STARCH DIGESTION BY FEEDLOT CATTLE: INFLUENCE OF ROUGHAGE AND INTAKE LEVEL AND PARTICLE SIZE

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Story in Brief

Three steers were fed an 80 percent concentrate diet at 1.5 or 2 percent of body weight or a 60 percent concentrate diet a 2 percent of body weight. Cottonseed hulls were added to decrease the concentrate level. Addition of cottonseed hulls to the diet increased starch digestion in the total tract by about 3 percent and reduced the amount of starch found in fecal particles over 2000 microns in diameter. Starch digestion in the rumen tended to decrease with added cottonseed hulls. Of the starch found in the feces, over 85 percent was in particles exceeding 2000 microns in diameter. Starch particles greater than 2000 microns in diameter escaped intestinal digestion while particles under 1000 microns in diameter were extensively digested in the rumen. Particles between 1000 and 2000 microns tended to escape ruminal digestion and disappear most extensively in the intestines. Particle size reduction by grain processing will increase extent of starch digestion in the total tract, especially in the rumen. Accelerating rate of passage of processed grain or addition of certain roughages like cottonseed hulls should shift site of digestion to the intestines and may improve energetic efficiency.

(Key Words: Starch Digestion, Particle Size, Feed Intake, Roughage Level.)

Introduction

Extent of digestion of dietary starch is usually much higher in swine, poultry and sheep than in feedlot cattle (>99 percent versus 85 to 98 percent). Various factors such as low enzyme activity or limited absorptive capacity have been proposed to be responsible. Steam flaking will increase extent of starch digestion and this response has generally been attributed to gelatinization of the starch. But fine grinding also can increase extent of starch digestion. Smaller particles expose more surface area both to microbial attack in the rumen and large intestine and to enzymatic action in the small intestine. Passage rate of particles from the rumen can be influenced by particle size. Particles of forage greater than 1200 microns (1.2 millimeters) in diameter seldom leave the rumen while forage particles less than 100 microns (.1 millimeter) tend to be flushed along with fluids from the rumen. Density also influences passage rate, with very dense or very light particles being retained in the rumen for a longer times and continued digestion. Hence, particle size can alter site and extent of digestion.

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Feed particle size can be reduced by 1) mechanical processing prior to feeding, 2) chewing of feeds during eating and rumination and 3) microbial fermentation which weakens the physical structure and combined with ruminal contractions will gradually reduce particle size. Previous studies (Zinn and Owens, 1983) suggest that at higher feed intake levels, ruminal digestion of organic matter is reduced. In another study (Teeter and Owens, 1981), addition of cottonseed hulls to a whole corn grain diet increased extent of starch digestion. Both of these observations might be related to extent of particle size reduction in the rumen due to decreased fermentation time or to increased chewing or rumination of the grain. The objective of this study was to check the influence of feed intake level and cottonseed hull addition to the diet on particle sizes at the start and end of the small intestine and in feces and on starch digestion of a high concentrate diet fed to growing steers.

Materials and Methods

Three steers (250 kg) equipped with "T" cannulas in the proximal duodenum and distal ileum were used in a 3 by 3 Latin square experiment to measure the influence of level of feed intake on starch digestion, N metabolism and particle size distribution at the start (duodenum) and end (ileum) of the small intestine and in feces. The basal rolled corn diet (Table 1) was fed twice daily (0800 and 2000) at a daily level equal to 1.5 or 2 percent of body weight or at 1.5 percent of body weight with .5 percent of body weight added from cottonseed hulls.

Table 1. Concentrate composition.

Ingredient	Percentage (as fed)
Rolled corn	65.7
Cottonseed hulls	20.0
Soybean meal	10.0
Cane molasses	3.0
Limestone	0.5
Trace mineralized salt	0.5
Chromic oxide	0.3

Experimental periods lasted 11 days with digesta samples collected the final 3 days of each period. During the collection period, samples were obtained simultaneously from the duodenum, ileum and rectum at 2, 6 and 10 hours postfeeding with a minimum of 12 h between sampling times. Chromic oxide was used as a digesta marker. Rumen samples were obtained for measurement of pH and NH_3 and isolation of ruminal bacteria by differential centrifugation 2 h post-feeding after digesta samples had been collected on the final day of each period. Samples of feed, duodenal digesta, ileal digesta and feces were separated into particle sizes by flushing the sample with 25 C water though standard screen sieves with mesh sizes of 4000, 2000, 1000, 500, 250 and 125 microns.

Dry matter content of feed, digesta and feces were determined through oven drying at 65 C. Dried samples were ground and subjected to all or part of the following analyses: Kjeldahl nitrogen, ammonia N, acid detergent fiber, chromium, starch, ash and purines.

Results and Discussion

The effects of intake and roughage level on digestive tract measurements are presented in Table 2. Higher intake of the high concentrate diet decreased ruminal pH but did not alter other measurements. Added cottonseed hulls tended to increase fecal pH and dry matter content of duodenal, ileal and fecal samples. Ruminal ammonia concentrations were all quite low considering that concentrate dry matter contained 13.6 percent crude protein.

Table 2. Digestive tract measurements.

