PROTEIN SUPPLEMENTATION OF GRAZING LIVESTOCK

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ABSTRACT

Protein nutrition of grazing ruminants has been intensively studied for years. For beef cattle receiving low quality forage based diets, urea alone does not appear to be an effective protein supplement. Urea may make up a portion of the protein supplement, but should not constitute all of the supplemental degradable intake protein. Provision of natural protein appears to have a stimulatory effect on rumen microbes. When natural protein supplements are provided to grazing beef cattle, forage intake and/or forage digestibility are usually increased, but responses are variable. Natural protein supplement may provide rumen microbes with branched chain volatile fatty acids which are required by fiber digesting bacteria. During lactation, the need for metabolizable protein (protein from the ruminal microbes and escape protein) increases. Provision of natural protein supplements generally increases milk production and, as a consequence, calf weight gain. Native range decreases in nutritive value as season advances, making supplementation necessary in many production systems if cattle are to graze dormant forages. Degradable intake protein appears to be the first limiting nutrient for cattle grazing dormant native range. Adoption of the 1996 NRC Beef Cattle Nutrient Requirements model for protein requirements can help better define the amount and type of protein required in supplementation programs. However, better data regarding requirements of the rumen microbial population, seasonal changes in degradability of forage crude protein, as well as forage intake is needed for successful and cost effective supplementation programs.

INTRODUCTION

Cow-calf producers in many areas of the northern Great Plains have access to dormant grasses during fall and winter months when lack of snow or ice cover permits grazing. Stockpiled forages (native range) represent a low-cost forage resource for these producers since it requires no haying or feeding operation to deliver it to cattle. Cattle do the harvesting themselves. To make any extensive dormant grazing program successful, strategic, accurate supplementation is necessary. Degradable intake protein (DIP), which is protein available to the rumen microbes, is the first limiting nutrient in dormant native range (Hollingsworth-Jenkins, 1996). Strategic supplementation will improve cattle performance on dormant grasses and improve forage utilization. This review will discuss protein supplementation of grazing cattle.

Non-Protein Nitrogen Supplements

If a source of ammonia is all that is necessary to improve digestion and intake of low quality forages, non-protein nitrogen (NPN) should provide adequate ammonia levels for this purpose. Clanton (1978) summarized several experiments conducted on native sandhills range using NPN in protein supplements and found that NPN was not as effective as all natural protein supplements as a source of protein for growing calves wintered on native range. Possibly the metabolizable protein requirement of these calves was high enough that they responded to the additional escape protein. Calves supplemented with biuret had similar rates of gain compared with calves supplemented with urea (Clanton 1978), indicating that biuret provided no additional benefit over and above urea.

When urea replaced soybean meal in supplements fed to cannulated steers fed low quality range forage, digestion of dry matter (DM) and organic matter (OM) decreased, but the synthesis of microbial protein was relatively unchanged (Kropp et al. 1977). In this study, soybean meal was replaced isocalorically and isonitrogenously with urea and ground sorghum. It is possible that the sorghum in the supplements influenced DM and OM digestibility due to negative associative effects of starch digestion on fiber utilization (Chase and Hibberd 1987; Mertens and Loften 1980). Ground sorghum levels ranged from 9.5 to 19.6% of the diet and dry matter intake averaged 4.6 kg/head/day. Starch content of the sorghum and starch intake was not reported.

The effectiveness of biuret or urea in dry or liquid supplements compared with all natural protein supplements for cows grazing dormant winter range was investigated by Rush and Totusek (1976). They found that cows fed the all natural protein supplement had less weight loss than isonitrogenous blends of molasses and urea when cows were wintered on native range. However, weight losses between supplements were similar if cows were provided prairie hay in addition to grazing native range. No advantage was noted with feeding either biuret in a dry supplement or urea in a liquid supplement compared with feeding urea in a dry supplement. These studies were conducted with gestating cows which calved during the trials, which makes interpretation difficult, because protein requirements change dramatically from gestation to lactation. Urea and biuret supply degradable protein needed by the ruminal microorganisms, but do not supply metabolizable protein required by the animal.

