

# Nitrogen Retention by Lambs Fed Oscillating Dietary Protein Concentrations<sup>1,2,3</sup>

N. Andy Cole

Conservation and Production Research Laboratory, ARS, USDA, Bushland, TX 79012

**ABSTRACT:** Nitrogen excreted by beef cattle can be retained in manure or lost by volatilization to the atmosphere or by runoff and percolation into surface or ground water. Increasing the retention of dietary N should decrease environmental losses. To this end, the effects of oscillating concentrations of dietary CP on nutrient retention were determined using lambs fed a 90% concentrate diet. Ten St. Croix lambs (average BW = 27 kg) were used in two 5 × 5 Latin square experiments. Dietary treatments were as follows: 1) 10% CP, 2) 12.5% CP, 3) 15% CP, 4) 10% and 15% CP diets oscillated at 24-h intervals, and 5) 10% and 15% CP diets oscillated at 48-h intervals. Supplemental N was provided by cottonseed meal in Trial 1 and by a 50:50 (N basis) blend of cottonseed meal and urea in Trial 2. Each period of the Latin square lasted 35 d, with excreta collection the final 8 d. Nitrogen retention increased linearly ( $P < .01$ ) with increasing

N intake in both trials (.77, 1.33, and 1.89 g/d for 10, 12.5, and 15% CP, respectively, in Trial 1; .94, 1.78, and 2.19 g/d for 10, 12.5, and 15% CP, respectively, in Trial 2). Compared with continuously feeding the 12.5% CP diet, oscillating the 10 and 15% CP diets on a 24-h basis did not affect N retention ( $P > .10$ ) in either trial (1.62 and 1.56 g/d for Trials 1 and 2, respectively). Oscillating dietary CP at 48-h intervals did not affect N retention in Trial 2 (1.82 g/d) but increased ( $P < .05$ ) N retention by 38% in Trial 1 (1.87 g/d). Phosphorus, K, and Na retention and excretion were not affected by dietary treatments in Trial 1. In Trial 2, P retention increased (linear,  $P < .05$ ) with increasing dietary CP and was greater ( $P < .05$ ) in lambs on the 48-h oscillation treatment than in lambs fed the 12.5% CP diet. These results suggest that oscillating the dietary CP concentrations might potentially increase the utilization of N by ruminants fed high-concentrate diets.

Key Words: Ruminants, Protein, Excretion, Environment

©1999 American Society of Animal Science. All rights reserved.

J. Anim. Sci. 1999. 77:215–222

## Introduction

Feeding livestock in confinement concentrates feed nutrients such as N into a relatively small area. Sixty to 100% of the N fed to ruminants is excreted in the feces and urine (Bierman, 1995). Fifty to 90% of the

excreted N can be volatilized to the atmosphere or lost by percolation and runoff (Stewart, 1970; Bierman, 1995), which results in manure with a lower fertilizer value because of a low (1:1) N:P ratio compared with fresh (5:1) manure. Increasing dietary N and P retention could improve animal performance, decrease N lost to the environment, and increase the fertilizer value of manure collected from confined feeding operations.

Providing cattle fed a low-quality roughage diet with a protein supplement every 48 h, rather than every 24 h, does not adversely affect animal performance (Collins and Pritchard, 1992; Brown et al., 1995) possibly because of changes in N recycling or in the pattern of absorption of nitrogenous compounds (Krehbiel et al., 1996). The effects of intermittent CP supplementation of ruminants fed high-concentrate diets for maximum performance has not been studied. Two trials were conducted with lambs to evaluate the effects of oscillating the CP content of high-concentrate diets on N, P, K, and Na retention.

<sup>1</sup>Contribution from USDA-ARS, Conservation and Production Research Laboratory, P.O. Drawer 10, Bushland TX 79012, in cooperation with the Texas Agric. Exp. Sta., Texas A&M Univ., College Station 77843. Phone: 806/356-5748; fax: 806/356-5750; E-mail: nacole@ag.gov.

<sup>2</sup>The mention of trade or manufacturer names is made for information only and does not imply an endorsement, recommendation, or exclusion by USDA-Agricultural Research Service.

<sup>3</sup>Appreciation is extended to Jeanette Herring for laboratory analysis, to Jonny Simmons for animal care, to Carole Perryman for typing the manuscript, and to Top Popham for statistical assistance.

Received March 20, 1998.

Accepted August 28, 1998.

## Materials and Methods

The experimental protocol was approved by the Laboratory Animal Care Committee, and animals were treated as prescribed in the *Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching* (Consortium, 1988).

