PARTICLE SIZE (1,000 vs 500 μm) AFFECTS NUTRITIONAL VALUE OF SIMPLE AND COMPLEX DIETS FOR WEANLING PIGS AND BROILER CHICKS

I. H. Kim, J. D. Hancock, M. R. Cabrera, R. H. Hines, M. M. Rantanen, and K. C. Behnke[1]

Summary

Nursery pigs fed complex diets had greater ADG than those fed simple diets, and as particle size was reduced, ADG and F/G tended to improve. There was a trend for reducing particle size to increase ADG more for pigs fed simple versus complex diets, but the response in efficiency of gain was of similar magnitude regardless of diet complexity. A second experiment was designed to determine if broiler chicks were an acceptable model for predicting the effects of feed processing procedures on nursery pigs. Chicks responded somewhat differently than pigs to the diet complexity × particle size treatments, with reduction of particle size having an effect only in simple diets.

(Key Words: Nursery, Diet Complexity, Particle Size.)

Introduction

Cereal grains typically are processed before incorporation into diets for pigs. This processing nearly always involves grinding in a hammermill or roller mill to reduce particle size and, thus, improve nutrient digestibility. In the past several KSU Swine Day Reports, we have given much attention to the positive effects of reducing mean particle size of cereal grains. From those experiments, we emphasized that reducing mean particle size of cereal grains to <600 μm resulted in greater nutrient digestibility, efficiency of growth, lactation performance, and decreased fecal excretion of nutrients compared to the coarser sizes of 900 to 1,000 μm. However, these marked benefits were observed in pigs fed relatively simple diets with high proportions as cereal grain. With only 30 to 40% of a complex starter diet as cereal, the benefits of reducing particle size conceivably could be reduced greatly. The experiment reported herein was designed to determine the effects of reducing particle size of corn from 1,000 to 500 μm in simple and complex diets for weanling pigs. Also, a chick bioassay was conducted to determine the merits of using broiler chicks as a quick and inexpensive model for the response of nursery pigs to feed-processing technologies.

Procedures

A total of 192 weanling pigs (initial wt of 11.7 lb and 21 d of age) was used in a 24-day growth assay. The pigs were blocked by weight and allotted (based on sex and ancestry) with eight pigs per pen and six pens per treatment. Treatments were: 1) 1,000 μm corn in a simple diet; 2) 500 μm corn in a simple diet; 3) 1,000 μm corn in a complex diet; and 4) 500 μm corn in a complex diet. The corn (mill-run) was ground in a hammermill through screens with openings of 1/2 in and 1/16 in to yield the 1,000 and 500 μm particle size treatments. The simple diet regimen was corn-soybean meal-whey-based for d 0 to 10 and 10 to 24 (Table 1). The complex diet regimen had dried whey, lactose, spray-dried plasma protein, spray-dried vital wheat gluten, and spray-dried blood meal for d 0 to 10 and dried whey and spray-dried blood meal for d 10 to 24. All diets had 1.6% lysine, .45% methionine, .9% Ca, and .8% P for d 0 to 10 and 1.3% lysine,

[1]Department of Grain Science and Industry.

.36% methionine, .8% Ca, and .7% P for d 10 to 24. The diets were fed in pelleted form.

The pigs were housed in an environmentally controlled nursery room. The temperature was maintained at 90°F during wk 1 and decreased 5°F each week thereafter. Each pen had a self-feeder and nipple water to allow ad libitum consumption of feed and water. Pigs and feeders were weighed on d 0, 10, and 24 to allow calculation of ADG, ADFI, and F/G. Chromic oxide (.15%) was included in the diets as an indigestible marker and fecal samples were collected on d 9 and 23 from four pigs per pen by rectal massage. The samples were dried, ground, and analyzed for DM, N, GE, and Cr concentrations to allow calculation of apparent nutrient digestibilities using the indirect ratio method.

The data were analyzed as a randomized complete block design (initial wt as the blocking criterion) with pen as the experimental unit. Treatment comparisons were : 1) simple vs complex diet formulation; 2) 1,000 vs 500 μm mean particle size; and 3) the simple vs complex × 1,000 vs 500 μm interaction.

In a second experiment, 480 broiler chicks (4 d old and 94 g average wt) were used to determine the effects of simple (cereal grain-soybean meal-based) vs complex (cereal grain-soybean meal-based with 6% tallow, 4% meat and bone meal, and 1% feather meal) diet formulation; diet form (meal vs crumble); and corn particle size (1,000 vs 500 μm) in a 2 × 2 × 2 factorial arrangement of treatments. The diets were formulated to 1.32% lysine, .61% methionine, 1.1% Ca, and .5% available P (Table 2). The chicks were allotted by weight into battery brooders (five chicks per cage and 12 cages per treatment), and given ad libitum access to feed and water during the 14-d experiment. Weights were collected at the beginning and end of the experiment to determine ADG, ADFI, and F/G. The data were analyzed as a randomized complete block design with pen as the experimental unit.

