CONTROLLED RUMINAL INFUSION OF SODIUM BICARBONATE: II. INFLUENCE OF INFUSION INTERVAL ON THE RUMINAL CONDITIONS IN LACTATING COWS

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Story in Brief

Four ruminally cannulated, lactating Holstein cows in a 4 x 4 Latin square were used to evaluate the effect of $NaHCO_3$ infusion on ruminal acid-base status. Treatments consisted of infusing water (3.8 liters) alone from 0 to 2 hour postfeeding or infusing 110 grams $NaHCO_3$ in 3.8 liters of water from 0 to 2, 2 to 4, or 4 to 6 hours postfeeding, twice daily. Diets contained sorghum silage and concentrate in a 35:65 ratio (dry matter basis) and were offered for 45 minutes twice daily. Ruminal fluid performance data was collected at feeding and every 30 minutes thereafter for 8 hours on the last day of each experimental period. Free proton concentration in fluid from the rumen was reduced and, with the exception of 2 to 4 hour infusion, buffering capacity increased with $NaHCO_3$ infusion. The acetate to propionate ratio tended to be reduced by $NaHCO_3$ infusion, whereas total VFA concentration was unchanged. Ruminal liquid volume tended to be increased by 0 to 2 hours infusion whereas ruminal outflow rate tended to be reduced by 2 to 4 hours $NaHCO_3$ infusion. Sodium bicarbonate infusion (approximately .73%) into cows receiving supplemental dietary $NaHCO_3$ (.5%) altered ruminal acid base status; however, these alterations were not accompanied by shifts in ruminal VFA patterns that previously have accompanied dietary buffer supplementation.

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

Material and Methods

Four ruminally cannulated Holstein cows were arranged in a 4 x 4 Latin square with 1 week experimental periods. A total mixed diet containing .5% $NaHCO_3$ (DM basis; Table 1) with sorghum silage and concentrate in a 35:65 ratio being offered to the cows for 45 minutes, twice daily. Amounts of feed

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Table 1. Ingredient and nutrient composition of diet DM.

Ingredient:	%
Sorghum silage	35.01
Ground shelled corn	40.57
Soybean meal, 44% CP	21.64
Limestone	.92
Dicalcium phosphate	.54
Dynamate[1]	.36
Trace mineralized salt[2]	.46
Sodium bicarbonate	.50
Nutrient[3]:	
DM (as fed)	43.3
Crude protein	17.3
ADF	20.3
NDF	32.4
NE_l, Mcal/kg[4]	1.59
Ca	.57
P	.48
Mg	.33
K	1.39
Na	.39
S	.31
Cl	.42

[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.

consumed were recorded. Treatments consisted of infusion of water alone from 0 to 2 hours postfeeding (Ctrl) or infusion of $NaHCO_3$ for 2 hours beginning either at 0 (0-2bic), 2 (2-4bic) or 4 hours (4-6bic) postfeeding. The sodium bicarbonate solution was prepared by dissolving 110 grams $NaHCO_3$ in 3.8 liters of water. The infusion solution was allowed to flow by gravity into the rumen at a controlled rate.

On the morning of the last day of each experimental period, cows were intraruminally dosed with 550 mg Cr as Cr-EDTA immediately before feeding; thereafter, ruminal fluid samples were collected every 30 minutes from 0 to 8 hours postfeeding. Ruminal fluid pH was determined; ruminal fluid was filtered and two, 100 ml aliquots were collected in polyethylene vials and frozen for subsequent measurement of buffering capacity, VFA and Cr.

Buffering capacity was calculated as the amount of acid or base required to titrate ruminal fluid from pH 5 to pH 7, and was expressed as meq/L. Buffer value index (BVI; Hogue, 1991) was calculated utilizing the pH and buffering capacity of the ruminal fluid. A higher BVI indicates that ruminal fluid had greater acid-neutralizing power.

Results and Discussion

Dry Matter Intake, Milk Yield and Milk Composition

DM intake (Table 2) was not affected by any $NaHCO_3$ infusion intervals. Erdman et al. (1980) observed an increase in DM intake with dietary $NaHCO_3$ supplementation.

