Effect of Ruminal pH Alteration on Digestion in Steers Fed a High Concentrate Diet

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Story in Brief

Mature Angus steers were intraruminally infused with base to increase ruminal pH. Base infusions, increasing rumen pH from 5.8 to 6.2, did not change duodenal pH but tended to reduce fecal pH. Increased ruminal pH tended to increase digestion of fiber (9 percent) but reduced ruminal digestion of starch by 18 percent ($P > .05$). Ruminal pH and ruminal starch digestion were negatively correlated ($P < .05$). Rate of passage of fluid and particulates tended to be faster with base infusion. Results suggest that rumen pH alters digestion of dietary constituents and digesta kinetics.

Introduction

Grain addition to high roughage diets increases lag time and reduces extent of fiber digestion. Explanations include decreased activity of the enzyme cellulase, shifts in microbial strains or metabolism and preferential attack of more readily degradable substrates. Decreased rumen pH with added grain may be the cause of some of these changes. Ruminal buffers, elevating pH, have sometimes alleviated depressed fiber digestibility.

Increasing rumen pH with buffer infusions have altered volatile fatty acid molar proportions and increased feed intake (Esdale and Satter, 1972; Fulton et al., 1979). However, control animals often have not received infusions of similar minerals. Activity of starch-digesting enzymes decreases with pH in the intestine, but little information is available on enzyme levels or activity for starch digestion in the rumen. Rate of protein degradation, like fiber digestion, is faster with high roughage diets. Such diets produce faster fluid passage rates and lower ruminal acidity than high concentrate feeds. Whether diet composition, pH or passage rate differences are responsible for these effects has not been determined. This study examined the influence of ruminal pH on ruminal and total tract digestion with a high concentrate diet.

Experimental Procedure

Four mature Angus steers (1,094 lb), fitted with permanent ruminal and duodenal cannulas, were used in a switchback design. Steers in metabolism stalls were fed a 90 percent concentrate diet (Table 1) four times each day (0500, 1100, 1700 and 2300 hr) at 1.2 percent of body weight (dry matter). Steers

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Table 1. Diet composition

Ingredient	%[a]
Dry rolled corn	73.0
Ground alfalfa hay[b]	10.0
Soybean meal	10.0
Molasses	5.0
Trace mineral salt	.5
Vitamin supplement	.2
$CaCO_3$	.8
$CaHPO_4$	.2
Urea	.1
Cr_2O_3	.2
Composition	**%**
Dry matter	87.4
Ash	6.7
Crude protein	16.6
Starch	41.4
Acid detergent fiber	7.2

[a] Dry matter basis.
[b] Ground through a 3/8 inch screen.

were continuously infused intraruminally with approximately 1 quart of base or salt solution per day. Ruminal fluid samples taken before trial initiation were analyzed for Na and K concentrations to infuse base without disturbing the Na to K ratio. The base solution consisted of 1.58 M NaOH plus .19 M KOH while the salt solution contained isomolar amounts of Na and K as chloride salts.

Steers were infused with the highest concentration of buffers and salts a minimum of 5 days before collections and sampling periods lasted four days. On the first day of collection, steers were fed corn labelled with a metal (Yb) and dosed with another marker which follows fluids (Co-EDTA). Ruminal fluid volume and dilution rate and particulate passage rate were calculated from these markers. Samples from the rumen, the start of the small intestine (duodenum) and the rectum were taken and pH, ammonia, fiber, starch and markers were measured in appropriate samples.

Results and Discussion

Mean rumen pH (Table 2) was higher with base infusion as expected. The difference was greater at 1 hr (6.13 and 5.58) than 3 (6.23 and 5.89) and 5 hr (6.27 and 5.90) after feeding. This may be due to more rapid fermentation rate shortly after feeding. It is interesting that the large amount of base infused increased pH by only .4 units. Duodenal pH tended to be higher at 1 hr postfeeding for base infused animals, but not at 3 or 5 so that overall, base infusion did not alter duodenal pH. More rapid starch digestion and volatile fatty acid production in salt receiving steers might be reflected in

Table 2. Ammonia and pH measurements.

Site	Item	Treatment Base	Salt	Significance
Rumen	pH	6.21	5.81	.07
Rumen	NH_3, mg/dl	22.9	17.5	NS
Duodenum	pH	2.26	2.27	NS
Rectum	pH	6.20	6.40	.21

duodenal pH in the early hours following meal consumption. Bicarbonate feeding does not alter duodenal pH but added limestone has been reported to cause an increase. Time postfeeding may have influenced present results.

