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EFFECTS OF HAMMERMILLS AND ROLLER MILLS ON GROWTH PERFORMANCE, NUTRIENT DIGESTIBILITY, AND STOMACH MORPHOLOGY IN FINISHING PIGS

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Summary

The effects of particle size and mill type used to grind corn were determined with 128 pigs (122 lb average initial body wt). Treatments were corn ground in a hammermill and a roller mill to 800 and 400 µm. The roller mill was more efficient than the hammermill when grinding the corn, with less energy consumption and greater production rate per horsepower hour. For the 800 µm treatments, greater uniformity of particle size was achieved with the roller mill than the hammermill; however, at the 400 µm treatments, corn ground with the hammermill was slightly more uniform. Pigs fed corn ground to 400 µm had 7% greater efficiency of gain, and had greater digestibilities of dry matter, nitrogen, and energy than pigs fed corn ground to 800 µm. Mill type did not affect growth performance, but pigs fed corn ground in the roller mill had greater digestibilities of dry matter, nitrogen, and energy and excreted 18% less dry matter and 13% less nitrogen as feces than pigs fed corn ground in a hammermill. There were interactions among mill type and particle size, with digestibilities much greater for the diet with corn ground to 800 µm in the roller mill compared to the hammermill, but only small advantages in nutrient digestibility for diets with corn ground to 400 µm in the roller mill. Mill type did not affect rate or efficiency of gain, but pigs fed diets with roller-milled corn had greater digestibilities of nutrients and, thus, lower excretions of nutrients in feces.

(Key Words: Finishing, Process, Roller Mill.)

Introduction

In the last few KSU Swine Day Reports, we have given much attention to the positive effects of reducing mean particle size of cereal grains for nursery pigs (1991, page 56), finishing pigs (1992, page 122), and lactating sows (1992, page 6). From these experiments, we emphasized that reducing mean particle size of cereal grains to ≤ 600 µm resulted in marked improvements in nutrient digestibility and efficiency of growth compared to the relatively coarse sizes of 900 to 1,000 µm. Also, results from other experiments (1992 KSU Swine Day Report, page 126) indicated that particle size uniformity affected nutrient digestibility. This observation has implications for the mill type a producer might elect to purchase. For example, milling with a hammermill to a mean particle size > 800 µm typically yields products with much variation in particle size, but variation decreases with milling to smaller (< 500 µm) particle sizes. In contrast, milling with a roller mill yields grain with a high degree of particle size uniformity regardless of mean particle size. Thus, the experiment reported herein was designed to determine the effects of mill type (hammermill vs roller mill) and particle size (800 vs 400 µm) on grain milling, growth performance, and nutrient utilization.

Procedures

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A total of 128 crossbred finishing pigs (122 lb average initial body wt) was allotted to dietary treatments on the basis of weight, sex, and ancestry. They were housed in a modified open-front building (16 pens of five barrows and three gilts), with 50% solid concrete and 50% concrete slat flooring, and four pens per treatment. Each pen (6 ft × 16 ft) had a two-hole self-feeder and a nipple waterer to allow ad libitum consumption of feed and water.

Corn was ground in a 30 horsepower hammermill (P-240D Pulverator, Jacobson Machine Works) equipped with screens having openings of 3/8 and 1/16 in for the 800 and 400 µm treatments, respectively. Corn also was milled to the same particle sizes using a roller mill (three high; 1:1, 1.5:1, and 1.5:1 differential drives; 6:6, 10:12, and 16:18 corrugations per in for the fast:slow rolls; and 1 in of spiral per ft of roller; Model K, Roskamp Manufacturing). Particle size, particle size uniformity, and surface area of the ground grains and diets were determined with .22 lb samples using a Ro-Tap® shaker and a set of 14 sieves. The motor load of the hammermill and roller mill was held constant at 70% of capacity during milling so that production rate and electrical energy consumption could be measured. The basal diet was the corn-soybean meal-based diet (.65% lysine) given in Table 1. All diets were fed in meal form.

