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Protein Supplementation of Low-quality Forage: Influence of Frequency of Supplementation on Ewe Performance and Lamb Nutrient Utilization[1]

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Summary

Supplementation frequency (SF) of CP for ruminants consuming low-quality forage can be decreased to once every 7 d; however, no data are available describing the effects of decreasing SF to once every 10 d. Our objectives were to evaluate the influence of length of SF on forage intake, digestibility, N balance, digested N retained, and plasma concentration of urea-N in lambs and reproductive performance in pregnant ewes. Supplementation frequency included daily (D), once every 5 d (5D), or once every 10 d (10D) supplementation, and an unsupplemented control (CON). Sixteen wethers (31 ± 1 kg BW) were individually fed in a digestibility study (n = 4 wethers / treatment). The amount of CP supplied by each supplement was approximately 0.15 percent of BW/d (averaged over a 10-d period) and formulated to meet CP requirements. Sixty pregnant Rambouillet ewes (75 ± 0.4 kg BW) in the last third of gestation were used in a performance study. The amount of CP supplied by each supplement was approximately 0.11 percent of BW/d (averaged over a 10-d period) and formulated to meet CP requirements, not including CON. Basal diets consisted of low-quality (5 percent CP) barley straw. Total DMI and OM intake were not affected ($P \geq 0.93$) by supplementation. However, forage DMI, OM intake, and N intake by lambs decreased ($P \leq 0.06$) linearly as SF decreased. Apparent total tract digestibility of N for supplemented lambs was approximately 300 percent greater ($P < 0.001$) than the CON, with no difference ($P = 0.57$) as SF decreased. Digested N retained and N balance were greater ($P \leq 0.01$) for supplemented wethers than for CON, with no difference ($P > 0.31$) due to SF. Plasma urea (PU; mM) was measured over the10-d period. Supplemented lambs had increased ($P < 0.001$) PU compared with CON, but was not effected ($P = 0.32$) by SF. Crude protein SF had no affect ($P > 0.21$) on post-lambing weight change, pre- and post-lambing BCS change, lambing date, and average lamb birth weight. Results suggest ruminants consuming low-quality forage can be supplemented with protein as infrequently as once every 10 d, while not negatively affecting nutrient digestibility or ewe performance.

Key Words: Crude Protein, Lamb, Reproduction, Sheep, Supplementation Frequency

Introduction

In the northern Great Plains, calculated winter feed costs are often $20 to $50 per ewe per year. Management and nutritional practices that decrease winter feed costs, while maintaining rangeland health, may increase profitability for livestock producers. One management alternative that may decrease winter feed costs is to extend the grazing season through the winter months of December, January, and February. Protein supplementation may be necessary during this time period (Schauer et al., 2001), and the non-feed costs associated with providing supplemental protein can be substantial (labor, fuel, hours, etc.). Current research suggests that the frequency of protein supplementation may be decreased to once every 7 days while maintaining livestock performance (Huston et al., 1999; Bohnert et al., 2002; Schauer et al., 2005). However, as supplementation frequency decreases, N retention decreases and can alter rumen microbial populations (Farmer et al., 2004b). If supplementation frequency (SF) can be decreased from daily to once every 10 d, labor and fuel costs can be further reduced. Therefore, our objectives were to evaluate the influence of length of supplementation frequency on forage intake, digestibility, N balance, digested N retained, and plasma concentration of urea-N in lambs (as a model for ewes) and reproductive performance in pregnant ewes.

Materials and Methods

All animal care and handling procedures were approved by the North Dakota State University Institutional Animal Care and Use Committee before the initiation of the research.

Digestion Study

Sixteen wethers (31 ± 1 kg BW; approximately 90 d of age) were used in a completely randomized design (Cochran and Cox, 1957) to evaluate the efficacy of N use in lambs fed low-quality forage (5 percent CP) and supplemented with soybean meal (SBM) daily or infrequently. Wethers were randomly allotted to SF treatments (n = 4 wethers/treatment) and housed in individual metabolism crates within an enclosed barn with continuous lighting.

