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First limiting nutrient for summer calving cows grazing autumn-winter range

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Abstract

Two trials were conducted in 1994, 1995, and 1996 to determine the first limiting nutrient for summer calving cows grazing Sandhills range. In Trial 1, 48 lactating summer calving cows grazing native range during the breeding season were assigned to 1 of 4 supplement treatments: 1) control-no supplement, 2) energy, 3) degradable intake protein (DIP), and 4) DIP + undegraded intake protein (UIP). Cows were group-fed supplements in 8 pastures (2 pastures/treatment). The trial began 4 September and ended 4 November each year. Diet samples from esophageally fistulated cows averaged 7.5% crude protein and 54.5% in vitro organic matter digestibility. Supplemented cows lost less body condition compared to control cows (P = 0.04). Cow and calf weight gains were increased by supplemental DIP or DIP + UIP combination compared to energy supplement (P = 0.09 and 0.08, respectively). Forage intake and digestibility were not different among treatments (P>0.20). Milk production was lower for non-supplemented than supplemented cows (P = 0.10). Trial 2 began 5 November and ended 10 January in 1994-1995, 1995-1996, and 1996–1997. Treatments and pastures were the same as described in Trial 1, however, only 40 cows were used. In Trial 2, diet samples from esophageally fistulated cows averaged 6.2% crude protein and 52.3% in vitro organic matter digestibility. No differences (P>0.10) in body condition score were detected. Total organic matter intake was lower for control compared to supplemented treatments (13.5 vs.15.5 kg day^{-1}; P < 0.10). We concluded that DIP was the first limiting nutrient for summer calving cows during the breeding season and during autumn-winter lactation after the breeding season.

Key Words: Supplementation, forage intake, forage digestibility, rumen degradable protein, undegraded intake protein

Resumen

Durante 1994, 1995, y 1996 se condujeron dos ensayos para determinar el el primer nutriente limitante para vacas amamantando durante el verano y apacentando pastizales "Sandhills". En el ensayo 1, 48 vacas lactantes amamantando en verano y apacentando pastizal nativo durante la época de empadre fueron asignadas a 1 de 4 tratamientos de suplementación: 1) sin suplemento (control), 2) energía, 3) consumo de proteína degradable (DIP) y 4) DIP + consumo de proteína no degradada (UIP) Las vacas fueron agrupadas por suplemento en 8 potreros (2 potreros/tratamiento). El estudio inició el 4 de Septiembre y terminó el 4 de Noviembre de cada año. Las muestras de la dieta obtenidas de vacas con fístula de esófago promediaron 7.5% de proteína cruda y 54.5% de digestibilidad in vitro de la materia orgánica. Las vacas suplementadas perdieron menos condición corporal comparadas con las vacas del tratamiento control (P = 0.04). Las ganacias de peso de la vaca y el becerro incrementaron por la suplementacion DIP o la combinación DIP + UIP en comparación con el suplemeto de energía (P = 0.09 y 0.08 respectivamente). El consumo de forraj y la digestibilidad no difirieron entre tratamientos (P>0.20). La producción de leche fue menor para las vacas no suplementadas que para las suplemetadas (P = 0.10). El ensayo 2 inició en Noviembre 5 y teminó en Enero 10 de 1994–1995, 1995–1996, y 1996–1997. Los tratamientos y potreros fueron los mismos descritos en el ensayo 1, sin embargo, solo 40 vacas fueron utilizadas. En el ensayo 2, las muestras de la dieta colectadas vía fístula esofágica promediaron 6.2% de proteína cruda y 52.3% de digestibilidad in vitro de la materia orgánica. No se detectaron diferencias (P>0.10) en la calificación de la condición corporal. El consumo total de materia orgánica fue menor para el grupo control comparado con los tratamientos suplementados (13.5 vs 15.5 kg dia-1; P<0.01). Concluimos que DIP fue el primer nutriente limitante para vacas amamantando en verano durante la época de empadre y durante la lactación de otoño-invierno después de la época de empadre.

Nutrient requirements of beef cattle have been well defined (NRC 1996). However, nutrient intake of grazing cattle is not well defined due to problems associated with measurement of forage intake and digestibility of grazing cattle. Data related to supplementation of spring (Blasi et al. 1991, Sowell et al. 1992, Marston and Lusby 1995, Marston et al. 1995) and autumn calving cows (Rakestraw et al. 1986, Gonzalez et al. 1988, Hibberd et al. 1988, Ovenell et al. 1989) are plentiful in

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the literature. However, limited information is available regarding whether energy or protein is first limiting for lactating summer calving cows grazing native range during the autumn-winter months.

Warm-season grasses on Nebraska Sandhills range decline in quality in late summer, a time corresponding to the breeding season for the summer calving cow (Lardy 1997). We hypothesized that summer calving cows would respond to undegraded intake protein (UIP; as defined by NRC 1996), in addition to degraded intake protein (DIP; as defined by NRC 1996) due to the demands of lactation on metabolizable protein requirements. Our objectives were to determine whether energy, DIP, or DIP + UIP was the first limiting nutrient for lactating summer calving cows grazing native range during the breeding season and late lactation.