Ten St. Croix lambs (average age 4 mo) were used in two 5 × 5 Latin square design experiments (average BW 25 ± 2 kg in Trial 1, and 29 ± 4 kg in Trial 2). In both trials, lambs were fed 90% concentrate diets formulated to meet or exceed NRC (1985) requirements for energy, vitamins, and minerals (Table 1). Dietary treatments consisted of the following: 1) continuous feeding of a 10% CP diet, 2) continuous feeding of a 12.5% CP diet, 3) continuous feeding of a 15% CP diet, 4) oscillating feeding of 10 and 15% CP diets every 24 h, and 5) oscillating feeding of 10 and 15% CP diets every 48 h. In Trial 1, supplemental protein was provided by cottonseed meal, whereas, in Trial 2, supplemental protein was provided by a 50:50 (N basis) blend of cottonseed meal and urea. In both trials, the 10% CP diet was calculated to provide sufficient CP for maintenance, and the 12.5% CP diet was formulated to provide sufficient CP for an ADG of approximately 50 g.

In both trials, periods of the Latin squares were 35 d in duration. During the 1st 20 d of each period, lambs were housed in individual pens with slotted floors (4 × 1 m) and limit-fed (1.6% of BW) their

experimental diets. Based on preliminary studies, this level of intake eliminated feed refusals during the trials. During the final 15 d, lambs were housed in stainless steel digestion stalls (102 × 64 cm) and fed their experimental diets (1.6% of BW). This final 15 d included a 7-d period for adjustment to the digestion stalls, after which total feces and urine excreted were collected daily for 8 d. Excreted feces and urine were weighed daily, and a subsample was stored at 3°C until subsamples were composited by animal at the end of each period. Urine was collected in buckets that contained 100 mL of 20% (vol/vol) HCl. Feed samples were collected daily during the collection period and composited at the end of each period. Composited feed, urine, and feces samples were stored at -20°C. Ambient temperature in the indoor facility was maintained at 17 to 20°C, with the relative humidity between 40 and 60%. Lambs were weighed on the days they were moved into and out of digestion stalls, and feed intakes for the subsequent period were adjusted to maintain DMI at a constant 1.6% of BW.

Blood samples were obtained via jugular venipuncture twice during each period of the Latin square on the day that lambs entered and exited the digestion stalls. The feeding and blood sampling times were staggered so that lambs fed oscillating dietary CP concentrations were sampled once on a day after being fed the 10% CP diet and once on a day after being fed the 15% CP diet. Before the morning feeding, blood samples (10 mL) were collected into tubes that

Table 1. Composition of experimental diets in Trials 1 and 2 (DM basis)

Ingredient	Trial 1			Trial 2	
	10% <sup>a</sup>	12.5%	15%	12.5%	15%
Dry rolled corn, %	78.6	71.8	65.1	75.0	71.3
Alfalfa pellets, %	5.0	5.0	5.0	5.0	5.0
Cottonseed hulls, %	5.0	5.0	5.0	5.0	5.0
Cottonseed meal, %	—	7.0	14.0	3.3	6.6
Fat, % <sup>b</sup>	3.0	3.0	3.0	3.0	3.0
Molasses, %	5.0	5.0	5.0	5.0	5.0
Urea, %	—	—	—	.5	1.0
Ammonium sulfate, %	.75	.75	.75	.75	.75
Supplement, % <sup>c</sup>	2.65	2.45	2.15	2.45	2.35
Chemical composition <sup>d</sup>					
CP, %	9.9	12.2	15.1	13.1	16.1
NE <sub>m</sub> , Mcal/kg	2.08	2.06	2.04	2.06	2.04
NE <sub>g</sub> , Mcal/kg	1.42	1.40	1.38	1.40	1.38
NDF, %	12.3	13.4	14.5	12.8	13.3

<sup>a</sup>Percentage of CP (DM basis). The same 10% CP diet was fed in both trials.

<sup>b</sup>A blend of 50% tallow and 50% vegetable oil.

<sup>c</sup>Supplements for each diet contained sodium chloride, ground limestone, dicalcium phosphate, cobalt chloride, copper sulfate, iron sulfate, magnesium oxide, manganese sulfate, potassium chloride, potassium iodide, sodium selenite, zinc sulfate, vitamin E, vitamin A, vitamin D, and monensin sodium (Rumensin, Eli Lilly Co., Greenfield, IN). Supplements were formulated to obtain total diet compositions as follows: Ca, .62%; Mg, .23%; P, .42% in Trial 1 and .35% in Trial 2; K, .84%; Na, .23%; Co, .17 mg/kg; Cu, 10.9 mg/kg; I, .56 mg/kg; Fe, 90 mg/kg; Mn, 55 mg/kg; Se, .2 mg/kg; Zn, 70 mg/kg; vitamin A, 5,000 IU/kg; vitamin D, 500 IU/kg; vitamin E, 75 IU/kg; and monensin, 25 mg/kg.

<sup>d</sup>Crude protein and NDF values were analyzed. The NE<sub>m</sub> and NE<sub>g</sub> values are calculated from NRC (1985).

contained Li heparin and were immediately placed on ice. Plasma was harvested by centrifugation at 2,500 × g for 30 min at 10°C and stored at -10°C.

Feed and feces were dried to a constant weight at 60°C in a forced-air oven and ground to pass a 1-mm screen in a Wiley mill. After wet digestion, feed, feces, and urine were analyzed for N and P by automated procedures (Technicon, 1977) and for Na and K by atomic absorption spectroscopy using an air-plus-acetylene flame. Blood was analyzed for plasma urea (PUN) and urine was analyzed for urea N and ammonia N by spectrophotometric methods using a commercial enzymatic kit (Sigma Kit no. 640, Sigma Chemical Co., St. Louis, MO).

