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RUMINAL ALKALIZING POTENTIAL OF BRUCITE (MAGNESIUM HYDROXIDE) AND SODIUM BICARBONATE FOR FEEDLOT CATTLE

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ABSTRACT: Four Holstein steers (320 kg) with ruminal cannulas were used in a 4×4 Latin square design experiment to evaluate the effect of brucite (**BR**; a natural source of magnesium hydroxide) and sodium bicarbonate (**SB**) on ruminal characteristics following a glucose challenge. Dietary treatments were (DM basis): 1) control (no supplemental buffer); 2) .5% BR ; 3) 1% BR, and 4) 1% SB. The basal diet contained 70% steam-flaked wheat, 4% yellow grease, and 12% forage. On the day of collection, 500 g of glucose was introduced into the rumen via the ruminal cannula 1 h after the morning feeding. The T_{50} (time required for 50% reactivity at pH 6.0) of BR and SB was 450 and .5 min, respectively. Ruminal pH was lower ($P < .05$), but ruminal fluid buffer capacity was higher ($P < .05$) 1 h after feeding (just before the glucose challenge) for control than for buffer supplemented diets. Subsequently, treatment effects on ruminal pH and buffer capacity were small ($P > .10$). There was an inverse relationship ($R^2 = .61$) between ruminal pH and lactate concentration. Ruminal lactate was highest during the first 2 h following the glucose challenge. Supplementation with .5% BR or 1% SB decreased ($P < .05$) ruminal lactate ($P < .05$) during the first h following the glucose challenge. Supplementation with 1% BR or 1% SB decreased ($P < .05$) ruminal VFA concentrations 1 h before feeding. There were no treatment effects ($P > .10$) on ruminal VFA concentrations during the 3-h period following the glucose challenge. Buffer supplementation decreased ($P < .05$) ruminal protozoal numbers. Supplemental BR decreased ($P < .05$) ruminal glucose concentration. We conclude that the ruminal alkalizing equivalence of BR and SB are similar. Although neither BR nor SB are effective in altering ruminal buffering capacity, both can lower ruminal lactate accumulation following a glucose challenge.

Key Words: Cattle, Magnesium Hydroxide, Buffer

Introduction

Brucite (**BR**) is a naturally occurring form of magnesium hydroxide, containing 35% magnesium and 2.5% calcium. Although, its apparent total tract digestibility is similar to that of magnesium oxide (Thomas et al., 1984; Devanport et al., 1990). The ruminal availability of Mg in BR has not been reported. The influence of BR supplementation on acceptability or palatability of diets fed to feedlot cattle has not been evaluated. Supplementing a high-energy lactation diet with .5% BR decreased DM intake and milk yield in Holstein cows (Thomas et al., 1984), but increased DM intake was observed in lambs fed a barley-based finishing diet (Boukila et al., 1995). This latter response was attributed to the ruminal alkalizing potential of BR. On an equivalent cation basis, BR has 240% (28.5 vs 11.9 mEq H^+/g) the acid consuming or alkalizing capacity of sodium bicarbonate(**SB**). However, the value of a buffering agent is a function of both, its alkalizing capacity and ruminal reactivity or solubility. The ruminal reactivity of SB is very high (50% reacted in .6 min at pH 6.0; James and Wohlt, 1985). The ruminal reactivity of BR has not been reported, but based on the low reactivity of magnesium oxide (50% reacted in 130 min at pH 6.0; James and Wohlt, 1985), it is likely that the ruminal reactivity of BR is substantially slower and less complete than that of SB. The objective of this trial was to evaluate the ruminal alkalizing potential and ruminal effects of BR versus SB in steers fed a high concentrate finishing diet.