Materials and Methods

Trial 1

The study was conducted on native range at the University of Nebraska-Lincoln Gudmundsen Sandhills Laboratory (elevation 1,073 m, 42° 05' north latitude, 101° 26' west longitude) near Whitman, Neb. Forty-eight lactating MARC II crossbred (1/4 Hereford, 1/4 Angus, 1/4 Simmental, and 1/4 Gelbvieh) multiparous summer calving (avg calving date = 1 July) beef cows and their calves were assigned to 4 replicated supplement treatments from 4 September to 4 November in 1994 (body weight = 578.4 kg ± 53), 1995 (body weight = 590 kg ± 55), and 1996 (body weight = 601 kg ± 58). Treatments were assigned randomly to pastures (i.e., replicates) each year. Cows were stratified by calving date and calf sex and assigned to pastures at the initiation of the trial. Treatments were: 1) control, no supplement; 2) control and supplemental energy, fed at isocaloric levels to the protein supplements; 3) Degraded intake protein (DIP) supplement; and 4) DIP + undegraded intake protein (UIP) combination. Composition of supplements is given in Table 1. Supplements were not isonitrogenous, but were formulated to meet calculated requirements for DIP and metabolizable protein (NRC 1996). In 1994 and 1995 cows were group-fed their supplements daily in 35.6 hectare pastures. In 1996, cows were fed supplements 4 times week^{-1}.

Table 1. Composition (g day^{-1}) of protein and energy supplements fed in Trial 1.

	Treatment			
Item	Control	Energy	Degraded intake protein (DIP)	Degraded intake protein + undegraded intake protein (UIP)
	(g day^{-1})			
Soyhulls	—	425	153	—
Tallow-	—	47	17	—
Corn steep liquor	—	—	284	—
Sulfite liquor treated soybean meal	—	—	—	470
Feather meal	—	—	—	118

The estimated DIP requirement was 663 g, of which 555 g was supplied by the forage. These estimates were based on the assumptions that the average cow weighed 545 kg and would consume a 53% total digestible nutrients (TDN) forage at 2.3% of body weight) Hollingsworth-Jenkins 1994). Net synthesis of bacterial crude protein was assumed to be 10% of the TDN intake (Burroughs et al. 1974, Villalobos 1993). The degraded intake protein (DIP) content of the forage was estimated to be 4.44% of organic matter (OM; Hollingsworth-Jenkins et al. 1996). Corn steep liquor, a byproduct of the wet corn milling industry, is 38% crude protein, of which 100% is DIP (Karges 1990). The metabolizable protein requirement was estimated to be 720 g, which was based on an average body weight of 545 kg and a peak milk production of 8.2 kg day^{-1}. The forage was assumed to supply 125 g of metabolizable protein and bacteria would supply 424 g (12.5 kg dry matter intake X 53% TDN X 10% efficiency X 80% true protein X 80% digestibility; NRC 1996). The sulfite liquor treated soybean (Glycine max L. Merr) meal:feather meal supplement was estimated to be 52% crude protein, of which 70% was undegraded intake protein (UIP) (Britton et al. 1978). Therefore, the sulfite liquor treated soybean meal:feather meal supplement provided both DIP and UIP. The energy supplement, DIP supplement, and the DIP and UIP supplement were formulated to be isocaloric. The energy supplement was not intended to meet the energy requirements of the cows but provided an isocaloric control to determine if energy and not DIP or the DIP + UIP were the first limiting nutrients.

The range was sands and choppy sands sites. The soil was Valentine fine sands (mixed, mesic, ustpamments). The dominant grass species on the native range pastures were: little bluestem [*Schizachrium scoparium* (Michx.) Nash], prairie sandreed [*Calamovilfa longifolia* (Hook.) Scribn.], sand bluestem (*Andropogon gerardii* var. *paucipilus* Hack.), switchgrass (*Panicum virgatum* L.), sand lovegrass [*Eragrostis trichodes* (Nutt.) Wood], indiangrass [*Sorghastrum nutrans* (L.) Nash], and blue grama [*Bouteloua gracilis* (H.B.K.) Lag. ex Griffiths]. Common forbs and shrubs included western ragweed (*Ambrosia psilostachya* DC.) and leadplant [Amorpha canescens (Nutt.) Pursh].

Cows and calves were weighed and cows scored for body condition at the beginning and end of the trial. Body condition scores were based on a palpated determination of fleshing over the ribs and thoracic vertebrae. Body condition was scored from 1 (thinnest) to 9 (fattest) according to the system described by Richards et al. (1986).

Fecal output for estimation of forage intake was determined on 24 cows (6 cows/treatment) during September and again in October of 1994 and 1995. Sample collection dates were 15 September through 19 September, 1994; 29 October through 2 November, 1994; 18 September through 22 September, 1995; and 24 October through 27 October, 1995. Three cows were selected randomly from each pasture and brought to a common pasture for intake determinations. The common pasture was located adjacent to the treatment pastures and was also a choppy sands site with similar forage characteristics as

treatment pastures. The use of a common pasture facilitated individual feeding and fecal collection procedures necessary to measure fecal output. Cows remained in the common pasture for 10 days during each collection period. Cows were individually fed supplements for 5 days before intake determinations and during the fecal collection period. During the October 1995 collection period, a blizzard prevented collection of samples over a 5-day period; consequently, samples were only collected over 4 days. Each cow on the intake trial was orally dosed with an intraruminal continuous chromium (Cr)-releasing device[1] 5 days before the 5-day fecal collection period. Three hundred to 500 g of feces were obtained from the rectum of each cow daily at about 0800 hours. Forage intake was estimated by dividing fecal output by the indigestibility of the forage diet after accounting for the supplement (Kartchner 1980).