Nutrient digestion and retention data in each trial were analyzed by ANOVA as a 5 × 5 Latin square design using the PROC GLM procedures of SAS (1988). Treatment effects were compared using the following preplanned contrasts: 1) linear effect of 10, 12.5, and 15% CP, 2) 24-h oscillating CP vs 12.5% CP, 3) 48-h oscillating CP vs 12.5% CP, and 4) 24-h oscillating CP vs 48-h oscillating CP. The initial statistical analysis indicated a number of variable results in N and P retention between trials. Therefore, in order to facilitate discussion of the between-trial differences, the data for both trials were subsequently combined and analyzed by ANOVA as a split-plot design. Trials were analyzed as the main plot with trial effects and trial × treatment interactions tested using period(square) as the error term.

## Results and Discussion

Water intakes and volumes of urine excreted were not affected ( $P > .15$ ) by treatments in Trials 1 or 2 (Table 2). In both trials, apparent DM digestibility tended (linear effect:  $P < .09$ ) to decrease and DM

excreted tended (linear effect:  $P < .09$ ) to increase with increasing dietary CP; however, DM digestibility was not affected ( $P > .10$ ) by oscillating dietary CP concentrations. These findings agree with those of Brown et al. (1995), who reported that feeding a N supplement at 1-, 2-, or 3-d intervals did not affect the DM digestibility of a straw diet by lambs, and the findings agree with those of Collins and Pritchard (1992), who noted that feeding protein supplements at 24- or 48-h intervals did not affect the digestibility of corn stalks by lambs.

Nitrogen intake ( $P < .01$ ), fecal N excretion ( $P < .05$ ), urinary N excretion ( $P < .01$ ), N absorbed ( $P < .01$ ), and N retention ( $P < .01$ ) increased as dietary CP concentration increased in Trials 1 (Table 3) and 2 (Table 4). Compared with continuous feeding of the 12.5% CP diet, oscillating dietary CP concentration at 24-h intervals did not affect ( $P > .10$ ) apparent N digestion, N retention, or urinary N excretion in either trial. Similarly, oscillating dietary CP concentrations at 48-h intervals did not affect ( $P > .10$ ) apparent N digestion, or urinary N excretion compared with lambs continuously fed the 12.5% CP diet in either trial. However, in Trial 1, oscillating dietary CP concentration at 48-h intervals increased ( $P < .05$ ) N retention by 38% compared with continuously feeding the 12.5% CP diet (Table 3). This finding was primarily the result of a nonsignificant decrease in urinary N excretion with 48-h oscillating CP concentrations. Thus, N retention, as a percentage of N apparently absorbed, was increased ( $P < .05$ ) in lambs fed oscillating CP concentrations at 48-h intervals compared with lambs continuously fed the 12.5% CP diet, suggesting that the increase in N retention was the result of improved utilization of absorbed N. In contrast to Trial 1, oscillating dietary CP concentration at 48-h intervals did not affect ( $P > .10$ ) N metabolism in Trial 2 compared with continuously feeding the 12.5% CP diet.

Table 2. Mean daily dry matter intake and digestion in Trials 1 and 2

Item	Treatment					SEM
	10% <sup>a</sup>	12.5%	15%	A1	A2	
	Trial 1					
DM intake, g/d	395.6	401.4	398.3	396.7	396.9	1.51
Water intake, L/d	2.98	4.13	3.56	3.23	3.46	.28
Urine excreted, L/d	2.20	3.39	2.67	2.31	2.67	.25
DM digestibility, % <sup>b</sup>	86.2	85.6	84.8	85.6	85.0	.23
DM excreted, g/d <sup>b</sup>	54.7	57.7	60.7	57.2	59.3	.91
	Trial 2					
DM intake, g/d	457.5	458.1	464.6	466.4	464.6	7.38
Water intake, L/d	3.78	3.51	3.71	3.09	3.42	.30
Urine excreted, L/d	2.84	2.64	2.85	2.27	2.74	.28
DM digestibility, % <sup>b</sup>	85.5	85.6	83.9	84.1	85.0	.30
DM excreted, g/d <sup>b</sup>	66.6	65.7	75.0	74.2	69.8	2.01

<sup>a</sup>Diets contained 10, 12.5, or 15% CP. A1 = 10 and 15% CP diets oscillated at 24-h intervals, A2 = 10 and 15% diets oscillated at 48-h intervals. SEM = standard error of the mean. n = five lambs/treatment.

<sup>b</sup>Linear effect of dietary CP concentration ( $P < .09$ ).

