Sodium, Calcium and Potassium Salts for Cattle Fed High Concentration Rations

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Story in Brief

The influence of sodium, calcium and potassium salts on site and extent of digestion was measured in two trials. In the first trial, 2.5 percent supplemental $CaCO_3$ or 2.5 percent $CaCO_3$ + 1 percent $NaHCO_3$ were added to an 80 percent concentrate ration. Either buffer treatment increased ruminal digestion of organic matter and starch. $NaHCO_3$ addition increased passage of non-ammonia nitrogen to the small intestine. Duodenal, ileal and fecal pH were not related. Digestion of organic matter and starch in the small intestine was greater for animals fed the control than the buffer-supplemented ration. Results indicate buffers influence site rather than extent of digestion. In the second trial, 45 heifers were fed a high-concentrate corn-based ration with or without 2.5 percent supplemental $CaCO_3$ or 1 percent supplemental KCl. Daily gain and feed efficiency tended to favor the supplemented diet. Dry matter digestibility was greater for the KCl-supplemented ration than for the $CaCO_3$-supplemented ration.

Materials and Methods

Trial 1

Thre Angus steers (308 kg) with dual re-entrant intestinal cannulas were used to evaluate the influence of ruminal and intestinal buffers on digestive function. Three treatments were: 1) basal (Table 1), 2) basal + 2.5 percent $CaCO_3$ and 3) basal + 2.5 percent $CaCO_3$ + 1 percent $NaHCO_3$. Steers were fed 2.5 kg of feed twice daily. Chromic oxide was incorporated into the rations at the time of feeding. Duodenal, ileal and fecal samples were used to determine extent of digestion at various sites in the digestive tract.

Trial 2

A 28-day performance trial was conducted with 45 finished Hereford heifers (1015 lb). Animals were allotted three per pen, five pens per treatment. Treatments evaluated were: 1) basal (Table 1), 2) basal + 2.5 percent $CaCO_3$ and 3) basal + 1 percent KCl. After 18 days on trial, chromic oxide was incorporated into the ration and digestibilities of dry matter and starch were determined using fecal grab samples.

Results and Discussion

Trial 1

Chemical analysis of basal diet is presented in Table 2. Digestibility in the total gastro-intestinal tract of organic matter, starch, fiber and nitrogen were not significantly changed with $CaCO_3$ or $CaCO_3$ plus $NaHCO_3$ addition (Table 3). This agrees

Table 1. Ingredient composition of basal diets for trials 1 and 2.

Ingredients	Basal diet Trial 1	Basal diet Trial 2
	--------- %	---------
Dry rolled corn	72.2	62.8
Prairie hay	20.0	—
Dehydrated alfalfa pellets	—	6.0
Cottonseed hulls	—	14.0
Soybean meal	6.4	10.0
Molasses	0.7	5.0
TM Salt	0.3	0.5
Limestone	—	0.5
Dicalcium phosphate	—	0.5
Urea	—	0.1
KCl	0.4	—
Vit. A	+	—
Vit. D	+	—

Table 2. Chemical analysis of basal diet.

Ingredient	%
Starch	52.99
Crude protein	15.13
Acid detergent fiber	14.25
Ash	5.02
Ca	0.17[a]
P	0.37
K	0.66

[a]Unsupplemented ration contained a sub-optimal Ca concentration.

with previous findings and might lead one to suggest that treatments were not altering digestive function. But when one subdivides the tract and examines digestion in the rumen, small intestine and cecum plus large intestine, a different picture emerges. Buffer supplementation greatly increased ruminal digestion of organic matter and starch. Starch digestion in the rumen was increased by over 30 percent. The further addition of 1 percent $NaHCO_3$ did not stimulate ruminal digestion of organic matter, starch, or fiber, but bicarbonate (Table 4) did increase both the flow rate of fluid into the small intestine (39 percent) and the amount of non-ammonia nitrogen (primarily protein) flowing into the small intestine (14 percent). Increased outflow of rumen contents and increased duodenal protein flow with buffers have been previously suggested by others. Since buffers increased digestion of starch in the rumen, less remained to flow to the small intestine. Thereby, more starch was digested in small intestines of steers fed the basal diet. Of the residue flowing to the small intestine, buffer addition did increase percent digestion of organic matter, starch and non-ammonia

Table 3. Influence of supplemented $CaCO_3$ or $CaCO_3$ + $NaHCO_3$ on site and extent of digestion.