Total fecal collections were taken from 6 steers in September 1994 and 5 steers in September and October 1995. Total fecal collections were not made in October 1994. The correction factor from the September 1994 collection period was assumed to represent the data collected in October 1994 because boluses were manufactured in the same lot and forage was similar. Steers used for total fecal collection received no supplement (Hollingsworth et al. 1995). Steers were dosed with the same intraruminal continuous Cr releasing device as the cows on the trial and fitted with fecal collection bags for total fecal collection to obtain a correction factor for fecal output (Adams et al. 1991a, Hollingsworth et al. 1995). Feces collected in fecal collection bags were weighed, mixed, subsampled (300 to 500 g), and bags emptied. In September 1994 and September 1995, bags were emptied twice daily at 0800 and 1700 hours during the 5-day fecal collection period. In October 1995, feces were lower in moisture and fecal bags were emptied once daily at 0800 hours.

Forage diet samples were collected in September and October of 1994 and 1995 using 6 to 8 esophageally fistulated cows. Diet samples were collected in the pasture designated for the forage intake determination. Cows were held off feed overnight and allowed to graze for 20 to 40 minutes for sample collections. Cows had been fistulated for 1 to 4 years previously as described by Adams et al. (1991b) with modifications for adult cattle. The surgical preparation and post-surgical care procedures were reviewed and approved by the University of Nebraska Institutional Animal Care and Use Committee. Diet extrusia samples were collected in screen bottom bags and immediately frozen.

Milk production was measured using the weigh-suckle-weigh technique on 23 September 1995, 28 October 1995, 19 October 1996, and 5 November 1996. Three cows from each pasture (6/treatment) were randomly selected for measurement of milk production at each time. Pregnancy was determined by rectal palpation approximately 70 days following the conclusion of the breeding season.

All fecal and extrusa samples were stored frozen until chemical analyses were performed. Extrusa and fecal samples were freeze dried. Fecal samples were ground to pass through a 1-mm screen in a Wiley Mill. Extrusa samples were ground to pass through a 2-mm screen in a Wiley Mill for analysis of diet protein degradability. Extrusa samples were ground to pass through a 1-mm screen in a Wiley Mill for analysis of dry matter, organic matter, crude protein, neutral detergent fiber (NDF), acid detergent fiber (ADF), and in vitro organic matter digestibility (IVOMD). Dry matter, organic matter, and crude protein were determined by standard methods (AOAC 1990). Neutral detergent fiber was determined according to Van Soest et al. (1991), and ADF by the method of Van Soest (1963). In vitro organic matter digestibility of extrusa samples was determined by the modified procedures of Tilley and Terry (1963) with the addition of 1 g of urea to the inoculum-buffer mixture (Weiss 1994). Inoculum from 2 steers, 1 fed a grass hay diet and 1 fed a corn cob diet supplemented with soybean meal, was mixed in a 50:50 ratio with prewarmed (39°C) McDougall's solution. Samples were incubated for 48 hours with inoculum:buffer mixture followed by 24-hour pepsin digestion. Fecal samples were analyzed for chromium concentration by atomic absorption spectrophotometry using an air plus acetylene flame (Williams et al. 1962).

Undegraded intake protein (UIP) of extrusa samples was determined by the method of Mass et al. (1996). Briefly, 5 g samples were incubated in dacron bags[2]. Samples were incubated for 2, 12, and 96 hours. Three separate incubation runs were performed over 3 days. Bags were washed according to Wilkerson et al. (1995) and subjected to analysis of neutral detergent fiber nitrogen. Amounts of neutral detergent fiber nitrogen remaining after incubation were log transformed and a rate of degradation calculated. The UIP was calculated using the following formula: $UIP = B \times (k_p/(k_d+k_p)) + C$; where B is the pool size or potential UIP calculated from the intercept of the log transformation of degradation, k_p is the rate of passage, k_d is the rate of degradation of neutral detergent fiber nitrogen, and C is the undegradable fraction (Broderick 1994). Passage rates were determined at the Gudmundsen Sandhills Laboratory by Lamb (1996). The UIP content of the sulfite-liquor treated soybean meal-feather meal supplement fed in this study was determined using the ammonia release procedure of Britton et al. (1978).