Table 3. Mean daily N metabolism of lambs in Trial 1

Item <sup>a</sup>	Treatment					SEM
	10% <sup>b</sup>	12.5%	15%	A1	A2	
Intake, g/d <sup>c</sup>	6.25	7.83	9.64	7.93	7.94	.22
Fecal, g/d <sup>d</sup>	1.85	2.02	2.19	1.93	2.02	.05
Urine, g/d <sup>c</sup>	3.63	4.48	5.55	4.38	4.05	.17
Urine, % N excreted <sup>d</sup>	66.0	68.5	71.6	69.1	66.8	.90
Absorbed, g/d <sup>c</sup>	4.40	5.81	7.44	6.00	5.92	.20
Retention, g/d <sup>c,e</sup>	.77	1.33	1.89	1.62	1.87	.15
Digested, % <sup>c</sup>	70.4	74.2	77.2	75.6	74.6	.74
Retention, % intake <sup>de</sup>	12.1	16.9	19.6	20.3	23.6	1.75
Retention, % absorbed <sup>de</sup>	17.2	22.6	25.3	27.0	31.5	2.31
UUN, % total urine N	83.7	89.6	83.3	86.3	89.0	4.30
UUN, mg/100 mL <sup>d</sup>	146.0	130.8	217.4	187.0	149.8	15.07
NH <sub>3</sub> N, % total urine N	4.7	2.2	1.2	3.8	1.3	.97
NH <sub>3</sub> N, mg/100 mL	11.4	3.6	1.8	15.0	2.0	3.31
PUN, mg/100 mL <sup>c</sup>	11.2	12.5	15.8	11.8	12.3	.57

<sup>a</sup>UUN = Urinary urea N; NH<sub>3</sub> N = Urinary ammonia N; PUN = Plasma urea N.

<sup>b</sup>Diets contained 10, 12.5, or 15% CP. A1 = 10 and 15% CP diets oscillated at 24-h intervals, A2 = 10 and 15% diets oscillated at 48-h intervals. SEM = standard error of the mean. n = five lambs/treatment.

<sup>c</sup>Linear effect of dietary CP concentration ( $P < .01$ ).

<sup>d</sup>Linear effect of dietary CP concentration ( $P < .05$ ).

<sup>e</sup>Treatment 12.5% different from treatment A2 ( $P < .05$ ).

The discrepancy between Trials 1 and 2, in effects of the 48-h oscillating dietary CP regimen on N retention, could be the result of several factors. Compared with Trial 1, lambs in Trial 2 were heavier and had higher ( $P < .01$ ) CP intakes (Tables 3 and 4). In Trial 1, the average increase in N retention when dietary CP concentration increased from 12.5 to 15% was 31% of additional N intake, whereas, in Trial 2, the mean increase was only 18% of additional N intake. Thus, the N intake of lambs fed the 12.5% CP

diet in Trial 1 may have been deficient or marginal, whereas the N intake of lambs fed the 12.5% CP (actual CP = 13.1%) in Trial 2 may have been adequate. Differences in the ruminal degradability of dietary CP between the trials may also have been involved. The calculated (NRC, 1996) quantity of microbial CP synthesized on each of the experimental diets was similar within each trial, but was greater ( $P < .05$ ) in Trial 2 than in Trial 1 (mean  $30.9 \pm .2$  vs  $26.7 \pm .1$  g/d, respectively). Assuming that bacterial

Table 4. Mean daily N metabolism of lambs in Trial 2

Item <sup>a</sup>	Treatment					SEM
	10% <sup>b</sup>	12.5%	15%	A1	A2	
Intake, g/d <sup>c</sup>	7.23	9.60	11.99	9.70	9.66	.35
Fecal, g/d <sup>c</sup>	1.93	2.09	2.30	2.25	2.18	.06
Urine, g/d <sup>c</sup>	4.36	5.75	7.50	5.88	5.67	.25
Urine, % N excreted <sup>c</sup>	69.5	73.3	76.5	72.2	72.3	.68
Absorbed, g/d <sup>c</sup>	5.30	7.52	9.69	7.45	7.49	.31
Retention, g/d <sup>c</sup>	.94	1.77	2.19	1.57	1.82	.12
Digested, % <sup>c</sup>	73.5	78.1	80.8	76.8	77.6	.64
Retention, % intake	13.1	18.4	18.4	16.2	18.9	1.04
Retention, % absorbed	17.8	23.6	22.8	21.0	24.3	1.29
UUN, % total urine N	85.5	85.1	86.4	90.7	85.4	2.54
UUN, mg/100 mL <sup>d</sup>	189.8	215.4	337.8	317.8	219.4	30.8
NH <sub>3</sub> N, % total urine N	6.9	7.5	0	3.6	1.3	1.61
NH <sub>3</sub> N, mg/100 mL <sup>e</sup>	22.4	16.2	0	17.2	13.0	4.95
PUN, mg/100 mL <sup>c</sup>	12.0	12.9	15.9	13.9	14.3	.49

<sup>a</sup>UUN = Urinary urea N; NH<sub>3</sub> N = Urinary ammonia N; PUN = Plasma urea N.

