PROCESSED GRAINS: DISAPPEARANCE OF PROTEIN FROM MOBILE DACRON BAGS

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Story in Brief

Site and extent of disappearance of crude protein from 14 different combinations of grains and processing methods were measured using calves equipped with ruminal and intestinal cannulas and ileo-rectal anastomoses. As an estimate of digestion in the rumen, disappearance after 15 h of incubation was measured. For postruminal digestion, bags were incubated for 3 h in pepsin-HCl, inserted into the duodenal cannula and recovered when defecated. Rolling whole corn or oats increased ruminal and postruminal protein digestion. Further processing (high moisture or steam flaking) increased ruminal and total tract digestion of protein from corn, milo and oats but had little effect on wheat or barley grain. Small intestinal digestion of protein escaping from the rumen was increased by processing of the grain except for wheat grain. But the total quantity of protein disappearing from the small intestine decreased with more extensive processing of the grain because of increased ruminal digestion. Effects of steam flaking on site of digestion were minor for wheat and barley grains. Ensiling rolled corn, especially at 35% moisture, more than doubled crude protein disappearance in the rumen.

(Key Words: Mobile Dacron Bag, Protein Digestion, Grains, Processing, Ruminal Bypass.)

Introduction

Values for extent of protein digestion in the rumen and intestines for various grains are rare. In the NRC (1985) publication only three estimates of ruminal escape protein are provided: barley (21%), corn (65%) and sorghum (52%). Commercial grain processing procedures, commonly used to increase total tract digestion of starch, will alter ruminal escape of cereal grain protein (Aguirre et al., 1984). The magnitude and even the direction of change can vary with the method of processing. Effects of various methods of processing of cereals on ruminal escape and small intestinal digestion of protein need to be tested.

The mobile dacron bag technique has been used in pigs to measure digestibilities of various protein sources and cereals (Sauer et al., 1983) and in ruminants to test ruminal and postruminal degradation of several protein sources (de Boer et al., 1987; Nalsen et al., 1987). Although these reports provide information on disappearance of DM and crude protein, information on the effect of grain processing on protein disappearance is not available.

The objective of this experiment was to determine the impact of grain source and processing on the extent of disappearance of protein in the rumen and the small intestine of calves.

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Materials and Methods

Two Holstein calves (330 lb) were fitted with duodenal cannulas and also with anastomoses between the distal ileum and the distal rectum so that digesta from the small intestine would bypass the large intestine and flow directly from the small intestine to the rectum for defecation. The calves were housed in individual pens and had free access to water. Calves were fed a concentrate diet composed of 20.1% dry rolled corn, 20% chopped prairie hay, 19.8% dry rolled sorghum, 13.8% soybean meal, 12.6% dehydrated alfalfa hay crumbles, 5.9% molasses, 5.9% dry ground wheat, .9% dicalcium phosphate and 1% salt plus a trace mineral supplement. Animals were adjusted to their diets for a minimum of 14 days prior to being used in experiments and were fed 2.5% (dry matter basis, DM) of body weight daily in two equal feedings at 0800 and 1600 hours.

Protein disappearance was measured at two different sites. Ruminal disappearance consisted of ruminal incubation for 15 hours. Total tract disappearance consisted of ruminal incubation plus a 3 h pepsin-HCl digestion followed by insertion into the duodenum and recovery from feces. Extent of digestion in the small intestine was calculated as total tract minus ruminal disappearance because the ileo-rectal anastamosis forced bags physically to bypass the large intestine. To calculate digestion as a percent of input or duodenal flow, extent of digestion was divided by ruminal escape.

The mobile dacron bags (3.5 by 5.5 cm) were constructed of dacron cloth with a mesh size of 60 to 70 microns. Approximately 2.0 g of each feedstuff were placed in each bag; bags were sewn shut. Corners of bags were rounded to reduce abrasion of the intestine.