Data were analyzed using the MIXED procedures of SAS (1990) appropriate for a repeated measures design. For body weight, body condition score, and pregnancy data, pasture within treatment was considered random. Treatment effects were tested using pasture within treatment as the error term. Year and year X treatment interaction were tested using the residual error. For intake data, pasture within treatment and year X pasture within treatment were considered random. Treatment effects were tested using pasture within treatment as the error term. Year and the year X treatment interaction were tested using year X pasture within treatment. Period, period X treatment, period X year, and period X treatment X year were tested using the residual error term. For milk production data, year X period X treatment was considered random. Treatment, period, year, and the 2-way interactions were tested using year X period X treatment as the error term. For all data, pre-

[1]Captec Chrome manufactured by Captec Pty. Ltd., Australia, distributed internationally by Nufarm Limited, Manu Street, P.O. Box 22-407, Otahunu, Auckland 6, New Zealand.

[2]Ankom, Inc., Fairport, N.Y.

planned contrasts were used to compare: 1) the control vs all supplemented treatments, 2) the energy control vs degraded intake protein (DIP) supplement + DIP + UIP combination, and 3) DIP vs DIP + UIP combination. Pregnancy data were transformed using the arc sine of the square root before analysis (Snedecor and Cochran 1989).

Trial 2

The study was conducted on native range at the University of Nebraska-Lincoln Gudmundsen Sandhills Laboratory in the same pastures as described for Trial 1. Forty lactating MARC II crossbred summer calving beef cows were assigned to 4 supplement treatments from 5 November to 10 January in 1994–95 (body weight = 578 kg ± 55), 1995–96 (body weight = 575 kg ± 47), and 1996–97 (body weight = 608 kg ± 58). Supplement composition is given in Table 2. Experimental protocols followed in Trial 2 were the same as used in Trial 1.

Assumptions used to calculate supplemental needs in Trial 2 were the same as in Trial 1 with the following exceptions. Diet crude protein was assumed to be 5%, with 2.95% of the organic matter as degraded intake protein (DIP), and 2.05% undegraded intake protein (UIP). Diet in vitro organic matter digestibility was assumed to be 57%. The DIP requirements were calculated using 8% microbial efficiency. For Trial 2 in 1994 and 1995, the amount of DIP in the DIP + UIP supplement was inadequate in DIP. In 1996, the amount of DIP in the DIP + UIP supplement was increased (Table 2).

Fecal output for determination of forage intake was measured on 24 cows (6 cows/treatment) during December of 1994 and 1995. Sample collection dates were 7 December to 12 December 1994 and 12 December to 16 December 1995. Total fecal collections were made using 5 steers in 1994 and 6 steers in 1995 to obtain a correction factor for chromium release rate from the bolus as described for Trial 1. Forage intake was calculated as described for Trial 1.

Milk production was measured using the weigh-suckle-weigh technique on 16 December 1995 and 13 December 1996. Storage, preparation, and analysis of diet and fecal samples followed the procedures described in Trial 1.

Table 2. Composition (g day^{-1}) of protein and energy supplements fed in Trial 2.

	Treatment			
Item	Control	Energy	Degraded intake protein (DIP)	Degraded intake protein + undegraded intake protein (UIP)
			(g day^{-1})	
Years 1 and 2				
Soyhulls	—	425	—	288
Tallow	—	47	—	32
Corn steep liquor	—	—	508	—
Sulfite liquor treated soybean meal	—	—	—	175
Feather Meal	—	—	—	44
Year 3				
Soyhulls	—	499	75	—
Tallow	—	55	8	—
Corn steep liquor	—	—	508	426
Sulfite liquor treated soybean meal	—	—	—	159
Feather Meal	—	—	—	40

Data from Trial 2 were analyzed using the assumptions, procedures and preplanned contrasts described for Trial 1. For Trial 1 and Trial 2, significant differences are noted at $P<0.10$.

Results and Discussion

Trial 1

Table 3 shows precipitation and temperatures for the months during which the trial was conducted and the long term averages. Average ambient temperatures during the trials were generally cooler than average, and yearly precipitation was 6% higher than average in 1994 and 57% higher than average in 1995.

Diet samples averaged 7.5% crude protein, 1.4% undegraded intake protein (UIP), and 55% in vitro organic matter disappearance during the breeding season (Table 4). The degraded intake protein (DIP) and digestibility values of the diets selected were similar to the estimates used to formulate the supplements. However, the crude protein level was 1.8 percentage units higher than expected.

Year effects were detected for initial cow body condition, weight change, calf weight gain, body condition score change, and final body condition score ($P = 0.004$, $P = 0.12$, $P = 0.003$, $P = 0.0002$, and $P = 0.004$, respectively). However, year by treatment interactions were not detected for these variables ($P = 0.88$, $P = 1.00$, $P = 0.17$, $P = 0.65$, and $P = 0.57$, respectively).

Cow weight loss was greater ($P = 0.08$) for control cows than the mean of cows receiving supplements (Table 5). Cows supplemented with DIP and DIP + UIP lost less weight compared to cows receiving the energy supplement ($P = 0.09$). No differences were detected when DIP and DIP + UIP supplements were compared ($P = 0.23$). This is inconsistent with the findings of Dhuyvetter et al. (1992) who reported decreased weight loss when lactating

Table 3. Monthly and yearly precipitation and temperature profiles for 1994 and 1995 at the Gudmundsen Sandhills Laboratory, Whitman, Neb.

