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Abstract

A total of 240 weanling pigs (avg initial wt of 11.7 lb) was used to determine the effects of particle size of corn and two sorghum genotypes on growth performance. In addition to the pig feeding experiment, 420 broiler chicks (avg initial wt of .15 lb) were fed the same grain treatments to determine if they were a reliable model for the effects of diet particle size on nursery pig performance. Milling characteristics of the cereal grains were measured. Treatments were corn, hard endosperm sorghum, and soft endosperm sorghum, ground to particle sizes of 900, 700, 500, and 300 Âµm (geometric mean), with a 3 x 4 factorial arrangement of treatments. In general, reducing particle size increased electrical energy required for milling and decreased production rate. However, there were differences among the grain sources for energy required for milling and production rates, e.g., grinding the sorghums to 500 Âµm took less energy than grinding corn to 900 Âµm. In starter pigs, the most efficient gains were achieved at 300 Âµm for d 0 to 7, 300 to 500 Âµm for d 0 to 14, and at 500 Âµm for d 0 to 35. It should be noted that the pig diets were in pelleted form, so problems with bridging and reduced flowability were not a concern with the finely ground grain sources. Overall, pigs fed diets containing corn grew faster, consumed more feed, and were more efficient than those fed sorghum. When compared at their optimum particle sizes, hard and soft sorghum supported ADGs that were 80 and 84%that of corn, and efficiencies of gain that were 96% that of corn. For broiler chicks, reducing particle size of corn below 900 Âµm did not improve gain to d 21, but grinding sorghum to 500 to 700 Âµm did improve gain. Efficiency of gain also was improved more with fine grinding of sorghum than corn. Optimum particle sizes for F/G were 300 and 500 Âµm for hard and soft sorghum, respectively. It is important to note that relative to corn, at 900 p.m feeding values for chicks fed hard and soft sorghums were 92%, but at the optimum particle size for each grain, relative feeding values for hard and soft sorghum were 99% that of corn. These data suggest that sorghums can equal corn in feeding value for broiler chicks when milled to their optimum particle size, and that as pigs and chicks get older, optimum particle size increases. However, starter pigs fed corn had 15 to 20% greater ADG and 4% greater efficiency of gain than pigs fed the sorghums.; Swine Day, Manhattan, KS, November 21. 1991

Keywords

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OPTIMUM PARTICLE SIZE OF CORN AND HARD AND SOFT SORGHUM GRAIN FOR NURSERY PIGS AND BROILER CHICKS

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Summary

A total of 240 weanling pigs (avg initial wt of 11.7 lb) was used to determine the effects of particle size of corn and two sorghum genotypes on growth performance. In addition to the pig feeding experiment, 420 broiler chicks (avg initial wt of .15 lb) were fed the same grain treatments to determine if they were a reliable model for the effects of diet particle size on nursery pig performance. Milling characteristics of the cereal grains were measured. Treatments were corn, hard endosperm sorghum, and soft endosperm sorghum, ground to particle sizes of 900, 700, 500, and 300 μm (geometric mean), with a 3 × 4 factorial arrangement of treatments. In general, reducing particle size increased electrical energy required for milling and decreased production rate. However, there were differences among the grain sources for energy required for milling and production rates, e.g., grinding the sorghums to 500 μm took less energy than grinding corn to 900 μm. In starter pigs, the most efficient gains were achieved at 300 μm for d 0 to 7, 300 to 500 μm for d 0 to 14, and at 500 μm for d 0 to 35. It should be noted that the pig diets were in pelleted form, so problems with bridging and reduced flowability were not a concern with the finely ground grain sources. Overall, pigs fed diets containing corn grew faster, consumed more feed, and were more efficient than those fed sorghum. When compared at their optimum particle sizes, hard and soft sorghum supported ADGs that were 80 and 84% that of corn, and efficiencies of gain that were 96% that of corn. For broiler chicks, reducing particle size of corn below 900 μm did not improve gain to d 21, but grinding sorghum to 500 to 700 μm did improve gain. Efficiency of gain also was improved more with fine grinding of sorghum than corn. Optimum particle sizes for F/G were 300 and 500 μm for hard and soft sorghum, respectively. It is important to note that relative to corn, at 900 μm feeding values for chicks fed hard and soft sorghums were 92%, but at the optimum particle size for each grain, relative feeding values for hard and soft sorghum were 99% that of corn. These data suggest that sorghums can equal corn in feeding value for broiler chicks when milled to their optimum particle size, and that as pigs and chicks get older, optimum particle size increases. However, starter pigs fed corn had 15 to 20% greater ADG and 4% greater efficiency of gain than pigs fed the sorghums.

