Table 5. Nylon bag DMD of three particle sizes of sorghum

Time	Particle size		
	3.0 mm.	1.5 mm.	0.75 mm.
2	8.4[a]	8.1[a]	22.8[b]
4	15.5[a]	9.7[b]	24.4[c]
6	15.4[a]	12.1	28.8[b]
8	20.9[a]	16.3[b]	36.2[c]

[abc]Means in a row with different superscripts are significantly different ($p<.05$)

rumen than those of layer size is dependent on the other factors. If large particles are held back in the rumen for longer times than small particles, diets of large size may be digested to the same extent as diets of small particle size. More information relative to ruminal outflow rate of grains of different particle sizes is needed to fully understand *in vivo* particle size, digestion relationships.

Influence of Particle Size and Level of Intake on Site and Extent of Digestion in Steers Fed Corn Based Diets

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Story in Brief

Four young Hereford X Brown Swiss steers were utilized to examine the site and extent of dry matter, organic matter and starch digestion in corn based diets. Corn ground through either 3.18, 4.76 and 7.94 mm. screens or left in the whole form was fed in 72 percent corn diets to determine the influence of corn particles size on site of digestion (Trial 1). In Trial 2 a basal corn diet (84 percent corn) was fed at 1.00, 1.33, 1.67 or 2.00 times calculated maintenance dry matter needs in an effort to investigate the influence of level of intake on site of digestion.

Results of Trial 1 showed that total tract dry matter (DMD) and organic matter (OMD) digestion tended to increase as particle size increased. Rumi-

nal DMD, however, was lower for whole corn (44.87 percent) than for 3.18 mm. (62.29 percent), 4.76 mm. (63.62 percent) and 7.94 mm. (60.78 percent). Total tract starch digestion was lower for whole corn than other treatments as was ruminal starch digestion. More starch passed to the intestine with whole than with ground treatments. Data suggest that some alteration of the whole kernel (beyond mastication damage) is needed to obtain maximum ruminal starch digestion.

Increasing level of intake (Trial 2) resulted in decreased total tract DMD, OMD and starch digestion. Ruminal digestion of these nutrients (five) was similar across treatment, but followed the same trend (decreasing with level of intake). Much more dry matter bypassed to the intestine as level of intake increased from 1.00 to 2.00 times maintenance. Level of intake appears to be an important factor relative to starch digestion, and thus efficiency of dietary energy use.

Introduction

Previous work at this laboratory has demonstrated that particle size has an important effect on nylon bag dry matter digestion of corn, whether processed or unprocessed. Whether particle size affects total digestion depends on the time grain stays in the rumen; that is, if large particles are held back for longer periods than small particles, they may be digested to the same extent as small particles. Methods which allow separation of digestion into that occuring ruminally or intestinally may help answer this question. In addition, most digestion studies with cattle are done with animals fed at or near maintenance intake. Increasing level of intake might alter results of these studies.

Therefore, two trials were conducted to determine the influence of particle size (Trial 1), and level of intake (Trial 2) on the site and extent of dry matter (DM), organic matter (OM), and starch digestion in cattle fed high concentrate, corn diets.

Materials and Methods

Trial 1—Four Brown Swiss X Hereford steers (avg. 272 kg.), fitted with permanent rumen cannulae and housed in individual metabolism stalls were used in a 4X4 Latin square design. In this design, four ten-day feeding periods were used, and each steer received a different ration in each period so that by the end of the trial each diet had been fed to all four steers.

Steers were fed one of four diets in eight equal portions daily by means of an automatic feeding system. Treatments were particle sizes of corn in the diet. One lot of corn was either ground through 3.18, 4.76, and 7.94 mm. screens or left in the whole form. These four particle sizes of corn were mixed in 72 percent corn diets (Table 1).