Material and Methods

Four Holstein steers (320 kg) with ruminal cannulas were used in a 4×4 Latin square design experiment. Steers were housed individually in slotted-floor pens (1.42 x 2.74 m) equipped with automatic waterers. Ambient temperature in the metabolism unit was maintained between 21 and 26°C. The trial consisted of four 21-d periods. Each experimental period included a 16-d diet adjustment period followed by a 5-d collection period. Dry matter intake was restricted to 2.2% of body weight. Diets (Table 1) were fed in equal proportions at 0800 and 2000 daily. A 500-g dose of glucose was dumped at 0900, via the ruminal cannula on each collection day. Ruminal fluid samples (300 mL) were collected via the ruminal cannula according to the following schedule: 0700, 0900 (just before the glucose challenge), and at 1000, 1100, 1200, 1300, 1400, 1500. Ruminal fluid pH was determined on fresh samples. Ruminal fluid samples were strained through 4 layers of cheesecloth. Freshly prepared 25% (wt/vol) *m*-phosphoric acid (2 mL) was added to 8 mL of strained ruminal fluid. Samples were then centrifuged (17,000 × g for 10 min) and supernatant fluid stored at -20° C for analysis of L (+) lactic acid (Sigma Procedure No. 826-UV;Sigma®, St. Louis, MO), VFA concentrations (gas chromatography; Zinn, 1988); and glucose (Zinn, 1990). A separate sample of strained ruminal

fluid (100 mL) was used for measuring ruminal soluble magnesium (atomic absorption spectrophotometer), buffer capacity (Stroud et al., 1985), osmotic pressure (Micro Osmeete 5004 Precision System. Tech Circle. Natick, Mass.), and total protozoa (1 mL of strained ruminal fluid was mixed with 8 mL of .16 N saline solution plus 1 mL of a 10% formol solution, and protozal counts determined using a Neubauer counter). This trial was analyzed as a 4×4 Latin square (Hicks, 1973). Comparisons of treatment means were based on LSD (Ostle, 1963).

Results and Discussion

The reactivities of BR and SB at pH 6.0, were recorded. Whereas BR has 240% the ruminal alkalizing capacity of SB , its solubility in the rumen is much lower. The T_{50} (time required for 50% reactivity at pH 6.0) of BR was 900 X that of SB (450 vs .5 min). Prior estimates of the T_{50} of SB have ranged from .6 to 1.2 min (Schaefer et al., 1982; James and Wohlt, 1985). Assuming a ruminal passage rate of 5%/h, the ruminal availabilities of BR and SB are 43 and 95% respectively.

Treatment effects on ruminal pH are shown in Table 2. The drop in ruminal pH 1 h after feeding (just before the glucose challenge) was greater ($P < .05$) for control than for buffer supplemented diets, and differences across treatments in ruminal pH were small ($P > .10$). Although buffer treatments differed greatly in ruminally available alkalizing equivalents (particularly during the first hour after feeding: .103, .206, .306 mE for .5% BR, 1% BR or 1% SB, respectively), differences between alkalizing agents with respect to ruminal pH were small.

The ineffectiveness of the buffers in ameliorating the effect of the glucose challenge on ruminal pH was surprising. Although, in previous studies, the effects of buffer supplementation on ruminal pH have not been consistent. Of the 11 studies shown in Table 3, buffer supplementation increased ruminal pH in 45% of the cases.

Treatment effects on ruminal L-lactic acid concentrations are shown in Table 4. Consistent with previous studies (Counotte et al.,1979; Ha et al., 1983; Nagaraja et al., 1981, 1982) there was an inverse relationship ($R^2 = .64$) between ruminal pH and L-lactic acid concentration. In agreement with Horn et al. (1979), ruminal lactic acid was highest during the first 2 h following the glucose challenge. Supplementation with .5% BR or 1% SB decreased ($P < .05$) ruminal lactic acid concentration ($P < .05$) at 1 and 5 h after the glucose challenge. Supplementation with SB decreased ($P < .05$) ruminal lactic acid concentrations at 1, 5 and 6 h after the glucose challenge. Xu et al. (1994) also decreased ruminal lactic acid concentrations with buffer additions to a high concentrate diet. However, in lambs fed a 61% concentrate diet, supplementation with 2% SB did not influence ruminal lactic acid concentration (Hart and Doyle,1985). Nor did .8% SB influence ruminal lactic acid concentrations in cows fed a 50% concentrate-diet (Kilmer et al., 1981).

