WHOLE OR GROUND CORN WITH DIFFERENT ROUGHAGE SOURCES IN HIGH CONCENTRATE DIETS FOR BEEF HEIFERS

A.L. Goetsch[1], F.N. Owens[2] and B.E. Doran[3]

Story in Brief

Two forms of corn (whole or ground) were fed with three roughage sources (chopped alfalfa, cottonseed hulls or chopped prairie hay) to cannulated beef heifers (807 lb) in 90% concentrate diets at a daily dry matter intake level of 1.44% of body weight. Ruminal pH at 2 and 6 h postfeeding was lower for ground than whole corn diets. Ruminal fluid buffering capacity at 2 h after feeding was greater for whole than ground corn diets. Ruminal organic matter and starch digestibilities with ground corn diets tended to be greatest with alfalfa, intermediate with cottonseed hulls and lowest for diets with prairie hay as a source of roughage. The same trends were noted with whole corn for organic matter though ruminal digestion of starch did not vary. Postruminal disappearance of organic matter was lower with the alfalfa diets, making total tract organic matter digestion lower for diets with alfalfa than cottonseed hulls. When fed at 10% of the diet, cottonseed hulls and prairie hay were more valuable than alfalfa hay. Duodenal flow of microbial and feed nitrogen were greater for whole than for ground corn. Ruminal disappearance of feed nitrogen was higher for ground than whole corn diets. This suggests that feeding corn in the whole rather than the ground form will decrease the dietary crude protein requirement and increase the need for urea.

(Key Words: Corn, Grinding, Processing, Roughage Form)

Introduction

Currently, cost, availability and ease of handling are primary considerations for choosing the type of roughage to be used in high grain finishing diets. Chemical and physical attributes of roughage in high concentrate diets have received limited attention. Since roughage processing will influence the propensity for acidosis and site of digestion (Goetsch et al., 1986), roughage processing and source in high grain diets deserves more study. Because specific types of roughage may affect efficiency of digestion of high grain diets differently, the objective of this study was to investigate effects of several types of roughage on site of digestion in beef heifers fed diets containing high amounts of whole or ground corn.

Materials and Methods

Six cannulated Hereford X Angus heifers (807 lb) equipped with ruminal and duodenal cannulas were fed the 6 diets (Table 1) in rotation at a level equal to 1.44% of body weight per day. Corn was fed ground (3mm screen; G) or whole (W), while roughages, included at 10% of diet

[1]Former Research Associate [2]Professor [3]Graduate Assistant

Table 1. Diet composition (percentage of dry matter).

	Corn Form and Roughage Source					
	Ground			Whole		
Item	Alfalfa Hay	Cotton-seed Hulls	Prairie Hay	Alfalfa Hay	Cotton-seed Hulls	Prairie Hay
Corn, ground	87.06	83.04	83.37	-----	-----	-----
Corn, whole	-----	-----	-----	87.06	83.04	83.37
Alfalfa hay	10.00	-----	-----	10.00	-----	-----
Cottonseed hulls	-----	10.00	-----	-----	10.00	-----
Prairie hay	-----	-----	10.00	-----	-----	10.00
Soybean meal	1.20	4.81	4.63	1.20	4.81	4.63
Limestone	.94	1.25	1.20	.94	1.25	1.20
Trace mineralized salt	.50	.50	.50	.50	.50	.50
Chromic oxide	.30	.30	.30	.30	.30	.30

dry matter (DM), were alfalfa hay (chopped through a 3.8 cm screen), cottonseed hulls or prairie hay (chopped through a 3.8 cm screen).

Periods lasted 14 days with the first ten days for adaptation to the new diets and the last four days for sampling of ruminal, duodenal and rectal materials twice each day. Samples were subjected to all or part of the following analyses: DM, ash, nitrogen (N), starch, nucleic acid-N, ammonia-N, pH, buffering capacity and chromium. Buffering capacity was measured by adjusting the pH to 7 and adding acid to decrease pH incrementally.

Results and Discussion

Ruminal pH was greater for whole than ground corn diets at 2 ($P<.05$) and 6 h postfeeding ($P<.12$; Table 2). Greater chewing and rumination of whole corn as well as slower fermentation of whole than ground corn leads to a more constant rumen environment with whole than with processed corn diets. Processed grains promote a peak fermentation activity 1 to 3 h after a meal. Roughage type did not affect, or interact with corn form to affect, ruminal pH. However, at 2 h postfeeding, ruminal pH for diets with alfalfa tended to be lowest of the roughage sources with ground corn but the highest with whole corn. Overall, roughage source did not markedly alter ruminal pH with this low dietary level of roughage though ruminal pH was consistently high due to the low level of feed intake used.