Fourteen different unground feedstuffs were employed. They consisted of dry rolled, whole shelled, steam flaked and high moisture corn, with the latter at both 25 and 35% moisture levels; dry rolled and steam flaked milo; whole and dry rolled oats; dry rolled and steam flaked wheat; dry rolled and steam rolled barley. Table 1 presents the chemical composition and the particle sizes of these feedstuffs. The same batch of grain was processed to produce each of the processed forms by a number of feedlots and feed companies.

Twelve bags containing each of the 14 feedstuffs were inserted into nylon stockings and incubated for 15 h in the rumen of an 850 lb cannulated beef steer fed the diet described above. Upon removal from the rumen, four bags of each feedstuff were washed thoroughly, dried and analyzed. The other eight bags of each feed were incubated for 3 h in a pepsin-HCl solution. After pepsin digestion, each bag was inserted into the small intestine via the duodenal cannula at a rate of one bag each 30 min. Upon defecation, the dacron bags were collected, rinsed under cold running tap water until the wash water was clear and dried in a forced air oven at 90 C for 24 h.

Feed samples and bags containing residues were subjected to dry matter and Kjeldahl nitrogen analyses. Blank bags containing a known weight of sliced Tygon tubing were used to correct for influx of non-adherent nitrogen. Bags plus residue contents were weighed and digested intact for Kjeldahl nitrogen analysis.

To detect specific effects of processing method, a total of 72 contrasts were drawn: whole vs rolled, corn vs oats and their interaction; steam flaked vs rolled, comparison of all grains, and their interaction; high moisture vs rolled corn and high moisture (35%) vs lower moisture (25%) corn.

Table 1. Chemical composition of processed cereal grains.

Feedstuff	Dry matter %	Crude protein %	Starch %	Particle size diameter um	SD[a] um
Corn					
Whole shelled	88.8	9.9	49.5	4758	1006
Dry rolled	88.4	10.3	65.3	2785	823
25% moisture	75.0	10.1	53.7	2329	716
35% moisture	65.0	10.2	82.1	2430	737
Steam flaked	83.8	9.9	53.5	3388	1007
Milo					
Dry rolled	87.0	10.8	55.3	1482	472
Steam flaked	85.0	11.1	50.7	1333	444
Oats					
Whole	91.8	13.3	29.0	2438	655
Dry rolled	91.5	12.0	31.7	2096	639
Wheat					
Dry rolled	89.7	15.7	42.7	1865	576
Steam flaked	88.1	15.9	44.9	2245	682
Barley					
Dry rolled	88.7	14.1	39.2	2418	722
Steam rolled	88.2	15.0	40.6	2644	780
Diet	91.4	19.0	36.5	1922	624

[a]Standard deviation in particle size.

Results and Discussion

Because washing should remove endogenous secretions and a portion of the bacteria in the bags, disappearance estimates by this procedure should more closely approximate true than apparent digestibility of dry matter and crude protein and would be expected to exceed apparent digestion values. As cattle were equipped with anastomoses to bypass the large intestine, disappearance values from this study do not include additional fermentation losses which would occur in the large intestine and cecum.

Rolling of whole corn or oats greatly increased ($P<.05$) protein disappearance, both in the rumen (38 vs 4%; 52 vs 2%) and the total tract (60 vs 4%; 61 vs 3%; table 2). Rolling of either corn or oats also increased ($P<.05$) both the fractional and the total disappearance of protein from the small intestine. Intestinal disappearance of crude protein was very low compared to the theoretical true protein digestibility of most protein sources (90%; NRC, 1976) or the mean intestinal digestibility of escape protein of 66% (NRC, 1985). Only with thoroughly processed grains were these values attained. Except for wheat and 25% moisture corn, more extensive processing and smaller particle size increased fractional protein disappearance in the small intestine. This is the first time that processing effects on postruminal protein disappearance has been quantitated directly. Perhaps previous estimates of true total digestibility by regression are in error due to underestimation of microbial protein digestion or that the large particle size of the grain and lack of mastication severely limited intestinal protein digestion from the bags.

Table 2. Effect of processing grains on protein disappearance from mobile dacron bags.