There was no relationship ($P > .10$) between ruminal lactic acid concentration and ruminal fluid buffer capacity. Though Ruyet et al, (1992) reported that reduced rumen concentrations of fermentation acids may increases buffer capacity on rumen, a significant relation was not observed in this trial.

Treatment effects on osmolality (tonicity) of ruminal fluid are shown in Table 5. Ruminal fluid osmolality fluctuated between 242 to 368 mOsm/kg. These values are within the normal range, as reported by Bergen et al. (1972) and Marshall et al. (1992). Osmolality was greatest 1 h after the glucose challenge, returning to pre-feeding values by 3 h after the glucose challenge. During this 3-h period, supplementation with 1% BR or 1% SB decreased ruminal osmolality ($P < .05$). Supplementing with .5% BR did not affect ($P > .10$) ruminal osmolality . No relationships were observed ($P > .10$) between osmolality and ruminal pH or lactic acid concentrations. Horn et al.(1979) did not observe any effects of 2% buffer (2% bentonite, 1% bentonite + 1% limestone, or 1% bentonite + 1% potassium bicarbonate) supplementation on ruminal fluid osmolality at 0, 1, 2, 4, 8, 12, and 24 h after feeding in steers fed an 85% corn-based diet. Stroud et al. (1985) also did not observe any effect of 1% SB supplementation on ruminal fluid osmolality in steers fed a 76% cracked corn-based diet.

Consistent with Dehority and Males (1974), there was no relationship ($P > .10$) between ruminal osmolality and ruminal protozoal numbers (Table 8). This is understandable, because ruminal fermentation products and mineral ion concentrations play the primary roll in determining ruminal osmolality (Nagaraja et al. 1978; Carter and Grovum, 1990). However, Mendoza et al. (1993) reported increased ruminal osmolality following defaunation.

Treatment effects on ruminal VFA concentration are shown in Table 6. Supplementation with 1% BR or 1% SB decreased ($P < .05$) ruminal VFA concentrations 1 h before feeding. There were no treatment effects ($P > .10$) on ruminal VFA concentrations during the initial 3-h period following the glucose challenge. In some studies (Horn et al., 1979; Thomas et al., 1984; James and Wohlt,1985; Stroud et al. 1985), buffer supplementation has decreased ruminal VFA concentrations. However, in others (Russell et al., 1980; Peirce et al., 1983; Kezar and Church., 1979) no differences were observed.

Supplementation with 1% BR or 1% SB decreased ($P < .05$) ruminal buffering capacity (Table 7) 1 h before and 1 h after feeding. There were no differences in ruminal buffering capacity during the 3-h period following the glucose challenge. Haaland and Tyrrell (1982) and Thomas et al. (1984) also observed no differences in ruminal buffering capacity between control and buffer-supplemented steers.

Supplementation with either BR or SB decreased ($P < .05$) ruminal protozoal numbers (Table 8). Similar responses to dietary buffers were reported by Garg and Nangia (1991). The basis for this apparent toxic effect is not apparent. Nykolov (1966) reported a significant correlation between ruminal pH and ruminal protozoa. However, in agreement with Dehority and Males (1974) Nagaraja et al. (1995), and Towne

et al. (1990) we did not observe (P > .10) an association between ruminal pH and ruminal protozoal numbers. It has been proposed that ruminal protoza may modify ruminal lactic acid production by rapidly taking up soluble starch and glucose, and thereby decreasing the intensity of fermentation during the early postprandial period. Nevertheless, we found no relationship (P > .10) between ruminal protozoal numbers (Table 8) and ruminal lactic acid concentrations. Mendoza et al. (1993) and Nagaraja et al. (1995), also observe no direct relationship between ruminal protozoal numbers and ruminal lactic acid concentration.

