CONTROLLED RUMINAL INFUSION OF SODIUM BICARBONATE: I. INFLUENCE OF POSTFEEDING INFUSION INTERVAL ON RUMINAL ACID-BASE STATUS

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Story in Brief

Four ruminally cannulated, lactating Holstein cows were assigned to a 4 X 4 Latin square to monitor the effects of intra-ruminal sodium bicarbonate infusion on changes in the rumen environment. Sodium bicarbonate (110 g), dissolved in 3.8 L of water, was infused twice daily at a constant rate for 2 hours starting at 0, 2 or 4 hours postfeeding. All cows had access to their diet containing sorghum silage and concentrate in a 35:65 ratio (DM basis) for 45 minutes twice daily. Ruminal fluid was collected at feeding and every 30 minutes postfeeding for 12 hours on the last day of each 7-day period. Compared to the water infusion, the 2 to 4 hour sodium bicarbonate infusion most effectively prevented the postfeeding increase in ruminal free proton concentration. Based upon alternations in ruminal acid-base status, exogenous buffer ideally should be provided to the rumen at 2 to 4 hour postfeeding; however, our results indicate that the effectiveness of this regimen might be improved if combined with a rapidly released or unprotected dietary buffer.

(Key Words: Sodium Bicarbonate, Rumen pH, Buffering Capacity.)

Materials and Methods

Four pluriparous, ruminally cannulated Holstein cows were arranged in a 4x4 Latin square; each experimental period lasted 1 week. A total mixed diet (Table 1) of sorghum silage and concentrate (35:65 ratio; DM basis) was fed at 0300 and 1500 hours in an amount consumed within 45 minutes. Samples of this total mixed diet were collected weekly and composited at the end of the trial for nutrient analysis by a commercial laboratory. Dry matter composition of the sorghum silage was determined weekly and utilized to maintain a consistent ratio of ingredients in diet DM.

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Table 1. Ingredient and nutrient composition of experimental diet DM.

Ingredient:	%
Sorghum silage	35.03
Ground shelled corn	41.04
Soybean meal, 44% CP	21.66
Limestone	.92
Dicalcium phosphate	.54
Dynamate[1]	.36
Trace mineralized salt[2]	.46
Nutrient[3]:	
CP	16.8
ADF	19.7
NDF	30.2
NE_1[4], Mcal/kg	1.61
Ca	.66
P	.45
Mg	.28
K	1.20
Na	.23

1 Double sulfate of K and Mg.
2 Contained 92% NaCl, .250% Mn, .200% Fe, .033% Cu, .007% I, .005% Zn, and .0025% Co.
3 Composition from laboratory analyses.
4 Calculated from ADF.

Treatments consisted of infusion water from 0 to 2 hour (Ctrl), or sodium bicarbonate ($NaHCO_3$) for 2 hour intervals at 0 (0-2bic), 2 (2-4bic) or 4 hour (4-6bic) postfeeding, twice daily throughout the experimental period. Sodium bicarbonate solution was prepared for infusion at each feeding by dissolving 110 g $NaHCO_3$ in 3.8 L of water; this solution was allowed to flow by gravity at a controlled rate into the rumen. Although interval postfeeding at which infusions were initiated differed among treatments, the amount of $NaHCO_3$ (110 g) per infusion was constant across all treatments.

On the morning of the last day of each experimental period, ruminal fluid was collected every 30 minutes from 0 to 12 hours postfeeding. Ruminal fluid pH was measured (Model 950 pH/ion analyzer, Fisher Scientific, Pittsburgh, PA), and ruminal fluid was then strained through four layers of cheesecloth

and a 100-ml aliquot was collected in polyethylene vials, tightly capped and frozen for buffering capacity analysis.

Buffering capacity was determined by titrating a 30-ml aliquot of ruminal fluid with continuous stirring from its initial pH to a pH of 5 with HCl (.5 or 1.0N), and titrating an additional 30-ml aliquot from its initial pH to a pH of 7 with NaOH (.1 or 1.0N). All pH measurements were recorded following 30 s of equilibration. Total volume of base and acid added to each sample was summed and utilized to calculate buffering capacity. Buffering capacity was expressed as total milliequivalents free protons required to change 1 L of rumen fluid from pH 5 to pH 7.

A buffer value index (BVI) was calculated, which allowed evaluation of the combined effects of exogenous buffers on ruminal pH and buffering capacity.

Statistical analysis consisted of a linear model ANPVA for each sampling time for ruminal variables. Cow, period, treatment and residual error were included in the model. Contrasts were employed to compare Ctrl to 0-2bic, Ctrl to 2-4bic, and Ctrl to 4-6bic, with statistical significance declared at $P<.15$.

Results and Discussion

As contrasted with Ctrl, free proton concentration ($[H^+]$) in the rumen was reduced by 0-2bic and 2-4bic, and was numerically lower for 4-6bic during the periods of infusion, i.e., 0 to 2, 2 to 4, and 4 to 6 hours, respectively (Table 2). Response of ruminal $[H^+]$ to $NaHCO_3$ infusion was rapid; reductions were evident within .5 hour of infusion. Moreover, responses to cessation of infusion were equally rapid. Ruminal $[H^+]$ of cows receiving $NaHCO_3$ infusion rebounded and was similar to those of Ctrl cows within .5 hour after infusion ended. Hence, alterations in ruminal acid-base status effected by dietary $NaHCO_3$ were transient. Ruminal acid concentration is highest 4 to 6 hours postfeeding with twice per day feeding (Tucker et al., 1988); to be most effective in maintaining ruminal $[H^+]$ within a range which promotes fiber digestion, buffering capacity should be greatest immediately prior to this interval.