Duodenal pH (Table 2) was lower ($P<.05$) for diets with whole than ground corn as has been observed previously (Goetsch et al., 1986). This may be due to lower total buffering capacity of rumen fluid from steers fed whole corn diets. Fecal pH was lowest ($P<.05$) for the ground corn diet with alfalfa. Production of short chain fatty acids by hindgut microbes has been suggested to be responsible for the lower fecal pH. Postruminal organic matter (OM) digestibilities (Table 3) do not support that concept.

Table 2. Digesta pH and ruminal ammonia-nitrogen concentration and buffering capacity.

		Corn Form and Roughage Source					
		Ground			Whole		
Item	Time After Feeding	Alfalfa Hay	Cottonseed Hulls	Prairie Hay	Alfalfa Hay	Cottonseed Hulls	Prairie Hay
Ruminal pH	2	5.96[a]	6.11[ab]	6.04[a]	6.43[c]	6.31[b]	6.34[bc]
	6	6.25	6.30	6.20	6.52	6.30	6.37
	10	6.53	6.62	6.56	6.58	6.48	6.54
Duodenal pH	Mean	2.58	2.62	2.65	2.43	2.49	2.47
Fecal pH	Mean	5.35[a]	5.76[b]	5.87[b]	5.90[b]	6.03[b]	5.98[b]
Ruminal ammonia-nitrogen concentration, mg/dl							
	2	3.3	5.1	4.4	5.5	7.9	4.1
	6	4.0	4.9	4.4	4.8	6.6	4.5
	10	7.0	5.9	6.8	6.1	6.9	5.6
Ruminal buffering capacity, milli-equivalents of H ions/40 ml fluid							
pH range:							
7.0-6.0	Mean	1.18	1.24	1.18	1.25	1.17	1.21
6.0-5.0	Mean	1.68	1.58	1.59	1.65	1.70	1.58
5.0-3.0	Mean	3.47	3.04	3.38	2.97	3.18	2.98

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

Ruminal ammonia-N concentrations (Table 2) were reasonably low with all diets reflecting the low level (8.8 to 9.2% protein) and low ruminal degradation of dietary crude protein. Ruminal ammonia-N concentration at 2 h after feeding was greater for whole than ground corn ($P<.07$). This may reflect reduced breakdown of feed protein or reduced use of ammonia-N in the rumen for microbial growth with whole than ground corn diets. Grinding probably increased energy availability immediately after the meal which increased ammonia utilization and dropped pH shortly after the meal. The concentration of ammonia-N in rumen fluid of heifers fed ground and whole corn diets became more similar as time after feeding increased. Concentration of ammonia-N was not altered by source of roughage. Nitrogen flow to the postruminal digestive tract averaged 90% of consumed N with ground corn and 113% of consumed N with whole corn (Table 3) indicating that recycling of N to the rumen was substantial with whole corn diet. The relatively constant ruminal ammonia-N concentration is probably due to coincident release of available N and energy from OM fermented during the feeding interval together with adequate recycling of N to the rumen to maintain normal microbial digestion.

Ruminal fluid buffering capacity from pH 6 to 7 (Table 2), averaged for samples taken at 2, 6 and 10 h postfeeding, was similar for whole and ground corn diets. Buffering capacity at 2 h tended to be slightly greater for whole than ground corn between 5.5 to 7.0. Differences between whole and ground corn diets in buffering capacity from pH 5.5 to 7 at 2 h after feeding were previously detected in beef heifers fed concentrate diets with 15% prairie hay (Goetsch et al., 1986). From pH

Table 3. Digestion measures.