Treatment effects on ruminal glucose concentrations are shown in Table 9. As was expected, ruminal glucose concentration increased during the first hour after feeding and after the glucose challenge, returning to pre-feeding levels by 4 to 5 h after feeding. The high ruminal glucose concentration 1 h after the glucose challenge indicates that the metabolism of free glucose by ruminal microorganisms may be much slower than has been suggested (500%/h, NRC, 1996). Measurements obtained in this experiment do not permit a direct determination of glucose degradation rate. However, assuming that ruminal volume is 40 L, ruminal glucose passage rate is 10%/h, and that the change in ruminal glucose concentration during the first hour following the glucose challenge (208 mg/dL) represents residual from the glucose challenge, then the ruminal degradation rate of glucose would have been 73%/h.

Supplementation with SB did not influence (P > .10) ruminal glucose concentrations. However, supplementation with either .5 or 1% BR decreased (P < .05) ruminal glucose concentration. The decrease in glucose concentration was greater (P < .05) for 1% then for .5% BR. Consistent with Slyter, (1976), we did not observe (P > .10) a relationship between ruminal glucose and lactic acid concentration.

As expected, ruminal fluid Mg concentration increased (P < .05) with level of BR supplementation (Table 10). Thomas et al. (1984) also reported increased concentration of ruminal Mg after supplementing cows fed a 50% concentrate diet with magnesium oxide or magnesium hydroxide.

Implications

Brucite has 240% the alkalizing potential of sodium bicarbonate. However, the ruminal alkalizing equivalence of the two are similar, due to the lower ruminal availability of brucite. Neither brucite nor sodium bicarbonate are effective in altering ruminal buffering capacity, and have only mior effects on ruminal pH. However, both are effective in lowering ruminal lactic acid accumulation during the first few hours following a glucose challenge, when lactic acid accumulation is normally greatest. Supplementation with either brucite or sodium bicarbonate may depress ruminal protozoal population.

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Table 1. Composition of experimental diets fed to steers.

	Treatments			
Item	1	2	3	4
Ingredient Composition, % (DM basis)				
Alfalfa hay	4.00	4.00	4.00	4.00
Sudangrass hay	8.00	8.00	8.00	8.00
Flaked wheat	70.60	70.10	69.60	69.60
Cottonseed meal	2.20	2.20	2.20	2.20
Yellow grease	4.00	4.00	4.00	4.00
Cane molasses	8.00	8.00	8.00	8.00
Urea	1.00	1.00	1.00	1.00
Ammonium sulfate	.20	.20	.20	.20
Limestone	1.40	1.40	1.40	1.40
Magnesium hydroxide		.50	1.00	
Sodium bicarbonate				1.00
Dicalcium phosphate	.20	.20	.20	.20
Trace mineral salt[a]	.40	.40	.40	.40
Nutrient composition (DM basis)[b]				
NE, Mcal/kg				
Maintenence	2.2	2.24	2.23	2.23
Gain	1.26	1.55	1.55	1.55
Crude protein, %	12.5	12.4	12.4	12.4
ADF, %	6.9	6.9	6.9	6.9
Lipid, %	7.2	7.2	7.2	7.2

[a]Trace mineral salt contained: $CoSO_4$, .068%; $CuSO_4$, 1.04%; $FeSO_4$, 3.57%; ZnO, 1.24%; $MnSO_4$, 1.07%; KI, .052% ; and NaCl, 92.96%.

[b]Based on tabular values for individual feed ingredients (NRC, 1984) with exception of supplemented fat which was assigned NE_m and NE_g values of 6.03 and 4.79, respectively.

Table 2. Influence of buffers on ruminal fluid pH.

	Treatments				
Item	1	2	3	4	SEM
Ruminal fluid pH					
Sampling time					
0700	6.32	6.29	6.21	6.32	0.12
0900	6.05[a]	6.27[bc]	6.18[abc]	6.32[c]	0.08
1000	5.51	5.50	5.51	5.64	0.08
1100	5.44	5.48	5.55	5.53	0.09
1200	5.85	5.70	5.80	5.87	0.09
1300	5.84	5.79	5.84	5.97	0.11
1400	5.94	5.85	5.88	5.94	0.10
1500	5.93	5.88	5.84	6.06	0.09

[a] Means in the same row with different letters differ, $P < .05$.