(Key Words: Particle size, Corn, Sorghum, Endosperm Hardness, Starter, Broiler Chicks.)

Introduction

Cereal grains are typically processed before they are incorporated into diets for swine. This processing nearly always involves grinding in a hammermill or roller mill to reduce particle size and, thus, improve nutrient digestibility. However, finely ground grains have been implicated as a cause of stomach ulcers in

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growing-finishing pigs. This occurs as the result of increased fluidity of stomach contents, which greatly increases contact of acid and enzyme secretions from the lower stomach with the relatively unprotected upper region of the stomach. Most research investigations of ulceration in the pig stomach have been done with finishing pigs fed corn and wheat. The research reported herein concerns the effects of particle size reduction on growth performance and gastrointestinal morphology of starter pigs fed corn and sorghums with different endosperm hardness. Additionally, comparable measurements of growth aned intestinal morphology were made on broiler chicks to determine how closely chick assays parallel growth in young pigs. If data from chick growth assays can be extrapolated to nursery-age pigs, this would greatly increase the pool of knowledge available to swine producers and add many options for researchers.

Procedures

Corn and two sorghum grains that differed in endosperm hardness were ground to four particle sizes (900, 700, 500, and 300 μm). This resulted in a 3 × 4 factorial arrangement of treatments. When processed, the three grain sources were between 12.5 and 13% moisture. Great effort was taken to ensure that targeted particle sizes were obtained and that particle sizes between grains were constant. The three coarser particle sizes (900, 700, and 500 μm) were obtained with a roller mill, and the finest particle size (300 μm) was obtained with a hammermill by grinding through a 1/16" and then a 3/64" screen. The roller mill settings were determined by setting the rolls, processing grain under full motor load, sampling the milled grain, and calculating mean particle size. The rolls were adjusted based on the particle size determination, and the process was repeated until the targeted particle size was achieved. Electrical energy consumption and production rate were recorded to allow calculation of electrical energy cost per ton of grain processed.

Diets were formulated with corn, and the sorghums were substituted for corn on a lb per lb basis. The diets were fed in pelleted form to the pigs and meal form to the broiler chicks. Energy consumption, pellet durability, and production of fines were recorded for the pelleted diets. Response criteria for the experiment were ADG, ADFI, F/G, and changes in intestinal morphology (e.g., lesions in the stomach of pigs; wt, and lesions of the proventriculus and gizzard of chicks).

A total of 240 weanling pigs, with an avg initial wt of 11.7 lb, was used in a 35-d growth assay. The pigs were allotted, based on ancestry, sex, and wt, to the 12 grain treatments. The pigs were housed (five pigs/pen and four pens/treatment) in an environmentally controlled nursery with 4 ft × 5 ft pens. Feed and water were consumed ad libitum, and pig and feeder weights were recorded weekly. Composition of the experimental diets is given in Table 1. At the end of the growth assay, five pigs from the 900 and 300 μm treatments of each grain source were sacrificed to evaluate stomach morphology.

For comparison of pig and chick growth performance, 420 broiler chicks (7 d of age and .15 lb avg initial wt) were used in a 21-d growth assay (five chicks/cage and seven cages/treatment). Chicks were randomly allotted to the 12 dietary treatments based on sex and weight. Diets were formulated to contain at least 110% of NRC for all essential nutrients. Composition of the diets is given in Table 1. Feed and water were consumed ad libitum, and chick and feed weights were recorded weekly. At conclusion of the growth assay, 15 chicks from the 900 and 300 μm treatments of each grain source were sacrificed for evaluation of the gastrointestinal tract.

Results and Discussion

Measurements of milling characteristics are given in Table 2. When averaged across all particle sizes, corn required over twice as much electrical energy to mill as the sorghums. This difference was greatest for grain ground to 500 μm through the roller mill, where corn required nearly four times as much energy to grind compared to the sorghums (e.g., 14.3 kwh/ton vs 3.7 kwh/ton). It is interesting to note that both sorghums could be ground to 500 μm with less electrical energy than that required to grind corn to 900 μm. Production rates for the sorghums vs corn also favored milling the sorghums to 500 μm vs milling corn to 900 μm.