Intake level	1.5	2.0	2.0
Concentrate level, %	80	80	60
Ruminal pH	6.17	5.98	6.15
Ruminal NH_3, mg/dl	2.14	2.53	2.25
Duodenal pH	2.20	2.17	2.13
Duodenal dry matter, %	4.9	7.4	6.8
Ileal pH	7.53	7.58	7.59
Ileal dry matter, %	10.3	12.5	14.4
Fecal pH	6.29	6.23	6.44
Fecal dry matter, %	19.3	22.8	22.8

Site and extent of digestion of organic matter, starch and nitrogen are presented in Table 3. Increased feed intake increased flow of organic matter to the duodenum and ileum and decreased extent of ruminal digestion of organic matter. In this study, increasing feed intake did not increase flow of starch to the duodenum in agreement with results of Zinn and Owens (1983). Total tract starch digestion was not reduced, as might be expected with higher feed intakes. With an even higher feed intake or ad libitum access to feed of feedlot cattle, extent of chewing may be reduced which would increase particle size in the rumen and possibly depress both ruminal and total tract starch digestion. Adding cottonseed hulls to this cracked corn diet shifted site of starch digestion from the rumen to the small intestine and also tended to increase total tract starch digestibility. Small intestinal digestibility tended to be low but was not reduced by added cottonseed hulls. These results support the earlier work of Teeter et al (1981) where cottonseed hulls increased the extent of starch digestion. Previously, this was thought to be due to greater rumination and increased digestion in the rumen, not in the small intestine as suggested from the present study. Total tract digestion of dry matter, starch and N were all lower than anticipated with the basal diet.

To determine the influence of particle size on site and extent of starch digestion, feed, duodenal, ileal and fecal samples were sieved and starch content of subsamples measured (Table 4). Most of the starch in all samples had a particle size greater than 2000 microns.

Table 3. Site and extent of digestion.

Intake level	1.5	2.0	2.0
Concentrate level, %	80	80	60
Organic matter			
Intake, g	2923	3907	3936
Duodenal, g	786	1240	1297
Ileal, g	574	662	666
Fecal, g	668	661	624
Digestibility, %			
Total tract	77.2	82.4	84.6
Ruminal			
Apparent	73.5	68.9	66.6
True	81.4	78.0	74.9
Starch			
Intake, g	904	1208	925
Duodenal, g	130	105	159
Ileal, g	70	76	54
Fecal, g	61	61	25
Digestibility, %			
Total tract	93.3	94.5	97.4
Ruminal	86.0	90.9	82.2
Small intestine	6.2	2.7	11.7
Large intestine	1.0	0.9	3.5
Digesta ash percent			
Duodenum	11.9	11.7	13.0
Ileum	9.7	10.9	11.4
Feces	5.9	7.7	7.4

Table 4. Passage of starch in particles of various size.

Measurement site	Feed	Duodenum	Ileum	Feces
Particle size, microns	---------- g starch daily ----------			
->4000	246	21.1	0.6	13.8
2000-4000	542	27.3	15.5	27.2
1000-2000	137	13.8	13.4	0.9
500-1000	499	0.4	2.6	2.7
250-500	24	1.3	1.3	0.8
125-250	12	0.0	0.3	0.3

Passage of large particles conflicts with the concept developed from forage diets that few particles greater than 1200 microns in diameter leave the rumen. The high density of grain particles and absence of a ruminal mat to filter and trap coarse particles may be responsible for the more extensive passage of large particles with a high concentrate diet.

From the amount of starch of each particle size at various points in the digestive tract, digestion of each particle size was calculated (Table 5) even though particle may be reduced in size during rumination or digestion. Sampling through T-cannulas will reduce recovery of very large or whole corn kernels, but with the smaller particles, digesta samples should be representative.

Table 5. Disappearance of starch from particles of various sizes.

Digestion site	Rumen	Small plus Large intestine	Total tract
Particle size, microns	---------	Percent digested	---------
>4000	91.4	34.6	94.3
>2000	95.0	0.4	95.0
>1000	89.9	93.5	99.3
>500	99.9	-575.0	99.5
>250	94.6	38.4	96.6
>125	100.0	----	97.5

Generally the smaller the grain particle, the more extensively it was digested in the rumen and in the total digestive tract. Extent of starch digestion in the rumen appeared lower for particles between 1000 and 2000 microns than smaller particles which would be more rapidly digested and larger particles which may be retained in the rumen for further digestion. Galyean et al. (1981) illustrated that the rate of ruminal disappearance from dacron bags suspended in the rumen was much greater for small than large particles but possible differences in rate of passage prevented extrapolation of that work to extent of ruminal digestion. These results show that extent of ruminal digestion of cracked corn is low for larger particles. The fact that fine grinding and steam flaking increase extent of digestion in the rumen and total tract partially reflect surface area for fermentation. Extent of digestion of starch in the small intestine and renewed fermentation in the large intestine did not react in a similar fashion to size of particles entering those points. Over 89 percent of fecal starch was in particles exceeding 2000 microns or one-tenth of an inch in diameter. With added CSH in the diet, very little starch was found to exceed 2000 microns as observed previously by Teeter (1981) with whole corn diets.

The prevalence of large particles containing starch in duodenal, ileal and fecal samples leads to the suggestion that particle size is a major factor limiting digestion of starch in both the rumen and the intestines. Though larger particles escape digestion in the rumen more extensively than small particles, large particles pass through the intestines largely intact. Further study of particle sizes of digesta samples is needed to examine the optimal particle size to escape the rumen but not escape digestion in the small intestine.

Literature cited

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