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SORGHUM GENOTYPE AND PARTICLE SIZE AFFECT GROWTH PERFORMANCE, NUTRIENT DIGESTIBILITY, AND STOMACH MORPHOLOGY IN FINISHING PIGS

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Summary

Seventy pigs (average initial body wt of 119 lb) were used to determine the effects of sorghum genotype on milling characteristics, growth performance, nutrient digestibility, and stomach morphology in finishing pigs. The pigs were fed a corn-soybean meal-based control diet, with the corn (Pioneer 3377) milled to a mean particle size of 600 µm. Hard-endosperm sorghum (Pioneer 8585) and soft-endosperm sorghum (Pioneer 894) were milled to mean particle sizes of 800, 600, and 400 µm and substituted for the corn in the control diet on a wt/wt basis, so that the overall treatment arrangement was a 2 × 3 factorial plus control. The sorghums required less energy to grind, had greater production rates, and produced less noise during milling than the corn. Pigs fed the diets with hard and soft endosperm sorghum had average daily gain, average daily feed intake, and feed/gain similar to those fed corn. Pigs fed hard sorghum grew faster, but pigs fed soft sorghum were more efficient. As particle size was decreased, energy required for grinding increased and production rate slowed. Efficiency of gain and nutrient digestibility were maximized and excretion of nutrients as feces was minimized at 400 µm for both hard- and soft-endosperm sorghum. Considering the positive effects of fine grinding on efficiency of gain and nutrient digestibility, but the negative effects on energy required for milling, production rate and stomach morphology, an acceptable compromise for particle size of soft and hard sorghum in pelleted diets for finishing pigs will still likely be less than 600 µm.

(Key Words: Sorghum, Process, Noise, Stomach, Digestibility, Finishing.)

Introduction

Grain sorghums have agronomic characteristics, such as resistance to heat stress and drought, that contribute to their cultivation in preference to corn in several regions of the world. However, sorghum grain is usually considered to have about 5% less feeding value than corn.

In the past few years, several experiments have been conducted to identify processing procedures that give consistent improvements in performance of pigs fed sorghum. Researchers at Arkansas reported that micronizing brown-seeded sorghum improved feed/gain (F/G) in finishing pigs, and data from KSU indicated improved F/G in nursery and finishing pigs fed diets with extruded sorghum compared to ground sorghum. However, cold grinding is by far the most common method of preparing cereals for use in livestock diets, and few data are available to determine the particle size of sorghum grain that would make it most competitive with corn. We used two sorghum genotypes that differed in endosperm hardness to determine if soft sorghum grain might require less processing

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that hard sorghum grain to achieve maximum nutritive value.

Materials and Methods

Corn (Pioneer 3377), hard-endosperm sorghum (Pioneer 8585), and soft-endosperm sorghum (Pioneer 894) were grown at Manhattan, KS and harvested in the fall of 1992. The grains were analyzed for crude protein, fat, ash, gross energy, and moisture using standard analytical procedures. Also, tannin content of the sorghums was determined and expressed as catechin equivalents. Treatments included a corn-based control diet, with the corn milled to a mean particle size of 600 µm. This particle size was suggested as the optimum for corn in meal or pelleted finishing diets by Wondra et al. in the 1992 KSU Swine Day Report (page 122). The hard- and soft-endosperm sorghums were milled to mean particle sizes of 800, 600, and 400 µm, so that the overall treatment arrangement was a 2 × 3 factorial plus control. The corn, hard-endosperm sorghum, and soft-endosperm sorghum had 12.9, 13.0, and 13.0% moisture, respectively, when milled, and the particle size determinations were made using sieves with Tyler numbers 4, 6, 8, 10, 14, 20, 28, 35, 48, 65, 100, 150, 200, 270, and a pan. A Ro-Tap® shaker was used to sift the 100 g samples for 10 minutes. The cereal grains were milled using a three-high roller mill (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). An audio dosimeter was used to measure the noise level during grinding of each grain. All diets were formulated to .7% lysine, .65% Ca, and .55% P (Table 1) and were pelleted in a 30 horsepower pellet mill. The die of the pelleter was 1.5 in thick with 3/16 in diameter holes, and steam was used before pelleting to condition the diets to 149° F. Samples of the finished diets were analyzed for pellet durability. Electrical energy consumption during grinding and pelleting was measured using an amperage/voltage strip chart recorder. The average voltage and amperage during processing were calculated and used to determine electrical consumption for each batch of feed.