Site	Basal	Basal + $CaCO_3$	Basal + $CaCO_3$ + $NaHCO_3$
Rumen		(% of total digestion)	
Organic matter	53	69	64
Starch	54	72	68
Fiber	64	70	74
Small intestine			
Organic matter	33	34	38
Starch	28	22	24
Cecum & large intestine			
Organic matter	27	11	13
Starch	18	6	8
Fiber	36	30	26
Total tract			
Organic matter	74	75	75
Starch	95	97	96
Fiber	55	54	47

nitrogen. The ability of the cecum plus large intestine to compensate for incomplete digestion in the rumen is illustrated in Table 3. With added buffers, less residue reached the cecum and large intestine. The major impact of buffers was in ruminal digestion with intestinal digestion being similar across treatments.

Previous workers have suggested that buffers decrease intestinal acidity and thereby increase the activity of starch-digesting enzymes and increase intestinal starch digestion. Activity of amylase is maximum at a pH of 6.9. Increased starch digestion with increased intestinal pH is supported by observations that lowered fecal pH may be related to a higher percentage of starch in fecal dry matter.

The influence of buffer supplementation on proximal duodenal, ileal and fecal pH is shown in Table 5. Duodenal pH was increased with added buffers. Distal ileal and fecal pH were not significantly influenced. Duodenal, ileal and fecal pH's were found to be poorly correlated. The relationship between buffer capacity (the ability of the intestinal fluid to resist a change in pH) of duodenal and ileal contents of animals fed basal and buffer supplemented diets is presented in Figure 1. Differences between treatments were small. Duodenal fluid has very little buffer capacity, but buffering capacity of ileal contents is somewhat greater. The low buffer capacity of duodenal fluid is reflected by the poor association ($r < .20$) of duodenal pH and intestinal starch digestion. Some workers have suggested that fecal pH and starch digestion are closely related. In this study, no such association was apparent. As fecal pH increased, the amount of starch digested in the small intestine decreased ($r = .71$, $P < .05$), opposite the direction proposed by others. Fecal pH, like rumen pH, reflects the type and extent of fermentation occurring as well as the dry matter content of the digesta.

Table 4. Effect on supplemental $CaCO_3$ or $CaCO_3$ + $NaHCO_3$ on digestion.

	Treatments			
	Basal	Basal + $CaCO_3$	Basal + $CaCO_3$ $NaHCO_3$	(C.V.)[a]
Intake, g/day				
Organic matter	4278	4299	4332	
Starch	2387	2387	2387	
Nitrogen	109	107	102	
Acid detergent fiber	642	704	659	
Leaving abomasum, g/day				
Chyme[b]	44	53	60	4.1
Organic matter	3003	2511	2713	1.5
Starch	1173	708	828	1.5
Acid detergent fiber	415	435	425	24.1
Non-ammonia nitrogen	118	119	134	4.9
Microbial nitrogen	41	47	46	11.7
Rumen digestion, %				
Organic matter	39	52	48	8.1
Starch	51	70	65	1.5
Acid detergent fiber	35	38	35	1.1
Leaving ileum, g/day				
Chyme[b]	21	16	21	14.2
Organic matter	1957	1417	1480	19.6
Starch	542	195	277	24.0
Non-ammonia nitrogen	45	39	42	27.0
Acid detergent fiber	434	391	426	19.3
Intestinal digestion, %				
Organic matter	35	44	45	1.4
Starch	53	73	63	6.2
Non-ammonia nitrogen	63	68	69	0.5
Cecal & large intestinal digestion, %				
Organic matter	52	37	39	
Starch	72	64	74	
Non-ammonia nitrogen	57	44	42	
Acid detergent fiber	33	18	18	

[a]Coefficient of variation, %.
[b]Liters per day.