The use of 15% urea/85% corn, 100% soybean meal, 10% corn/40% soybean meal/50% urea, or 14% corn/36% blood meal/50% urea as supplements for low quality native forage was investigated by Petersen et al. (1985). They found OM digestibility, bacterial nitrogen flow to the abomasum, feed nitrogen flow to the abomasum, and microbial efficiency were not different among these supplements. In a companion nitrogen balance study (Peterson et al. 1985), no supplement, soybean meal, soybean meal and urea, and urea and blood meal were fed with low quality native forage. Supplementation increased digestibility of DM and NDF, and nitrogen retention was greater for steers fed soybean meal or blood meal/urea. They concluded that a blend of blood meal and urea was an effective supplement for cattle consuming low quality native grass.

Köster et al. (2002) conducted four trials to evaluate the effect of increasing level of urea in protein supplements on performance of cows grazing dormant native range or cannulated steers fed low quality dormant native range. They concluded that urea could replace from 20 to 40% of the supplemental degradable protein in 30% CP supplements without significantly altering either supplement palatability or cow performance. Farmer et al. (2004) investigated the interaction between urea level and supplementation frequency. They noted increased supplement refusal when greater levels of urea were included in the supplement. In addition, increasing level of urea in the supplement resulted in increased body weight loss in cows grazing dormant tallgrass prairie.

Urea and other forms of NPN do not appear to be adequate sources of degradable intake protein for cattle consuming low quality forage diets. The stimulatory effect of natural protein, peptides, and/or amino acids in vitro indicate that rumen microbes require natural protein and/or amino acids for optimum growth. The results of supplementation trials comparing NPN to natural protein supplements indicate that urea alone is not an effective N supplement for cattle grazing dormant native range unless a portion of the N is supplied by protein or peptides.

Effects of Feeding Natural Protein Supplements

Several broad categories of effects are reported when supplementing low quality forages with natural protein based supplements. These include increases in forage intake, increased digestibility, and increased rate of passage. Variation in responses is common and not all effects are observed in each trial.

Most responses to protein supplements are observed when forage crude protein levels were reported below 7% CP (Paterson et al. 1994). In most studies reported, protein supplements were based on oilseed meals which contain both rumen degradable and escape protein which makes ascertaining the biological mechanism responsible for eliciting responses difficult. In addition, protein deficiency has not always been demonstrated. Because of differential responses between urea based supplements and natural protein, a factor other than rumen ammonia provided by natural protein supplements may be responsible for the effects observed when natural protein supplements are fed. These factors could include 1) provision of nitrogen in a form other than ammonia, i.e. amino acids or peptides which are possibly stimulatory toward the rumen microbial population, 2) provision of some other growth factor required by the ruminal bacteria, which could include branched chain volatile fatty acids, 3) provision of escape protein which helps to meet the metabolizable protein needs of the animal, or 4) stimulation of ruminal kinetics allowing increased flow of non-nitrogen and nitrogen containing compounds is increased (Petersen 1987).

A review of literature pertaining to supplementation programs for ruminants grazing dormant native range indicates that responses to supplemental protein have been highly variable and vary from year to year. This fact alone argues for more complete data regarding seasonal effects on nutrient content, protein degradability, and microbial efficiency. Factors contributing to or influencing this variation include weather conditions, which includes temperature and snow cover (Kartchner 1980), animal factors such as cow age (Adams et al. 1986), and differences in forage quality from year to year (Kartchner 1980, Soder et al. 1995).

Protein supplementation of forages, which are low in CP, increases intake (Kartchner 1980, Hennessy et al. 1983, McCollum and Galyean 1985, Krysl et al. 1987, Fleck et al. 1988, Guthrie and Wagner 1988, Stokes et al. 1988, DelCurto et al. 1990a, DelCurto et al. 1990b, Hannah et al. 1991, Nunez-Hernandez et al. 1991, Ovenell et al. 1991, Marston and Lusby 1995, Horney et al. 1996, Köster et al. 1996, Stafford et al. 1996, Mathis et al., 1999; Gilbery et al., 2006). Forage CP levels in these trials ranged from 1.9 to 8.1% CP. Mathis et al (1999) fed increasing levels of soybean meal to beef steers consuming 5.3% CP native grass hay. Forage OM intake increased until supplemental soybean meal intake reached 0.16% BW.