The experimental diets were fed to a total of 70 crossbred barrows (119 lb average initial body wt). The pigs were housed in an enclosed, environmentally controlled building with slatted flooring. There were two pigs per pen and five pens per treatment. Each pen (5 ft × 5 ft) had a nipple waterer and a single-hole self-feeder so water and feed could be consumed on an ad libitum basis. On d 50 of the experiment, chromic oxide was added to the diets as an indigestible marker. After a 5-d adjustment period, samples of feces were collected from each pig and pooled within pen. The feed and fecal samples were dried and analyzed for dry matter (DM), nitrogen (N), gross energy (GE), and chromium concentrations to allow calculation of apparent DM, N, and GE digestibilities. The pigs were fed to an average ending weight of 250 lb and slaughtered for collection of hot carcass weights, last rib fat thicknesses, and stomach tissues. Stomach tissues were evaluated for severity of keratinization and esophagogastric ulcers using scoring systems where keratinization was 1 = normal, 2 = mild parakeratosis, 3 = moderate parakeratosis, and 4 = severe parakeratosis and ulceration was 1 = normal, 2 = erosion, 3 = ulcer, and 4 = severe ulcer.

Pig performance, nutrient utilization, and carcass data were analyzed as a randomized complete block design, with a 2 × 3 factorial plus control arrangement of treatments. Pen served as the experimental unit. Final body wt was used as a covariate for analyses of backfat thickness and dressing percentage. Treatment comparisons were made using the contrasts: 1) corn vs sorghum treatments; 2) hard sorghum vs soft sorghum; 3) linear effect of particle size; 4) quadratic effect of particle size; 5) hard sorghum vs soft sorghum × linear effect of particle size; and 6) hard sorghum vs soft sorghum × quadratic effect of particle size. Because the stomach scores were categorical data, they were tested for significant main effects of grain type and particle size using a row mean scores differ test for categorical data.

Results and Discussion

The soft- and hard-endosperm sorghums were genotypes with normal (nonwaxy) white starch, red pericarp, and low tannin (Table 2). Crude protein concentrations were 7.7 for corn, 9.5 for hard sorghum, and 10.5 for soft sorghum. Percentage fat, ash, and gross energy were similar for the three grains.

As mean particle size was decreased, energy required for grinding increased and production rate was slowed (Table 3). More energy was required to grind corn to 600 µm than to grind the sorghums to 600 µm. Also, hard-endosperm sorghum required more energy for grinding to 800 and 600 µm than soft sorghum, but similar energy inputs were required to grind the sorghums to 400 µm. Sorghum genotype had little effect on pelleting efficiency or pellet durability.

Noise pollution was greater during milling of the corn than of the sorghums, and hard sorghum produced more noise than soft sorghum. When compared to OSHA standards for tolerable noise levels, these data suggest that hearing protection would be required when corn is ground, but not when sorghums are ground. Further research in this area is needed to evaluate the potential for hearing damage during cold grinding of different grains.

For ADG, ADFI, and F/G, no differences were observed ($P>.10$) among the corn control and sorghums (Table 4). Pigs fed the hard-endosperm sorghum gained 4% faster than pigs fed soft-endosperm sorghum ($P<.05$). However, pigs fed soft-endosperm sorghum consumed 7% less feed ($P<.01$) and were 3% more efficient ($P<.01$) than pigs fed hard-endosperm sorghum. Linear decreases in ADFI and F/G were noted as mean particle size of the diets was reduced from 800 to 400 µm ($P<.01$). These results agree with previous reports of improved efficiency of gain as particle size is reduced below the typical sizes of 800 to 1,000 µm.

Several researchers have reported little or no difference in carcass characteristics as particle size of diets is decreased. In our experiment, reduction of particle size did not affect dressing percentage or last rib backfat thickness ($P>.10$). However, sorghum genotype did affect carcass measurements, with pigs fed hard endosperm sorghum having 8% greater last rib backfat thickness ($P<.05$). This increase in last rib backfat thickness in pigs fed the hard-endosperm sorghum probably resulted from their greater feed intakes.