Wethers had continuous access to fresh water and chopped barley straw (4 cm to 8 cm length). Barley straw was provided (in 2 equal portions; 0700 h and 1700 h) daily at 120 percent of the average intake for the previous 5 d, with feed refusals from the previous day determined before feeding. A trace mineral salt mix was available free choice (22 percent Ca, 8 percent P, 16.5 percent Na, 0.25 percent Mg, 1 percent S, 5 ppm Co, 35 ppm I, 1350 ppm Mn, 2.5 ppm Se, 1890 ppm Zn, and 90,909, 12,727, and 227 IU/kg vitamins A, D, and E, respectively; DM basis). In addition, an intramuscular injection of vitamins A and D (500,000 IU and 75,000 IU of vitamins A and D, respectively) was administered to each wether at the onset of the trial. Supplementation frequency included daily (D), once every 5 d (5D), or once every 10 d (10D) supplementation, and an unsupplemented control (CON). All supplemented wethers received the same total amount of supplement over a 10-d period; therefore, the 5D and 10D treatments received fivefold and tenfold the amount of supplement (N basis) on their respective supplementation day compared with D treatments. The amount of CP supplied by each supplement was 0.15 percent of initial BW/d (averaged over 10-d) based on intake and protein requirements (NRC, 1985). To prevent bias due to weight change due to treatment during each period, the quantity of supplement provided in each period was based on initial BW. Ingredient and nutrient content of the barley straw and supplement are described in Table 1.

The experimental period was 30 d. Forage intake was determined on d 19 to d 28. Samples of barley straw, SBM, and orts were collected on d 19 to d 28 and dried at 55°C for 48 h. On d 21 to d 30, total fecal and urine output were collected. Urine was composited daily by wether (25 percent of total; weight basis) and stored at 4°C. Sufficient 6 N HCl (150 mL) was added to urinals daily to maintain urine pH < 3. A sub-sample of each daily fecal sample (7.5 percent; weight basis) was dried at 55°C for 96 h to calculate fecal DM. On d 21 to d 30, 12 mL of blood was collected from the jugular vein at 4 h after feeding using a heparinized syringe. Blood samples were immediately transferred to vacutainers (Fisher Scientific, catalog no. 0268360), placed on ice, centrifuged (5000 x g, 15 min), and plasma harvested and stored (-20°C).

Dried feed and fecal samples were ground through a Wiley mill (1-mm screen). Daily samples of barley straw, SBM, and orts were composited by lamb on an equal weight basis (20 percent as-fed). Feed, orts, and fecal samples were analyzed for DM and OM (AOAC, 1997). Concentrations of NDF (Van Soest et al, 1991, as modified by Ankom Technology, Fairport, NY) and ADF (Goering and Van Soest, 1970, as modified by Ankom Technology) were determined using an Ankom 200 Fiber Analyzer (Ankom Technology) without sodium sulfite, with amylase, and without ash corrections as sequentials. Feed, orts, fecal, and urine samples were analyzed for Kjeldahl N (AOAC, 1997) and plasma samples were assayed for urea-N using a colorimetric diacetyl monoxine procedure (Urea Nitrogen, Procedure No. 535, Sigma Diagnostics, St. Louis, Mo.)

Ewe Performance Study

Sixty pregnant Rambouillet ewes (75 ± 0.4 kg BW; 3.1 ± 0.1 BCS) in the last third of gestation were stratified by age and BCS (1 = emaciated, 5 = obese)

Table 1. Dietary ingredient and nutrient composition of lamb and ewe diets (DM basis).