Table 4. Influence of buffers on ruminal lactic acid.

	Treatments				
	1	2	3	4	SEM
Lactic acid, mg/dL					
Time					
0700	9.85	8.75	9.89	9.24	.58
0900	12.33[abc]	10.54[b]	12.73[c]	10.44[b]	.78
1000	36.13[a]	24.40[b]	29.38[ab]	22.86[b]	4.47
1100	29.45	26.65	19.25	20.02	4.62
1200	12.25	12.92	13.11	11.97	1.73
1300	11.81	11.78	11.77	12.79	.58
1400	11.77[a]	9.48[b]	9.99[ab]	9.14[b]	.86
1500	12.09[a]	11.52[ab]	9.79[ab]	9.01[b]	1.21

[a]Means in the same row with different letters differ, P < .05.

Table 3. Effects of buffer supplementation on ruminal fluid pH.

Author	Diet	Buffer	Sampling	Control	Buffer
Rusell et al., (1980)	87% Whole shelled corn	.9%$NaHCO_3$	Stomach tube	6.6	6.7[a]
Ha et al., (1983)	97% Corn	2%$NaHCO_3$	Stomach tube	5.1	5.7[b]
Thomas and Hall, (1984)	62% Cracked corn	1 and 2%$NaHCO_3$	Stomach tube	5.8	6.2[b]
James and Wohlt, (1985)	58% Corn	.18%MgO or 75%NaHCO	Stomach tube	6.2	6.3[a]
Hart and Doyle, (1985)	62% Ground corn	2%$NaHCO_3$	Stomach tube	5.7	5.8[a]
Haaland and Tyrrell, (1982)	55% Cracked corn	2%$NaHCO_3$	Rumen cannula	6.2	6.2[a]
Peirce et al., (1983)	38%Whole shelled corn	1%$NaHCO_3$	Rumen cannula	6.2	6.3[a]
Stroud et al., (1985)	76% Cracked corn	1%$NaHCO_3$	Rumen cannula	5.4	5.7[b]
Boerner et al.,(1987)	75% Cracked corn	.9%$NaHCO_3$	Rumen cannula	5.55	5.61[b]
Zinn et al., (1991)	75% Steam-flaked corn	.75%$NaHCO_3$	Rumen cannula	5.87	6.23[b]
Zinn and Borques, (1993)	75% Steam-flaked corn	.75%$NaHCO_3$	Rumen cannula	5.76	5.65[a]

[a]No effect (P > .10) of buffer supplementation on ruminal pH.
[b]Buffer supplementation increased, (P < .05) ruminal pH.

Table 5. Influence of buffers on rumen fluid osmolality.

	Treatments				
Item	1	2	3	4	SEM
Osmolality, mOsm/kg					
Time					
0700	325.75	323.63	309.38	301.62	16.76
0900	354.37[a]	335.37[a]	310.25[b]	329.37[ab]	17.67
1000	367.87[a]	356.25[ab]	322.37[c]	332.75[bc]	12.02
1100	331.50[ab]	333.37[ac]	283.37[d]	329.75[bc]	8.81
1200	317.00[ab]	326.00[a]	303.25[bc]	298.50[c]	7.11
1300	313.00	317.87	299.00	322.37	10.88
1400	313.62	283.50	263.50	251.87	32.44
1500	328.50[a]	273.12[ab]	253.37[b]	242.25[b]	22.65

[a]Means in the same row with different letters differ, P < .05.

Table 6. Influence of buffers on total volatile fatty acids.