Milk yield was higher for Ctrl than for 4-6bic potentially a result of the tendency for lower DM intake with 4-6bic. Cows were released from the stanchions immediately following termination of their infusion interval; therefore, 4-6bic cows were confined for a longer interval than the other cows. This added stress may have reduced milk yield. Fat yield and protein yield were not affected by treatment. Milk protein yield, lactose yield, percentage SNF and SNF yield all were reduced for 4-6bic vs Ctrl, potentially a result of reduced intake or increased stress for that treatment.

Ruminal acid base status

Ruminal free proton concentration or acidity ($[H^+]$) tended to be lower for 0-2bic (solid line) than Ctrl (dotted line) at 1.5 but greater at 3.5 hours postfeeding (Figure 1a). The difference at 1.5 hour was during the period of $NaHCO_3$ infusion. Compared to Ctrl, mean ruminal [H^+] from 0 to 8 hours postfeeding was lowered by 2-4bic and 4-6bic, but not affected by 0-2bic (Table 3). The rapid rise in $[H^+]$ during 2 to 4 hour postfeeding (Table 3) for Ctrl and 0-2bic indicated that, whether from dietary or exogenous origin, ruminal effects of this buffer dissipated rapidly.

Overall, ruminal infusion of $NaHCO_3$ tended to increase buffering capacity above that for the water infusion throughout the post feeding interval (Table 3), but the increases did not always correspond temporally to $NaHCO_3$

Table 2. Dry matter intake, milk yield and milk composition of cows receiving ruminal infusion 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 Water	2 0-2 h $NaHCO_3$	3 2-4 h $NaHCO_3$	4 4-6 h $NaHCO_3$	SE	Effect	P Value
DM intake, kg/d	14.8	15.2	14.5	14.2	.5	NS[1]	
Milk:							
Yield, kg/d	21.2	20.0	21.2	19.1	.7	1 vs. 4	.073
Fat, %	3.39	3.54	3.40	3.45	.18	NS	
Fat yield, kg/d	0.71	.72	.71	.65	.04	NS	
Protein, %	3.00	3.03	2.97	2.98	.03	NS	
Protein yield, kg/d	.63	.61	.62	.56	.02	1 vs. 4	.063
Lactose, %	5.05	5.00	5.06	5.01	.02	1 vs. 2	.071
Lactose yield, kg/d	1.07	1.00	1.07	0.96	.03	1 vs. 4	.052
SNF, %	8.68	8.66	8.65	8.62	.02	1 vs. 4	.038
SNF yield, kg/d	1.84	1.73	1.83	1.64	.06	1 vs. 4	.054
SCC (1,000)	130	161	127	132	24	NS	

[1] Nonsignificant; $P > .15$.

(Figure is continued on pages 264 and 265)