	Date					
	Sept.	Oct.	Nov.	Dec.	Annual	Average (1982–1994)[1]
1994 Precipitation (cm)	3.00	3.58	1.88	1.93	59.33	56.03
1994 Avg. daily temperature (°C)	17.2	9.9	1.7	-0.3	8.9	9.8
1995 Precipitation (cm)	14.63	11.66	1.02	0.51	88.29	56.03
1995 Avg. daily temperature (°C)	15.6	8.3	2.1	–2.0	8.4	9.8

[1]Collection of weather data began in 1982.

Table 4. Percentage crude protein (CP), undegraded intake protein (UIP), neutral detergent fiber (NDF), acid detergent fiber (ADF) concentrations, and in vitro organic matter digestibility (IVOMD) of diets collected from esophageally-fistulated cows grazing native range during Trial 1 (OM Basis).

Date	CP	UIP	NDF	ADF	IVOMD
			%		
17 Sep 1994	7.79	0.63	80.9	50.2	59.5
3 Nov 1994	5.89	0.93	84.4	56.1	48.3
9 Sep 1995	9.20	2.33	68.1	46.1	53.8
26 Oct 1995	7.09	1.54	80.1	51.6	56.8

spring calving cows were supplemented with supplements containing 50% of the supplemental protein as UIP compared with supplements containing 25% of the supplemental protein as UIP. Hibberd et al. (1988) reported decreased weight loss in lactating autumn calving cows when fed supplements containing increased levels of UIP. Triplett et al. (1995) reported no difference in weight or body condition score changes of mature and primiparous cows fed low, medium, or high UIP supplements while grazing rye (*Secale cereale* L.)-ryegrass (*Lolium perenne* L.) overseeded into Coastal bermudagrass [*Cynodon dactylon* (L.) Pers.] pastures. Blasi et al. (1991) reported no differences in weight gain for lactating spring calving cows grazing big bluestem pastures and supplemented with increasing levels of UIP.

Body condition score loss was greater for cows on the control treatment (P = 0.04, Table 5) than cows that received a supplement. Short et al. (1996) reported spring calving cows grazing native range during the autumn and supplemented with a cottonseed meal (Gossypium spp.) based supplement gained more weight and body condition than cows receiving no supplement. Marston et al. (1995) reported similar body weight loss when either a protein (soybean meal based) or an energy (soyhull based) supplement were fed to provide similar amounts of crude protein for lactating spring calving cows grazing native range. In the work of Marston et al. (1995), the energy supplement provided approximately 2 times the metabolizable energy of the protein supplement. The sulfite liquor treated soybean meal-feather meal combination used in the DIP + UIP treatment would supply more UIP than cottonseed meal or soybean meal based supplements used by Short et al. (1996) and Marston et al. (1995), respectively. No difference in body condition score change was detected among the supplements (P>0.45, Table 5).

Control cows tended (P = 0.16) to have lower conception rates (87.5% vs 95.8%) than the mean of the supplemented cows. Triplett et al. (1995) found higher first service conception rates for cows fed medium and high UIP supplements than for cows fed a low UIP supplement. Pregnancy rate was not the primary criteria by which we intended to evaluate the effects of supplementation. However, this trend does merit further investigation with larger numbers of cows. Dhuyvetter et al. (1992) found no differences in pregnancy rates when cows were supplemented with either 25 or 50% UIP.

Calves nursing control cows gained less weight than calves which nursed cows receiving supplements (P = 0.03). Calves nursing cows receiving supplemental protein gained more weight than calves nursing cows receiving the energy supplement (P = 0.08). Cows consumed supplements rapidly and calves

Table 5. Least squares means for initial body condition score, final body condition score, body condition score change, initial cow weight, final cow weight, cow weight change, initial calf weight, final calf weight, calf weight gain, and pregnancy rate during Trial 1.

	Treatment					
Item	Control	Energy	Degraded intake protein (DIP)	Degraded intake protein + undegraded intake protein (UIP)	SE[1]	Contrast[2]
Initial BCS	5.76	5.57	5.63	5.57	0.08	NS[3]
Final BCS	5.13	5.17	5.27	5.28	0.09	NS
BCS change	–.63	–.40	-.36	–.29	0.08	1
			(kg)			
Cow initial weight	590.5	578.2	592.3	597.6	5.18	2
Cow final weight	571.4	563.1	585.1	599.7	6.84	2
Cow weight change	–19.1	–15.1	–7.1	2.0	4.60	1, 2
Calf initial weight	109.1	104.4	107.6	105.5	2.63	NS
Calf final weight	162.0	161.0	168.9	167.7	3.32	NS
Calf weight gain	52.9	56.6	61.3	62.2	1.85	1, 2
24-hr milk production	5.69	6.06	7.59	6.98	0.52	1
			Number cows bred/number exposed			
Pregnancy[4]	33/36	35/36	35/36	35/36	0.07	NS

[1]SE, Standard error of the mean.
[2]Contrasts: 1, control vs. supplemented treatments; 2, energy vs. degraded intake protein + degraded intake protein undegraded intake protein combination; 3, degraded intake protein vs. degraded intake protein undegraded intake protein combination.
[3]NS, Not significant (P>0.10)
[4]Pregnancy rate analyzed as the arc sine transformation of the proportion of number bred divided by the number exposed.