	Treatments				
Item	1	2	3	4	SEM
Total VFA, mmol/mL					
Time					
0700	66.44[a]	57.65[ab]	50.14[bc]	44.65[c]	.04
0900	65.66[abc]	68.09[b]	53.59[cd]	51.93[d]	.05
1000	65.10	69.66	63.09	62.43	.04
1100	67.71	64.21	66.49	65.75	.03
1200	55.33	63.82	64.67	62.34	.04
1300	58.17[ab]	64.09[a]	64.11[a]	50.75[b]	.05
1400	64.56	62.62	51.72	54.04	.05
1500	62.55[ab]	68.37[a]	56.20[ac]	47.10[bc]	.05

[a]Means in the same row with different letters differ, P < .05.

Table 7. Influence of buffers on rumen fluid buffering capacity

	Treatments				
Item	1	2	3	4	SEM
Buffering capacity, mEq/L					
Time					
0700	94.12[ab]	86.50[c]	80.00[d]	88.66[ac]	2.20
0900	80.73	77.89	71.31	74.25	5.01
1000	73.92[ab]	79.68[a]	70.80[ac]	68.29[bc]	4.60
1100	72.91[ab]	77.30[a]	75.91[a]	66.73[b]	2.53
1200	70.75[ab]	76.05[a]	74.04[a]	65.29[b]	2.58
1300	74.80[ab]	73.84[ab]	78.79[b]	68.19[a]	3.19
1400	75.04[a]	65.60[ab]	64.13[ab]	56.79[b]	7.24
1500	79.36	73.98	70.84	68.78	7.20

[a]Means in the same row with different letters differ, P < .05.

Table 8. Influence of buffers on ruminal protozoa.

	Treatments				
Item	1	2	3	4	SEM
Protozoa, n x 10^5					
Time					
0700	14.59[a]	5.72[b]	5.50[b]	9.88[ab]	3.62
0900	11.31[a]	4.81[bc]	5.25[c]	7.47[abc]	2.34
1000	12.03[a]	3.81[b]	3.78[b]	6.72[ab]	2.75
1100	11.78[a]	4.41[b]	5.09[b]	5.34[b]	2.22
1200	10.44[a]	2.56[b]	3.78[b]	5.41[b]	1.80
1300	10.96[a]	2.68[b]	3.44[b]	6.59[ab]	2.08
1400	11.37[a]	2.03[b]	3.25[b]	4.28[b]	2.41
1500	10.13[a]	4.53[b]	3.53[b]	3.69[b]	1.87

[a]Means in the same row with different letters differ, P < .05.

Table 9. Influence of buffers on ruminal fluid glucose.

	Treatments				
Item	1	2	3	4	SEM
Glucose, mg/dL					
Time					
0700	3.09	2.80	.95	.77	1.05
0900	5.55	4.65	5.99	4.79	1.14
1000	245.69[ab]	162.89[ab]	148.81[a]	297.10[b]	58.00
1100	11.93	3.73	1.55	23.82	10.46
1200	2.79	2.45	4.47	4.96	1.12
1300	2.39[a]	2.44[a]	1.57[ab]	.85[b]	.56
1400	3.65[a]	3.48[a]	1.41[b]	2.20[ab]	.77
1500	2.73	4.32	3.88	4.77	1.11

[a]Means in the same row with different letters differ, P < .05.

Table 10. Influence of buffers on ruminal fluid Mg.

	Treatments				
Item	1	2	3	4	SEM
Magnesium, mg/dL					
Time					
0700	4.47[a]	5.18[a]	9.94[b]	5.49[a]	1.2
0900	4.59[a]	6.46[a]	11.30[b]	6.17[a]	0.5
1000	6.73[a]	11.27[b]	15.70[c]	7.80[a]	0.4
1100	9.09[ab]	13.44[ac]	17.23[c]	6.88[b]	0.7
1200	8.92[ab]	13.90[ac]	17.54[c]	7.73[b]	0.8
1300	9.36[ab]	14.24[ac]	17.45[c]	7.87[b]	0.8
1400	7.39[a]	11.69[b]	14.80[b]	5.73[a]	0.6
1500	7.39[a]	11.18[b]	15.04[c]	5.56[a]	0.5

[a]Means in the same row with different letters differ, P < .05.