Feedstuff	Mobile bag disappearance of protein			
	Ruminal (15 h) %	Total tract %	Small intestine by difference %	% of supply
Corn				
Whole shelled	3.5[f]	3.8[g]	.3[e]	.3
Dry rolled	38.3[d]	60.0[ef]	21.7[bcd]	35.1
25% moisture	72.2[b]	74.4[c]	2.2[e]	7.9
35% moisture	90.4[a]	100.0[a]	9.6[de]	100.0
Steam flaked	99.0[a]	100.0[a]	1.0[e]	100.0
Milo				
Dry rolled	60.4[c]	75.8[c]	15.4[cde]	38.9
Steam flaked	97.9[a]	100.0[a]	2.1[e]	100.0
Oats				
Whole	2.5[f]	2.6[g]	.1[e]	.1
Dry rolled	51.5[c]	61.3[ef]	9.8[de]	20.2
Wheat				
Dry rolled	55.6[c]	89.8[b]	34.2[ab]	77.0
Steam flaked	55.6[c]	76.8[c]	21.2[bcd]	47.7
Barley				
Dry rolled	57.2[c]	72.8[cd]	15.6[cde]	36.4
Steam rolled	52.6[c]	77.9[c]	25.3[bc]	53.4
Diet	22.4[e]	68.5[cde]	46.1[a]	59.4
SE[g]	3.2	3.1	4.6	

[abcdef]Means with similar superscripts in a column do not differ (P<.05).
[g]Standard error of the means.

For crude protein, differences (P<.05) between methods of processing grains were found for whole vs rolled grains, steam flaked vs rolled, high moisture vs dry rolled corn and 25% vs 35% high moisture corn in total tract disappearance. Steam flaked and rolled grains differed (P<.02) in ruminal and intestinal disappearance of crude protein.

As compared with dry rolled grain, steam flaking greatly increased ruminal, intestinal (as a fraction of supply) and total tract disappearance of protein from corn and milo grains. With these grains, total tract disappearance was virtually complete. The amount of protein reaching the small intestine from the grain, however, was reduced by flaking. This contrasts with the suggestion of Hinman and Johnson (1974) that flaking denatures milo protein and increases ruminal escape. They attributed an increased post-ruminal protein flow to the grain alone and may not have accounted fully for increased microbial protein synthesis associated with flaking of milo. Flaking or steam rolling of wheat and barley had little impact beyond dry rolling on site or extent of protein disappearance from these grains.

Published information on the effects of grain source and grain processing on site and extent of digestion is limited. Total tract apparent digestibility of nitrogen from whole and dry rolled corn was reported by Aguirre et al. (1984) to be 69.4 and 70.9%, respectively,

compared with bag losses of only 4 and 60% for these corn forms in our anastomosed steers (table 2). Differences are presumably due to particle size and animal preparation. Hvelplund (1985) indicated that recovery of the bags from the ileum gave 6% lower estimates for protein digestion than recovery of bags from the feces.

Four ground cereals (rye, triticale, wheat and barley) were tested in pigs using mobile dacron bags by Graham et al. (1985). Crude protein disappearance from all four grains exceeded 94%. Only steam flaked corn and milo attained degradations that high in our trial, but again, particle size reduction will increase protein exposure and digestion.

Increases in the surface area of the cereal for contact with the ruminal microbes and enzymes presumably is responsible for the extensive disappearance of crude protein from steam flaked corn and milo. The higher the amount of corneus endosperm (corn, milo) the greater the response in protein disappearance to starch gelatinization and fine grinding.

In summary, moderate processing by rolling whole corn or oats increased ruminal and postruminal protein digestion whereas further processing (high moisture or steam flaking) increased ruminal and total tract digestion of protein from corn, milo and oats but had little effect on wheat or barley grain. Generally, processing increased small intestinal digestion of protein escaping from the rumen, but the total quantity of protein disappearing from the small intestine was decreased by extensive grain processing. Effects of steam flaking on site of digestion were most drastic with corn and milo grains. Although the mobile bag shows promise for evaluating protein escape and intestinal protein digestion, effects of grain particle size on digestibility, both from bags and in vivo, deserves further scrutiny.

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