ROLLED VERSUS WHOLE CORN: EFFECTS ON RUMINAL FERMENTATION OF FEEDLOT STEERS

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Story in Brief

The differences between rolled (2 particle sizes) and whole corn on ruminal fermentation were investigated using three ruminally fistulated steers given ad libitum access to 92% concentrate diets. At feeding time (24 h after fresh feed was last provided), steers fed whole corn tended to have the lowest ruminal pH and the highest total VFA concentration. However, 4 and 12 h later, ruminal pH was lower and VFA concentrations tended to be higher when steers received corn with the smaller particle sizes. Lactate concentration was highest 4 h after feeding finely rolled corn. The ratio of acetate to propionate was greater with corn with larger particle size at both 4 h and 12 h post feeding. In a companion growth trial, steers fed whole corn grew faster and more efficiently, the diet that yielded the lowest ruminal VFA concentration and the lowest proportion of propionate. Hence, higher total VFA concentrations and higher propionate percentages were not predictive of improved feedlot efficiency. Other factors such as metabolic disorders and small intestinal starch digestion may play a greater role than fermentation pattern in determining efficiency of feed use. Despite providing these steers with ad libitum access to feed, ruminal pH, total VFA concentrations and propionate percentages changed drastically with time after feeding, especially with processed corn. Effects of such wide swings in fermentation on feed intake and rate and efficiency of gain need further attention.

(Key Words: Corn grain, Grain Processing, Steers, Ruminal Fermentation.)

Introduction

By influencing the site and extent of digestion, corn processing can alter performance of feedlot steers (Hale, 1973; Turgeon et al., 1983; Secrist et al., 1995). Digestion of starch from smaller particles is faster and more complete both in the rumen and in the total digestive tract (Waldo, 1973) and increased ruminal digestion usually leads to higher total tract digestion of starch (Hale, 1973). However, energetic efficiency may be greater for starch digested in the small intestine than starch fermented in the rumen (Owens et al., 1986). Compared with finely ground, flaked or high moisture corn, dry corn fed whole and coarsely processed increases flow of starch to the small intestine (Galyean

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et al., 1979). Compared with rolled corn, whole corn may produce superior feedlot gain and efficiency (Owens et al., 1995). Because whole corn is fermented in the rumen slower than processed corn ruminal fermentation, one would expect that meal-fed animals would have variable concentrations of ruminal end-productions, especially when fed rapidly fermented grain. However, with steers given ad libitum access to feed, one might expect ruminal conditions to be relatively stable over time. This experiment was designed to examine the effects of dry corn processing method (rolled to two particle sizes vs whole) onruminal fermentation by growing steers.

Materials and Methods

Three yearling beef steers (900 lb) fitted with permanent ruminal cannulas were housed individually in partially covered pens with slatted floors and cement fenceline feedbunks. Diets (Table 1) containing corn grain of three corn particle sizes (fine rolled, coarse rolled, and whole corn) were compared in a replicated 3 x 3 Latin square. Geometric mean particle size, analyzed at a commercial lab by the method of Ensor et al. (1970), are reported in Table 2. All diets were available to steers for ad libitum consumption. Pellets based on cottonseed hulls containing chromic oxide were fed daily to provide each steer with 10 g chromic oxide daily. Following a 7 d adaptation, ruminal and fecal samples were obtained at feeding and at 4 h and 12 h after fresh feed was provided. Feed remaining in the bunk was weighed and returned to the bunk at each sampling time.

Ruminal samples were strained through four layers of cheese cloth and pH was measured immediately. Volatile fatty acids were analyzed gas chromatographically and D- and L-lactate (both D and L isomers) were analyzed spectrophotometrically.

Fecal grab samples were taken per rectum from each steer at each sampling and composited across time but within sampling day and animal. Fecal samples were dried, ground through a 2 mm screen, and analyzed for starch, protein, purine content and chromium concentration. Total tract and starch digestibility were calculated.

Results and Discussion

Intakes, ruminal measurements, digestibilities, and fecal concentrations of nutrients are summarized in Table 2. Particle size did not alter either total tract digestibility (organic matter or starch) or fecal concentrations of starch, protein or purines. Feed intake tended (P=.08) to respond quadratically being lowest for coarsely rolled corn. Ruminal pH for steers fed whole corn (Figure 1) changed very little over time when compared with ruminal pH of steers fed finely or coarsely rolled corn. Steers fed whole corn consistently maintained a ruminal pH above 6.0 whereas pH of steers fed finely or coarsely rolled corn dropped drastically during the 12 h sampling period. Ruminal pH tended (P=.06) to respond linearly at the time fresh feed was provided (equal to 24 h since the last feeding) with finer particles producing the highest pH. Again at 12 h after feeding, a linear relationship between particle size and pH was evident but the slope of the line was completely opposite with finely rolled grain producing the lowest pH.