Apparent digestibilities of DM and GE were greater ($P<.01$) for the sorghums than for the corn (Table 5). This was especially true when the sorghum was ground to 400 µm. No difference in digestibility of N was observed among the corn-based control and the sorghum treatments ($P>.10$). These responses were unexpected, because corn routinely has greater nutrient digestibility than sorghum. Similar discrepancies with the "norm" (i.e., corn>sorghum) have been reported by other researchers from time to time and suggest that genotype, growing conditions, processing methods, and(or) other unknown factors can contribute to make sorghum similar to corn in nutritional value. When the two sorghum genotypes were compared, soft-endosperm sorghum had greater DM, N, and GE digestibility than hard-endosperm sorghum ($P<.01$). However, there were sorghum genotype × particle size interactions ($P<.05$) for digestibilities of DM, N, and GE. Nutrient digestibility increased in a linear manner as particle size of soft-endosperm sorghum was reduced from 800 to 400 µm. However, for the hard-endosperm sorghum, the apparent digestibilities decreased as particle size was reduced from 800 to 600 µm and then increased as particle size was reduced from 600 to 400 µm. This quadratic response for the hard sorghum is difficult to explain and likely can be attributed to random error in the titration curve.

In the last few years, the contribution of intensive animal production to environmental pollution has become a matter of concern. Some countries of the European community have already introduced strong regulations to reduce the amounts of DM, N, and mineral excretions. In our experiment, reducing particle size from 800 to 400 µm reduced fecal excretions of DM and N by 14 and 33%, respectively, for pigs fed hard-endosperm sorghum and by 59 and 60%, respectively, for pigs fed soft-endosperm sorghum. These results suggest that increased production costs, because of environmental regulations, can be reduced by proper processing of swine diets.

It is well documented that the incidence of stomach ulcers in swine can be increased by pelleting and use of finely ground grain. Some have suggested that reduction of particle size results in greater acid secretion and pepsin activity in the stomach. This mixture of stomach contents, acid, and enzymes contacts the relatively unprotected esophageal region of the stomach leading to development of ulcers. In our experiment, scores for degree of keratinization and gastric lesions were not affected by grain source (P>.10). Reduction of particle size increased the incidence and severity of gastric lesions for both hard- and soft-endosperm sorghums (P<.05), but even at 400 µm, the scores for the sorghums were less than those for corn ground to 600 µm.

In conclusion, pigs fed the diets with hard- or soft-endosperm sorghum had similar ADG, ADFI, and F/G to those fed corn. Also, the sorghums required less energy to grind, had greater production rates, and produced less noise during milling than the corn. Efficiency of gain and nutrient digestibility was maximized at 400 µm for both hard- and soft-endosperm sorghums. Considering the positive effects of fine-grinding on efficiency of gain and nutrient digestibility, but the negative effects on energy required for milling, production rate, and stomach morphology, an acceptable compromise for particle size of soft and hard sorghums in pelleted diets for finishing pigs will still likely be less than 600 µm.

Table 1. Diet Composition[a]

Item	Control Diet, %	Sorghum Diets, %
Corn	82.47	—
Sorghum	—	82.45
Soybean meal (48% CP)	14.75	14.75
Monocalcium phosphate	1.07	1.07
Limestone	1.02	1.02
L-lysine HCl	.04	.06
Salt	.30	.30
Vitamin premix[b]	.15	.15
Trace mineral premix[b]	.10	.10
Antibiotic[c]	.10	.10
Total	100	100

[a]The control diet was formulated to 14% CP, .7% lysine, .65% Ca, and .55% P with corn as the cereal grain. Soft- and hard-endosperm sorghums were used to replace corn on a wt/wt basis.
[b]KSU vitamin and mineral premixes.
[c]Provided 100 g/ton chlortetracycline.

Table 2. Chemical Analyses of the Experimental Grains

		Sorghum Endosperm	
Item	Corn	Soft	Hard
Crude protein, %	7.7	10.5	9.5
Fat, %	3.7	3.7	4.0
Ash, %	1.9	1.4	1.3
Gross energy, Mcal/lb	1.79	1.78	1.77
Moisture, %	16.4	15.5	16.9
Tannins, catechin equivalents	ND[a]	ND	ND

[a]ND= none detected (i.e., less than .03 mg/100 mg DM).