Other workers have not reported increases in intake when protein supplements were offered to cattle consuming low quality forages (Kartchner 1980, Krysl et al. 1989, Villalobos et al. 1997a, Villalobos 1997b, Forcherio et al. 1995, Hollingsworth-Jenkins et al. 1996; Reed et al., 2004, Gilbery et al., 2006). Forage CP levels in these trials ranged from 4.8% to 11.3%. Reasons why intake did not increase in the work of Villalobos et al (1997b) and Hollingsworth-Jenkins et al. (1996) are not readily apparent. However, intake of control cows in these studies was approaching 2.0% of body weight, while intake of control animals in studies which have reported responses are sometimes considerably lower, 0.49 (DelCurto et al. 1990b) and 0.87% of body weight (DelCurto et al. 1990a).

Responses in digestibility to protein supplements are also variable. Some workers have reported increased digestibility when protein supplements were fed (Fleck et al. 1988, Guthrie and Wagner 1988, Stokes et al. 1988, Krysl et al. 1989, DelCurto et al. 1990a, Nunez-Hernandez et al. 1991, Ovenell et al. 1991, Sunvold et al. 1991, Hollingsworth-Jenkins et al. 1996, Horney et al. 1996); while others have reported no differences in digestibility with supplementation (Kartchner 1980, Petersen et al. 1985, Köster et al. 1996). Villalobos et al (1997b) reported increases in digestibility with protein supplementation when measured in metabolism studies but was unable to show differences in digestibility with grazing cows fed similar supplements (Villalobos et al., 1997a). Some of these differences are attributable to methods used to determine digestibility in the various studies (Galyean et al. 1986, Cochran et al. 1987).

Effects of feeding supplemental protein are variable. Factors which affect this variation include environmental influences such as temperature and snow cover, forage quality, and physiological status of the animal.

<u>Provision of Microbial Growth Factors</u>

The effect mediated by natural protein supplements may be due, in part, to the provision of branched chain fatty acids through the fermentation of leucine, isoleucine, and valine. These branched chain fatty acids are either required or highly stimulatory to cellulolytic bacteria (Mackie and White 1990). No differences in intake, digestibility, or microbial crude protein production were found in steers given branched chain fatty acids, indicating that the supply of branched chain fatty acids were not limiting or had no effect on microbial fermentation with the diets tested (McCollum et al. 1987).

Natural protein supplements may also supply amino acids which are limiting. Blends of urea and DL-methionine, urea and ammonium sulfate, or soybean meal as supplements for ruminally cannulated crossbred beef cows fed a 75:25 blend of grass hay and barley straw were investigated by Clark and Peterson (1988). In situ rate of fermentation was increased with the methionine treatment. Similar treatments were imposed on weaned heifer calves, no differences were found between the soybean meal and urea-methionine supplements.

The use of a blend of sugar beet pulp and DL-methionine or soybean meal as a supplement for gestating beef cows grazing native range was investigated by Lodman et al. (1990). The methionine treatment did not support the same level of performance that the soybean meal treatment did. Momont et al. (1993), in a similar trial, compared soybean meal to a blend of urea, corn, and methionine for cows grazing dormant winter range. They found that the urea, corn, and methionine treatment did not support the same level of cow performance that the soybean meal did.

Feeding to Meet the Metabolizable Protein Needs

Patterson et al. (2003) evaluated the effects of feeding supplements balanced to meet the CP needs or the metabolizable protein needs of primiparous beef heifers. The research involved 2,120 primiparous heifers maintained in a commercial ranching environment in the Nebraska Sandhills. Heifers supplemented to meet their metabolizable protein needs had similar weights and body condition scores at the end of the feeding periods. However, heifers fed to meet their metabolizable protein needs were heavier at the time of pregnancy diagnosis as two-year olds. In addition pregnancy rates were also greater (91 vs. 86%) for heifers fed to meet their metabolizable protein needs compared to heifers fed to meet their CP needs.

Supplementation of the Lactating Beef Cow

Lactating cows grazing smooth bromegrass pastures and fed increasing levels of escape protein supplementation had increased milk production and increased calf weight gain (Blasi et al. 1991). No response was noted when cows grazed big bluestem, however. In situ analysis of forage samples suggested that escape protein content of smooth bromegrass was lower than that of big bluestem.