Concentrations of total ruminal VFA (Figure 2.) were inversely related to ruminal pH. Concentrations for steers fed whole and coarsely rolled corn were similar but higher than for steers fed finely rolled corn (linear effect, P=.07). Four hours after feeding, steers fed the smaller particles had numerically higher VFA concentrations, and by 12 h after feeding, total VFA were greater for steers fed finely and coarsely rolled corn than for those fed whole corn (linear effect, P<.01).

At the time of feeding, acetate and propionate proportions and lactate (D and L) concentration were not altered by particle size of grain being fed. Butyrate concentrations tended to remain consistently higher for steers fed whole corn. At both 4 and 12 h after feeding, the propionate proportion and the acetate:propionate ratio was greater for steers fed finer particles levels. At 12 h after feeding, the proportion of acetate was lower for steers fed whole corn. Lactate concentration at 4 h after feeding tended (P=.10) to be greater with the finely rolled grain as shown in Figure 3. At other sampling times, lactate concentration was not altered by the particle size of the corn being fed.

In this study, the finely processed corn (vs whole corn) produced lower ruminal pH, more lactate and a higher ruminal concentration of total VFA of which a higher proportion is made up of propionate. This implies that both rate and extent of ruminal fermentation probably increased as particle size was reduced. The higher propionate levels should increase ruminal efficiency by decreasing methane losses. Combined with the lower acetate:propionate ratio, ruminal measurements indicate that energetic efficiency should be best for steers fed the finely rolled corn; that is opposite from the results of the feeding trial with these grains reported elsewhere in this publication. Hence, predicting efficiency from ruminal measurements is imprecise at best. The observation that total tract organic matter and starch digestibility was not improved by processing the grain implies that these steers were chewing their food satisfactorily to achieve a reasonably high extent of digestion.

Despite having ad libitum access to feed, wide fluctuations in pH with time after fresh feed was provided indicates that these steers were consuming large meals and not nibbling throughout the day as might be expected. And with larger meals, much more fluctuation in pH was found with processed than with whole grain, both due to rate of fermentation and to less input of saliva during eating and rumination. How fluctuations in ruminal conditions may alter efficiency both in the rumen and metabolically remains to be determined.

Implications

Compared with feeding corn as whole kernels, rolling corn resulted in greater fluctuation in ruminal pH and VFA concentrations and a higher proportion of propionate in the VFA. Although that would be expected to improve feed efficiency, performance data from the companion trial discussed elsewhere report) indicates the reverse, namely that feed efficiency is superior with whole corn diets for steers fed ad libitum. Whether the benefit from feeding corn whole is due to decreased ruminal and metabolic stress from more steady-state ruminal conditions or to greater flow of digestible starch to the small intestine is not yet known. Although higher VFA concentrations and propionate proportions often are used as indicators of greater value of a diet, a processing method or a feed additive, they both presumably reflect a greater rate of fermentation. For the animal, total extent of digestion, not simply rate of fermentation should be most closely related to production, and an excessive rate of fermentation, as can be obtained with gelatinized grain, may adversely impact efficiency. Diurnal fluctuations both in ruminal conditions and in nutrient supply may be deleterious to ruminal health and to metabolic efficiency.

Literature Cited

Ensor, W. L. et al. 1970. J. DairySci. 53:689.

Galyean, M. L. et al. 1979. J.Anim. Sci. 49:204.

Hale, W. H. 1973. J.Anim. Sci. 37:1075.

NRC. 1984. Nutrient Requirements of Beef Cattle (6th Ed.). National Academy Press, Washington, DC.

Owens, F. N. et al. 1986. J.Anim. Sci. 63:1634.

Owens, F. N., D. S. Secrist, and D. R. Gill. 1995. Proc. Symp. Intake by feedlot cattle. Okla.Agr. Exp. Sta. P-942:235.

Secrist, D. S. et al. 1995. Okla.Agr. Exp. Sta. MP-943:99.

Turgeon, O. A. et al. 1983. J.Anim. Sci. 57:739.

Waldo, D. R. 1973. J.Anim. Sci. 37:1062.

Table 1. Diet and calculated nutrient composition (% of DM).

Ingredient	% of diet dry matter
Dry corn	82.05
Cottonseed hulls	8.00
Soybean meal	4.00
Cottonseed meal	4.00
Limestone	1.00
Urea	.60
Salt	.30
Manganous oxide	.004
Copper sulfate	.001
Zinc sulfate	.002
Vitamin A-30	.01
Rumensin-80	.017
Tylan-40	.013
Nutrient content., dry matter basis[a]	
NEm, Mcal/cwt	95.0
NEg, Mcal/kg	60.0
Crude protein, %[b]	13.4
Potassium, %[c]	.57
Calcium, %[c]	.44
Phosphorus, %[c]	..32
Magnesium, %	.16
Cobalt, ppm	.01
Copper, ppm	8.5
Iron, ppm	51.5
Manganese, ppm	44.0
Selenium, ppm	.17
Zinc, ppm	34.9

[a] NRC (1984).
[b] Based on Kjeldahl analysis of individual feeds.
[c] Analyzed by Servi-Tech Laboratories, Dodge City, KS.