Item	Barley Straw	Soybean Meal
Supplement composition		
Soybean meal, %	-	100
Nutrient composition, %		
CP	5.0	52.6
OM	90.9	92.7
NDF	71.8	18.2
ADF	43.7	4.9

and assigned randomly within stratification to 1 of 3 SF treatments (as described in the digestion study, but not including CON) in a completely randomized design to evaluate ewe performance and lamb birth weight when consuming low quality forage (5 percent CP) and supplemented with SBM daily or infrequently. Ewes were sorted by treatment and allotted randomly to 1 of 12 pens (n = 4 pens/treatment). Protein supplements were offered as D, 5D, or 10D at 0800 h to provide approximately 0.11 percent of BW/d of CP (averaged over a 10-d period; 145 g/d) until lambing based on intake and protein requirements (NRC, 1985). Ewes had continuous access to fresh water and chopped barley straw (4 cm to 8 cm length). A trace-mineralized-salt mix was available free choice (22 percent Ca, 8 percent P, 16.5 percent Na, 0.25 percent Mg, 1 percent S, 5 ppm Co, 35 ppm I, 1350 ppm Mn, 2.5 ppm Se, 1890 ppm Zn, and 90,909, 12,727, and 227 IU/kg vitamins A, D, and E, respectively; DM basis). Ingredient and nutrient content of the barley straw and supplement are described in Table 1.

Ewe BW and BCS (both visual appraisal and palpation of subcutaneous fat cover) were measured every 14 d until lambing and within 14 d following lambing for approximately 57 d. All weights were consecutive 2-d unshrunk weights. Ewe BCS was evaluated independently by the same two observers throughout the experiment. Forage and supplement samples (approximately 200 g) were collected weekly, dried at 55°C for 48 h, ground through a Wiley mill (1-mm screen), and composited by month for analysis of ADF and NDF, N, and OM as described in the digestion study.

Statistical Analysis

Nitrogen balance data (excluding plasma-urea-N data) were analyzed as a completely randomized design (Cochran and Cox, 1957) using the GLM procedure of SAS (SAS Inst. Inc., Cary, N.C.) with animal serving as experimental unit. The model included lamb and treatment. Plasma urea-N was analyzed using the Repeated statement with the Mixed procedure of SAS. The model included treatment, day, and treatment x day. Additionally, lamb x treatment was used to specify variation between lambs (using the RANDOM statement). Lamb x treatment was used as the SUBJECT and autoregression used as the covariance structure. Response variables included: 1) DM, OM, NDF, and N intake; 2) total tract digestibility of DM, OM, NDF, and N; 3) N balance; 4) digested N retained; and 5) plasma concentration of urea N. Orthogonal contrasts included: 1) CON vs. protein supplementation and 2) linear effect of supplementation frequency. Significance was declared at $P < 0.10$.

Ewe and lamb performance data were analyzed as a completely randomized design using the GLM procedure of SAS with pen serving as experimental unit. The model included treatment. Response variables included: 1) ewe weight change; 2) ewe BCS change; and 3) lamb birth date and average lamb weight. Orthogonal contrasts included: 1) D vs. infrequent supplementation; and 2) linear effect of supplementation frequency. Significance was declared at $P < 0.10$.

Results and Discussion

Digestion Study

The effect of supplementation frequency on lamb intake, diet digestibility, and nitrogen balance is reported in Table 2. Total DMI and OM intake were not affected ($P \geq 0.93$) by CP supplementation; however, intake of hay DM and OM was affected by CP supplementation ($P = 0.06$; Table 2), with 5D and 10D linearly decreasing (P < 0.06) hay DM and OM intake. Total DM and OM intake responded similarly, with total DM and OM intake exhibiting a linear decrease ($P = 0.06$) as SF decreased. Also, daily NDF and N intake decreased linearly ($P = 0.06$) as SF decreased; but all supplemented treatments had higher N intake than CON ($P < 0.001$; Table 2). Apparent total tract digestibility of DM and OM was greater ($P = 0.001$) for lambs fed supplements, with no difference ($P > 0.34$) resulting from SF. Additionally, no difference ($P = 0.18$) was observed for NDF digestibility. However, apparent total tract digestibility of N for supplemented lambs was greater ($P < 0.001$) than the CON, with no difference ($P = 0.57$) because of SF (Table 2). Daily fecal N excretion decreased ($P < 0.001$) and urinary N excretion increased ($P < 0.001$; Table 2) due to CP supplementation. As SF decreased, fecal N excretion exhibited a linear decrease ($P < 0.001$) from D to 5D; however, no difference was noted due to CP SF for urinary N excretion ($P = 0.95$). Daily N balance and digested N retained were greater ($P < 0.01$) with CP supplementation, with no difference observed for SF ($P \geq 0.31$).

