EFFECTS OF GRINDING CORN AND HAY ON SITE OF DIGESTION OF HIGH CONCENTRATE DIETS BY BEEF HEIFERS

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Story in Brief

Corn grain was fed whole or ground with prairie hay which was either coarsely chopped, ground through a 1.5 inch screen, or ground through a 1/6 inch screen to cannulated beef heifers (707 lb). Ruminal pH and buffering capacity were greater for whole than ground corn at 2 and 6 hours after feeding reflecting greater saliva flow with the whole corn diets. Passage rate of corn particles from the rumen tended to be lower for whole than ground corn but increased with particle size of the roughage. Long hay had different effects with the two forms of corn. With whole corn, coarser hay increased ruminal digestion of organic matter, starch, protein and fiber but decreased postruminal digestion of organic matter and starch. Effects of long hay on digestion of ground corn were opposite those with whole corn. To increase postruminal supply of starch from ground corn, increasing roughage level or length to the point that intake of energy is depressed may be advantageous. With whole corn, long hay reduced postruminal starch digestion, so lower roughage levels and grinding the roughage should be more useful.

(Key Words: Corn, Roughage Processing, Site of Digestion, Cattle.)

Introduction

Corn and roughage are commercially processed to various degrees. If corn is fed without processing (whole), lower roughage levels are generally recommended as whole corn kernels have an abrasive "roughage effect" in the rumen. Also, high intake of roughage may elevate outflow of intact grain from the rumen. Whole corn and large particles which escape from the rumen are not digested in the intestines. How roughage processing shifts site of digestion between the rumen and intestines is not known. Feed efficiency with whole corn has been superior to flaked corn in some studies (Gill et al., 1980; Lee et al., 1982) but as much as 13 percent inferior in other studies (Lee et al., 1982) for an overall average of 8 percent poorer feed efficiency for whole than steam flaked corn (Hale and Prouty, 1980). Level and type of roughage may be involved. In metabolism trials, source and level of roughage can alter total tract starch digestibility from whole corn (Teeter et al., 1980; Rust and Owens, 1982) though reasons for these effects remain unknown.

Shifting digestion from the rumen to the small intestine may improve energetic efficiency since heat and gas losses in the rumen are reduced, but the quantity of starch which can be digested in the small intestine may be limited. The objective of this study was to determine

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the effect of roughage processing on digestion and passage rate of two forms of corn in 85 percent concentrate diets fed to beef heifers.

Materials and Methods

Six cannulated Hereford x Angus heifers (707 lb) were fed a diet composed of corn (72 percent), prairie hay (15 percent), soybean meal (10 percent), molasses (1.45 percent), limestone (.75 percent), trace mineralized salt (.5 percent) and chromic oxide (.3 percent). Corn was fed whole (W) or ground in a hammermill through a 1/8 inch screen (G), while prairie hay was chopped in a hammermill without a screen (long, L), ground through a 1.5 inch (medium, M) or a 1/6 inch screen (Short, S). The six combinations of corn and hay, designated as GS, GM, GL, WS, WM and WL, were each fed to each of the six heifers in different periods. Heifers were fed equal amounts of feed at 0700 and 1900 hours for a total daily dry matter intake of 1.65 percent of body weight.

Feeding periods lasted 14 days with sampling of the rumen, duodenum and rectum the final 4 days of each period. Samples were analyzed for dry matter, ash, nitrogen (N), starch, acid detergent fiber (ADF), nucleic acid-N, ammonia-N, pH, buffering capacity, chromium and passage rate markers.

Results and Discussion

Ruminal pH was higher for heifers fed whole than ground corn at 2 and 6 hours after feeding (Table 1) whereas duodenal pH was lower for whole than ground corn. Ruminal differences with processing corn grain matched the results of Lee et al. (1982). Fecal pH tended to be lower for ground than whole corn. Roughage type did not affect pH in the rumen, duodenum or rectum. Ruminal ammonia-N concentration in ruminal fluid was similar for all diets.

Ruminal buffering capacity between pH 7 and 5.5 was greater for heifers fed whole than ground corn 2 h after feeding. This may reflect a longer meal and greater mastication with whole corn which would increase flow of saliva and increase ruminal input of buffer from saliva. Slower fermentation of whole than ground corn prevents rapid volatile fatty acid production in the early hours after feeding. Roughage form did not affect buffering capacity at 2 hours, implying that increasing length of dietary roughage may be ineffective to prevent ruminal acidosis. As some of the ruminal buffering is due to the hay present in rumen, an additional amount of hay in the diet should increase rumination which would help prevent acidosis.

At 10 hours postfeeding with ground corn diets, despite small pH differences, buffering capacity was lower for medium and short hay than for long hay which may reflect direct or indirect effects of retained roughage on buffering capacity. But effects of hay particle length on buffering with whole corn diets were opposite those with ground corn.