<sup>b</sup>Diets contained 10, 12.5, or 15% CP. A1 = 10 and 15% CP diets oscillated at 24-h intervals, A2 = 10 and 15% diets oscillated at 48 h intervals. SEM = standard error of the mean. n = five lambs/treatment.

<sup>c</sup>Linear effect of dietary CP concentration ( $P < .01$ ).

<sup>d</sup>Linear effect of dietary CP concentration ( $P < .05$ ).

<sup>e</sup>Linear effect of dietary CP concentration ( $P < .07$ ).

CP synthesis is equivalent to the degraded intake protein (**DIP**) requirement (NRC, 1996), the calculated intake of DIP was marginal (27.5 g/d) for lambs fed the 12.5% CP diet in Trial 1 but was well above requirements (36.9 g/d) for lambs fed the 12.5% CP diet in Trial 2.

Variable effects on N metabolism have also been reported with intermittent CP supplementation of ruminants fed high-forage diets. Brown et al. (1995) did not detect a significant effect of supplementation frequency (1-, 2-, or 3-d intervals) on N metabolism by lambs fed a straw diet, although they noted a trend toward an increased ( $P < .10$ ) apparent N digestion when supplements were provided at 48-h intervals. Similarly, Krehbiel et al. (1996) did not detect an effect of the frequency of protein supplementation (0, 1-, or 3-d intervals) on net absorption of N by ewes fed low-quality hay, although they suggested there were possible differences in the pattern of absorption of nitrogenous compounds. However, in agreement with our results, Collins and Pritchard (1992) reported that providing CP supplements at 48-h, rather than at 24-h, intervals increased N retention of lambs by two- to fourfold. In ruminants fed an oscillating or intermittent CP regimen, a greater N retention or increased utilization of absorbed N could be the result of several mechanisms, including increased N recycling, improved quality of protein entering the small intestine, increased metabolic use of absorbed amino acids, or by combinations of these and other factors.

Ruminants have the ability to conserve N by passive transfer of PUN from the circulation to the rumen and/or large intestine, where it can be used for synthesis of microbial protein (Egan et al., 1986). Krehbiel et al. (1996) did not note a difference in N recycling by ewes fed low-quality roughage diets and provided protein supplements at 0-, 1-, or 3-d intervals. However, one factor that controls the entry of urea into the rumen and large intestine is the rate of fermentation (Egan et al., 1986). Compared with ruminants fed low-energy diets, in ruminants fed high-concentrate diets, ruminal fermentation is more rapid, and appreciable quantities of starch may be fermented in the large intestine (Owens, et al., 1986; Theurer, 1986). Thus, as a result of greater ruminal and large intestinal fermentation, it could be expected that ruminants fed a high-concentrate diet have a greater potential to recycle N than ruminants fed high-roughage diets (Sarraseca et al., 1997).

The quantity of N transferred to the rumen and large intestine is also indirectly affected by the concentration and degradability of dietary CP. Nitrogen diffusion into the rumen and large intestine is positively related to PUN concentrations and negatively related to ammonia concentrations within the lumen of the gut (Egan et al., 1986). By oscillating dietary CP concentrations and/or degradability, it might be possible to increase N transfer from one

segment of the gut to another. If a N deficiency occurred within the rumen in concert with a N excess in the large intestine, a greater quantity of N could be absorbed from the large intestine and subsequently diffuse into the rumen. Similarly, if a N excess occurred within the rumen in combination with a N deficit within the large intestine, a greater quantity of PUN could diffuse into the large intestine, be converted to microbial protein, and be excreted in the feces, rather than in the urine (Ulyatt et al., 1975; Norton et al., 1982). In the present study and the study of Collins and Pritchard (1992), the increased N retention by lambs on oscillating CP supplementation regimens was the result of decreased urinary N excretion, and, in both studies, the response to oscillating CP was greater when the diet was higher in undegraded intake protein (**UIP**). However, oscillating dietary CP concentrations could also have adverse effects on N metabolism. If the ruminal degradability and/or concentration of CP in the low-CP diet was too low, ruminal fermentation could be affected adversely. Similarly, if the ruminal degradability and/or concentrations of CP in the high-CP diet were too high, excessive ammonia produced within the gut could be absorbed and irreversibly lost via the urine.

For an oscillating dietary CP regimen to increase N recycling and/or alter the route of N excretion, the timing of the dietary CP changes and the mean retention time of digesta in the gut would need to be synchronized. The 48-h oscillating CP regimen may have been in approximate synchrony with the anticipated retention time of digesta in this study (Lindberg, 1985). Because feed intake and dietary roughage content have appreciable effects on the rate of digesta passage, the appropriate timing of oscillating CP concentrations may vary with feed intake and diet composition.

Oscillating dietary CP content also might affect whole-body protein metabolism; however, the response(s) would have to be rapid and relatively short-lived. Liu et al. (1995) noted that, when lambs were switched from an adequate CP intake to a deficient CP intake, total-body protein flux, protein synthesis, and protein degradation all decreased immediately. Urinary N excretion decreased by 20% on d 1 of reduced CP intake and by 29% after d 2. Similarly, Collins and Pritchard (1992) noted a 30% decrease in urinary N excretion within 24 h of changing dietary CP concentrations. Thus, the modifications in protein metabolism associated with changes in dietary protein intake seem to be sufficiently rapid to permit an oscillating dietary CP regimen to affect whole-body protein metabolism.