Table 1. Composition of experimental diets

Ingredient	% (Trial 1)	% (Trial 2)
Corn	72.00	84.00
Cottonseed hulls	16.80	4.80
Dehy alfalfa	4.80	4.80
Soybean meal	4.42	4.42
Urea	0.64	0.64
Salt	0.50	0.50
Dicalcium phosphate	0.40	0.40
Calcium carbonate	0.40	0.40
Aurofor-50	0.02	0.02
Vitamin A (30,000 IU/gm)	0.02	0.02

The first six days of each feeding period served as an adjustment to new diets, and a total collection of feces was taken on days seven through ten. Feces was weighed daily, sampled, dried, and ground for chemical analysis. On days nine and ten of each period, rumen samples were obtained via the cannula, dried, and ground for analysis. Diet samples were also obtained during each period.

Diet, fecal, and rumen samples were analyzed for dry matter, ash, lignin, and starch. Ration and fecal samples were analyzed for crude protein. Digestion of nutrients in the rumen was determined by calculating the ratio of lignin in feed to lignin in rumen samples.

Trial 2—Methods used in this trial were the same as those reported in Trial 1. Steers weighed an average of 285 kg. and treatments were multiples of maintenance intake. An 84 percent corn diet (Table 1) was fed at 1.00, 1.33, 1.67 or 2.00 X calculated maintenance dry matter (M) needs (range of intake, 2.6 to 5.3 kg.). Geometric mean diameter of the corn grain which had been ground through a 4.76 mm. screen was 714.49 microns, and dry matter, organic matter, crude protein, starch, and lignin percentages, respectively, of the diet were 89.13, 96.36, 12.67, 67.20, and 3.09.

Statistical analysis were conducted on the data from both trials and significant differences are denoted by superscripts in the following tables.

Results and Discussion

Trial 1—Chemical composition of the four diets was similar as would be expected. Dry matter, organic matter, crude protein, starch, and lignin percentages, respectively, of the diets were as follows: whole (89.53, 96.27, 11.19, 57.80, 5.11); 3.18 mm. (89.56, 96.39, 11.81, 55.76, 4.16); 4.76 mm. (89.53, 96.16, 11.31, 57.99, 4.09), and 7.94 mm. (89.74, 96.08, 11.44, 56.64, 4.61). Geometric mean diameter (microns) of the grains was: whole (5977.87), 3.18 mm. (508.94), 4.76 mm. (587.56), and 7.94 mm. (832.22).

Because of problems associated with taking samples from the rumen rather than abomasum, and variable digestion of ligin; ruminal, and intestinal digestion coefficients are probably not accurate estimates, but should be sufficient indicators of trends. Total tract digestibilities are more valid estimates, however, since they were obtained by total collection methods.

Digestion coefficients as influenced by corn particle size are shown in Table 2. Total tract DMD was similar for all treatments, but tended to increase with increasing particle size. Total tract OMD followed a similar pattern. Ruminal DMD, however, was lower for whole (44.87 percent) than for 3.18 mm. (62.29 percent), 4.76 mm. (63.62 percent), and 7.94 mm. (60.78 percent). Since ruminal DMD was lower for whole, a greater percentage of dry matter passed to the intestines and was digested there, suggesting that intestinal digestive capacity was able to compensate for reduced ruminal digestion of whole corn. This might not be the case, if steers used in this study had been fed larger amounts of dry matter per day (intake in the study was about 3.5 kg. DM/day or 1.25 times maintenance).

Starch digestion coefficients suggest a trend for lower total tract starch digestion as particle size increased, (94.52 percent for ground diets *vs.* 88.18 percent for whole). Ruminal starch digestion was lower for whole (70.83 percent) than for 3.18 mm. (92.02 percent), 4.76 mm. (90.18 percent), and 7.94 mm. (92.96 percent). Due to sampling and marker problems mentioned previously, ruminal digestion coefficients are overestimates and resulted in low and sometimes negative calculated values for intestinal digestion. As can also be seen from Table 2, crude protein digestion was not different across particle size.