The effect of time of initiation of protein supplementation on cow performance was examined by Sowell et al. (1992) using spring calving cows. Protein supplementation began either pre-calving or post-calving. Cows which were supplemented pre-calving had less spring weight loss and higher prebreeding body condition scores than cows which did not receive supplement until after calving. However, no differences were noted in reproductive performance.

Ovenell et al. (1991) found no interactions between lactational status and supplement type (soybean meal, wheat middlings, or corn-soybean meal) in hay intake, digestibility, or particulate passage rate. Differences in intake were detected, 2.1% and 1.9% of body weight, respectively for lactating and pregnant cows. No differences were found in DM digestibility or particulate passage rate.

Hunter and Magner (1989) supplemented lactating primiparous cows with formaldehyde-treated casein. They found no differences in milk production during the first eight weeks of lactation; however during the second half of lactation, supplemented heifers produced less milk than unsupplemented heifers. Longer periods of anestrus were noted for unsupplemented heifers. No differences were detected in DM intake, possibly because the basal diet was 8.75% CP.

Supplements varying in ruminal degradability (25 or 50% undegraded intake protein as a % of CP) were fed to 2 groups of lactating spring calving cows (Dhuyvetter et al. 1992). Cows were split into groups based on calving date. Early calving cows grazed native range and were fed 5.4 kg of medium quality grass hay (10.5% crude protein); late calving cows grazed native range only. Late calving cows had similar weight losses no matter which supplement was fed. Early calving cows fed the 50% undegraded intake protein supplement lost 39 kg less weight than cows fed the 25% undegraded intake protein supplement. They concluded that the late calving cows did not respond to escape protein in the same manner as the early calving cows because rumen degradable protein may have been limiting.

Response to escape protein was dependent on inclusion level in the diet with lactating ewes (Loerch et al. 1985). When blood meal was fed at 3.3% of diet dry matter, milk production was increased from 2.5 to 3.2 kg/day, compared to a diet supplemented with soybean meal. In a second study, when the blood meal was included at 6.8% of the diet, feed intake and milk production tended to be lower as compared to the diet supplemented with soybean meal. The authors attributed this to the poor palatability of the diet which contained high levels of blood meal. Dry matter intake was 3.0 kg when soybean meal was used as the supplement and 2.7 kg when 6.8% blood meal was included in the diet.

Milk production increased with increasing level [0 to 21 g supplement/kg body weight$^{0.75}$] of protein supplementation in Hereford cows fed a low quality tropical grass hay (2.7% CP; Lee et al. 1985). They used a protein supplement which was made up of a blend of cottonseed meal, fishmeal, meat meal, and mineral mix at 75.5%, 9.45%, 9.45%, and 5.6% of the supplement dry matter, respectively. The authors stated that 53% of the nitrogen in the sample remained after a 15-hour in situ incubation. Non-supplemented cows lost 2.56 kg/day while cows on the highest level of supplementation gained 0.15 kg/day. Growth rates of calves which nursed cows receiving increasing level of supplement were also higher.

Sletmoen-Olson et al. (2000) fed lactating beef cows increasing levels of undegraded intake protein. Control cows (non-supplemented) had greater forage intake than supplemented cows. No differences between supplemented cows were noted. No differences in total (forage plus supplement) were noted. Supplemented cows had greater body weight during lactation than non supplemented controls but no differences existed between supplemented groups. Encinias et al. (2005) offered no supplement, an energy control, a degradable protein supplement, or a supplement containing both degradable and undegradable protein to lactating beef cows consuming moderate quality forage (9.6% CP). No differences in cow performance, milk production, or calf weight gain were noted in the study indicating that metabolizable protein supply from the forage and microbial protein were adequate under the conditions of this study.

The most consistent response from supplementing natural protein to the lactating beef cow was increased milk production. However, this is not observed in all studies and may be related to supply of essential amino acids in the supplemental source of protein. In many cases, calf gain increases when lactating cows are supplemented with natural protein due to the increase in milk production.