Table 2. The effects of corn particle size onruminal pH, VFA and Lactate and fecal nutrientcontent of steers: linear (L) or quadratic (Q) effects.

Item	Fine roll 1550µm	Coarse roll 3100µm	Whole 1500µm	SEM	P=
Total DMI, kg	10.7	9.4	11.2	.83	Q, .08
Pre-feeding					
pH	6.47	6.20	6.16	.14	L, .06
Acetate, %	50.2	47.7	48.2	2.29	Q .40
Propionate, %	40.3	43.5	37.3	3.07	Q, .14
Butyrate, %	9.5	8.8	14.5	2.59	Q, .06
L-lactate, mg/dl	4.17	4.58	5.33	1.22	L, .35
D-lactate, mg/dl	.58	1.83	1.92	1.31	L, .37
Acetate:propionate	1.25	1.11	1.41	.16	Q, .18
Total VFA, mM	91.17	137.45	138.75	21.70	L, .07
Four h post-feeding					
% of total DMI	49.5	65.7	49.4	14.90	Q, .24
pH	5.60	5.78	6.06	.17	L, .01
Acetate, %	45.1	44.8	47.6	2.70	L, .34
Propionate, %	45.5	46.2	36.4	3.52	L, .02
Butyrate, %	9.3	9.0	15.9	2.81	L, .03
L-lactate, mg/dl	24.08	4.83	4.00	10.18	L, .10
D-lactate, mg/dl	17.08	.50	.75	8.21	L, .10
Acetate:propionate	1.00	.99	1.45	.18	L, .02
Total VFA, mM	161.85	161.45	146.49	13.00	L, .24
Twelve h post-feeding					
% of total DMI	91.4	92.5	87.3	5.7	Q, .61
pH	5.42	5.67	6.20	.18	L, .01
Acetate, %	42.4	42.1	48.4	1.61	L, .01
Propionate, %	47.7	46.4	33.7	3.46	L, .01
Butyrate, %	9.9	11.5	17.9	3.45	L, .04
L-lactate, mg/dl	4.67	4.17	4.83	.63	Q, .33
D-lactate, mg/dl	1.50	.58	2.67	1.24	Q, .24
Acetate:propionateo	.90	.93	1.57	.15	L, .01
Total VFA, mM	176.82	167.76	133.79	9.42	L, .01
Fecal starch, %	18.3	18.8	18.8	1.9	L, .79
Fecal protein, %	16.8	15.6	17.6	.94	L, .39
Fecal purine, %	18.9	17.0	14.8	2.0	L, .50
OM digestibility, %	78.5	77.8	79.4	2.8	Q, .69
Starch digestibility, %	94.5	93.9	94.4	1.1	Q, .57

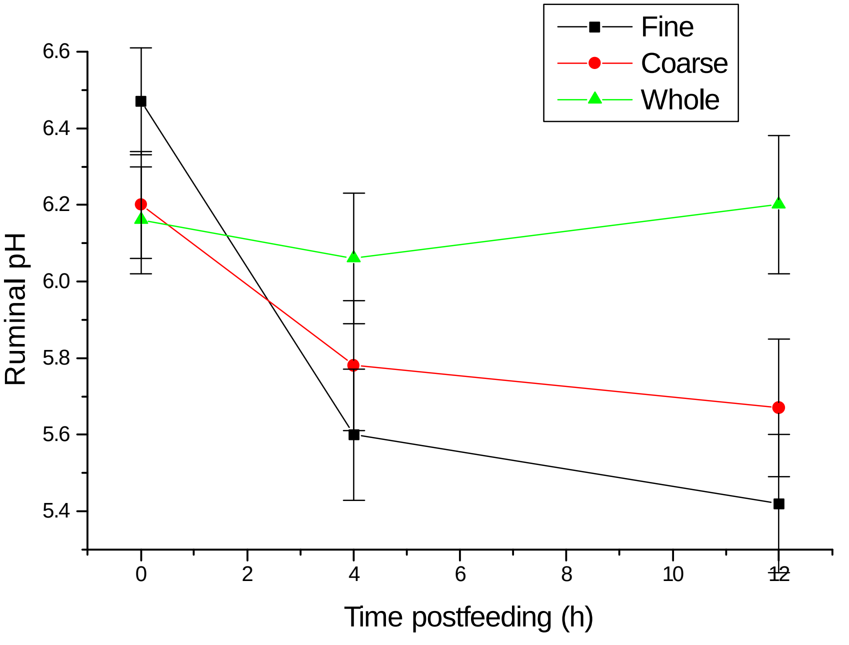

Figure 1. Effects of corn particle size on ruminal pH.