Data from Trial 1 suggest that corn particle size has little effect on site and extent of digestion if corn is ground to some degree. It appears, however, that

Table 2. Digestion coefficients of corn based diets as influenced by particle size

Item	3.18 mm.	4.76 mm.	7.94 mm.	Whole
Total DMD %	75.55	76.12	76.52	77.10
Total OMD %	76.07	76.69	77.08	77.43
Ruminal DMD %	62.29[a]	63.62[a]	60.78[a]	44.87[b]
Ruminal OMD %	64.88[a]	65.71[a]	63.89[a]	47.34[b]
DM entering intestinal, dig %	33.33[a]	34.06[a]	39.72[a]	54.50[b]
OM entering int, dig %	28.85[a]	31.26[a]	35.87[a]	51.99[b]
Total starch dig %	94.52	93.65	93.52	88.18
Ruminal Starch dig %	92.02[a]	90.18[a]	92.96[a]	70.83[b]
Starch entering int, dig %	15.93	5.19	-31.11	-2.18
Crude protein dig %	69.23	67.88	67.57	69.56
Total lignin digestion %	27.88[a]	27.99[a]	38.55[b]	53.27[c]

[ab]Means in a row with different superscripts are significantly different ($p<.05$).

Table 3. Digestion coefficients of a corn based diet as influenced by level of intake[c] (percent)

Item	1.00 X M	1.33 X M	1.67 X M	2.00 X M
Total DMD, %	85.70[a]	84.09[a]	78.89[b]	77.64[b]
Total OMD, %	86.36[a]	84.69[a]	79.45[b]	78.22[b]
Ruminal DMD, %	66.22	63.27	59.40	60.14
Ruminal OMD, %	69.92	67.04	63.07	63.12
DM entering int, dig %	52.58	55.98	46.75	41.40
OM entering int, dig %	48.72	51.96	42.29	37.53
Total starch dig %	99.64[a]	98.38[a]	93.80[b]	90.41[b]
Ruminal starch dig %	94.48[a]	92.79[ab]	92.36[ab]	89.46[b]
Starch entering int, dig %	23.00	31.54	-35.09	-25.31
Crude protein dig %	78.86	77.43	74.15	76.79
Total lignin dig %	51.61	52.92	51.54	51.58

[ab]Means in a row with different superscripts are significantly different ($p<.05$).
[c]Least squares means. One steer failed to eat 2.00 m resulting in one missing value in the Latin square.

some alteration of the whole kernel, beyond mastication damage, is necessary to obtain maximum ruminal starch digestion and perhaps greater efficiency of dietary energy use.

Trial 2—Crude protein digestion (Table 3) was similar across treatment, but tended to decrease with increased intake. Problems associated with ruminal sampling methods and marker recovery as noted previously in Trial 1, make estimates of ruminal and intestinal digestion coefficients useful to indicate only relative treatment differences in this trial also.

Total tract DMD was significantly lower for 2.00 times maintenance (2.00 X M), and 1.67 X M than for 1.33 X M, and 1.00 X M, as was total OMD. Part of the decrease in total DMD and OMD may be due to a trend for lower ruminal DMD and OMD coefficients as intake increased. Ruminal DMD declined from 66.22 percent (1.00 X M) to 60.14 percent (2.00 X M) as intake doubled. Intestinal DM and OM digestion coefficients tended to decline as intake increased, suggesting as more feed bypassed fermentation, intestinal digestive capacity may have been too limited.

Steers fed 1.00 X M (99.64 percent), and 1.33 X M (98.38 percent) had higher total starch digestibilities than those fed 1.67 X M (93.80 percent), and 2.00 X M (90.41 percent). Less starch was digested in the rumen as intake increased from 1.00 X M (94.48 percent) to 2.00 X M (89.46 percent). Overestimates of ruminal digestion, as in Trial 1, resulted in low and negative intestinal digestion coefficients in this trial also.

Trial 2 data suggest level of intake has important effects on site and extent of dry matter, organic matter and starch digestion. Researchers should attempt to obtain maximum intake in future digestion studies with cattle fed high concentrate diets to more closely simulate feedlot conditions.