Supplementation Frequency

Protein supplements do not need to be provided on a daily basis. Many reports in the literature indicate only small changes in forage utilization, cow weight change, or cow body condition score change when supplements are provided as often as daily or as infrequently as weekly (Farmer et al., 2001; Beaty et al., 1994; Kartchner and Adams, 1982). Schauer et al. (2005) investigated the effect of supplementation frequency (daily or every six days) on performance, grazing behavior, and variation in supplement intake. No differences in performance, grazing behavior, or variation in supplement intake were noted. Even when small differences exist in forage utilization, cow weight change, or cow body condition score change, most often the economics of the situation justify alternate day or twice weekly feeding of protein supplements.

Interaction Between Supplemental Degradable Protein and Energy

Level of supplemental protein fed when feeding cereal grain supplements also seems to interact with forage quality. Bodine et al. (2000) fed supplemental corn at 0 or 0.75% of BW to beef steers consuming low quality (6% CP) grass hay. When supplemental degradable intake protein was provided, the negative associative effects of corn feeding were less apparent. Additional research at Oklahoma State University investigated the relationship between supplemental degradable protein and energy supplementation for cattle grazing dormant forages (Bodine and Purvis, 2003). These researchers noted improved performance in growing steers grazing dormant tallgrass prairie when the supply of rumen degradable protein was balanced with total dietary TDN supply. Baumann et al. (2004) reported interactions between source of energy supplement (corn vs. soyhulls) and provision of a rumen degradable protein supplement when cattle were fed a low quality forage diet.

Seasonal Changes in Nutrient Quality of Native Range

Numerous research stations have investigated seasonal changes in nutrient quality of native range over the growing season. Year to year variation in forage quality occurs. Much of this variation is related to environmental conditions such as amount and timing of precipitation, date of frost at the beginning and end of the growing season, and other conditions which affect plant growth. Table 1 gives the seasonal changes in nutritive value of subirrigated meadow in the Nebraska Sandhills. Table 2 gives the seasonal changes in nutritive value of native range in the Nebraska Sandhills. Table 3 gives the seasonal changes in nutritive value of native range in southwestern North Dakota. Crude protein and digestibility of native range decreases as the growing season advances, making supplementation necessary for a portion of the grazing season in most production systems. Additional data regarding seasonal changes in degradable protein content of native forage under various growing conditions is necessary to better understand the need for supplementation (Lardy et al., 2004).

Table 1. Means and standard deviations of laboratory analysis of meadow diet samples collected at Gudmundsen Sandhills Laboratory, Whitman, Nebraska, in 1992 and 1994 (OM Basis).[1, 2]

Date	Type[3]	# OBS	CP (%)	NDIN (%)	ADIN (%)	UIP (%)	DIP (%)	NDF (%)	ADF (%)	IVOMD (%)
JAN	Regrowth	1	12.1	0.76	0.12	1.4	10.7	77.2	50.2	53.4
MAR	Primary	1	16.6	0.91	0.22	1.2	15.4	66.8	42.4	60.2
APR	Primary	1	29.4	0.92	0.03	4.2	25.3	49.3	27.3	68.3
MAY	Primary	1	17.6	1.09	0.17	3.1	14.5	73.0	42.3	68.3
JUN	Primary	3	17.3±4.58	0.75±0.13	0.13±0.01	2.3±0.41	15.0±4.28	68.6±11.99	39.2±6.17	70.8±5.49
JUL	Primary	3	12.4±2.74	0.67±0.09	0.13±0.04	2.0±0.20	10.4±2.56	72.0±4.69	41.7±4.65	66.0±5.28
AUG	Regrowth	2	17.2±3.58	0.63±0.18	0.08±0.03	2.3±0.78	14.8±2.81	63.2±11.56	44.4±4.29	64.4±4.39
SEPT	Regrowth	3	15.6±1.73	0.67±0.07	0.14±0.03	1.8±0.25	13.9±1.48	70.52±5.01	43.7±4.61	63.4±4.18
OCT	Regrowth	1	14.9	0.68	0.14	1.3	13.6	63.8	44.1	67.7
NOV	Regrowth	1	9.1	0.48	0.23	1.2	7.9	78.6	53.8	47.5
DEC	Regrowth	2	8.1±0.31	0.47±0.01	0.19±0.02	1.0±0.06	7.0±0.25	83.1±0.65	55.8±0.98	54.2±1.94