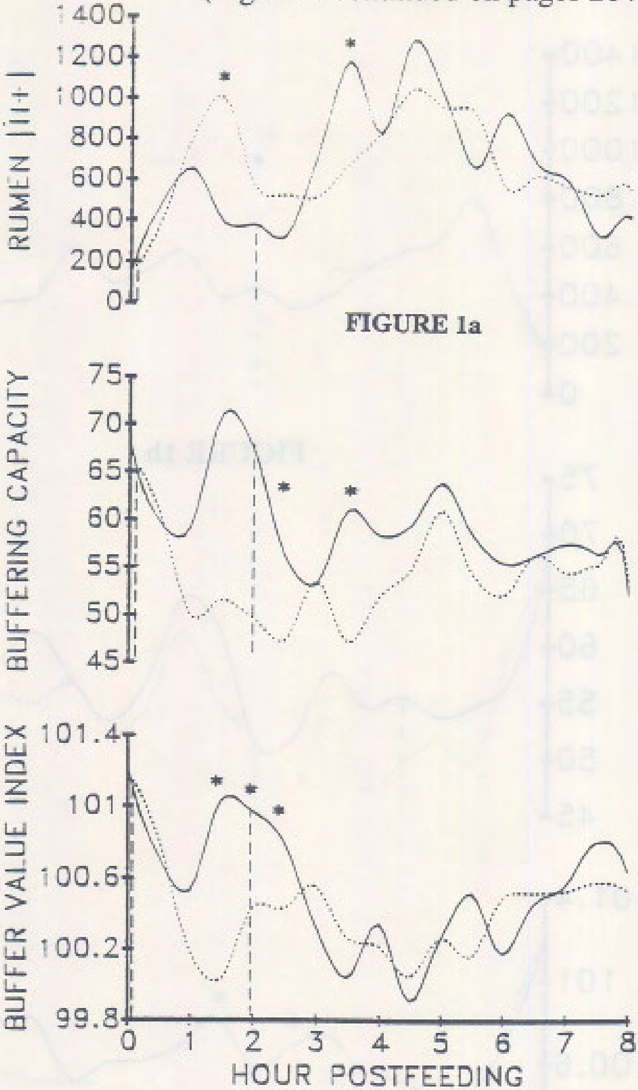


Figure 1. Ruminal buffer value index, buffering capacity (Meq/L) and free proton concentration (neq/L) for Ctrl vs. 0 to 2 hour $NaHCO_3$ infusion, panel A; Ctrl vs. 2 to 4 hour $NaHCO_3$ infusion, panel B; and Ctrl vs. 4 to 6 hour $NaHCO_3$ infusion, panel C. Ctrl = (····); $NaHCO_3$ infusion = (----). Free proton concentration of 1,000 neq/L = a pH of 6; 316 neq/L = a pH of 6.5; and 100 neq/L = a pH of 7. Vertical, dashed lines represent beginning and end of $NaHCO_3$ infusion. * = probability that treatment means are not different ($P<.15$).

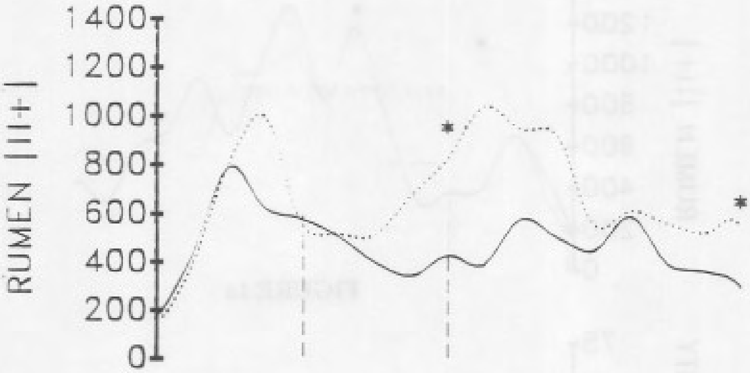
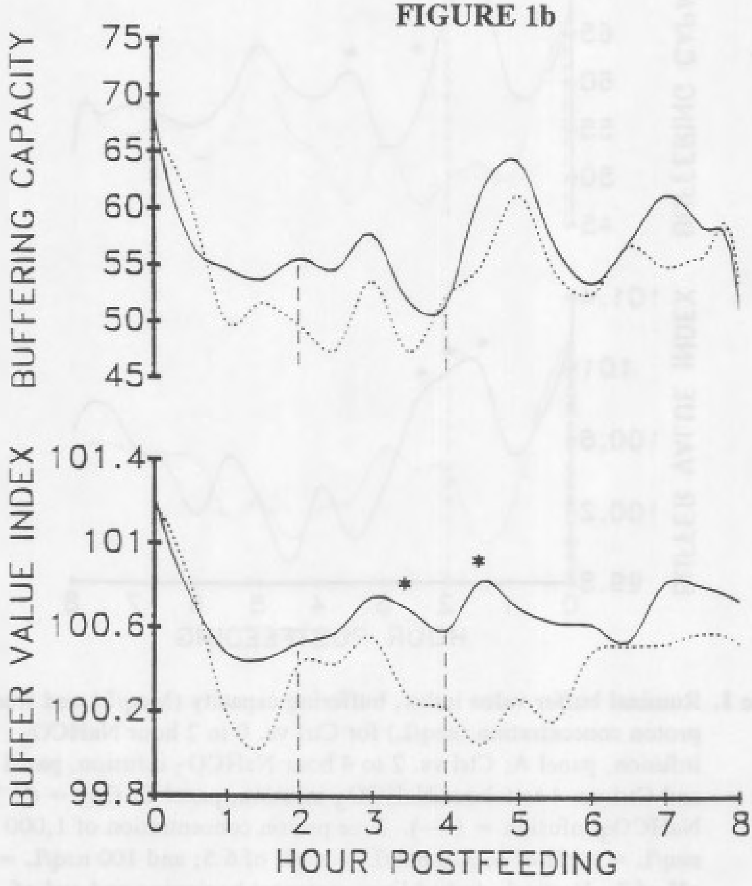