Item	Corn Form and Roughage Source					
	Ground			Whole		
	Alfalfa Hay	Cotton-seed Hulls	Prairie Hay	Alfalfa Hay	Cotton-seed Hulls	Prairie Hay
Organic matter digestion:						
Apparent ruminal[1]	63.3	59.8	51.5	57.4	56.8	52.3
True ruminal[1]	68.8	64.4	58.1	65.1	63.0	59.2
Postruminal[1]	17.4[a]	24.3[ab]	31.2[b]	21.6[ab]	27.7[ab]	28.9[ab]
Postruminal[2]	44.7	55.4	58.4	49.0	63.7	59.8
Total tract[1]	80.7	84.1	82.7	79.1	84.5	81.3
Roughage digestibility:						
Calculated[3]	13.4	53.2	37.8	-2.6	57.2	23.8
NRC value	58	42	51	58	42	51
Starch digestion:						
Ruminal[1]	74.9	70.5	61.6	70.6	71.9	67.2
Postruminal[1]	17.6	22.4	31.6	17.1	21.5	21.5
Postruminal[2]	66.0	71.8	69.8	45.9	77.8	60.5
Total tract[1]	92.5	93.0	93.1	87.7	93.4	88.7
Nitrogen passage, g:						
Intake	76.2	76.4	74.2	75.0	75.3	73.1
Entering Duodenum:						
Total	65.0	65.7	73.2	81.1	84.3	86.2
Microbial	26.3	23.2	33.5	38.4	30.6	34.8
Feed	35.7	39.4	35.5	37.6	48.4	47.4
Exiting rectum	29.3	21.9	23.1	28.5	21.8	24.7
Nitrogen digestion:						
Apparent ruminal[1]	10.5	14.6	1.9	-10.3	-12.3	-17.2
True ruminal[1]	50.8	48.4	51.5	48.1	35.7	35.3
Postruminal[1]	50.3	56.8	66.7	71.8	83.1	83.9
Postruminal[2]	47.9	63.5	64.1	62.8	73.8	71.5
Total tract[1]	60.9	71.4	68.6	61.5	70.8	66.7
Microbial efficiency, g microbial/kg organic matter fermented	8.8	7.9	13.5	12.1	10.0	13.3

[1]Percent of intake.
[2]Percent of available.
[3]Calculated by difference using TDN values from NRC (1984) for corn (90%) and soybean meal (84%).
[abc]Means in a row with different superscripts differ (P<.05).

5 to 7, the range in which bicarbonate is the primary buffering component, buffering capacity with whole corn diets tended to be greater, but from pH 3 to 5, the range of buffering from volatile fatty acids, buffering was greater with ground corn. These probably reflect differences in salivary bicarbonate input from saliva and salivary dilution of volatile fatty acids. Effects of roughage type within corn form on buffering capacity were minor. With these low levels of dietary roughage, roughage provides little protection from acidotic conditions in the rumen. In a previous study, also, prairie hay of different

lengths in 85% concentrate diets had only minor effects on buffering capacity 2 h after feeding (Goetsch et al., 1986).

Interactions between corn form and roughage type on site of digestion were not detected (P>.05). Ruminal digestion (Table 3) tended to be slightly greater for ground than whole corn diets. Passage of microbial organic matter and N to the duodenum were greater (P<.05) for whole than ground corn diets so that true ruminal OM digestion was similar for the two types of corn. In other experiments, extent of ruminal OM digestion generally has been greater for diets with processed than unprocessed corn, though in most studies more than 10% dietary roughage has been fed. The limited feed intake also may have reduced ruminal escape of corn particles possessing substantial amounts of organic matter. Ruminal organic matter digestion tended to be greatest with alfalfa, intermediate with cottonseed hulls and lowest for prairie hay with both corn forms. Lower cells wall content of alfalfa than cottonseed hulls or prairie hay should have increased ruminal digestion of roughage with alfalfa diets. Less digestible roughages may remain in the rumen longer and increase mastication, saliva flow, rumen motility and ruminal outflow. True ruminal organic matter digestion for prairie hay diets with ground corn was similar to a comparable diet with 15% prairie hay fed at a slightly greater level of intake in a previous experiment (Goetsch et al., 1986).

Extent of ruminal digestion in this experiment was less affected by roughage type with whole than with ground corn diets. Postruminal disappearance of organic matter was lower (P<.05) for alfalfa than cottonseed hull or prairie hay diets. This produced a lower total tract digestion of organic matter for alfalfa than cottonseed hull diets (P<.05). The lower percentage of soybean meal and higher percentage of corn in alfalfa diets (Table 2) also could be involved. Digestibilities for roughage in the diets were calculated assuming that organic matter digestibility of corn and soybean meal were 90 and 84 percent (NRC, 1984). Calculated digestibilities averaged 5.4, 55.2 and 30.8% for alfalfa hay, cottonseed hulls and prairie hay. These compare with literature digestibility values (NRC, 1984) for these three feedstuffs of 58, 42 and 51 percent. Comparison with measured values indicates that in these high concentrate diets, alfalfa had less than 10% of its tabular energy value whereas cottonseed hulls had 131% of its tabular value. Interactions between roughage and grain in the diet may explain why associative effects are observed with some roughages but not others (Rust and Owens, 1981).