Nucleic acid-N content of isolated bacterial cells isolated from the rumen was similar for all diets (Table 1) but nitrogen content was greater for WM than for WS and GM diets, and for WL than WS. Ruminal fluid liquid dilution rate was not affected by form of corn or roughage (Table 1). Feeding long prairie hay tended to elevate ruminal volume with ground corn but depress ruminal volume with whole corn. The lower the digestibility of ADF in the rumen, the greater the ruminal volume, possibly due to the fluid imbibed by the roughage.

Table 1. Ruminal pH, isolated bacterial cell composition and passage rate data.

Corn form	Ground			Whole		
Hay form	Ground	Medium	Long	Ground	Medium	Long
Ruminal pH, h after feeding						
2	6.18	6.05	6.20	6.47	6.33	6.43
6	6.28	6.17	6.39	6.47	6.42	6.57
10	6.69	6.37	6.80	6.63	6.53	6.65
Bacterial cell composition						
Nucleic acid-nitrogen,						
% of dry matter	1.50	1.38;	1.47	1.51	1.85	1.62
% of total nitrogen	21.0	21.9	22.2	25.8	23.6	21.9
Nitrogen, % of dry matter	6.86^{abc}	5.95^{ab}	6.60^{abc}	5.89^{a}	7.67^{c}	7.17^{bc}
Ruminal fluid dilution rate, %/h	10.8	9.0	10.0	11.0	10.1	10.4
Ruminal fluid volume, liters	44.9	46.7	62.5	46.5	46.3	40.9
Particulate passage rate, %/h	3.5	3.7	4.0	2.9	3.4	3.5

^{abc}Means in a row with differnt superscripts are different.

Passage rate from the rumen was faster ($P<.07$) for ground than whole corn (Table 1). This may be due to differences in density. Settling causes whole grain to be retained in the rumen. Filtration and rejection of coarse particles at the exit point from the rumen also would increase retention time in the rumen. Increasing particle size of hay tended to elevate passage rate of corn particles and shifted digestion from the rumen to the intestines with ground but not with whole corn (Table 2). Passage rate of particles was negatively related to extent of starch digestion in the rumen with diets of ground ($r = -.45$; $P<.06$) but not whole corn. This suggests that more rapid flushing of corn particles through the rumen reduced ruminal starch digestion of ground corn. The increase in passage rate with long hay may be attributable to increased saliva input, but if so, fluid dilution rate should have been elevated. Another explanation would be that long roughage occupies more space in the rumen during and after feeding. This could reduce ruminal space for concentrate and force more rapid exit of concentrate particles from the rumen. Long hay also would have reduced ruminal mixing and thereby increased ruminal exit of the ground grain after a meal as noted previously with low quality range forage (Johnson et al., 1981).

Extent of ruminal digestion of organic matter (OM) with fine and medium ground hays were similar, but both were greater with ground than whole corn. Long hay reduced ruminal digestion of OM with ground corn but increased ruminal digestion with whole corn. Postruminal digestion compensated for differences in ruminal digestion except with the whole corn-long hay diet. Had feed intake or dietary roughage level been higher, postruminal digestion might have been compromised as larger digesta particles would reach the small intestine and accelerate rate of intestinal passage.

Ruminal starch digestion was not altered by roughage form with ground corn (Table 2), but with whole corn, ruminal starch digestion increased with larger size roughage. Total tract starch digestion was lower for whole than ground corn as is often observed. Postruminal starch digestion, as a percentage of intake or of flow to the intestines was lower for whole than ground corn and, with whole corn, was lowest for the long hay as has been noted previously (Lee et al., 1982; Aguirre et al., 1984).

Intestinal digestion with high grain diets often is limited by size and surface area of particles exiting the rumen. Lower postruminal digestion of starch from whole than for ground corn suggests that size of corn particles leaving the rumen was larger with whole than ground corn diets. Grain processing enhanced both ruminal and intestinal digestion of starch reaching the duodenum. Particle size of grain may be more important for starch digestion in the intestines than in the rumen, at least with limited feed intake. In addition, dietary roughage passing from the rumen may reduce intestinal digestion of starch with high concentrate diets. Again roughage source and level may alter this effect. Although longer hay increased ruminal digestion of both starch and fiber when fed with whole corn, fiber particles passing to the intestines may have been longer and elevated passage rate of digesta through the intestines to depress starch disappearance. Rate of passage through the small intestine in another study was accelerated by adding hay but not by adding cottonseed hulls to the diet.

Ruminal disappearance of feed protein was higher and postruminal disappearance of input N was lower for long than short or medium forms of hay with ground corn. Opposite trends were noted for whole corn diets. Treatment effects on ruminal, postruminal and total N

Table 2. Digestion measures.