RUMEN [H+]
1400
1200
1000
800
600
400
200
0
*
*

FIGURE 1b


BUFFERING CAPACITY
75
70
65
60
55
50
45
BUFFER VALUE INDEX
101.4
101
100.6
100.2
99.8
*
*
0
1
2
3
4
5
6
7
8
HOUR POSTFEEDING

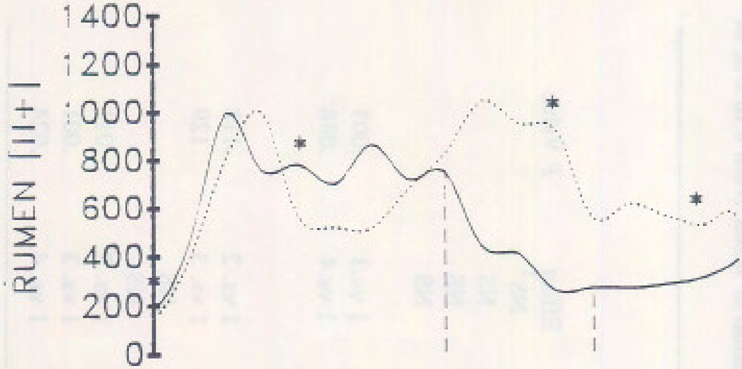

1400
1200
1000
800
600
400
200
0
RUMEN [H+]
*
*
*

FIGURE 1c

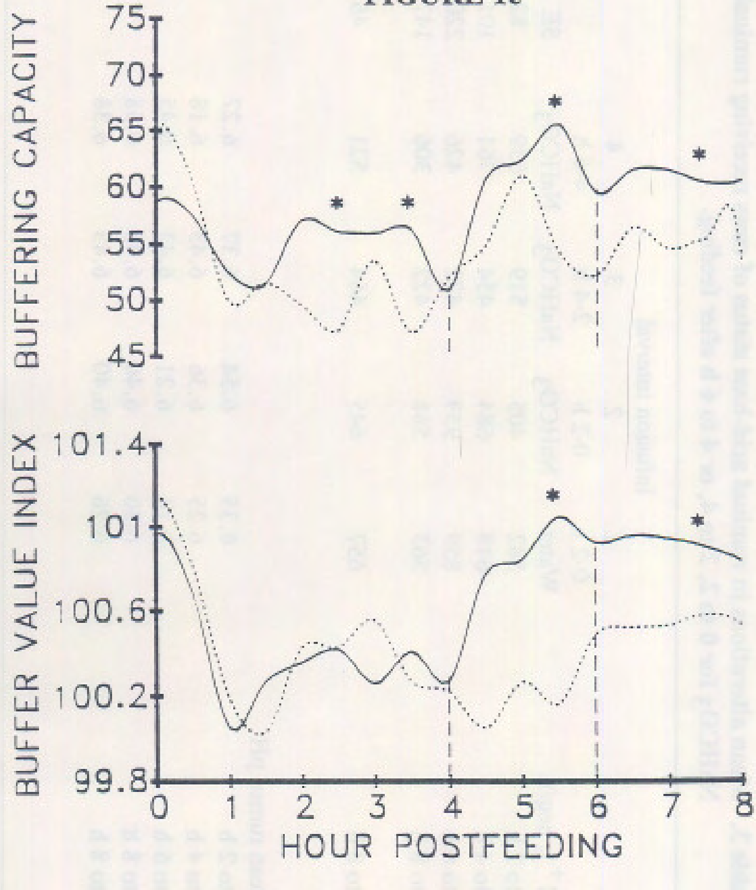

75
70
65
60
55
50
45
BUFFERING CAPACITY
*
*
*
*
101.4
101
100.6
100.2
99.8
BUFFER VALUE INDEX
*
*
0
1
2
3
4
5
6
7
8
HOUR POSTFEEDING

