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A rapid change of ruminants from high-roughage diets, often used in background feeding programs, to high-concentrate diets used in the finishing phase tends to promote various digestive tract disorders. A major change made in diets over a period of 3 to 4 weeks generally allows time for the rumen microflora to become adapted to the new conditions and minimizes digestive problems. However, performance during this period is often unsatisfactory.

In the short-term feedlot finishing of ruminants for slaughter at light weights, the importance of profitable weight gains during the initial adaptation phase of the feeding period becomes relatively more important. Methods of accelerating adaptation to high-concentrate diets are being studied, and bentonite, a native montmorillonite clay, is one of the materials that has received attention as a potential feeding aid to be used for this purpose.

The beneficial as well as the potential detrimental effects of bentonite upon feedlot performance during an initial period and subsequent intervals of a lamb finishing period were studied in experiment 1. The effects of bentonite upon digestion and retention of various nutrients were studied in experiment 2. These studies are described herein.

Experimental Procedure

Experiment 1

Five treatments consisted of 0, 2, 4, 8 and 12% bentonite added to lamb diets. The basal diet consisted of ground corn, 74.5%; ground alfalfa hay, 20%; soybean meal (44% protein), 5%; trace mineral salt, 0.5% and vitamin A, 2200 IU per kg of diet. Each of the five treatment diets was fed to four pens of 12 lambs each (total of 48 lambs per treatment). The bentonite was a small particle size, dust-grade material used to produce a very dusty diet, this being postulated to be a condition contributing to the occurrence of siliceous urinary calculi in sheep and cattle grazing under dry range conditions.

All lambs, previously vaccinated for preventation of enterotoxemia, were brought to full feed in 12 days and maintained on full feed for the duration of the 110-day experiment. Weight gain and feed consumption data were calculated for each 28-day period. Blood samples were collected on days 54 and 106. Twenty-four hour urine collections were made from four lambs selected at random from each pen during the 57th to 64th days of the experiment. After a determination of urine pH, the urines were acidified and stored frozen for later analysis. Urine and serum samples

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were analyzed for calcium, magnesium and phosphorus. In addition, the urines were also analyzed for sodium, potassium and silica. At slaughter, urinary bladders and kidneys were retained from all animals and examined for evidence of urinary calculi.

Experiment 2

The five treatment diets used in experiment 1 were fed to an additional 45 wether lambs in a metabolism study. Total urine and fecal collections were made after 57 or more days. The lambs were allowed 3 days to adapt to close confinement in the metabolism cages prior to the 5-day collection of excreta. During the collection period they were fed a daily ration equal to 3% of body weight. Blood samples were obtained and serum was analyzed as described for experiment 1. In addition, urine and feces were analyzed for the minerals and other nutrients pertinent to the digestion trial, and digestion coefficients and/or retention data were calculated for them. The lambs were slaughtered after 139 days on the experimental diets. In addition to examining the urinary bladders and kidneys for evidence of urinary calculi, the rumen and lungs of each animal were examined for evidence of a detrimental effect attributable to the feeding of dust-grade bentonite.

Results and Discussion

Experiment 1

Average daily gain (ADG), average daily ration (ADR) and feed per gain ratio (F/G) to date for each weigh period are shown in table 1. The addition of bentonite to the diet had an initial positive effect on feedlot performance, but the advantage was not sustained throughout the feeding period. This was particularly evident in the ADG of the 4% and 8% bentonite treatment groups which were significantly higher ($P<.05$) than the ADG of the control group for the initial 28-day period. There were no significant differences in ADG among the treatment groups for the remainder of the feeding period. ADR values for lambs fed the higher levels of bentonite were consistently higher than those of the controls which, with exception of the first 28 days, were accompanied by an increase in the F/G.

Many control lambs appeared to experience digestive disorders during the first 28 days resulting in erratic eating patterns and a high F/G ratio for the initial period. Feed intake and performance data indicate that the feeding of bentonite was beneficial in this regard. However, limitation of this benefit is evidenced by the four lambs that died during the experimental period, two were from the control group and one each from the 2% and 4% bentonite treatments. Postmortem examinations indicated acidosis resulting from feed overload to be the cause of death (S.D.S.U. Veterinary Diagnostic Laboratory).

