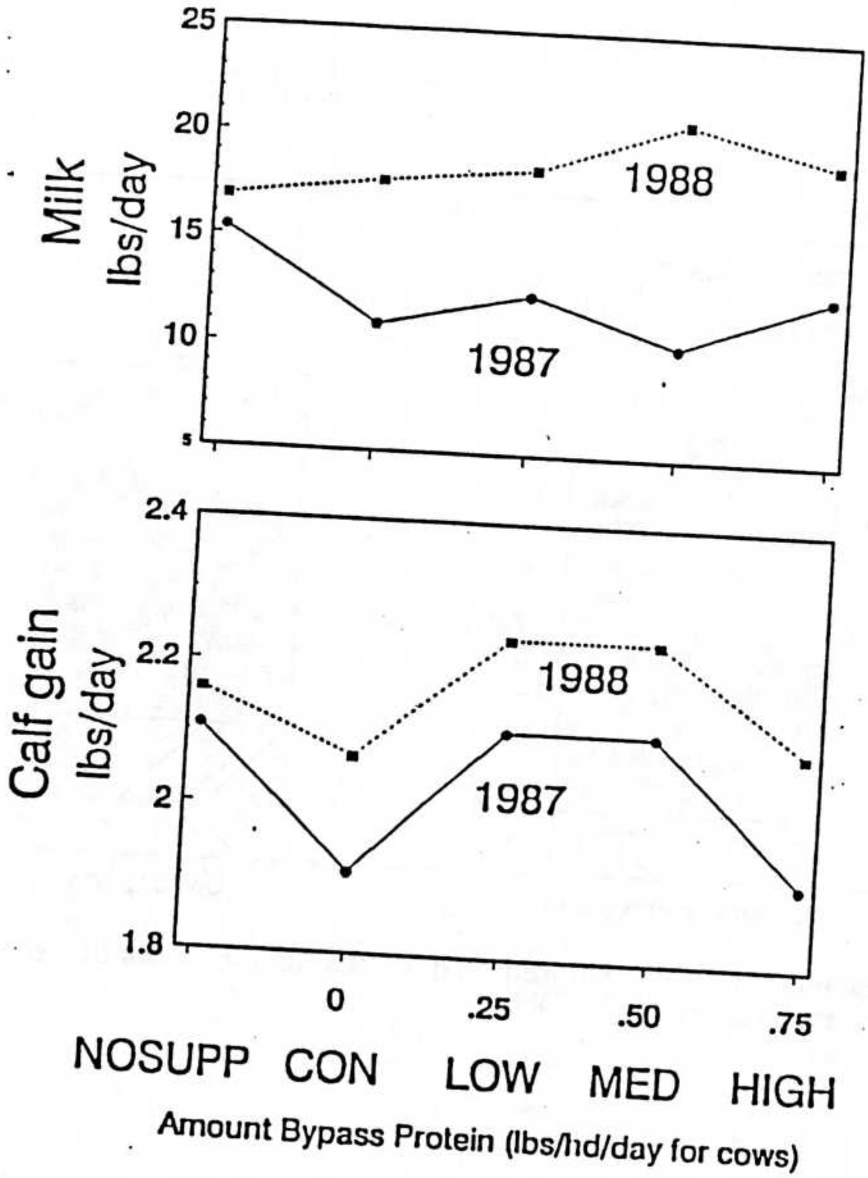

Figure 7. Response to bypass protein for big bluestem (Blasi et al., 1991).

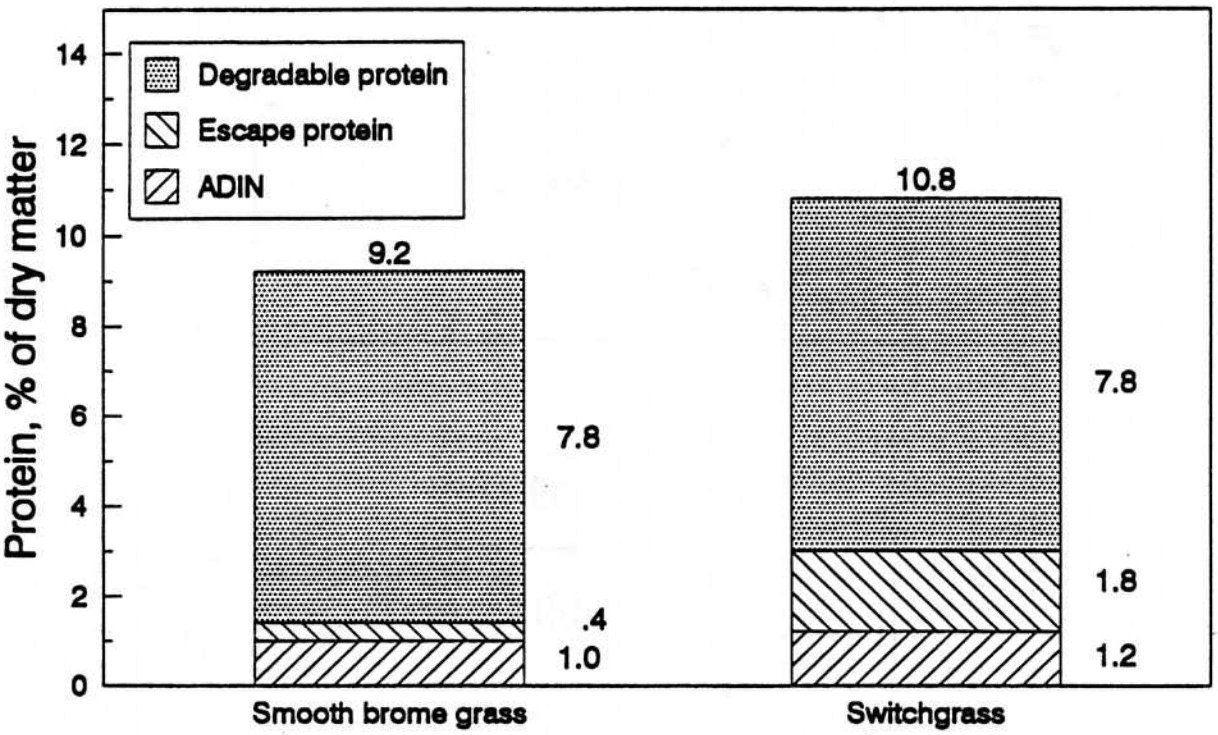

Figure 8. Estimated crude protein required in the diet of smooth bromegrass and switchgrass when both are 60% TDN.