Table 3. Mean alterations in ruminal acid-base status of cows receiving ruminal infusion 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	2	3	4			
	0-2 h	0-2 h	2-4 h	4-6 h			
$[H^+]$, neq/L	Water	$NaHCO_3$	$NaHCO_3$	$NaHCO_3$	SE	Effect	P Value
0 to 2 h	582	405	519	639	82	NS[1]	
2 to 4 h	618	684	454	761	101	NS	
4 to 6 h	859	939	472	426	220	NS	
6 to 8 h	563	588	422	306	147	NS	
0 to 8 h	657	645	464	521	46	1 vs.3	.003
						1 vs.4	.038
Mean rumen pH							
0 to 2 h	6.35	6.54	6.37	6.27		1 vs. 2	.118
2 to 4 h	6.25	6.36	6.43	6.18		1 vs. 3	.129
4 to 6 h	6.14	6.21	6.43	6.45		NS	
6 to 8 h	6.30	6.46	6.46	6.58		NS	
0 to 8 h	6.26	6.40	6.43	6.38		1 vs. 2	.011
						1 vs. 3	.001
						1 vs. 4	.024

Table 3. (Continued)

Mean buffering capacity, meq/L							
0 to 2 h	55.5	65.1	56.6	55.4	5.4	NS	
2 to 4 h	50.0	59.3	54.2	55.3	2.3	1 vs. 2	.028
4 to 6 h	54.9	59.2	57.3	59.9	1.7	1 vs. 2	.129
						1 vs. 4	.088
6 to 8 h	54.6	55.9	56.2	60.8	2.2	1 vs. 4	.093
0 to 8 h	54.2	59.8	56.3	58.2	1.1	1 vs. 2	.005
						1 vs. 4	.012
Mean buffer value index							
0 to 2 h	100.54	100.90	100.60	100.47	.16	NS	
2 to 4 h	100.38	100.50	100.63	100.34	.13	NS	
4 to 6 h	100.24	100.24	100.67	100.77	.23	NS	
6 to 8 h	101.53	100.53	100.70	100.91	.18	NS	
0 to 8 h	100.43	100.55	100.67	100.64	.05	1 vs. 2	.117
						1 vs. 3	.002
						1 vs. 4	.006

[1] Nonsignificant; P>.15.

infusion. In contrast to the present study, Hogue et al. (1991) observed that ruminal fluid buffering capacity increased during $NaHCO_3$ infusion. In the current study, .5% $NaHCO_3$ infusion treatments were compared to a Ctrl cow receiving some $NaHCO_3$ via the diet. This presence of buffer in the diet may explain why buffering capacity did not increase during each $NaHCO_3$ infusion.

Mean BVI from 0 to 8 hours postfeeding was higher for each of the $NaHCO_3$ infusion treatments than for Ctrl (Table 3) such differences were not detected for each $NaHCO_3$ infusion treatment for buffering capacity and ruminal $[H^+]$ during this interval.

Ruminal volatile fatty acids

Total ruminal fluid VFA concentrations (Figure 2) generally were not affected, whereas the ruminal acetate to propionate ratio (A:P) tended to be reduced by $NaHCO_3$ infusion (Figure 3). Hogue et al. (1991) and other researchers reported that A:P increased with $NaHCO_3$ infusion and with dietary $NaHCO_3$. The reason for this discrepancy is not clear.

Ruminal Kinetics

To evaluate ruminal liquid kinetics, the natural logrithm of ruminal fluid Cr concentration was regressed upon time postfeeding. Mean r^2 for linearity of regression was $.695 \pm .239$, $n=16$. Ruminal liquid volume (Table 4) was higher for 0-2bic than Ctrl. Liquid flow rate was lower for 2-4bic than for Ctrl and tended to be lower for 2-4bic than for other $NaHCO_3$ infusion intervals. This contrasts with results of Rogers et al. (1985) where supplementation of 1.4% dietary $NaHCO_3$ increased total daily ruminal fluid outflow in cows receiving either long-stemmed or chopped alfalfa hay.