As a proportion of total urinary N excreted, urea N and ammonia N excretion were not significantly affected by dietary CP concentrations in either trial (Tables 3 and 4); however, the concentration of urea N in the urine increased ( $P < .05$ ), and the

Table 5. Mean daily P and K metabolism of lambs in Trial 1

Item	Treatment					SEM
	10% <sup>a</sup>	12.5%	15%	A1	A2	
	Phosphorus					
Intake, g/d	1.38	1.40	1.39	1.39	1.39	.01
Absorbed, %	28.8	56.0	43.6	38.9	53.0	4.25
Retention, g/d	.36	.72	.56	.49	.68	.05
Retention, % intake	26.0	51.4	40.2	35.4	49.5	3.88
Retention, % absorbed <sup>b</sup>	92.5	94.2	96.0	97.1	95.5	.72
	Potassium					
Intake, g/d	3.80	3.85	3.82	3.81	3.81	.04
Absorbed, %	96.4	97.3	97.1	96.6	97.1	.23
Retention, g/d	.70	.88	.60	.73	.84	.05
Retention, % intake	18.4	22.8	15.8	19.1	22.1	1.34
Retention, % absorbed	19.0	23.5	16.3	19.8	22.7	1.37

<sup>a</sup>Diets contained 10, 12.5, or 15% CP. A1 = 10 and 15% CP diets oscillated at 24-h intervals, A2 = 10 and 15% diets oscillated at 48-h intervals. SEM = standard error of the mean. n = five lambs/treatment.

<sup>b</sup>Linear effect of dietary CP concentration ( $P < .09$ ).

concentrations of ammonia N tended ( $P < .07$  in Trial 2;  $P < .13$  in Trial 1) to decrease with increasing dietary CP concentration. Oscillating dietary CP concentrations did not affect excretion of urea N or ammonia N in either trial. Urea N excretion, as a proportion of total urinary N excretion (mean 86.5%), was higher than values reported in cattle by Huntington et al. (1996) (10 to 55%) or in ewes by Giraldez et al. (1997) (8 to 80%), and ammonia N excretion tended to be less than values reported by Giraldez et al. (1997) (4 to 28%). The relatively low contribution of urinary ammonia N to total urinary N in the present study may be the result of the relatively low feed intakes of lambs in the present studies. In ewes fed diets containing 36 to 70% concentrate, Giraldez et

al. (1997) noted that urinary ammonia N excretion increased with increasing digestible organic matter intakes. This agreed with the findings of Scott (1975), who reported that, in ruminants fed high-concentrate diets, the ammonium ion becomes a primary carrier of  $H^+$  in the urine. These high-urinary ammonia loads may be important for renal and systemic buffering in ruminants fed high-concentrate diets (Galyean, 1996).

Overall mean PUN concentrations were similar for Trials 1 (Table 3) and 2 (Table 4). As would be expected (Pfander et al., 1975), PUN concentrations increased ( $P < .01$ ) with increasing dietary CP concentration in both trials. During each period of the Latin squares, two prefeeding blood samples were

Table 6. Mean daily P and K metabolism of lambs in Trial 2

Item	Treatment					SEM
	10% <sup>a</sup>	12.5%	15%	A1	A2	
	Phosphorus					
Intake, g/d	1.88	1.87	1.90	1.91	1.90	.03
Absorbed, %	42.6	49.1	47.8	44.3	53.8	3.92
Retention, g/d <sup>bcd</sup>	.28	.42	.54	.40	.60	.02
Retention, % intake <sup>bcd</sup>	15.2	22.9	28.2	21.5	31.2	1.82
Retention, % absorbed <sup>d</sup>	40.7	53.2	66.0	53.5	61.5	3.83
	Potassium					
Intake, g/d	4.39	4.40	4.46	4.47	4.46	.07
Absorbed, %	96.1	96.7	95.3	94.6	96.6	.34
Retention, g/d <sup>bd</sup>	.38	.62	.69	.42	.73	.05
Retention, % intake <sup>bd</sup>	9.0	14.1	15.6	9.6	16.4	1.05
Retention, % absorbed <sup>bd</sup>	9.4	14.5	16.4	10.1	17.0	1.08

<sup>a</sup>Diets contained 10, 12.5, or 15% CP. A1 = 10 and 15% CP diets oscillated at 24-h intervals, A2 = 10 and 15% diets oscillated at 48-h intervals. SEM = standard error of the mean. n = five lambs/treatment.

<sup>b</sup>Treatment A1 different from treatment A2 ( $P < .05$ ).

<sup>c</sup>Treatment 12.5% different from treatment A2 ( $P < .05$ ).