Blood serum data are shown in table 2. A trend toward lower serum magnesium and phosphorus levels in bentonite-fed lambs, significant ($P<.05$) for some treatment groups, in connection with the 54-day collection was not evident at 106 days. Although average serum magnesium values of all treatment groups were within a range considered to be normal at 54 days, a comparison of serum magnesium levels of lambs bled at both times showed significant increases in magnesium as the feeding period progressed to 106 days.

Based upon 24-hour urine collections (table 3), the 12% bentonite group had a significantly lower ($P<.05$) average daily urine output than the controls. Although highly variable, none of the bentonite treatments differed significantly from the controls with respect to urine pH or in urine concentrations of phosphorus, magnesium, calcium, sodium or potassium. The urine concentration of silica increased as the level of bentonite in the diet was increased, but the values were significantly higher ($P<.05$) only for the 4% and 12% bentonite groups. Previous efforts to increase urinary silica levels by feeding inorganic silica have generally been unsuccessful. A review of experimental procedures and a comparison of average daily urine output of lambs in experiments 1 and 2 indicate that those in experiment 1 were not accustomed to the metabolism cages in which the 24-hour urine collections were made. Further, they were accustomed to drinking from automatic waterers rather than the drinking cups used with the metabolism cages. Therefore, in consideration of these factors, it is concluded that the urine output of lambs in experiment 1 may not be indicative of their normal urine volumes.

Examination of the kidneys and urinary bladders of the 236 lambs slaughtered at termination of the experiment showed that only one lamb from the controls and one from the 8% bentonite group had developed renal calculi. Chemical characterization showed that the calculi were of the phosphatic type and were not siliceous. Factors contributing to phosphatic urinary calculi have been the subject of numerous previous reports from this station.

Experiment 2

Data from this balance study are presented in tables 4 (digestion coefficients) and 5 (excretion and retention data). A tendency toward slightly lower nitrogen digestibility of diets containing bentonite appears to be related to the greater bulk of these diets and the larger quantities of inert material moving through the digestive tract. This would be expected to increase the metabolic nitrogen fraction excreted in the feces. However, this is not unique to bentonite but could occur with the feeding of any source of nondigestible diet diluents.

Increases in crude fiber digestibility were associated with 2, 4 and 12% bentonite. Other effects on digestibility coefficients were either small as with NFE or highly variable as with ether extract (fat). Variations in urinary or fecal excretion of the minerals calcium, magnesium, phosphorus, sodium and potassium were small and generally related to variations in intake due to the amount of each contained in the bentonite.

Conclusions

It appears that bentonite may be used as a dietary ingredient to aid in the adaptation of ruminants to high-concentrate diets. Benefits may be derived from approximately 4% of bentonite without any apparent adverse effects. The optimum level for various types of diets, the forms of bentonite best suited for sheep and the extent that the results obtained with sheep are applicable to cattle are aspects that require further study.

Table 1. Average Daily Gain, Average Daily Ration and Feed/Gain to Date (Experiment 1)

	Bentonite treatments				
Weigh periods	0%	2%	4%	8%	12%
Period I[a]					
ADG, kg	0.094	0.110	0.183*	0.194*	0.140
ADR, kg	0.976	0.986	1.062*	1.088**	1.061*
F/G	10.38	8.96	5.79*	5.61*	7.56
Period II[b]					
ADG	0.191	0.180	0.224	0.207	0.184
ADR	1.153	1.140	1.313**	1.353**	1.346**
F/G	6.04	6.32	5.86	6.54	7.32*
Period III[c]					
ADG	0.189	0.180	0.209	0.202	0.182
ADR	1.267	1.270	1.400**	1.471**	1.475**
F/G	6.71	7.04	6.70	7.29	8.10*
Period IV[d]					
ADG	0.191	0.171	0.203	0.196	0.179
ADR	1.351	1.342	1.474**	1.557**	1.559**
F/G	7.06	7.87**	7.26	7.96**	8.71**

[a] 28 days.
[b] 51 days to date.
[c] 78 days to date.
[d] 110 days to date.
* Significantly different from controls (P<.05).
** Significantly different from controls (P<.01).