Intra-ruminal infusion of $NaHCO_3$ into cows receiving supplemental dietary $NaHCO_3$ effected alterations in ruminal acid-base status; however, these alterations were not accompanied by shifts in ruminal VFA patterns or in milk composition. The effects of $NaHCO_3$ infused directly into the rumen may be different from those of dietary $NaHCO_3$.

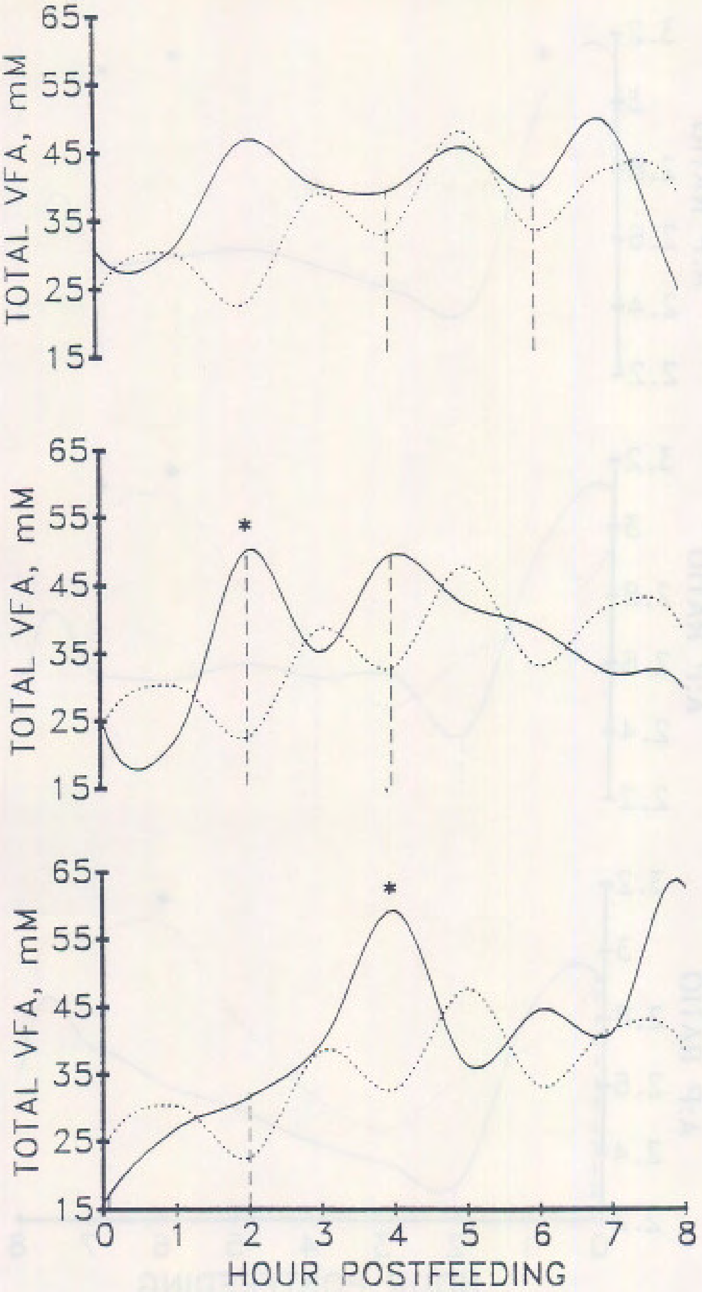


Figure 2. Total ruminal volatile fatty acids (mM) for Ctrl vs. 0 to 2 hour $NaHCO_3$ infusion, bottom panel; Ctrl vs. 2 to 4 hour $NaHCO_3$ infusion, middle panel; and Ctrl vs. 4 to 6 hour $NaHCO_3$ infusion, top panel. Ctrl = (....); $NaHCO_3$ infusion = (----). * = probability that treatment means are not different ($P < .15$).

