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EFFECT OF VARIOUS CHLORIDES AND CALCIUM CARBONATE ON CALCIUM, PHOSPHORUS, SODIUM, POTASSIUM AND CHLORIDE BALANCE AND THEIR RELATIONSHIP TO URINARY CALCULI IN LAMBS

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Various salts have been used in ruminant rations in attempts to reduce the incidence of urinary calculi. The relative effectiveness of 0.5 and 1.5% levels of ammonium chloride, calcium chloride, sodium chloride and calcium carbonate for the prevention of urinary calculi in sheep has been reported previously (South Dakota Sheep Field Day Reports, 1965). The studies reported herein were conducted to further determine the degree of protection afforded sheep against urinary calculi by the feeding of various salts, and to determine their effect on excretion and retention of the minerals.

Experimental

This study consisted of a feeding trial and balance trials. In the feeding trial, data pertaining to feedlot performance and urinary calculi incidence were obtained during an 88-day period under conditions of full feeding. In the balance trials, excretion and balance data were obtained during 7-day collection periods under conditions of equal and constant feed intake.

<u>Feeding trial</u>. One hundred and twenty crossbred wether lambs weighing approximately 84 lb. were allotted on the basis of weight into six replicated treatments. They were fed a basal ration consisting of ground shelled corn, 75.0%; ground alfalfa hay, 20.0%; soybean meal, 2.9%; disodium phosphate, 1.6%; and trace mineralized salt, 0.5%. This ration contained 11% crude protein (calculated) and was shown by chemical analysis to contain 0.64% phosphorus, 0.33% calcium, 0.30% chloride, 0.87% sodium and 0.67% potassium. Similar rations have previously been used at this station for the experimental production of phosphatic urinary calculi.

Treatments in addition to the control consisted of the following additions to the basal ration: ammonium chloride, 1%; calcium chloride, 1%; potassium chloride, 1%; sodium chloride, 4%; and calcium carbonate, 2%. Commerical-grade anhydrous chloride salts and feed-grade calcium carbonate (ground limestone) were used. The rations were fed once daily in an amount so feed would be available at all times.

The lambs were observed for symptoms of urinary calculi throughout the experiment. Lambs with apparent blockage were removed and slaughtered, and the urinary tracts were examined. At the termination of the experiment, the remaining lambs were slaughtered and the bladders and kidneys examined for calculi. Data pertaining

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to average daily gain and feed consumption were calculated only for those lambs finishing the experiment. Since lambs with urinary calculi were removed from the experiment when symptoms were first observed, feed consumption data were corrected by subtracting an average value for each animal removed.

Balance trials. An additional 96 wether lambs were fed the basal ration used in the feeding trial, omitting disodium phosphate during the pretreatment period. At 3-week intervals, 24 lambs were removed, allotted into six treatments of four lambs each and placed in metabolism cages. This procedure was repeated four times with 24 different lambs being used each time. The treatments during these periods that the lambs were in metabolism cages were identical to those used in the feeding trial.

After being placed in the metabolism cages, the lambs were allowed 2 weeks to adapt to the treatments. The lambs were fed 1 lb. of the appropriate ration twice daily during the adaptation and collection periods. Water was available at all times and water consumption was measured during the collection periods. Lambs failing to eat during the latter part of the adaptation period or during the collection period were removed from the experiment. Urine and feces were collected daily during the 7-day collection period. Blood samples were obtained at the end of the period. Urine, feces and blood serum were analyzed for each of the minerals studied.

Results and Discussion

Feeding trial. Data pertaining to the feedlot trial are presented in table 1. Control lambs had a 50% incidence of urinary calculi. The feeding of ammonium chloride resulted in a significant ($P < .01$) reduction of urinary calculi with only one nonobstructive case occurring in lambs on this treatment. Lambs receiving calcium chloride had one obstructive case of calculi early in the experiment and two additional cases that were encountered at slaughter. This reduction attributed to calcium chloride, 16% incidence vs. a 50% incidence in the controls, was significant at the 5% level of probability. Feeding 1% potassium chloride significantly ($P < .05$) increased the incidence of urinary calculi resulting in a total (obstructive plus nonobstructive) incidence of 85%. In this instance, obstructive cases alone accounted for a 35% incidence.