Table 6. Least squares means for forage intake and total intake (e.g. forage plus supplement) for summer calving cows grazing autumn range in Trial 1.

Item	Treatment				SE[1]	Contrast[2]
	Control	Energy	Degraded intake protein (DIP)	Degraded intake protein + undegraded intake protein (UIP)		
Forage intake (kg organic matter day^{-1})	16.7	16.6	17.8	15.8	0.79	NS[3]
Total intake (kg organic matter day^{-1})	16.7	17.1	18.3	16.4	0.77	NS
Forage intake (kg/100 kg body weight^{-1} day^{-1})	2.95	2.87	3.15	2.72	0.144	NS
Total intake (kg/100 kg body weight^{-1} day^{-1})	2.95	2.95	3.23	2.82	0.146	NS

[1]SE, Standard error of the mean.
[2]Contrasts: 1, control vs. supplemented treatments; 2, energy vs. degraded intake protein + degraded intake protein undegraded intake protein combination; 3, degraded intake protein vs. degraded intake protein undegraded intake protein combination.

were not given access to supplements; consequently, increased calf weight gain was not influenced by calf consumption of supplements. Milk production (Table 5) was higher for supplemented cows than for control cows (P = 0.10). Milk represents an important source of nutrients for growing calves (Baker et al. 1976, Lamb et al. 1997, Lardy 1997). Milk production was not different when lactating spring calving cows were fed increasing levels of undegraded intake protein (UIP) while grazing big bluestem pastures (Blasi et al. 1991). Cows fed high UIP supplements produced more milk. Milk production also increased when cows were fed higher amounts of TDN (Hibberd et al. 1988). No differences in milk production or calf weight gain were found when cows were fed supplements containing low, medium, or high UIP levels (Triplett et al. 1995). Cows fed 100 g UIP/day produced more milk than cows fed 200 g UIP/day when grazing endophyte [*Neotyphodium coenophialum* Morgan-Jones and Gams (Glen, Bacon, and Hanlin)]-infected tall fescue (*Festuca arundinacea* Schreb.; Forcherio et al. 1995). In addition, calves nursing cows receiving 100 g UIP/day gained more weight compared to calves nursing cows receiving 200 g UIP protein/day (Forcherio et al. 1995). Milk production increased linearly in cows given low quality hay and supplemented with increasing levels of a protein supplement based on a blend of cottonseed meal, fish meal, and meat meal (Lee et al. 1985). In contrast, Hunter and Magner (1988) found that milk production was not affected by supplementation in the first 8 weeks of lactation and during late lactation milk production was decreased when heifers were supplemented with formaldehyde-treated casein.

No differences (P>0.45) were detected in forage intake or total intake (e.g., forage plus supplement) on a kg/100 kg body weight basis among treatments (Table 6). Marston and Lusby (1995) found lactating spring calving cows fed a soybean meal based protein supplement had higher hay dry matter intake than cows fed a soyhull based energy supplement. Marston and Lusby (1995) found hay digestibility was higher for the protein supplemented cows in year 2 but not in year 1. Forage intakes and forage digestibility were lower for cows supplemented with protein compared to cows receiving no supplement (Short et al. 1996).

Period by year interactions (P = 0.03) were detected for forage intake, total intake, forage intake as a percentage of body weight, total intake as a percentage of body weight, and digestibility (Table 7). Significant snowfall events occurred during the collection period in 1995, which possibly influenced grazing behavior of the cows (Adams et al. 1986), consequently affecting intake and digestibility. During the September 1995 collection period, snow only remained on the ground 2 days. During the October 1995 collection period, snow remained on the ground throughout the collection period. The September snowfall event and colder temperatures may have caused the reductions in forage intake observed when comparing September 1994 to September 1995 (Adams et al. 1986). The in vitro organic matter digestibility of the samples indicated lower digestibility in November 1994 compared to October 1995 (Table 4). An explanation for the low digestibility observed in November

Table 7. Least squares means forage intake and total intake (e.g. forage plus supplement) for summer calving cows grazing autumn range by period and year in Trial 1.

Item	September		October		Period X year interaction P value
	Year 1	Year 2	Year 1	Year 2	
Forage intake (kg organic matter day^{-1})	19.9	16.3	15.4	15.3	0.03
Total intake (kg organic matter day^{-1})	20.3	16.7	15.8	15.7	0.03
Forage intake (kg/100 kg body weight day^{-1})	3.45	2.82	2.72	2.69	0.038
Total intake (kg/100 kg body weight day^{-1})	3.52	2.88	2.79	2.75	0.039
	Climatic data during intake determinations				
Snowfall (cm)	—	20.3	—	40.6	—
Average high temp (°C)	26.3	10.9	17.6	10.6	—
Average low temp (°C)	5.8	0.9	-3.0	–3.2	

1994 compared to October 1995 is not readily apparent.