Hard sorghum required slightly less energy to roller mill than soft sorghum at particle sizes of 900, 700 and 500 μm, but hard sorghum required more energy to hammermill to 300 μm than soft sorghum. Energy required to pellet was similar between grain sources with small improvements as particle size was reduced to 500 μm. Likewise, pellet durability was not different for the cereal grains, but there was a trend for slight decreases in durability as particle size was reduced from 900 to 500 μm.

Growth data for the weanling pigs are given in Table 3. For d 0 to 7, as particle size was reduced from 900 to 300 μm, ADG and F/G were improved for pigs fed all grain sources, with the greatest positive response in pigs fed corn. At 300 μm, pigs fed hard sorghum were 4% more efficient than pigs fed corn, but had 7% lower ADG. Pigs fed soft sorghum had 7 and 8% poorer ADG and F/G than pigs fed corn milled to 300 μm.

For d 0 to 14, pigs fed sorghum ground to 900 μm had greater ADG than pigs fed corn ground to 900 μm, but at 300 μm, pigs fed corn had 8 and 15% greater ADG than pigs fed hard and soft sorghum, respectively. Optimum particle sizes for F/G were 500 μm for corn and soft sorghum and 300 μm for hard sorghum. At these optimum particle sizes, the feeding values of hard and soft sorghum, relative to corn, were 94 and 93%, respectively.

For d 0 to 35, pigs fed diets containing corn gained 23% faster, consumed 16% more feed, and were 6% more efficient than pigs fed the sorghums. Optimum particle size for F/G was 500 μm for all grain sources, with ADG for pigs fed hard and soft sorghum at 80 and 84% that of corn, respectively, and efficiency of gain at 96% that of corn for both sorghums.

Stomachs from pigs sacrificed at the end of the growth assay were subjectively scored for lesions of the epithelium in the upper esophageal region. No ulcers were found, but there were differences in the epithelial surface. For corn and hard sorghum, pigs fed the 300 μm treatment had greater keratinization than pigs fed the 900 μm treatment. In contrast, pigs fed soft sorghum had less keratinization when fed the 300 μm treatment versus the 900 μm treatment. These data casts doubt on the significance of fine-grinding as a cause of stomach ulcers in nursery-age pigs.

Growth performance and intestinal tract morphology data from the chick assay are given in Table 4. For d 0 to 7, chicks fed sorghum at 900 μm had poorer gains and F/G than chicks fed corn at 900 μm. However, when compared at the optimum particle size for each grain (300 μm for corn, 500 μm for hard sorghum and 300 μm for soft sorghum) the hard and soft sorghums supported gain and F/G that were 108 and 99% that of corn.

For d 0 to 21, chicks fed corn were more efficient than chicks fed the sorghums, but that response was affected by particle size. At 900 μm, chicks fed corn had 11% greater ADG and were 5% more efficient than chicks fed sorghum, but at the optimum particle size for each grain source, chicks fed sorghum gained 3% more weight and were 99% as efficient as chicks fed corn. This was because of less response to particle size reduction in corn than sorghum. Maximum gain was achieved at 700 μm and maximum efficiency of gain was achieved at 300 μm for corn and hard sorghum. Maximum gain and efficiency of gain was achieved at 500 μm for soft sorghum.

Gizzard weights were reduced by 14, 21 and 29% for corn, hard sorghum and soft sorghum, respectively, when the grains were milled to 300 μm versus 900 μm. Proventriculus weights were reduced 1, 23 and 21% for chicks fed corn, hard and soft sorghum milled to 300 μm versus 900 μm. There is currently a great deal of interest in the energy required to maintain the gastrointestinal tract and liver of livestock; energy that could have been used for growth of lean tissue. It is possible that these differences in organ weights are contributing to improved feed efficiency of chicks fed grains milled to small particle sizes.

Gizzards were subjectively scored on a scale of 1 to 3, with 1=normal appearance, 2=moderate abrasions and 3=severe abrasions and(or) erosions. Chicks fed corn ground to 300 μm had higher scores than those fed corn ground to 900 μm, but the reverse was true for chicks fed the sorghums.