Ruminal $[H^+]$ was reduced consistently during the periods of $NaHCO_3$ infusion. However, beginning at 7 to 8 hours postfeeding, ruminal $[H^+]$ consistently was higher for each $NaHCO_3$ infusion treatment than for the Ctrl (Table 2). The reason for this response is not readily apparent, but it may relate to a feedback mechanism reducing salivary buffer flow in response to increased ruminal fluid pH for the cows receiving $NaHCO_3$ infusion. However, by 7 hours postfeeding, ruminal $[H^+]$ was low enough (i.e., pH

Table 2. Mean alterations in ruminal pH and hydrogen ion concentration of cows receiving ruminal infusions of water from 0 to 2 h, or $NaHCO_3$ for 0 to 2, 2 to 4, or 4 to 6 h after feeding.

	Infusion interval						
	1 0-2 h	2 0-2 h	3 2-4 h	4 4-6 h			
	Water	NaHCO3	NaHCO3	NaHCO3	SE	Effect	P Value
Mean rumen pH							
0 to 2 h	6.25	6.24	6.22	6.13		1 vs 2	.012
					1 vs 4	.102	
2 to 4 h	6.12	6.17	6.37	5.99	1 vs 3	.024	
4 to 6 h	6.07	6.03	6.24	6.29	NS		
6 to 12 h	6.36	6.43	6.42	6.48	1 vs 2	.038	
						1 vs 3	.031
						1 vs 4	.091
0 to 12 h	6.40	6.34	6.36	6.31		1 vs 4	.058
Mean [H+], neq/L							
0 to 2 h	736	485	772	956	107	NS[1]	
2 to 4 h	846	846	522	1127	107	1 vs 3	.077
4 to 6 h	1075	1144	803	648	208	NS	
6 to 12 h	305	553	552	403	63	1 vs 2	.032
						1 vs 3	.033
0 to 12 h	585	677	612	650	46	NS	

1 NS ($P > .15$).

was high enough) for all treatments so that fiber digestion should not have been affected by these differences.

Buffering capacity (Table 3) tended to be elevated during $NaHCO_3$ infusion at each infusion interval; this response was most dramatic for 2-4bic. This elevation continued for several hours after infusion ceased for 0-2bic and 2-4bic, but ended at 6 hours postfeeding for 4-6bic. In each case, buffering capacity fell below that of Ctrl at approximately 7 hours postfeeding, corresponding to the time frame for the elevated ruminal $[H^+]$ mentioned previously for the $NaHCO_3$ treatments. However, by 7 hour postfeeding, ruminal $[H^+]$ was low enough, and ruminal fermentation had subsided enough that the lack of buffering capacity for the $NaHCO_3$ treatments at this stage may not be biologically important.

Responses in BVI to $NaHCO_3$ infusion (Table 3) were similar to those of ruminal $[H^+]$ and buffering capacity; as $NaHCO_3$ was infused, BVI increased. This elevation also was transient; by 7 hours postfeeding, BVI was lower for all $NaHCO_3$ treatments. Buffer value index provided a more sensitive index of exogenous buffer-effected alterations in ruminal acid-base status than either ruminal $[H^+]$ or ruminal fluid buffering capacity alone. For example, ruminal $[H^+]$ was lower for 0-2bic than for Ctrl at .5 and 1 hour postfeeding, whereas buffering capacity was unaffected by $NaHCO_3$ infusion during this interval. Despite the absence of any effect on buffering capacity, the difference in ruminal $[H^+]$ was sharp enough that BVI was higher for 0-2bic than for Ctrl. The reverse occurred at 4.5 and 5 hours postfeeding for 4-6bic. Ruminal $[H^+]$ was unaffected, whereas buffering capacity was significantly higher for 4-6bic than Ctrl, resulting in a higher BVI for $NaHCO_3$ infusion during that interval.

Buffering capacity of feedstuffs varies depending upon their ion content (Jasaitis et al., 1987). This variation may affect the requirement for exogenous dietary buffers in practical diets. Identification of the pH and buffering capacity of specific feedstuffs would allow calculation of a BVI both for individual feeds and for any combination of feeds utilized in a diet. Moreover, ranges of total dietary BVI for which supplementation of buffers is justified could be identified.

Table 3. Mean alterations in ruminal buffering capacity and buffer value index of cows receiving ruminal infusions of water from 0 to 2 h, or NaHCO3 for 0 to 2, 2 to 4, or 4 to 6 h after feeding.

	Infusion interval						
	1 0-2 h	2 0-2 h	3 2-4 h	4 4-6 h			
	Water	NaHCO3	NaHCO3	NaHCO3	SE	Effect	P Value
Mean buffering capacity, meq/L							
0 to 2 h	66.0	70.5	63.9	67.1	2.9	NS	
2 to 4 h	59.7	63.5	66.1	63.0	2.8	NS	
4 to 6 h	57.6	61.3	66.9	63.5	1.6	1 vs 3	.007
						1 vs 4	.044
6 to 12 h	69.6	64.2	67.6	63.8	1.7	1 vs 2	.063
						1 vs 4	.050
0 to 12 h	65.9	65.2	66.6	64.1	1.0	NS	
Mean buffer value index							
0 to 2 h	100.58	100.93	100.51	100.39	.09	1 vs 2	.037
2 to 4 h	100.35	100.42	100.77	100.13	.15	1 vs 3	.086
4 to 6 h	100.08	100.08	100.53	100.62	.22	1 vs 4	.131
6 to 12 h	101.09	100.73	100.80	100.87	.07	1 vs 2	.013
						1 vs 3	.031
						1 vs 4	.084
0 to 12 h	100.73	100.63	100.71	100.63	.05	NS	

1 NS (P > .15).

Literature Cited

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