The fact that cows did not respond to undegraded intake protein (UIP) in addition to degraded intake protein (DIP) did not fit our hypothesis. Several things likely influenced this lack of response. Forage intake was higher than expected, which results in higher bacterial crude protein production in addition to more total forage protein escaping from the rumen. Metabolizable protein supply would be increased by 114 g due to the increased intake (3.27 kg additional intake X 10% efficiency X 80% digestibility X 80% true protein), metabolizable protein supply would also increase by 35 g (3.27 kg additional intake X 1.35% UIP X 80% digestibility) due to additional UIP from the forage. In addition, milk production was lower than expected which reduces the metabolizable protein requirement. This results in a metabolizable protein requirement of 796 g and a metabolizable protein supply of 698 g. Based on measured intakes, digestibility, protein degradability, and milk production, the magnitude of the difference between the metabolizable protein requirement and supply was smaller than expected, which may explain the lack of response to the additional UIP. In addition, the fact that milk production was higher for cows receiving supplements would tend to reduce the magnitude of a response in weight change or body condition score change, because nutrients would be partitioned toward milk production rather than energy reserves for the cow.

Table 8. Percentage crude protein (CP), undegraded intake protein (UIP), neutral detergent fiber (NDF), acid detergent fiber (ADF) concentrations, and in vitro organic matter digestibility (IVOMD) of diets collected from esophageally-fistulated cows grazing native range during Trial 2 (organic matter basis).

Date	CP	UIP	NDF	ADF	IVOMD
			(%)		
12 Dec 1994	5.89	0.85	85.0	54.1	48.4
12 Dec 1995	6.54	1.44	78.0	49.1	56.2

Another variable that affects metabolizable protein supply is the efficiency of conversion of TDN to bacterial crude protein. With high quality forages, a 13% efficiency is used by NRC (1996). However, with low quality forages, lower efficiencies (7 to 10%) have been measured (Villalobos 1993, Hollingsworth-Jenkins et al. 1996, NRC 1996). Reductions in passage rate with low quality forages increase maintenance requirements because proportionally more energy is used for bacterial maintenance rather than growth. Hollingsworth-Jenkins et al. (1996) used nonlactating gestating beef cows and Villalobos (1993) used steers fed low quality prairie hay to determine these efficiencies. Hollingsworth-Jenkins et al. (1996) reported organic matter intakes of 2.1% of body weight, while the intakes reported here are considerably higher. Passage rate increases with increased intake (Adams and Kartchner 1984); microbial efficiency may also increase with increases in passage rate. The beef cattle nutrient requirements model (NRC 1996) was used to calculate the microbial efficiency at which degraded intake protein (DIP) supply was equal to DIP requirement. For these calculations, we assumed that the DIP and DIP + undegraded intake protein (UIP) supplements both met the DIP requirement. These calculations indicated that the microbial efficiency was 11% rather than 10% as we used in formulating supplements. The net effect of a greater efficiency would be to increase the amount of DIP required and increase the amount of metabolizable protein supplied (NRC 1996). This would also help to explain the lack of response to supplemental UIP.

Trial 2

Five cm of snow remained on the ground throughout the December 1994 collection period. No snowfall was recorded during the December 1995 collection period. Average high and low temperatures were –0.6°C and –12.8°C during the December 1994 collection period and 9.4°C and 5.9°C during the December 1995 collection periods.

Table 9. Least squares means for initial body condition score, final body condition score, body condition score change, initial cow weight, final cow weight, cow weight change, initial calf weight, final calf weight, and calf weight gain during Trial 2.

	Treatment					
Item	Control	Energy	Degraded intake protein (DIP)	Degraded intake protein + undegraded intake protein (UIP)	SE[1]	Contrast[2]
Initial BCS	5.10	5.13	5.29	5.34	0.10	NS
Final BCS	4.17	4.38	4.41	4.71	0.15	NS
BCS change	–.93	–.75	–.88	–.62	0.12	NS
			(kg)			
Cow initial weight	582.1	578.4	590.3	596.4	12.3	NS
Cow final weight	491.2	500.4	524.1	530.3	8.19	1, 2
Cow weight change	–90.9	–78.0	–66.2	-66.0	11.8	NS
Calf initial weight	170.9	168.7	175.9	163.4	5.12	NS
Calf final weight	191.6	195.8	202.3	192.7	5.17	NS
Calf weight gain	20.7	27.1	26.4	29.3	3.71	NS
24-hr milk production	2.87	3.21	3.43	5.22	0.58	NS

[1]SE, Standard error of the mean.
[2]Contrasts: 1, control vs. supplemented treatments; 2, energy vs. degraded intake protein + degraded intake protein undegraded intake protein combination; 3, degraded intake protein vs. degraded intake protein undegraded intake protein combination.
[3]NS, Not significant (P>0.10).

Table 10. Forage intake, total intake, forage intake as a percentage of body weight, and total intake as a percentage of body weight in Trial 2.