Corn form	Ground			Whole		
Hay form	Ground	Medium	Long	Ground	Medium	Long
Organic matter digestion						
Apparent ruminal, % of intake	54.6	53.6	45.5	40.9	42.3	59.6
True ruminal, % of intake	63.0	62.3	53.8	52.3	49.9	66.6
Postruminal, % of intake	26.7	26.1	35.3	37.1	36.2	21.2
Postruminal, % of available	56.4	53.3	61.7	59.8	59.0	45.1
Total tract, % of intake	81.3	79.7	80.8	77.9	78.5	80.8
Starch digestion						
Ruminal, % of intake	67.5	62.6	62.8	52.7	61.3	68.4
Postruminal, % ofintake	27.5	31.5	30.8	34.9	28.3	19.3
Postruminal, % of available	82.5	80.7	78.3	68.9	67.4	43.4
Total tract, % of intake	93.6	91.2	92.2	86.8	86.6	83.7
Nitrogen						
Passage, g						
Intake	103.2	101.1	103.4	99.7	102.9	108.4
Entering duodenum						
Total	95.1	85.9	108.7	109.9	119.9	84.4
Microbial	34.4	27.0	34.0	37.4	34.0	29.1
Feed	54.8	54.1	67.6	64.7	79.4	49.4
Exiting rectum	30.2	30.5	30.1	31.3	31.8	28.1
Digestion						
Ruminal, % of intake	45.7	46.6	34.1	32.3	24.1	55.0
Postruminal, % of intake	25.0	23.6	36.3	35.5	44.1	18.4
Postruminal, % of available	67.0	64.2	71.3	70.5	71.7	62.4
Total tract, % of intake	70.7	70.2	70.4	67.7	68.2	73.5
Ruminal acid detergent fiber digestion, %	61.7	46.4	40.6	29.8	53.2	63.5
Microbial efficiency, g microbial nitrogen/kg organic matter fermented	10.8	8.5	13.0	17.0	16.3	9.7

disappearance resemble those observed for organic matter. Digestion of protein in the rumen often is greater if ruminal pH is higher. Though this pattern fits these data for ground corn, it doesn't apply with whole corn diets. Particle size restrictions rather than pH probably had more impact upon ruminal digestion of feed N with whole corn. The high disappearance of N and starch in the rumen for the WL diet probably is responsible for low postruminal disappearance of available N. Total tract digestion of N was similar for all diets. Microbial efficiency tended to be greater for diets with whole than ground corn as was noted by Aguirre et al. (1984) but also tended to decrease as particle length of hay increased.

Digestion of ADF in the rumen tended to be greater for ground than whole corn with short hay, even though ruminal pH tended to be greater for whole corn at 2 hours after feeding. Ruminal pH differences narrowed with time after feeding so that pH at 10 hours after feeding was similar. Also, ruminal pH seldom fell below 6.0, a critical level for survival of fiber-digesting bacteria. Since microbial digestion of concentrate usually precedes attack of roughage, pH during the first few hours after a meal may not depress the total extent of fiber digestion in the rumen. At higher feed intakes or with frequent meals, ruminal fiber digestion can be reduced drastically (Zinn and Owens, 1983) which should increase the effects of level and form of roughage.

Ruminal ADF digestion tended to decrease as hay particle size increased in ground corn diets, whereas the reverse was true for whole corn diets. Differences in rate of fiber digestion and rate of passage are probably responsible. Grinding fiber to make it more accessible will increase rate of fiber digestion or decrease lag time before fiber digestion begins and should increase rate of digestion. Effects with whole corn probably relate to ruminal retention of fiber. Compared with long hay, ground hay has more chance to be flushed out of the rumen before being fully digested. Hence, ruminal separation and layering may be involved. Longer retention of long roughage particles should enhance the extent of fiber digestion in the rumen. Extents of both starch and fiber digestion in the rumen were elevated by long roughage with whole corn but were decreased with ground corn. These interactions deserve further study.

In conclusion, effects of corn processing on site of digestion in beef cattle fed a high grain diet were altered by physical form of the roughage. Increasing hay particle size from a fine to a medium grind had little effect on ruminal digestion with either form of corn. Ruminal digestion of organic matter, starch, protein and fiber were greater for ground than for whole corn with ground hay. With coarsely chopped prairie hay, however, ruminal digestion decreased with ground corn but increased with whole corn; differences in mastication and ruminal outflow rates are probably responsible. To maximize total tract digestion of starch, grinding roughage appears useful. To increase postruminal starch digestion, long hay was beneficial with ground corn but detrimental with whole corn. With whole corn, long hay reduced postruminal starch digestion. Results indicate that effects of processing of grain are dependent on characteristics of the dietary roughage being fed. Research is needed to check these effects with lower dietary roughage levels, with other types of roughage, with higher feed intakes and more frequent feeding.

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