Treatment x day interactions ($P < 0.001$; Figure 1) were observed for plasma concentration of urea-N. However, after considering the nature of the interactions, we concluded that discussing treatment means while providing the treatment x day figure would aid in interpretation and discussion of the data. Lamb plasma urea-N was greater ($P < 0.001$) in CP-supplemented lambs than in CON (Table 2). No difference was observed due to CP SF ($P = 0.32$) for lamb plasma urea-N concentrations.

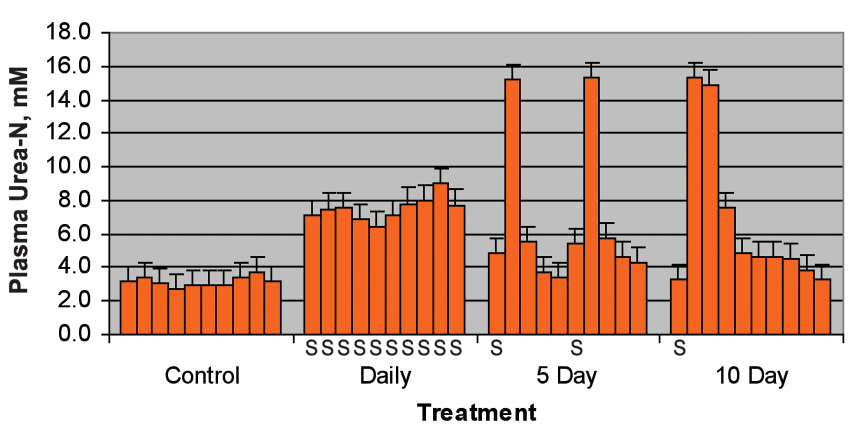
While lamb forage intake data were similar to those reported by some researchers (Ferrell et al., 1999; Bohnert et al., 2002), they contrasted with other studies evaluating protein supplementation of low-quality forage (DelCurto et al., 1990; Köster et al., 1996; Bandyk et al., 2001). Bohnert et al. (2002) reported no affect of CP supplementation on hay DM and OM intake, with total DM, OM, and N intake increasing with supplementation. Our results support the conclusions of Bohnert et al. (2002) and Mertens (1985, 1994) who all concluded that, when daily NDF intake is greater than 12.5 g/kg BW per d dry matter intake is maximized, with no expected increase in DMI when supplemental CP is supplied. This conclusion is further supported by Ferrell et al. (1999) who reported no increase in forage intake when lambs supplemented with CP were already consuming 13.0 g NDF / kg BW per d. In the current study, daily NDF intake by control lambs was 13.1 g/kg BW per d with a range of 10.8 g/kg to 13.1 g/kg for supplemented lambs. In experiments which showed that supplemental CP elicited an increase in forage intake, NDF intake of unsupplemented controls was 6.4 g/kg , 5.1 g/kg , and 8.2 g/kg BW per d (DelCurto et al., 1990; Köster et al., 1996; Bandyk et al., 2001, respectively). Based on our results and the results of others, it appears that protein supplementation to lambs consuming at least 12.5 g/kg BW per d of NDF will not result in an increase in forage intake.

Table 2. Effect of supplementation frequency on lamb intake, diet digestibility, and nitrogen balance.