Item	Treatment				SE[1]	Contrast[2]
	Control	Energy	Degraded intake protein (DIP)	Degraded intake protein + undegraded intake protein (UIP)		
Forage intake (kg organic matter day^{-1})	13.5	14.0	16.5	14.7	0.80	NS
Total intake (kg organic matter day^{-1})	13.5	14.4	17.0	15.2	0.80	1
Forage intake (kg/100 kg body weight^{-1} day^{-1})	2.68	2.62	3.04	2.67	0.16	NS
Total intake (kg/100 kg body weight^{-1} day^{-1})	2.67	2.71	3.13	2.77	0.16	NS

[1]SE, Standard error of the mean.
[2]Contrasts: 1, control vs. supplemented treatments; 2, energy vs. degraded intake protein + degraded intake protein undegraded intake protein combination; 3, degraded intake protein vs. degraded intake protein undegraded intake protein combination.
NS, Not significant (P>0.10).

Forage intake and total intake (forage plus supplement; kg/100 kg body weight) was higher (P = 0.03) in 1994 compared to 1995 (3.0 vs 2.5 kg/100 kg body weight and 3.1 vs 2.6 kg/100 kg body weight). Cold temperatures likely reduced intakes in 1995 (Adams et al. 1986). However, based on the in vitro organic matter digestibility, we expected higher intakes in 1995 because forage quality was higher (Table 8).

The need for supplemental degraded intake protein (DIP) was underestimated in years 1 and 2 and the DIP + undegraded intake protein (UIP) protein combination supplement failed to supply adequate DIP. We estimated the requirement for DIP to be 547 g. However, in years 1 and 2, the DIP + UIP supplement only supplied 416 g DIP. Consequently, supplement formulations were changed in year 3 (Table 2). In year 3, the DIP +UIP supplement was formulated to supply 547 g DIP. The implication of underfeeding DIP while supplying excess UIP is unclear. No improvement in cow or calf performance was noted, as evidenced by the lack of a significant year by treatment interaction for body condition score change (P > 0.15) cow weight gain (P > 0.50), or calf weight gain (P > 0.50). Ruminants recycle nitrogen (NRC 1996); consequently, excess UIP could potentially substitute for DIP. The fact that cows perform similarly when supplemented daily or 3 times weekly indicates that recycling is important in production settings (Beaty et al. 1994).

Diets collected from esophageally cannulated cows averaged 6.2% crude protein, 1.2% UIP, and 52% in vitro organic matter digestibility during Trial 2. Crude protein was higher while UIP and digestibility were lower than we had estimated when supplements were formulated.

No differences were detected among treatments for cow weight change, cow body condition score change, or calf weight gain during the late lactation period (Table 9). Cow final weights were lower for control cows compared to cows receiving a supplement (P = 0.05). Cows receiving the energy supplement had lower final weights compared to protein supplemented cows (P = 0.06). Cows on all treatments lost body weight over the 70-day period. Average weight loss for the late lactation period was 75 kg. Large weight losses during late lactation are a concern; however, summer calving cows in this herd have access to vegetative forage for at least 30 days before calving and increases in body condition score to a score of 6 (on a 9 point scale) are common. Large loss of body condition could negatively impact winter performance of cows post weaning, because thin cows are likely to have higher maintenance requirements (Thompson et al. 1983).

Milk production tended (P = 0.12) to be higher for cows receiving the degraded intake protein degraded intake protein (DIP) + undegraded intake protein undegraded intake protein (UIP) supplement compared to the DIP. This is in agreement with the work of Lee et al. (1985) and Hibberd et al. (1988). No differences in milk production were reported when primiparous crossbred 2-year-old cows were fed 8.8% CP meadow hay and received either no supplement or 0.5 kg of a 40% CP soybean meal based supplement (Farthing 1993). Calf weight gain was not different among treatments.

No differences among treatments were detected (P > 0.17) for forage intake, forage intake as a percentage of body weight, and total intake as a percentage of body weight (Table 10). Total intake (kg/d) was higher for supplemented cows compared to the control (P < 0.10). No difference in hay intake by non-supplemented and supplemented primiparous cows were fed subirrigated meadow hay averaging 8.8% CP (Farthing 1993).

Again, the fact that cows did not respond to undegraded intake protein (UIP) in addition to degraded intake protein (DIP) may be due to the fact that estimated metabolizable protein requirement was too high, because milk production of the cows was overestimated. In addition, measured intakes were higher than expected, resulting in greater supply of metabolizable protein than expected. Based on average body weights, milk production, intake, digestibility, and protein degradability measured during Trial 2, the metabolizable protein requirement was 626 g and the metabolizable protein supply was 626 g. A response to additional UIP would not be expected based on this metabolizable protein requirement and supply.

Conclusions

Degraded intake protein was the first limiting nutrient before undegraded intake protein (UIP) and energy for summer calving cows grazing native range during the breeding season and

late lactation. Supplementation with degraded intake protein (DIP) protein resulted in decreased weight and condition score losses during the autumn and winter periods. Calf gains were increased due to higher milk production during the autumn. Protein supplements such as alfalfa (*Medicago sativa* L.), soybean [*Glycine max* (L.) Merr.] meal, sunflower (*Helianthus annuus* L.) meal, or steep liquor, which are relatively high in degradability, are readily accessible for producers in the Nebraska Sandhills and can meet the supplemental protein requirements of summer calving cows during the breeding season and late lactation. Accurate estimates of milk production, intake, digestibility, and protein degradability are necessary to formulate supplements for grazing beef cattle based on DIP and metabolizable protein.

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