While feeding 4% sodium chloride or 2% calcium carbonate appeared to lower the incidence of urinary calculi, the reductions were not significant. Data previously reported from this station showed that the protective effect of calcium carbonate added to high-phosphorus rations improved up to the highest calcium-to-phosphorus ratio (2.3:1) used. The calcium-to-phosphorus ratio of the 2% calcium carbonate ration fed in the current experiment was 1.7:1.

Lambs receiving ammonium chloride, potassium chloride or sodium chloride had the lowest feed consumption and, subsequently, the lowest average daily weight gains. Average daily gain of lambs fed potassium chloride was significantly ($P < .05$) lower than that attained by control lambs. A reduction in weight gain attributable to ammonium chloride approached significance at the same level of probability. Lambs making the lower weight gains had slightly, but not significantly, lower carcass grades. In previous work at this station, ammonium chloride fed at a slightly higher level (1.5%) than the 1% used in this study had no affect on performance of lambs when it was mixed in a complete ration, but an equivalent amount fed in a supplement lowered feed consumption and weight gain.

Balance trials. Data pertaining to the balance trials are presented in table 2. Feeding either calcium chloride or calcium carbonate resulted in a significant ($P < .01$) increase in calcium retention. Of these two compounds, only calcium chloride resulted in an increase in calcium concentration and excretion in the urine. This increase in excretion was significant ($P < .05$), and the increase in concentration in mg. of calcium per 100 ml. of urine approached significance at this level of probability. Both calcium sources significantly ($P < .05$) increased fecal calcium.

Ammonium chloride significantly ($P < .05$) increased both the concentration and total excretion of urinary calcium. However, this variation was not apparent in the fecal calcium or calcium retention values, and calcium excretion in the urine was relatively small in all instances with a maximum of 0.5 gm. being excreted in 7 days. Potassium chloride and sodium chloride had no effect on excretion or retention of calcium.

We have previously reported that feeding 1.5% of ammonium chloride or calcium chloride increased the concentration of calcium in the urine of lambs. It was suggested at that time that increased urinary calcium was probably not a primary factor in the reduction of urinary calculi. Rather, the mode of action of these two compounds was thought to be through a reduction in urinary pH. This is supported by the data herein showing that only ammonium chloride resulted in a significant ($P < .01$) decrease in urinary pH with this treatment yielding the greatest reduction in the incidence of calculi.

The reduction of urinary pH attributed to the feeding of 1% ammonium chloride in this study was considerably smaller than that obtained by feeding 1.5% of ammonium chloride in the previous experiment. A level of 0.5% ammonium chloride had no effect on urinary pH in the previous experiment.

There was no significant affect on phosphorus retention or excretion by any of the compounds fed. However, there was a trend toward increased urinary phosphorus excretion in lambs fed 1% ammonium chloride, and the feeding of calcium carbonate resulted in a reduction in urinary phosphorus excretion approaching significance at the 5% level of probability. A reduction of urinary phosphorus excretion by increased levels of dietary calcium has been postulated to be the principal mechanism whereby calcium carbonate reduces the incidence of urinary calculi.

All of the chloride supplements significantly increased the concentration ($P < .05$) and the total excretion ($P < .01$) of chloride in the urine. However, ammonium chloride and calcium chloride resulted in a much lower incidence of urinary calculi than did sodium chloride, and potassium chloride increased calculi formation. Feeding 4% sodium chloride resulted in the highest concentration of chloride in the urine with only a slight reduction in calculi formation. These results support our contention that an elevated urinary excretion of chloride does not in itself offer protection against calculi formation.