Item	Supplementation frequency[a]				SEM[b]	P-value[c]	
	CON	D	5D	10D		CON vs. supp.	Linear SF
Daily DMI, g/kg BW							
Hay	18.3	17.7	15.0	14.4	1.1	0.06	0.06
Supplement[d]	0.0	2.8	2.8	2.8			
Total	18.3	20.4	17.8	17.1	1.07	0.94	0.06
Daily OM intake, g/kg BW							
Hay	16.7	16.1	13.7	13.1	1.0	0.06	0.05
Supplement[e]	0.0	2.5	2.5	2.5			
Total	16.7	18.7	16.2	15.6	1.0	0.93	0.06
Daily NDF intake, g/kg BW	13.1	13.1	11.3	10.8	0.7	0.14	0.06
Daily N intake, g/kg BW	0.147	0.373	0.344	0.335	0.012	<0.001	0.06
Total tract digestibility, %							
DM	43.8	50.7	51.6	52.1	0.01	0.001	0.43
OM	45.0	52.3	53.0	54.1	0.01	0.001	0.34
NDF	43.9	46.0	46.2	47.9	0.02	0.18	0.45
N	16.1	64.1	66.6	65.7	0.02	<0.001	0.57
Daily N excretion, g/kg BW							
Fecal	0.123	0.134	0.115	0.116	0.009	<0.001	<0.001
Urinary	0.096	0.247	0.256	0.248	0.014	<0.001	0.95
Daily N balance, g/kg BW	-0.072	-0.008	-0.027	-0.029	0.014	0.01	0.31
Daily digested N retained, %[f]	-308.7	-3.4	-11.7	-13.8	9.0	<0.001	0.43
Plasma urea-N, mM	3.12	7.49	6.80	6.69	0.55	<0.001	0.32

[a] CON = no supplement; D = soybean meal every day; 5D = soybean meal every 5th day; 10D = soybean meal every 10th day.
[b] n = 4 wethers / treatment.
[c] CON vs. supp. = control vs. supplemented treatments; Linear SF = linear effect of supplementation frequency.
[d] D received 2.8 g/kg BW daily; 5D received 14 g/kg BW once every 5 d; 10D received 28 g/kg BW once every 10 d;
[e] D received 2.5 g/kg BW daily; 5D received 12.5 g/kg BW every 5th d; 10D received 25 g/kg BW every 10th d.
[f] Calculated as (Daily N retention, g/kg BW/Daily N digested, g/kg BW) x 100.

Figure 1. Effect of crude protein supplementation frequency on plasma urea-N (mM) of lambs. Columns from left to right for each treatment represent d 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 of a 10-d supplementation window, respectively. Treatments were as follows: Control = no supplement; Daily = soybean meal every day; 5 Day = soybean meal every 5th day; 10 Day = soybean meal every 10th day. Each column with an S below represents a supplementation day. Treatment x day interaction (*P* < 0.001). SEM = 0.91.



The effect of supplementation frequency on forage intake has been reported as both positive and negative (Beaty et al., 1994; Huston et al., 1999; Krehbiel et al., 1998; Bohnert et al., 2002). Beaty et al. (1994) observed that when steers consuming wheat straw were supplemented daily or three times weekly, three times weekly supplemented steers consumed 17 percent less straw and 12 percent less total DM compared to daily supplemented steers. Bohnert et al. (2002) reported that as SF decreased from daily to once every 6 d, forage intake decreased by approximately 13.5 percent (average of degradable and undegradable intake protein treatments) and total DM intake decreased by approximately 12 percent. As SF decreased in the current study from D to 5D and 10D, hay DM intake decreased by 12 percent and 19 percent, respectively, and total DM intake decreased by 13 percent and 16 percent, respectively.