In conclusion, production rate slowed and energy requirements increased as particle size was decreased. However, the sorghums required less energy to grind and had greater production rates compared to corn. There were improvements in F/G in both starter pigs and broiler chicks as particle size was reduced. This reached an optimum at 300 to 500 μm for both species, and was somewhat dependent on grain source and age of the animals. It should be noted that differences in utilization (especially ADG) of sorghum versus corn were greater in nursery pigs compared to broiler chicks. Considering energy required for milling, production rate, and growth performance, milling sorghum and corn to 500 μm is recommended in pelleted diets for newly weaned pigs, a response that corresponds quite well with the chick data. However, even though growth performance was improved for weanling pigs as particle size was decreased, fine-grinding has been associated with stomach ulcers in finishing pigs. Microscopic evaluations of the intestinal tracts of the pigs and chicks are in progress and will be used to ensure that well-being of the animals was not compromised by fine-grinding of the cereal grains.

Table 1. Composition of Basal Diets[a]

	Nursery pigs		
Ingredient	Phase 1	Phase 2	Broilers
Corn[b]	40.24	58.54	54.42
Soybean meal (48%)	32.40	29.30	39.30
Soy oil	3.00	2.00	1.00
Whey	20.00	5.00	—
Vit/Min/Antibiotic[c]	4.26	4.81	4.93
Lysine-HCl	.10	.10	—
DL-methionine	—	—	.25
Chromic oxide	—	.25	.10

[a]Diets were formulated to contain 1.25 lysine, .9% Ca, and .8% P in Phase I and 1.15% lysine, .8% Ca, and .7% P in Phase II. Broiler diets were formulated to contain 23% CP, 1.1% Ca, and 1.0% P.

[b]Hard and soft sorghums replaced corn on an lb per lb basis.

[c]KSU vitamin, mineral and selenium premixes, monocalcium phosphate, limestone, and .3% salt. Antibiotic supplied 100 g/ton chlortetracyine, 100 g/ton sulfathiazole, 50 g/ton penicillin, and 250 ppm Cu in the pig diets, and 100 g/ton chlortetracycline and .05% amprolium in the broiler diets.

Table 2. **Effects of Grain Source on Milling Characteristics and Pellet Durability**

	Corn				Hard sorghum				Soft sorghum			
	900	700	500	300	900	700	500	300	900	700	500	300
Particle size, µm	919	702	487	369	902	741	512	345	888	715	497	341
Variation in particle size (Sgw)	1.92	1.86	1.65	1.69	2.1	2.03	1.90	1.60	2.02	1.83	1.82	1.66
Grinding energy, kwh/ton	4.8	8.4	14.3	22.2	1.5	2.1	3.4	18.2	1.7	2.3	3.9	13.9
Production rate, ton/h	1.9	1.1	.7	.7	6.6	4.5	2.6	.8	4.9	3.8	2.1	1.3
Pelleting energy (Phase 1), kwh/ton	27.4	26.3	26.4	26.5	28.5	28.7	27.0	27.6	27.9	27.8	27.7	29.1
Pelleting energy (Phase 2), kwh/ton	34.8	34.0	33.0	33.3	34.2	26.7	33.8	34.3	36.6	35.4	31.9	34.0
Pellet durability (Phase 1), %	97.3	95.3	95.3	96.0	96.0	95.3	94.7	97.3	95.3	95.3	95.3	96.0
Pellet durability (Phase 2), %	91.4	90.0	89.7	90.8	90.9	88.8	84.9	86.2	88.6	91.5	87.1	91.2
Fines (Phase 1), %	3.5	3.6	3.8	3.8	3.5	2.9	3.1	2.9	3.8	3.1	3.0	3.8
Fines (Phase 2), %	7.6	6.5	6.0	5.6	8.8	7.1	7.9	6.5	9.1	7.4	6.8	5.5

Table 3. **Effect of Grain Type and Particle Size on Growth Performance and Stomach Lesions in Starter Pigs[a]**