Ruminal starch digestion was similar for all three roughages when fed with whole corn (Table 3). With ground corn, digestion of starch in the rumen tended to be greatest with alfalfa, intermediate with cottonseed hulls and lowest with prairie hay paralleling differences in ruminal organic matter digestion. Effects of roughage type with whole corn, however, were quite small. Postruminal starch disappearance of ground corn diets varied inversely with ruminal digestion. Total tract starch digestion tended to be lower for whole corn diets with alfalfa or prairie hay than with cottonseed hulls and was lower (P<.05) for diets with whole than ground corn as previously observed (Goetsch et al., 1986). Postruminal digestion of available starch, similar to organic matter, tended to be lowest with alfalfa diets, probably due primarily to greater digestion of starch in the rumen.

Ruminal disappearance of feed N was higher for whole than for ground corn diets (P<.05; Table 3). Flow of N to the duodenum exceeded intake with whole but not with ground corn diets. Greater passage of undegraded dietary N to the duodenum with whole corn would reduce ruminal ammonia release which should elevate net recycling of N into the rumen. Feed N passage from the rumen was lower with ground than whole corn diets. This could be due to reduced solubilization of corn protein with a higher ruminal fluid pH or due to greater exposure of the protein due to grinding. But as grinding of corn did not alter ruminal digestibilities of organic matter and starch, it is surprising that grinding should alter protein escape from the grain.

Ruminal incorporation of recycled N is limited by the amount of energy provided by organic matter fermentation in the rumen. With whole corn, a greater portion of the recycled N was incorporated since less N was liberated from the corn in the rumen. Hence, postruminal flows of both microbial ($P<.05$) and feed N ($P<.07$) were greater with whole than with ground corn diets. Increased microbial flow is due entirely to increased efficiency of microbial growth. This could be due to more constant ruminal pH and starch digestion with whole corn diets reducing stress on ruminal microbes or to faster passage rates with whole corn. This also suggests that dietary crude protein requirements with whole corn diets may be lower than with diets of processed corn. Levels of feed intake and roughage which modulate ruminal passage rate and rumen degradation of dietary protein might alter N recycling.

Much of the dietary protein came from corn grain in this study. Dietary escape values for protein bypass for whole and ground corn were between 35 and 50% in this study. This is much lower than most other estimates (55 to 70%) of ruminal escape of corn protein. This may be due in part to the low level of feed intake which reduced rate of particle passage and subjected feed to more extensive ruminal digestion.

Postruminal N disappearance was greater ($P<.05$) for whole than ground corn (Table 3) reflecting greater flow of microbial and feed N to the intestines. Total tract digestion of N was similar for both forms of corn, but lower ($P<.05$) for diets with alfalfa than the other roughage. Greater N from roughage and less from soybean meal with the alfalfa than other roughages may be responsible for this difference.

The efficiency of microbial growth (Table 3) tended to be low suggesting that despite unrestricted ruminal digestion and supposedly adequate levels of ammonia-N, production of microbial protein was limited. This, also, may be due to the low level of feeding used and low passage rate in this experiment. Efficiency of microbial growth tended to be higher with whole than ground corn diets as noted previously (Goetsch et al., 1986).

In summary, roughage type had little effect on ruminal pH and buffering capacity. Extent of ruminal digestion did not vary greatly between forms of corn. Yet, with ground corn, ruminal digestion tended to be greatest with alfalfa, intermediate with cottonseed hulls and lowest with prairie hay as a source of roughage. Roughage type had negligible effects on extent of ruminal digestion with whole corn through total tract digestion was lowest for diets with alfalfa. Ruminal recycling of nitrogen was greatest for whole corn diets while flow of both feed and microbial nitrogen to the postruminal digestive tract was greater with whole than ground corn diets.

Overall, effects of roughage type on site of digestion of concentrate diets with 10% roughage in the diet were minimal. Due to associative effects of roughage with grain, the greater value of a more digestible roughage (alfalfa versus cottonseed hulls) disappears when fed in a high concentrate diet. Rather than placing greater value on a low fiber, high protein roughage source as appears practical with lactating dairy cows fed higher roughage diets, a roughage source in a feedlot diet appears more valuable if it stimulates chewing, rumination and outflow from the rumen without interfering with starch digestion in the small intestine.

Literature Cited

Goetsch, A.L. et al. 1986. Whole or ground corn and different roughage sources in high concentrate diets for beef heifers. Okla. Agr. Exp. Sta. Res. Rep. MP-118:154.

Rust, S.R. and F.N. Owens. 1981. Roughage sources in feedlot diets. Okla. Agr. Exp. Sta. MP-112:150.