Similar to the report by Bohnert et al. (2002), this decrease in forage and total DM intake can be partially explained by depressions in intake in the days following supplementation (data not shown). However, these responses are not similar to results reported by Huston et al. (1999) and Krehbiel et al. (1998). Huston et al. (1999) reported that hay and total DM intake was not affected when ewes consuming wheat straw were supplemented with cottonseed meal daily or once every 7 d. In a similar fashion, Krehbiel et al. (1998) reported an increase in total intake of bromegrass hay by ewes supplemented with soybean meal every 24 or 72 h, compared to unsupplemented controls.

Our results suggest that apparent total tract digestibility of DM and OM was increased by CP supplementation, with no differences due to SF. These results support conclusions reached by other researchers (DelCurto et al., 1990; Beaty et al., 1994; Bandyk et al., 2001; Bohnert et al., 2002). Wickersham et al. (2008a) observed increases in both OM and NDF total tract digestibility as the amount of DIP was increased in daily supplementation. Research by Petersen (1987) suggests that increases in DM and OM digestibility following CP supplementation are largely the result of increased N availability for ruminal microflora. It is not readily apparent why NDF apparent total tract digestibility did not increase in the current study. Other researchers (DelCurto et al., 1990; Beaty et al., 1994; Bandyk et al., 2001; Bohnert et al., 2002) have demonstrated that NDF digestibility usually follows DM and OM digestibility, increasing with CP supplementation.

Apparent total tract N digestibility for supplemented lambs was approximately 309 percent greater than the CON. While greater in magnitude, this increase in N digestibility is similar to responses reported by Bohnert et al. (2002). In both the current trial and in the experiment by Bohnert et al. (2002), the low N digestibility can largely be attributed to the high fiber content and low N content of the low-quality forage utilized. Additionally, results from Bohnert et al. (2002) and Ferrell et al. (1999) indicated that, for diets containing low-quality forage, a large portion of the fecal N is metabolic fecal N. In fact, Ferrell et al. (1999) reported that up to 105 percent of observed fecal N loss may be the result of metabolic fecal N. This large excretion of fecal N in studies utilizing low-quality forage fed to ruminants led Ferrell et al. (1999) to the conclusion that caution should be used when interpreting apparent total tract N digestibility.

In the current study, daily N excretion behaved differently than previously reported (Coleman and Wyatt, 1982; Bohnert et al., 2002). Coleman and Wyatt (1982) reported that steers consuming low-quality forage and supplemented with cottonseed meal every d, every 2 d, or every 3 d had no difference in daily fecal N excretion compared with a control. In contrast, Bohnert et al. (2002) supplemented CP daily, once every 3 d, or once every 6 d to lambs consuming low-quality forage and reported an increase in daily fecal N excretion. Similar results were reported by Wickersham et al. (2008a) where steers fed low-quality forage had an increase in both fecal and urinary N excretion as the amount of daily supplemented DIP increased. In the current study, we observed a 2 percent decrease in daily fecal N excretion for supplemented lambs compared to the CON, and a linear decrease as SF decreased. However, urinary N excretion in our study behaved in a similar fashion to Coleman and Wyatt (1982) and Bohnert et al. (2002), increasing with CP supplementation with no affect because of SF. Schmidt-Nielson and Osaki (1958) reported that, when fed a 3 percent digestible CP diet, ewes had a decrease in urea N excreted by the kidney compared to ewes fed a 7.5 percent digestible CP diet. In our trial, the lambs on the 5D and 10D treatments were fed a N deficient diet for 4 d or 9 d, respectively. The results observed in the current trial were similar to those of Schmidt-Nielson et al. (1957) when a N-deficient diet was fed to camels and a reduction in urea-N excretion was observed compared with a N sufficient diet. Daily urinary N excretion was similar across all supplementation frequencies, which would indicate that lambs have the ability to regulate renal N excretion.