<sup>d</sup>Linear effect of dietary CP concentration ( $P < .05$ ).

obtained from each lamb. The mean PUN concentrations of lambs fed oscillating dietary CP concentrations were similar to those of lambs continuously fed the 12.5% CP diet in both trials. However, individual PUN values tended to vary. In Trial 1, on the day after feeding the 10% CP diet, the mean PUN concentrations of lambs fed the 24- and 48-h oscillating CP regimens were 9.45 and 9.30 mg/100 mL, respectively. These concentrations were less ( $P < .05$ ) than values for lambs continuously fed the 10% CP diet. The mean PUN concentrations on the day after feeding the 15% CP diet were similar to values for lambs continuously fed the 15% CP diet (14.2 and 15.3 mg/100 mL, respectively). In contrast, Trial 2 mean PUN concentrations on the day after feeding of the 10% CP diet were similar in lambs fed oscillating dietary CP concentrations (mean  $12.2 \pm .2$  mg/100 mL) and lambs continuously fed the 10% CP diet. These discrepancies in PUN values between the two trials may have been the result of differences in the ruminal degradability of the supplemental CP fed in each trial. In steers fed corn stalk diets and provided protein supplements at 48-h intervals, Collins and Pritchard (1992) noted that PUN concentrations were not affected by day of supplementation when supplemental CP was provided by corn gluten meal, a CP supplement with low ruminal degradability but were significantly affected when supplemental CP was provided by more degradable soybean meal.

In Trial 1, dietary treatments did not affect ( $P > .10$ ) metabolism of P, although, as a percentage of P intake, P retention tended ( $P < .09$ ) to increase with increasing dietary CP concentration (Table 5). In Trial 2, P retention increased ( $P < .05$ ) with increasing dietary CP concentration (Table 6). Compared with lambs continuously fed the 12.5% CP diet and lambs fed the 24-h oscillating CP regimen, lambs fed the 48-h oscillating CP regimen had greater ( $P < .05$ ) P retention in Trial 2. In both trials, the proportions of dietary P retained were within the range reported by Harmon and Britton (1983). The linear increases in P retention with increasing dietary CP concentration in Trials 2 ( $P < .05$ ) and 1 ( $P < .09$ ) tend to agree with previous findings (Cole, 1992). It is not clear why lambs on the 48-h oscillating CP regimen had greater ( $P < .05$ ) P retention than lambs continuously fed the 12.5% CP diet in Trial 2. It is unlikely that the effect was the result of differences in the source of the dietary P because apparent P absorption was similar on all diets, the response in P retention was not detected in lambs fed oscillating CP at 24-h intervals, and the response was not noted in Trial 1, despite the fact that the source of P also varied in that trial. Phosphorus retention as a percentage of P apparently absorbed was less ( $P < .05$ ), and P retention as a percentage of P intake tended ( $P < .13$ ) to be less in Trial 2 than in Trial 1, which was primarily the result of greater ( $P < .05$ )

urinary P excretion in Trial 2 than in Trial 1. These across-trial differences may be the result of the higher DM and(or) P intakes in Trial 2 (Scott, 1988).

In Trial 1, dietary treatments did not significantly affect K metabolism (Table 5), whereas, in Trial 2, K retention increased (linear effect;  $P < .03$ ) with increasing dietary CP concentration (Table 6). In Trial 2, lambs fed oscillating CP concentrations at 24-h intervals had lower ( $P < .05$ ) K retention than lambs fed oscillating CP concentrations at 48-h intervals. As with P, the reasons for the dietary effects on K retention in Trial 2 are not clear because daily K intakes and apparent K absorption were similar for all dietary regimens. Over 94% of dietary K was apparently absorbed on all diets in both trials, suggesting that differences in K retention were the result of differences in metabolism of the absorbed K.

Dietary treatments did not significantly affect Na metabolism in either trial (data not shown). In the present trials, only  $7.6\% \pm 2.9$  (Trial 1) and  $1.6\% \pm 3.9$  (Trial 2) of Na consumed was retained by the lambs.

## Implications

Results of these studies indicate that intermittent supplementation of crude protein in high-concentrate diets may improve nitrogen (N) and(or) phosphorus (P) utilization by ruminants. A system of oscillating supplementation could potentially decrease the amounts of N and(or) P required in the diet of feedlot lambs and cattle, decrease nutrient accumulation in the waste stream, and produce manure with a more desirable N:P ratio for fertilizer. The effects of such a feeding regimen on animal performance and health under practical feeding conditions and production levels of feed intake need to be studied.

## Literature Cited

- Bierman, S. 1995. Nutritional effects on waste management. M.S. thesis. Univ. of Nebraska, Lincoln.
- Brown, D. R., F. C. Hinds, and R. M. Collins. 1995. Effect of supplementation frequency on diet digestion and nitrogen metabolism of growing lambs fed low-quality forage. *Prof. Anim. Sci.* 12:24-27.
- Cole, N. A. 1992. Influence of postfast dietary crude protein and phosphorus content on nitrogen, phosphorus, calcium, and magnesium repletion in sheep. *J. Anim. Sci.* 70:2893-2900.
- Collins, R. M., and R. H. Pritchard. 1992. Alternate day supplementation of corn stalk diets with soybean meal or corn gluten meal fed to ruminants. *J. Anim. Sci.* 70:3899-3908.
- Consortium. 1988. Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching. Consortium for Developing a Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching, Champaign, IL.
- Egan, A. R., K. Boda, and J. Varady. 1986. Regulation of nitrogen metabolism and recycling. In: L. P. Milligan, W. L. Grovum, and A. Dobson (Ed.) *Control of Digestion and Metabolism in Ruminants*. pp 386-402. Prentice-Hall, Englewood Cliffs, NJ.