The supplements providing sodium and potassium (sodium chloride and potassium chloride, respectively) significantly increased retention ($P < .01$) and urinary excretion ($P < .05$) of the respective cations. In addition, sodium chloride significantly ($P < .05$) decreased the fecal excretion of potassium. While there appeared to be no relationship between urinary sodium concentration and the occurrence of urinary calculi, it cannot be concluded at this time whether the increased urinary potassium concentration may have contributed to the higher incidence of calculi in lambs fed potassium chloride.

Supplemental dietary calcium resulted in a greater absorption of both sodium and potassium as evidenced by significantly ($P < .01$) lower fecal excretion of these cations in lambs receiving either 1% calcium chloride or 2% calcium carbonate. While there was a trend toward higher urinary excretions of sodium and potassium in lambs receiving either of the two sources of supplemental calcium, the values differed significantly ($P < .05$) from the controls only for urinary sodium excretion in lambs fed calcium carbonate. However, the comparable value for lambs fed calcium chloride approached significance at the same level of probability. The possibility that higher urinary sodium values may contribute, in part, to the protective effect of supplemental calcium appears unlikely in view of the small degree of protection provided by sodium chloride which contributed the highest urinary sodium level.

For lambs fed 4% sodium chloride and those fed 1% calcium chloride, urine volumes did not appear to be related to the differences in urinary calculi formation in this experiment. However, the average urine phosphorus value for lambs fed sodium chloride was comparable to that for the controls despite approximately a 2-fold difference in urine volumes. Thus, it appears that for an increase in urine volume to be effective in aiding against phosphatic urolithiasis, it may be necessary for it to be accompanied by a concomitant reduction in urinary phosphorus.

It can be concluded from these data that variations in the urinary cations, calcium, sodium and potassium, or the anion, chloride with a concomitant reduction in urinary pH, play no major role in the prevention of phosphatic urolithiasis by the dietary salts used in these studies. Postulations of protective effects for the various salts by modes of action other than those previously recognized, i.e., a lowering of urinary pH and a decrease in phosphate excretion, do not appear warranted on the basis of these data.

Blood serum data are presented in table 3. There was no significant treatment effect on serum calcium, phosphorus, chloride, sodium or potassium in this experiment.

Summary

A total of 216 wether lambs were used in an experiment including feeding and balance trials. The lambs were fed a high-phosphorus basal ration, known to be calculogenic, supplemented with either 1% ammonium chloride, 1% calcium chloride, 1% potassium chloride, 4% sodium chloride or 2% calcium carbonate.

During an 88-day period, the control lambs developed a 50% incidence of urinary calculi. The calculi incidence for lambs fed the various salts were ammonium chloride, 5%; calcium chloride, 16%; potassium chloride, 85%; sodium chloride, 35% and calcium carbonate, 30%. The reductions in urinary calculi incidence resulting from the feeding of ammonium chloride and calcium chloride, and the increase from the feeding of potassium chloride were significant ($P < .05$).

Excretion and retention data dispute the existence of any protective action manifested through variations in excretion patterns of calcium, sodium, potassium or chloride unless accompanied by a concomitant reduction in urine pH.

Average weight gain was reduced significantly ($P < .05$) by the feeding of 1% potassium chloride, and a reduction accompanying the feeding of 1% ammonium chloride approached significance at the same level of probability.

TABLE 1. EFFECT OF VARIOUS SALTS FED TO SHEEP, PHASE 1

Treatment	Control	1% NH_4Cl	1% $CaCl_2$	1% KCl	4% NaCl	2% $CaCO_3$
No. of lambs[a]	20	20	19	20	20	20
Av. daily gain, lb.[b]	0.322	0.258	0.328	0.234*	0.281	0.322
Daily ration, lb.	2.73	2.64	2.88	2.51	2.54	2.80
Feed per lb. gain, lb.	8.45	10.19	8.70	10.74	9.12	8.35
Carcass grade[c]	12.4	12.1	12.4	11.9	12.0	12.4
Urinary calculi incidence						
Clinical[d]	3	0	1	7	4	2
Total[e]	10	1**	3*	17*	7	6

[a]Originally 20 lambs per treatment, but one lamb died from enterotoxemia.