In the current trial daily N balance was improved (less negative) with CP supplementation compared to the CON lambs; however, as SF became less frequent N balance decreased numerically, though not significantly. Bohnert et al. (2002) reported similar results. This is partly explained by the reduction in N retained as supplementation frequency decreased. However, both N balance and N retained of the lambs supplemented less frequently were greater than that of the lambs that received CP supplemented daily. In contrast, Wickersham et al. (2008b) observed a tendency for increased N retained in steers fed low-quality forage as supplementation frequency of DIP decreased. This suggests that N efficiency was similar between lambs across the SF treatments. The results of the current trial and Bohnert et al. (2002) imply that lambs fed low-quality forage (5 percent CP) can conserve N efficiently when CP SF is as infrequent as 10 d.

Bohnert et al. (2002) reported that lambs supplemented CP as infrequently as once every 6 d had similar digested N retained to daily supplementation, even though in their trial N balance was decreasing as SF decreased. In our trial, the negative values for N balance and daily digested N retained indicate that the lambs were losing weight (data not shown); however, the values for 5D and 10D supplemented treatments were similar in magnitude to D, and in all cases were less negative than CON. These results suggest that ruminants consuming low-quality forage are capable of efficiently conserving N when supplemented with CP as infrequently as once every 10 d. Daily plasma urea N concentrations shown in Figure 1 support this conclusion. For the 10D supplemented-treatment, plasma-urea-N appeared to maintain a peak concentration for 2 d, whereas the peak for 5D was restrained to a single day. Maintenance of the plasma-urea-N peak for an additional day indicates that N may have been recycled longer for lambs with SF of 10D than for lambs with SF of 5D, resulting in similar N balance for the two treatments. Bimodal peaks were observed in the 5D treatment following supplementation by experimental design. The peaks of plasma-Urea-N concentrations in the current trial were similar to those observed in Huston et al. (1999), Krehbiel et al. (1998), and Bohnert et al. (2002). Wickersham et al. (2008b) also noted an increase in plasma-urea-N concentrations of steers on the day of supplementation when DIP was supplemented every third day, whereas plasma-urea-N concentrations remained steady when steers were supplemented daily. Similarly, Wickersham et al. (2008a) noted an increase in plasma-urea-N concentrations in steers as the amount of daily supplemented DIP in the diet increased linearly.

Low-protein diets and(or) restricted feeding can alter gastrointestinal tract permeability to urea and renal urea excretion regulation (Harmeyer and Martens, 1980 and Kennedy and Milligan, 1980). Harmeyer and Martens (1980) concluded that three factors influence urea excretion via the kidneys: 1) changes in plasma urea concentrations correspond to changes in filtered urea loads, 2) glomerular filtration rate changes, and 3) tubular resorption of urea changes. Urea-N removal via the portal drained viscera increased when supplementation frequency increased to every 3 d compared with every day supplementation (Krehbiel et al., 1998). Wickersham et al. (2008a) reported that as the amount of DIP increased in the supplement, urea production, gut entry, return to the ornithine cycle, fecal excretion, and anabolic use increased. This suggests that as DIP increased in the diet, steers were more efficient in N recycling. Although not significant, as DIP was supplemented at 183 mg of N/kg of BW every third day to steers, urea production, urea-gut entry, urea returned to the ornithine cycle, and anabolic use of urea decreased compared with daily supplementation of 61 mg of N/kg of BW (Wickersham et al., 2008b). However, when steers were supplemented with 549 mg of N/kg of BW every third day, increased urea production, gut entry, urea returned to the ornithine cycle, and anabolic use were observed compared with steers supplemented with 183 mg of N / kg of BW (Wickersham et al., 2008b). The results from Wickersham et al. (2008a, 2008b) would suggest that the lambs in the current trial were able to more efficiently conserve and recycle urea-N as supplementation frequency decreased.