[1]# OBS, number of sampling dates analyzed for a given month, each observation represents 4 to 7 diets collected by esophageal fistulated cows or ruminally cannulated steers; CP, crude protein; NDIN, neutral detergent insoluble nitrogen; ADIN, acid detergent insoluble nitrogen; UIP, undegraded intake protein; DIP, degraded intake protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; IVOMD, in vitro organic matter disappearance.
[2]Standard deviations listed are for averages of diets collected over 1992 and 1994 within each month, not for laboratory analysis within a particular sample collection.
[3]Sample type: Regrowth-growth following July haying; Primary-growth before July haying.

Table 2. Means and standard deviations of laboratory analysis of upland range diet samples collected at Gudmundsen Sandhills Laboratory in 1992 and 1994 (OM Basis).[1,2]

Sample Date	# OBS	CP (%)	NDIN (%)	ADIN (%)	UIP (%)	DIP (%)	NDF (%)	ADF (%)	IVOMD (%)
JAN	1	6.3	0.45	0.15	0.8	5.5	83.6	52.5	58.0
MAR	2	6.0±0.24	0.48±0.10	0.09±0.05	1.0±0.02	5.0±0.27	82.5±0.89	53.3±0.24	54.8±0.69
APR	2	11.4±1.86	0.79±0.05	0.11±0.01	1.2±0.11	10.2±1.75	77.5±5.29	43.2±6.17	67.6±9.30
JUN	3	13.8±2.53	0.85±0.15	0.12±0.02	2.5±0.15	11.3±2.38	72.4±2.70	40.6±2.52	67.6±2.57
JUL	4	12.3±1.50	0.90±0.06	0.14±0.01	2.2±0.30	10.1±1.31	79.8±3.62	43.6±4.26	67.5±2.4
AUG	3	11.3±2.52	0.79±0.11	0.16±0.02	1.8±0.43	9.5±2.26	77.9±4.42	46.4±4.28	63.7±3.62
SEPT	2	7.4±0.34	0.51±0.06	0.12±0.02	1.1±0.23	6.4±0.58	79.7±1.30	48.8±1.41	60.7±1.21
NOV	1	5.9	0.37	0.27	0.7	5.2	84.4	56.1	48.3
DEC	2	6.5±0.60	0.39±0.08	0.13±0.06	1.2±0.20	5.4±0.40	86.0±0.96	54.5±0.40	53.9±5.51

[1]# OBS, number of sampling dates analyzed for a given month, each observation represents 4 to 7 diets collected by esophageal fistulated cows or ruminally cannulated steers; CP, crude protein; NDIN, neutral detergent insoluble nitrogen; ADIN, acid detergent insoluble nitrogen; UIP, undegraded intake protein; DIP, degraded intake protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; IVOMD, in vitro organic matter disappearance.
[2]Standard deviations listed are for averages of diets collected over 1992 and 1994 within each month, not for laboratory analysis within a particular sample collection.

Table 3. Effect of advancing season on nutrient composition of native range in southwestern North Dakota.

Item	Mid-June	Late July	Early September	Early October	Mid-November	Mid-December
NDF (%)	59.5	51.0	58.7	59.6	67.9	72.1
ADF (%)	35.7	34.8	40.3	38.5	40.9	41.8
CP (%)	13.6	14.9	10.2	9.7	6.6	6.2
IVOMD (%)	68.1	60.5	55.6	54.3	57.3	53.3

Data adapted from Johnson et al. (1998).

TAKE-HOME MESSAGE

Degradable intake protein is limiting on low quality dormant forages and native range. Use of supplements high in protein degradability (sunflower meal, canola meal) should be considered in these situations. Urea or other NPN sources generally do not produce satisfactory results when used as the sole source of degradable intake protein. They may be used in combination with natural protein sources with a higher degree of success. Lactating beef cows may need supplemental escape protein when forage quality is low and/or when milk production is high. Use of starch-based energy supplements with low quality forages is generally not successful since intake and digestibility of the forage will be reduced. Producers should first provide adequate degradable intake protein and then supply additional energy as needed. Strategic supplementation will improve beef cattle performance and allow utilization of dormant native range with minimal cost.

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