Table 3. Effects of Sorghum Genotype on Milling Characteristics

	Corn	Soft Sorghum, µm			Hard Sorghum, µm		
Item	600, µm	800	600	400	800	600	400
Milled grains							
Mean particle size, µm	592	813	605	421	794	607	411
Variation in particle size (s_{gw})	2.12	1.79	1.83	1.77	1.77	1.83	1.77
Grinding							
Energy, kilowatt h/ton	7.0	2.4	4.5	9.1	3.0	6.4	9.1
Production rate, ton/h	.9	2.5	1.3	.8	1.9	1.1	.8
Noise, decibles	95	84	81	85	85	84	86
Pelleting							
Energy, kilowatt h/ton	10.8	9.8	10.1	9.8	10.5	9.3	10.2
Production rate, ton/h	1.3	1.8	1.5	1.2	1.2	1.4	1.2
Fines, %	10.3	9.4	9.5	7.7	10.7	8.9	8.3
Durability, %	89.6	90.6	90.5	92.3	89.3	89.1	91.7

Table 4. Effects of Grain Genotype and Particle Size on Performance, Carcass, and Stomach Lesions in Finishing Pigs[a]

	Corn	Soft Sorghum, µm			Hard Sorghum, µm			
Item	600, µm	800	600	400	800	600	400	CV
ADG,lb[b]	2.18	2.20	2.15	2.18	2.25	2.28	2.29	5.3
ADFI,lb[cd]	7.11	7.48	6.94	6.91	7.78	7.65	7.48	5.0
F/G[cd]	3.26	3.40	3.23	3.17	3.46	3.36	3.27	3.2
Dressing percentage	74.1	74.6	73.5	74.6	74.8	74.9	75.1	1.4
Fat thickness, in[b]	1.47	1.26	1.37	1.34	1.44	1.41	1.44	8.1
Stomach keratinization score	2.8	1.9	2.5	2.5	2.3	2.4	2.5	21.1
Stomach ulcer score[e]	1.6	1.2	1.0	1.4	1.0	1.3	1.6	31.2

[a]A total of 70 pigs with 2 pigs/pen and 5 pens/treatment (avg initial body wt of 119 lb).
[bc]Hard sorghum vs soft sorghum (P<.05; P<.01, respectively).
[d]Linear effect of particle size (P<.01).
[e]Particle size effect (P<.05; Cochran-Mantel-Haenszel statistic, row mean scores differ test).

Table 5. Effects of Grain Genotype and Particle Size on Apparent Digestibility, Intake, and Excretion of Nutrients in Finishing Pigs[a]

	Corn	Soft Sorghum, µm			Hard Sorghum, µm			
Item	600, µm	800	600	400	800	600	400	CV
Apparent digestibilities, %								
DM[cdegh]	86.21	87.07	89.09	90.24	88.38	86.52	89.57	.7
N[deghk]	79.78	75.55	80.99	90.68	79.14	75.47	83.89	1.9
GE[cdeghj]	86.93	87.07	89.23	94.56	88.82	86.87	90.83	.8
DM digested, lb/d[cdg]	5.51	5.86	5.56	5.86	6.19	5.95	6.03	5.0
N digested, lb/d[cdf]	.12	.15	.14	.16	.14	.13	.14	5.3
DM excretion, lb/d[cdeghi]	.88	.87	.68	.36	.81	.92	.70	8.4
N excretion, lb/d[beghk]	.03	.05	.03	.02	.03	.04	.02	10.0

[a]A total of 70 pigs with 2 pigs/pen and 5 pens/treatment (avg initial body wt of 119 lb).
[bc]Corn vs sorghums (P<.10; P<.01, respectively).
[d]Hard sorghum vs soft sorghum (P<.01).
[e]Linear effect of particle size (P<.001).
[fg]Quadratic effect of particle size (P<.10; P<.001, respectively).
[h]Sorghum genotype × linear effect of particle size (P<.001).
[ijk]Sorghum genotype × quadratic effect of particle size (P<.10; P<.05; P<.01, respectively).