Pigs and feeders were weighed at initiation and conclusion of the growth assay to determine average daily gain (ADG), average daily feed intake (ADFI), and feed/gain (F/G). Six weeks after initiation of the experiment, chromic oxide was added to the diets (.20%) as an indigestible marker. After a 5-d adjustment period, grab samples of feces were collected from two barrows and two gilts in each pen. The fecal samples were dried and pooled within pen on an equal weight basis. Concentrations of chromium, dry matter (DM), nitrogen (N), and gross energy (GE) in the feces and diets were determined to allow calculation of apparent digestibilities of DM, N, and GE using the indirect ratio method. Intakes of digestible DM, N, and GE were calculated by multiplying daily nutrient intakes by their respective apparent digestibilities. The portion of nutrient intake not digested was reported as fecal excretion.

Table 1. Composition of the Basal Diet[a]

Ingredient	%
Corn	82.73
Soybean meal (48% CP)	14.37
Monocalcium phosphate	1.08
Limestone	1.02
Salt	.30
Vitamins and minerals[b]	.40
Antibiotic[c]	.10
Total	100.00

[a]The basal diet was formulated to .65% lysine, .65% Ca, .55% P, and 1.56 Mcal DE/lb.
[b]KSU old vitamin mix (.25%), KSU old mineral mix (.10%), and KSU selenium mix (.05%).
[c]Antibiotic supplied 100 g/ton chlortetracycline.

When a pen in a weight block reached an average body wt of 250 lb, the entire group was removed from the growth assay. One block reached the end weight on d 54, two blocks on d 60, and the last block on d 67 of the experiment. The data were analyzed as a 2 × 2 factorial (main effects of mill type and particle size) with pen as the experimental unit.

Results and Discussion

The actual particle sizes of the ground grains were very close (i.e., within 26 µm) to the targeted particle sizes (Table 2). Reducing particle size decreased variation in particle size and increased surface area of the ground grain from 77.8 to 130.1 cm^2/g. Also, energy required for grinding was increased and production rate was decreased as particle size was reduced. In general, the effects of mill type were less pronounced than those of reducing particle size; nonetheless, mill type did affect particle size uniformity and surface area of the ground corn and diets. Variation in particle size of corn ground in the hammermill was decreased more as particle size was reduced (i.e., s_{gw} from 2.5 to 1.7) compared to corn ground in the roller mill (i.e., s_{gw} from 2.0 to 1.9). Less energy was required to mill corn in the roller mill than in the hammermill, especially at the small particle size. Actual production rates were less for the roller mill than the hammermill because the hammermill had larger capacity; however, standardized production rates, which account for the differences in horsepower capacity of the mills, were still greater for the roller mill. Changes in average particle size, particle size uniformity, and surface area of the complete diets were similar to those observed for the milled corn, which was expected because corn was 83% of the diet.

No interactions occurred among mill type and particle size for growth performance of the finishing pigs (Table 3). Also, the main effect of mill type did not affect growth performance. However, pigs fed the 400 µm treatments had the same ADG and lower ADFI than pigs fed the 800 µm treatments, with the result that F/G was improved 7% (P<.01) by grinding the corn to 400 µm.

Apparent digestibilities of DM (P<.001), N (P<.01), and GE (P<.001) were greater for diets with roller-milled corn than for diets with hammermilled corn and greater for corn ground to 400 vs 800 µm (P<.001). However, the effects of mill type and particle size were not independent. Digestibilities were much lower for the diet with corn ground to 800 µm in the hammermill than for diets with corn ground to 800 µm in the roller mill, resulting in a mill type × particle size interaction (P<.01) for DM and GE digestibilities. However, the advantages in nutrient digestibility for corn ground in the roller mill were less pronounced at 400 µm, where the corn ground in the hammermill had the lowest variation in particle size. This suggested a mill type effect separate from the particle size uniformity effect, albeit less pronounced. Other researchers have described particles of hammermilled corn as more spherical in shape with more uniform edges than particles of roller-milled corn. The spherical shape would reduce susceptibility to attack by enzymes, thus, decreasing digestibility of nutrients in hammermilled corn.