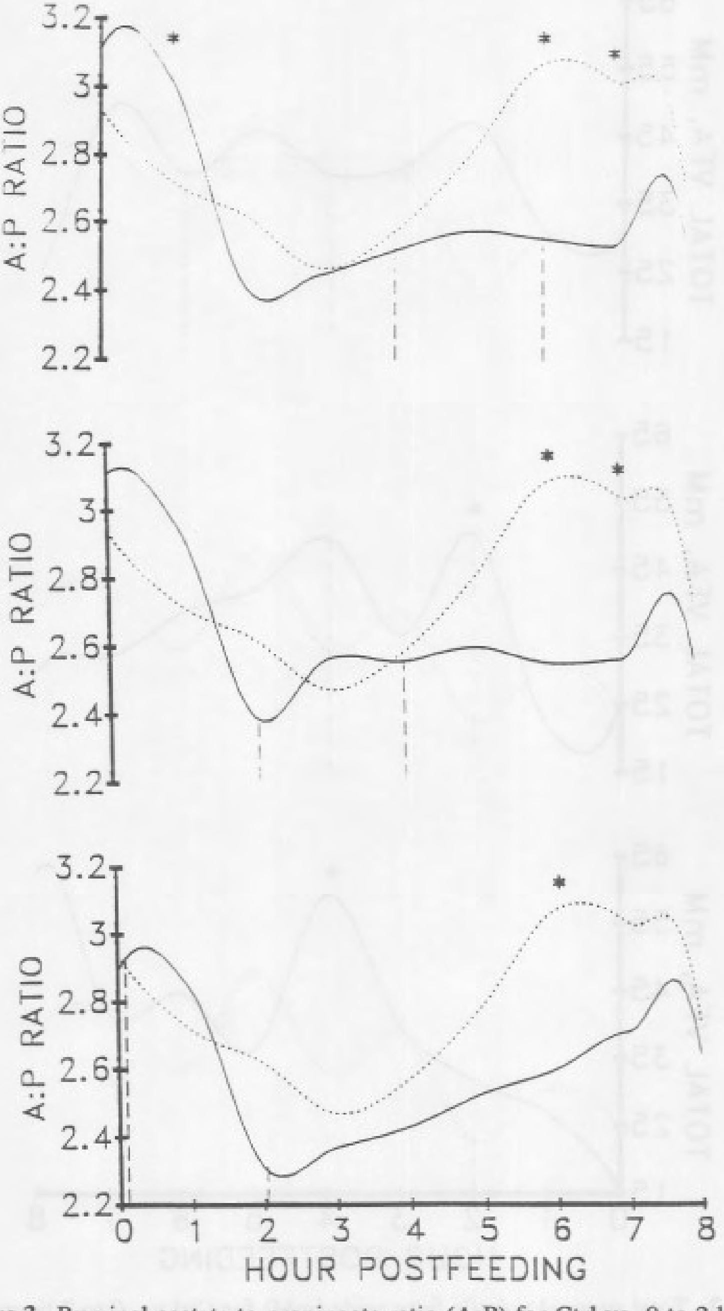


Figure 3. Ruminal acetate to propinoate ratio (A:P) for Ctrl vs. 0 to 2 hour $NaHCO_3$ infusion, bottom panel; Ctrl vs. 2 to 4 hour $NaHCO_3$ infusion, middle panel; and Ctrl vs. 4 to 6 hour $NaHCO_3$ infusion, top panel. Ctrl= (....); $NaHCO_3$ infusion= (----). * = probability that treatment means are not different (P<.15).

Table 4. Rumen kinetics of cows receiving ruminal infusion 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 Water	2 0-2 h $NaHCO_3$	3 2-4 h $NaHCO_3$	4 4-6 h $NaHCO_3$	SE	Effect	P Value
Rumen:							
Liquid Volume, L	54.1	62.0	52.2	51.1	3.2	1 vs. 2	.129
Flow rate, L/h	5.97	4.37	3.62	5.44	1.00	1 vs. 3	.148
Liquid dilution rate, %/h	11.46	7.16	6.89	10.35	2.23	NS[1]	
Liquid turnover time, h	9.58	27.86	20.33	9.99	10.19	NS	

[1] Nonsignificant; P>.15.

Literature Cited

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