- Galyean, M. L. 1996. Protein levels in beef cattle finishing diets: Industry application, university research, and systems results. *J. Anim. Sci.* 74:2860-2870.
- Giraldez, F. J., C. Valdes, R. Pelaez, P. Frutos, and A. R. Mantecon. 1997. The influence of digestible organic matter and nitrogen intake on faecal and urinary nitrogen losses in sheep. *Livest. Prod. Sci.* 51:183-190.
- Harmon, D. L., and R. A. Britton. 1983. Balance and urinary excretion of calcium, magnesium and phosphorus in response to high concentrate feeding and lactate infusion in lambs. *J. Anim. Sci.* 57:1306-1315.
- Huntington, G. B., E. J. Zetina, J. M. Whitt, and W. Potts. 1996. Effects of dietary concentrate level on nutrient absorption, liver metabolism, and urea kinetics of beef steers fed isonitrogenous and isoenergetic diets. *J. Anim. Sci.* 74:908-916.
- Krehbiel, C. R., C. L. Ferrell, and H. C. Freetly. 1996. Frequency of protein supplementation on net portal and hepatic flux of nutrients in mature ewes consuming low quality forage. *J. Anim. Sci.* 74(Suppl. 1):265 (Abstr.).
- Lindberg, J. E. 1985. Retention time of chromium-labeled feed particles and of water in the gut of sheep given hay and concentrate at maintenance. *Br. J. Nutr.* 53:559-567.
- Liu, S. M., G. E. Lobley, N. A. MacLeod, D. J. Kyle, X. B. Chen, and E. R. Ørskov. 1995. Effects of long-term protein excess or deficiency on whole-body protein turnover in sheep nourished by intragastric infusion of nutrients. *Br. J. Nutr.* 73:829-839.
- Norton, B. W., J. B. Mackintosh, and D. G. Armstrong. 1982. Urea synthesis and degradation in sheep given pelleted-grass diets containing flaked barley. *Br. J. Nutr.* 48:249-264.
- NRC. 1985. *Nutrient Requirements of Sheep* (6th Ed.). National Academy Press, Washington, DC.
- NRC. 1996. *Nutrient Requirements of Beef Cattle* (7th Ed.). National Academy Press, Washington, DC.
- Owens, F. N., R. A. Zinn, and Y. K. Kim. 1986. Limits to starch digestion in the ruminant small intestine. *J. Anim. Sci.* 63:1634-1648.
- Pfander, W. H., S. E. Grebing, C. M. Price, O. Lewis, J. M. Asplund, and C. V. Ross. 1975. Use of plasma urea nitrogen to vary protein allowances of lambs. *J. Anim. Sci.* 41:647-653.
- Sarraseca, A., E. Milne, M. J. Metcalf, and G. E. Lobley. 1997. Urea recycling in sheep: Effects of intake. *Br. J. Nutr.* 79:79-88.
- SAS. 1988. *SAS/STAT® User's Guide* (Release 6.03). SAS Inst. Inc., Cary, NC.
- Scott, D. 1975. Changes in mineral, water and acid-base balance associated with feeding and diet. In: I. W. McDonald and A.C.I. Warner (Ed.) *Digestion and Metabolism in the Ruminant*. pp 203-215. Univ. of New England Publishing Unit, Armidale, N.S.W., Australia.
- Scott, D. 1988. Control of phosphorus balance in ruminants. In: A. Dobson and M. J. Dobson (Ed.) *Aspects of Digestive Physiology in Ruminants*. pp 156-174. Comstock Publishing Assoc., Ithaca, NY.
- Stewart, B. A. 1970. Volatilization and nitrification of nitrogen from urine under simulated cattle feedlot conditions. *Environ. Sci. Technol.* 4:579-582.
- Technicon. 1977. Individual/simultaneous determination of nitrogen and/or phosphorus in BD acid digests. Technicon Autoanalyzer II Industrial Method No. 329-74W/B. Technicon, Tarrytown, NY.
- Theurer, C. B. 1986. Grain processing effects on starch utilization by ruminants. *J. Anim. Sci.* 63:1649-1662.
- Ulyatt, M. J., D. W. Dellow, C.S.W. Reid, and T. Bauchop. 1975. Structure and function of the large intestine of ruminants. In: I. W. McDonald and A.C.I. Warner (Ed.) *Digestion and Metabolism in the Ruminant*. pp 119-133. Univ. of New England Publishing Unit, Armidale, N.S.W., Australia.