Intake of digestible N was increased by 6% (P<.05) and excretions of DM (P<.001) and N (P<.05) in the feces were decreased 18 and 13%, respectively, when corn was ground in the roller mill vs the hammermill. Although there was a trend for intake of digestible N to increase, fecal excretions of DM and N were still reduced by 18 and 32% when particle size was decreased from 800 to 400 µm (P<.001). Nutrient excretions from animals in regions of intensive animal production can cause problems for the environment; indeed, some countries in Europe already limit animal production because of excretions of N and P. Therefore, any grain processing technique that reduces nutrient excretion has value to the swine industry. We should note that the effects of mill type and particle size on fecal excretion of DM were not independent (mill type × particle size interaction, P<.05); the improvement was markedly greater when particle size was decreased from 800 to 400 µm in the hammermill vs the roller mill.

In conclusion, increased particle size uniformity and using a roller mill to grind grain improved nutrient digestibility in diets. Also, these data make it difficult to attribute the benefits in nutrient digestibility from fine grinding of cereal grains to decreased mean particle size alone, because increased uniformity of particle size was a natural correlate to decreased mean particle size. Finally, it seems likely that the benefits of decreased mean particle size and increased uniformity of particle size may not be independent of mill type used to process the grain, an effect that may be related to particle shape. Further research is needed to verify this observation.

Table 2. Effects of Mill Type on Processing Characteristics when Milling Corn to Intermediate and Small Particle Sizes

	Hammermill		Roller Mill	
Item	800	400	800	400
Grain characteristics				
Mean particle size, µm	826	419	793	415
Variation in particle size, s_{gw}	2.5	1.7	2.0	1.9
Surface area, cm^2/g	82.5	126.8	73.0	133.3
Milling energy, kilowatt h/ton	4.2	11.7	3.9	8.9
Milling production rate, tons/h	4.3	2.2	1.9	1.2
Standardized production rate, lb/horsepower hour[b]	287	147	380	160
Diet characteristics				
Mean particle size, µm	860	558	758	543
Variation in particle size, s_{gw}	2.3	1.6	1.9	1.7
Surface area, cm^2/g	75.2	90.2	73.0	95.2

[a]Values are the percentage of a .22 lb sample retained on top of sieves after 15 min of shaking on a Ro-Tap® shaker.
[b]Standardized production rate = milling production rate/horsepower of mill.

Table 3. Effects of Mill Type and Particle Size on Growth Performance and Digestibility, Intake, and Excretion of Nutrients in Finishing Pigs

	Hammermill		Roller Mill		
Item	800	400	800	400	CV
Pig performance[a]					
ADG, lb/d	2.05	2.13	2.11	2.04	4.1
ADFI, lb/d[g]	7.23	6.91	7.26	6.68	3.6
F/G[g]	3.53	3.24	3.44	3.27	3.3
Apparent digestibility, %[b]					
DM[ehj]	82.5	86.0	86.6	87.3	.9
N[dh]	72.1	80.1	76.0	82.6	2.4
GE[ehj]	81.2	86.7	85.9	87.7	1.4
Intake of digestible nutrients[b]					
DM, lb/d[f]	5.37	5.34	5.66	5.25	3.4
N, lb/d[c]	.105	.112	.114	.115	3.9
GE, Mcal/d	10.54	10.83	11.30	10.71	3.6
Fecal excretion, lb/d[b]					
DM[ehi]	1.14	.87	.87	.77	7.2
N[ch]	.041	.028	.036	.024	10.0

[a]A total of 128 pigs (eight pigs/pen and four pens/treatment) with an avg initial body wt of 122 lb and an avg final body wt of 249 lb.
[b]A total of 64 pigs (four pigs/pen and four pens/treatment).
[cde]Hammermill vs roller mill ($P<.05$, $P<.01$, and $P<.001$, respectively).
[fgh]800 vs 400 µm ($P<.05$, $P<.01$, and $P<.001$, respectively).
[ij]Hammermill vs roller mill × 800 vs 400 µm ($P<.05$ and $P<.01$, respectively).