[b]Calculated only for those lambs surviving the entire experimental period.

[c]Choice = 11, Choice + = 12, Prime - = 13.

[d]Death due to urine blockage, or slaughtered when death appeared certain.

[e]Includes losses due to urine blockage and animals having mineral deposits at the termination of the experiment.

* Significantly ($P < .05$) different from control mean.

** Significantly ($P < .01$) different from control mean.

TABLE 2. BALANCE-TRIAL DATA, PHASE 2

Treatment	Control	1% NH_4Cl	1% $CaCl_2$	1% KCl	4% NaCl	2% $CaCO_3$
No. of lambs[a]	13	16	14	13	13	12
Intake, gm./7 days[b]						
Calcium	23.32	22.34	44.98	21.44	23.32	69.86
Phosphorus	39.53	39.54	39.54	38.03	39.71	39.66
Chloride	19.00	59.84	58.40	46.48	169.23	19.05
Sodium	54.10	54.11	54.17	52.03	155.13	54.23
Potassium	41.63	41.64	41.65	71.74	41.85	41.77
Fecal excretion, gm./7 days						
Calcium	17.55	17.50	32.72*	16.51	18.36	45.34**
Phosphorus	26.71	23.76	26.07	24.11	23.48	26.49
Sodium	5.353	5.162	2.256**	5.083	5.975	2.727**
Potassium	7.966	6.865	4.322**	7.879	5.713*	3.840**
Urine values mg./100 ml.						
Calcium	1.36	6.84**	4.40	2.02	2.18	1.66
Phosphorus	24.39	39.01	14.88	21.76	20.75	7.69
Chloride	170.1	679.2**	461.3*	491.3*	943.6**	268.4
Sodium	292.1	385.8	316.1	329.3	593.5**	487.0
Potassium	281.9	296.3	284.4	503.8*	173.6	378.4
Urine excretion, gm./7 days						
Calcium	0.127	0.506*	0.503*	0.139	0.354	0.121
Phosphorus	1.925	3.101	1.969	1.672	3.318	0.710
Chloride	14.30	45.46**	40.86**	34.11**	137.00**	17.35
Sodium	24.01	26.03	30.07	23.25	87.06**	30.86*
Potassium	22.87	21.23	27.94	37.90*	25.61	24.56
Retention, gm./7 days						
Calcium	4.14	4.34	11.85**	4.30	4.47	23.66**
Phosphorus	10.02	12.68	10.57	11.43	12.17	11.86
Chloride	4.34	14.38	17.77	11.39	31.20**	1.50
Sodium	23.64	22.79	21.78	22.60	61.17**	20.62
Potassium	9.84	13.67	9.59	22.38**	10.03	13.04
Urine volume, ml./day	1277	1295	1942	1172	2704	1122
Urine pH	8.73	8.35**	8.55	8.74	8.51	8.78

[a]Initially 16 lambs per treatment, but some lambs had to be removed for failure to eat during confinement in the metabolism cages.

[b]Intake data are presented as actual means, other data are presented as least square means.

*Significantly ($P < .05$) different from the corresponding control mean.

**Significantly ($P < .01$) different from the corresponding control mean.

TABLE 3. BLOOD SERUM VALUES, PHASE 2

Treatment	Control	1% NH_4Cl	1% $CaCl_2$	1% KCl	4% NaCl	2% $CaCO_3$
Serum values, mg. per 100 ml.[a]						
Calcium	9.49	10.07	10.88	10.49	10.08	10.17
Phosphorus	10.18	9.96	9.28	9.96	10.12	9.81
Chloride	420.9	448.8	431.5	433.5	435.2	420.6
Sodium	251.7	245.0	240.0	257.9	262.5	264.6
Potassium	24.12	22.64	22.72	26.66	29.94	22.84

[a]Samples taken at the end of the collection period.