	Corn				Hard sorghum				Soft sorghum				
	900	700	500	300	900	700	500	300	900	700	500	300	CV
d 0 to 7													
ADG, lb[ei]	.44	.49	.50	.59	.54	.53	.52	.55	.49	.49	.48	.55	15.1
ADFI, lb[l]	.54	.57	.52	.55	.52	.57	.54	.49	.56	.52	.50	.57	12.7
F/G[fj]	1.23	1.16	1.04	.93	.96	1.08	1.04	.89	1.14	1.06	1.04	1.04	11.1
d 0 to 14													
ADG, lb[fgj]	.61	.64	.73	.77	.67	.62	.66	.71	.67	.60	.63	.67	10.9
ADFI, lb[m]	.76	.79	.78	.83	.82	.76	.77	.80	.80	.73	.72	.79	11.2
F/G[fi]	1.25	1.23	1.06	1.07	1.22	1.23	1.18	1.13	1.20	1.23	1.14	1.17	7.7
d 0 to 35													
ADG, lb[b]	.94	.90	.96	.93	.76	.73	.77	.67	.81	.77	.81	.74	11.3
ADFI, lb[bd]	1.41	1.31	1.36	1.33	1.19	1.13	1.14	1.09	1.28	1.18	1.20	1.14	10.0
F/G[bh]	1.50	1.46	1.42	1.43	1.57	1.55	1.48	1.63	1.58	1.53	1.48	1.54	4.9
Stomach score[cekn]	1.00	—	—	1.75	1.20	—	—	2.00	1.35	—	—	1.05	35.3

[a]240 pigs, 5 pigs/pen, 4 pens/treatment (avg initial wt of 11.7 lb).
[b]Corn vs sorghums ($P < .001$).
[c]Hard vs soft ($P < .10$).
[def]Particle size linear ($P < .10$, $P < .05$, $P < .01$, respectively).
[gh]Particle size quadratic ($P < .10$, $P < .05$, respectively).
[ij]Corn vs sorghums x particle size linear ($P < .10$, $P < .05$, respectively).
[k]Hard vs soft × particle size linear ($P < .05$).
[l]Hard vs soft × particle size quadratic ($P < .05$).
[m]No treatment effect ($P > .10$).
[n]1 = normal, 2 = moderate keratinization, 3 = severe keratinization.

Table 4. Effect of Grain Type and Particle Size on Growth Performance Organ Weights and Gizzard Lesions in Broiler Chicks[a]

	Corn				Hard sorghum				Soft sorghum				
	900	700	500	300	900	700	500	300	900	700	500	300	CV
d 0 to 7													
Gain, lb[fin]	.24	.26	.27	.26	.21	.29	.28	.27	.23	.26	.27	.28	15.5
Feed intake, lb[h]	.36	.37	.36	.34	.33	.39	.37	.36	.36	.37	.36	.37	10.9
F/G[gjm]	1.50	1.42	1.33	1.31	1.57	1.34	1.32	1.33	1.57	1.42	1.33	1.32	7.7
d 0 to 21													
Gain, lb[ejl]	1.61	1.62	1.61	1.57	1.43	1.66	1.64	1.62	1.47	1.59	1.66	1.62	7.9
Feed intake, lb[il]	2.43	2.43	2.38	2.32	2.26	2.57	2.46	2.41	2.35	2.43	2.47	2.47	6.6
F/G[bdgio]	1.51	1.50	1.48	1.48	1.58	1.55	1.50	1.49	1.60	1.53	1.49	1.52	2.9
Gizzard wt, g/kg[cgk]	24.4	—	—	20.9	23.5	—	—	18.5	24.5	—	—	17.5	15.6
Proventriculus													
wt, g/kg[gl]	5.03	—	—	4.98	5.38	—	—	4.16	5.20	—	—	4.14	20.3
Gizzard score[lp]	1.27	—	—	2.00	1.92	—	—	1.76	1.71	—	—	1.60	34.8

[a]420 chicks, 5 chicks/cage, 7 cages/treatment (avg initial wt of .15 lb).
[bc]Corn vs sorghums ($P<.10$, $P<.05$, respectively).
[d]Hard sorghum vs soft sorghum ($P<.001$).
[efg]Particle size linear ($P<.05$, $P<.01$, $P<.001$, respectively).
[hij]Particle size quadratic ($P<.12$, $P<.05$, $P<.01$, respectively).
[kl]Corn vs sorghums x particle size linear ($P<.10$, $P<.05$, respectively).
[m]Corn vs sorghums x particle size quadratic ($P<.10$).
[no]Hard sorghum vs soft sorghum × particle size quadratic ($P<.10$, $P<.05$, respectively).
[p]1 = normal, 2 = moderate abrasion, 3 = severe abrasion and/or erosion.