When ruminal organic matter digestion decreases, the amount of dry matter presented to the small intestine increases. This could stress digestive capabilities of the small intestine. Do buffers increase intestinal digestion? In this study they did not. Across all three treatments, starch digestion in the small intestine, as a percentage of that in the total tract, was similar, ranging from 22 to 28 percent (the higher value representing the unbuffered diet). What other variables account for the variation in small intestinal starch digestion? Particles spend only 3 to 4 hours in the small intestine,

Table 5. **Influence of supplemental $CaCO_3$ or $CaCO_3$ + $NaHCO_3$ on proximal duodenal, distal ileal and fecal pH.**

Site	Treatment			
	Basal	Basal + $CaCO_3$	Basal + $CaCO_3$ $NaHCO_3$	(C.V.)
		pH		%
Proximal duodenum	2.84	3.48	3.53	4.9
Distal ileum	6.98	6.87	7.05	0.7
Feces	5.94	5.85	6.16	5.5

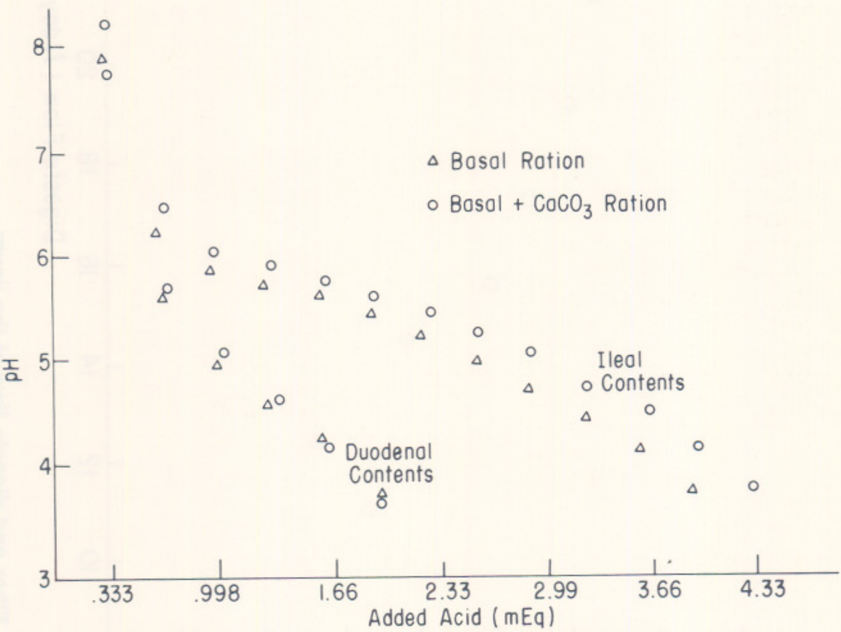

Figure 1. Buffer capacity of duodenal and ileal contents.

compared with over 24 hours in the rumen and 18 to 24 hours in the cecum plus large intestine. In this study, as ileal flow rate increased, digestibility of starch in the small intestine decreased. The volume of flow was closely related to the fiber content of the fluid (Figure 2). As passage of fiber to the small intestine increased, the flow of chyme (fluid contents) at that segment increased. This suggests that fiber flow through the