Rumen NH_3 concentrations (Table 2) were greater with base infusion, although, these differences declined with time after feeding. Results could imply a faster rate of degradation of protein or faster ammonia uptake by ruminal microbes. Absorption should remove more ammonia from the rumen at a higher pH. However, rumen fluid flow rates were 1.5 vs 1.6 liters per hour for the base and salt treatments, respectively. Increased ruminal protein breakdown with roughage diets and higher ruminal pH has been observed previously, but other factors, such as passage rate and various dietary characteristics may be important as well. Ruminal nitrogen digestion will be estimated when microbial contributions are estimated.

Organic matter digestibilities (Table 3) in the rumen and the total tract were not altered by base infusion, although rumen digestion of acid detergent fiber tended to increase with base infusion. This difference was smaller in the total tract fiber digestibility, implying that the large intestine and cecum were compensating for reduced digestion in the rumen. Increased fiber digestion with dietary sodium bicarbonate is often observed and these bases are soluble in rumen fluid like bicarbonate. Since roughage level was low (10 percent) and particle size small (<3/8 inches), one would not except large numbers of celluloytic organisms in the rumen with either treatment.

Table 3. Digestibility, %

Item	Site	Treatment Base	Salt
Organic matter	Total tract	75.6	77.1
	Ruminal[a]	31.6	32.3
	Postruminal	44.0	44.8
Starch[b]	Total tract	88.6	91.8
	Ruminal	49.8	60.5
	Postruminal	38.8	31.5
Acid detergent fiber[b]	Total tract	51.5	47.2
	Ruminal	43.0	35.2
	Postruminal	8.5	12.0
Crude protein[b]	Total tract	66.7	70.0

[a] Not corrected for passage of microbial organic matter.
[b] Dry matter basis.

Total tract starch digestion (Table 3) was similar for base and salt infused steers. However, ruminal digestion tended to be lower for the base treatment. No similar ruminal starch digestion estimates have been found, but trends for lower total tract starch digestion with $NaHCO_3$ have been reported (Erdman et al., 1982; Rogers and Davis, 1982). Both investigations employed ad libitum intakes and 50 to 60 percent concentrate diets. Unlimited feed consumption confounded their digestibility measurements but have more direct application than our intake level of 1.2 percent of body weight. Reduced compensatory intestinal digestion of starch with high intakes could cause reduced ruminal starch digestion to be reflected through the total tract. In addition, higher roughage levels should cause 1) greater numbers of fiber digesting microbes to be present in the rumen and 2) an increased flow rate through the small intestine. More cellulose digesting microbes may have been responsible for the increase in fiber digestion with bases and buffers and shifts from ruminal starch to fiber digestion. Fast passage would reduce capacity of the intestine to digest starch in the other experiments. With limited intake of our study, greater quantities of starch reaching the hindgut in base infused steers may have stimulated microbial fermentation in the large intestine which increased acid production to lower ($P<.21$) fecal pH. A closer relationship was noted between rumen pH and ruminal starch digestion ($r = -.82$; $P<.05$) than with ruminal fiber digestion ($r = .55$; NS). As pH increased, trends for decreased ruminal starch digestion and increased ruminal fiber digestion were noted; hence, ruminal starch digestion was inversely related to ruminal fiber digestion ($r = .70$; $P<.13$).

Fluid passage rate (Table 4) was faster ($P<.08$) in steers infused with base while rumen fluid volume tended to be reduced. Infusions of base and salt should have affected ruminal osmotic pressure to the same degree and changed fluid passage similarly. Since ruminal digestibilities differed, this would alter digesta composition which could influence ruminal mixing and stratification in the rumen. Greater particulates present may have reduced ruminal fluid space, although, at this low intake level, gut capacity is not likely to be a limiting factor.

Particulate dilution rate tended to be faster for steers infused with hydroxides. Diet particle size was small so that sufficiently hydrated particles in the proper position could flow from the rumen. The trend for decreased starch digestion (18 percent) with added base could be an indirect result of reduced time for ruminal digestion. Rumen particulate turnover time was decreased from 41 to 30 hours with base infusion. But, extent of ruminal fiber digestion tended to be greater for the base treatment despite a shorter time for ruminal digestion. Possible explanations for the increased solids flow in the base treatment may include 1) an increased rate of fiber digestion positively affecting corn particle hydratability and thereby enhancing positioning for rumen exit,

Table 4. Digesta kinetics

Item	Treatment	
	Base	Salt
Particulate passage rate, %/hr	3.37	2.44
Fluid passage rate, %/hr	5.92	4.80
Fluid volume, liters	25.2	34.1

2) infusion interactions with the particulate marker and 3) adjustment of salivation in response to gastrointestinal pH receptors. Since trends for decreased ruminal starch digestion in steers receiving base could result either from altered passage rates or pH or a combination, further work is necessary to investigate pH effects on rate of digestion and passage and their interrelationships using different diet types and intake levels.

Literature Cited

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