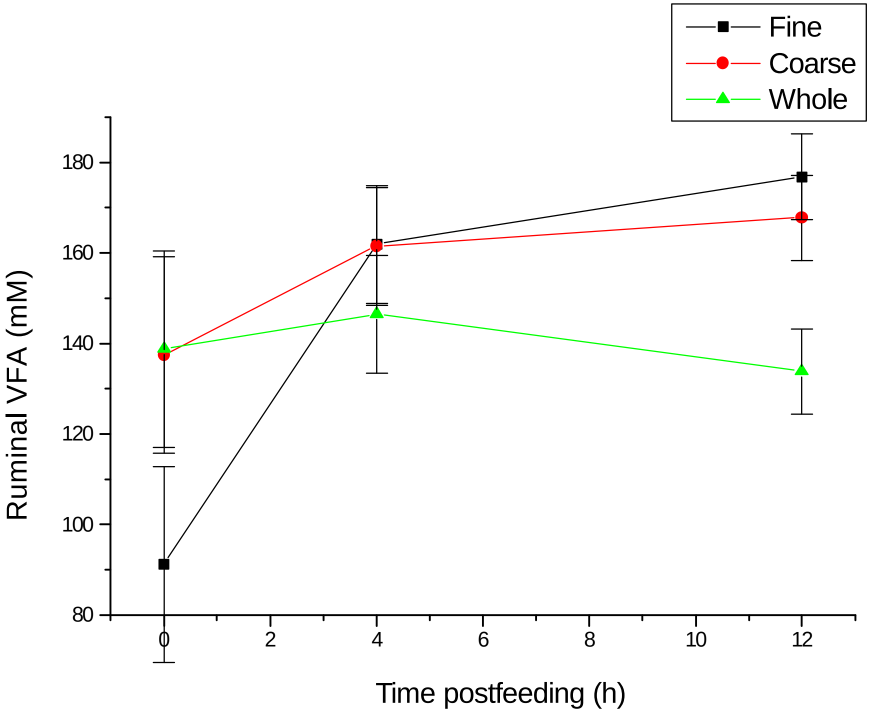

Figure 2. Effects of corn particle size on total ruminal VFA concentration.

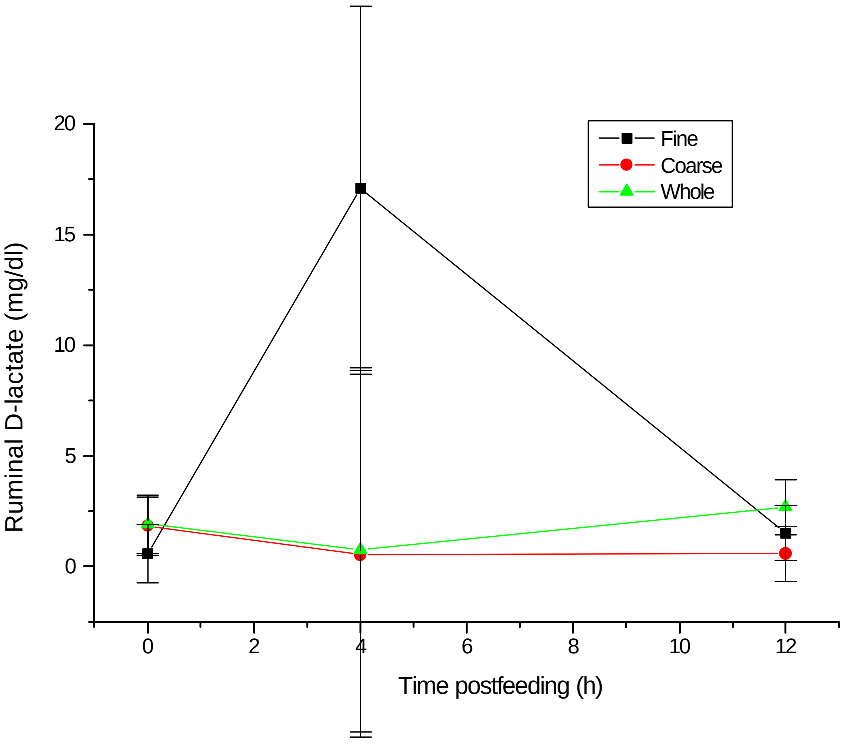

Figure 3. Effects of corn particle size on ruminal D-lactate concentration.