Table 2. Average Blood Serum Levels of Calcium, Magnesium and Phosphorus (Experiment 1)

	Bentonite treatments				
	0%	2%	4%	8%	12%
54-day collection[a]					
Calcium, mg/100 ml	9.7	9.7	10.1	9.8	9.7
Magnesium, mg/100 ml	2.9	2.9	2.7*	2.8	2.7*
Phosphorus, mg/100 ml	8.4	8.3	7.4*	8.0	8.2
106-day collection[b]					
Calcium, mg/100 ml	9.7	9.4	9.7	9.7	9.3
Magnesium, mg/100 ml	3.2	3.4	3.3	3.0	3.4*
Phosphorus, mg/100 ml	9.7	9.6	9.3	9.2	9.4

[a] Samples from all surviving sheep (236 total).
[b] Samples from five sheep from each pen (120 total).
* Significantly different from controls (P<.05).

Table 3. Average Daily Urine Volume, pH and Mineral Concentrations (Experiment 1)

	Bentonite treatments				
	0%	2%	4%	8%	12%
Avg. daily urine volume, ml	1303	802	1127	1045	663*
Urine pH	8.4	7.9	7.9	8.5	8.4
Calcium, mg/100 ml	2.2	2.3	3.1	2.0	6.0
Magnesium, mg/100 ml	65	68	69	73	132
Phosphorus, mg/100 ml	1.2	1.5	2.4	0.9	1.0
Sodium, mg/100 ml	382	427	351	274	321
Potassium, mg/100 ml	496	553	528	412	659
SiO_2, ppm	67	104	141*	120	210**

* Significantly different from controls (P<.05).
** Significantly different from controls (P<.01).

Table 4. Average Digestion Coefficients[a] Based on 100% Dry Matter (Experiment 2)

	Bentonite treatments				
	0%	2%	4%	8%	12%
Crude protein	69	68	65	65	60*
Crude fiber	42	45	45	41	50*
Ether extract	70	69	73	83**	80**
N.F.E.	89	89	88	86	85

[a] $\frac{\text{Intake - fecal excretion}}{\text{intake}} \times 100$ = digestion coefficient.

* Significantly different from controls (P<.05).

** Significantly different from controls (P<.01).

Table 5. Excretion and Retention of Dietary Nutrients, 5-Day Totals (Experiment 2)

	Bentonite treatments				
	0%	2%	4%	8%	12%
	Total intake, grams				
Nitrogen	93.4	99.0	89.0	82.4	76.2
Calcium	13.8	14.9	13.7	13.6	12.9
Magnesium	9.2	11.5	11.9	14.0	15.7
Phosphorus	13.0	13.4	12.4	11.1	10.4
Sodium	10.7	12.7	13.4	14.9	17.0
Potassium	33.2	35.2	38.2	30.2	28.6
	Excreted in feces, grams				
Nitrogen	28.8	31.8	30.9	29.0	30.6
Calcium	9.1	9.9	10.0	8.4	8.7
Magnesium	2.9	3.2	3.4	4.4	3.8
Phosphorus	8.8	8.6	7.9	9.1	7.4
Sodium	2.9	3.0	2.8	4.1	3.0
Potassium	5.5	5.3	4.3	5.3	4.5
	Excreted in urine, grams				
Nitrogen	35.5	40.1	36.7	36.7	33.8
Calcium	0.1	0.1	0.1	0.2	0.2
Magnesium	4.0	3.6	5.6	4.0	3.3
Phosphorus	0.3	0.4	0.5	0.3	0.2
Sodium	6.9	5.2	6.4	5.6	9.8
Potassium	18.7	17.6	14.2	12.5	13.7
	Retained, grams				
Nitrogen	29.1	27.1	21.4	16.7	11.8
Calcium	4.6	4.9	3.6	5.0	4.0
Magnesium	2.3	4.7	2.9	5.6	8.6
Phosphorus	3.9	4.4	4.0	1.7	2.8
Sodium	0.9	4.5	4.2	5.2	4.2
Potassium	9.0	12.3	19.7	12.4	10.4