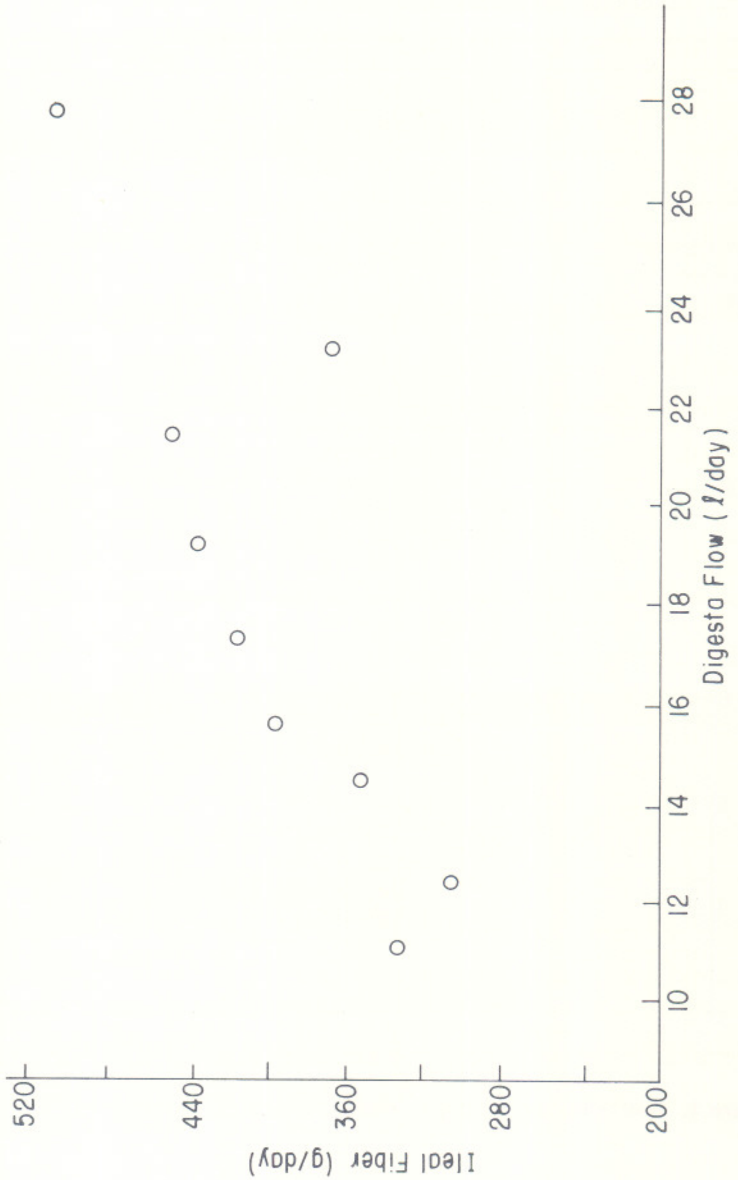

Figure 2. Fiber and digesta flow at the ileum.

small intestine, which is the product of fiber intake and fiber digestion in the rumen, may affect the passage rate of chyme in the small intestine and, thereby, digestibility in the small intestine. This concept is supported by another study (Influence of Roughage Level and Level of Intake on Digestive Function) reported elsewhere in this publication.

Since the small intestine in the ruminant has a limited capacity for starch digestion, the compensatory role of fermentation in the cecum plus large intestine is important for digestion of starch. Two points must be stressed from this study: 1) the major direct effect of buffers used in this trial was in the rumen, 2) large differences in site of digestion may occur without altering the extent of digestion in the total tract.

Trial 2

The influence of supplemental KCl and $CaCO_3$ on ration digestibility and animal performance is presented in Table 6. Potassium chloride can be considered a potential buffer, since the potassium is readily converted to potassium bicarbonate in the rumen. As compared with potassium carbonate or bicarbonate, the chloride will not elevate urinary pH. Feed efficiency and daily gains favored the buffer-supplemented diets. The ration with added KCl had greater digestibility than the $CaCO_3$-supplemented ration. The superiority of potassium salts over other buffers in reducing incidence of sub-acute and acute digestive disturbances has been reported previously. Further, potassium has increased digestibility in *in vitro* in some trials. Nevertheless, results from this trial must be regarded as exploratory. Current trials are under way to examine the influence of potassium on site and extent of digestion.

Table 6. Heifer performance results.

Item	Treatments: Control	Control + 2.5% $CaCO_3$	Control + 1% KCl	(C.V.) %
Pens	5	5	5	
Dry matter intake, lb/day	23.8	23.2	22.8	4.8
Dry matter digestibility, %	75.2[ab]	72.6[a]	78.2[b]	5.1
Starch digestibility, %	95.5	96.2	96.8	1.8
Average daily gain, lb/day	3.1	3.3	3.3	16.9
Feed to gain ratio	7.7	7.0	6.9	15.7

[ab]Means in a row with different superscripts differ statistically ($P<.05$).