Urea transporters are tightly regulated by dietary components, such as concentrates and silage (Simmons et al., 2009). Simmons et al. (2009) observed an increase in urea transporter, bUT-B, in all epithelial layers of the rumen in a concentrate-based diet compared with a silage-based diet. The urea transporter in the silage-based diet was mainly localized to the stratum basale layer (Simmons et al., 2009). Ludden et al. (2009) observed two distinct urea transporters in the gastrointestinal tract and related tissues of lambs fed low-quality forage and supplemented with both RDP and RUP. Urea-transporter-B expression was observed in the liver, which is significant because in mammals, the liver is the site of ureagenesis (Ludden et al., 2009). This would indicate that UT-B may be a major factor in transporting urea out of the liver in the N recycling process (Ludden et al., 2009). Ludden et al. (2009) reported there were no differences in UT-B expression due to RUP supplementation. However, in the same trial, N-glycosylated UT-B expression was increased in the ventral rumen of the lambs fed RDP daily. Ludden et al. (2009) suggests that N-glycosylated UT-B expression in the ventral rumen was increased due to the daily supplementation of RDP and may play a major role in urea excretion and not urea recycling. The increased daily urinary N excretion and plasma-urea-N concentrations of the CP-supplemented lambs would suggest that a urea transporter is playing a vital role in urea excretion. However, the increased daily N balance of the CP-supplemented lambs would suggest that urea transporters would play a vital role in urea recycling, especially in the 5D and 10D lambs.

Ewe Performance Study

Post-lambing (within 14-d post-lambing) weight change and pre-lambing (within 14-d pre-lambing) and post-lambing weight and BCS changes were not affected ($P > 0.90$) by CP SF (Table 3). However, as SF decreased pre-lambing-weight change trended towards

Table 3. Effect of supplementation frequency on ewe performance and lamb birth weight.

	Supplementation frequency[a]				P-value[c]
Item	D	5D	10D	SEM[b]	Linear SF
Supplement DMI, g/d[d]	145	145	145		
Initial weight, kg	75	75	75	0.4	
Initial body condition score	3.0	3.3	3.0	0.1	
Weight change, kg					
Prelambing[e]	1.7	1.5	5.6	1.3	0.06
Postlambing[f]	-3.2	-1.7	-3.3	1.4	0.96
Body condition score change					
Prelambing[e]	-0.1	-0.1	-0.1	0.1	0.95
Postlambing[f]	-0.2	-0.3	-0.2	0.2	0.90
Lamb birth date, Gregorian d	265	267	264	2	0.85
Lamb birth weight, kg	5	5	5	0.2	0.21

[a] D = soybean meal every day; 5D = soybean meal every 5th day; 10D = soybean meal every 10th day.
[b] n = 4 pens / treatment.
[c] Linear SF = linear effect of supplementation frequency.
[d] D received 145 g daily; 5D received 725 g once every 5 d; 10D received 1,450 g once every 10 d.
[e] Within 14 d prior of lambing.
[f] Within 14 d following lambing.

increasing linearly ($P = 0.06$). Crude protein SF had no affect ($P > 0.21$) on lambing date or average lamb birth weight (Table 3).

Results for the performance study support results derived from the digestion study, indicating that CP SF can be decreased to once every 10 d for ruminants consuming low-quality forages. Our performance results are similar to results for once every 6 d or 7 d CP supplementation observed by Bohnert et al. (2002) and Huston et al. (1999), respectively. However, Farmer et al. (2004a) observed an increase in BW loss when cows were supplemented with increasing amounts of urea (0 percent to 45 percent) 3 d/wk compared with beef cows supplemented with urea daily at increasing levels. Similar results were reported that when cows were supplemented daily with CP, BW loss was reduced compared with cows that were supplemented only 2 d/wk (Farmer et al., 2001). The results of the current trial are the first data, that we are aware of, suggesting that CP SF can be decreased to once every 10 d for ruminants consuming low-quality forage.

Conclusions

No negative effects on N balance, BW and BCS, lambing date, and birth weight were observed for once every 10-d supplementation of CP when compared to daily and once every 5-d supplementation. Sheep producers in the northern Great Plains may consider crude-protein supplementation with soybean meal once every 10 d as a management alternative for reducing dormant-season supplementation costs to ewes in the last trimester of pregnancy.

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