Results and Discussion

For the pig experiment, particle sizes of the milled corn were close to those desired (Table 3). As geometric mean particle size was decreased, log normal standard deviation of particle size decreased (from 2.4 to 1.9) and surface area of the milled corn increased (from 70.7 to 97.2 cm^2/g). Pellet durabilities were similar among all treatments (i.e., PDI values of 97.7 to 99.1%). Reducing particle size of the cereals in a diet typically improves PDI. However, with all of our diets above 97% PDI (very high by industry standards), it was not surprising that reducing particle size had little effect on pellet quality.

For d 0 to 10, pigs fed complex diets had 9% greater ADG ($P<.04$) than pigs fed simple diets (Table 4). Pigs fed the 500 μm treatments tended to have greater ADG than those fed the 1,000 μm treatments ($P<.06$), but no differences occurred in F/G ($P>.11$). Overall (d 0 to 24 postweanling), pigs fed complex diets had 8% greater ADG ($P<.005$) and 3% better F/G ($P<.01$) compared to pigs fed simple diets. Also, pigs fed the 500 μm treatments had 5% better overall F/G than those fed the 1,000 μm treatments ($P<.007$). When this experiment was designed, we anticipated that the response to reduction of particle size might be greater in simple diets (with their greater proportion as cereal grain) than in complex diets. There was a trend ($P<.07$) in the overall data for ADG of pigs fed simple diets to be improved more than ADG of pigs fed complex diets as particle size was reduced from 1,000 to 500 μm. However, the improvements in F/G with decreased particle size were similar in simple and complex diets. Finally, the ADG and F/G values for pigs fed simple diets with corn ground to 500 μm were essentially the same as those for pigs fed complex diets with corn ground to 1,000 μm. Thus, the added cost of complex diet formulations is wasted if proper attention is not given to particle size of the cereal grain in the diet.

At d 9, apparent digestibilities of DM, N, and GE were greater for pigs fed complex diets and diets with smaller particle size

(P<.02). At d 23, there was a trend (P<.06) for greater DM digestibility with greater diet complexity, and pigs fed diets with corn ground to 500 μm had greater digestibility of DM (P<.02) and GE (P<.003) than pigs fed diets with corn ground to 1,000 μm.

For the chick experiment (Table 5), no 3-way interactions occurred among diet complexity, diet form, and particle size (P>.2). However, 2-way interactions were observed. Reducing particle size of corn from 1,000 to 500 μm increased rate of gain in chicks fed complex diets but had little effect on rate of gain in chicks fed simple diets (diet complexity × particle size, P<.02). This response was not consistent with the diet complexity × particle size effect in nursery pigs (i.e., a trend for greater response to decreased particle size in simple diets). Also, F/G was improved when particle size was reduced in meal diets but not in diets fed as crumbles (diet form × particle size interaction, P<.005). Thus, noteworthy differences occurred between nursery pigs and broiler chicks for response to diet complexity and reduction of particle size, and caution should be used when extrapolating results from chick assays to expected responses in nursery pigs.

In conclusion, our data suggest that reducing particle size of corn is important for simple and complex diets fed to nursery pigs. Also, complex diets with 1,000 μm corn gave no better performance than simple diets with 500 μm corn.

Table 1. Diet Composition for the Pig Experiment, %

	Diets for d 0 to 10[a]		Diets for d 10 to 24[b]	
Ingredient	Simple	Complex	Simple	Complex
Corn	40.25	25.26	56.72	45.35
Soybean meal (46.5% CP)	21.93	23.84	31.68	24.58
Dried whey	20.00	20.00	5.00	20.00
Lactose	--	10.00	--	--
Soy isolate	10.00	--	--	--
Spray-dried plasma protein	--	4.00	--	--
Spray-dried wheat gluten	--	4.00	--	--
Spray-dried blood meal	--	2.00	--	2.00
Soybean oil	3.00	6.00	2.00	4.00
Lysine-HCl	.15	.20	.20	.10
DL-methionine	.07	.08	.04	.07
Monocalcium phosphate (21% P)	1.52	1.91	1.42	1.22
Limestone	.83	.61	.84	.68
Salt	.30	.15	.40	.30
Vitamin premix	.25	.25	.25	.25
Trace mineral premix	.15	.15	.15	.15
Selenium premix	.05	.05	.05	.05
Zinc oxide	.35	.35	--	--
Copper sulfate	--	--	.10	.10
Antibiotic[c]	1.00	1.00	1.00	1.00
Chromic oxide	.15	.15	.15	.15
Total	100.00	100.00	100.00	100.00

[a]Diets for d 0 to 10 were formulated to 1.6% lysine, .45% methionine, .9% Ca, and .8% P.
[b]Diets for d 10 to 24 were formulated to 1.3% lysine, .36% methionine, .8% Ca, and .7% P.
[c]Provided 150 g/ton of apramycin in diets for d 0 to 10 and 50 g/ton of carbadox in diets for d 10 to 24.

Table 2. Diet Composition for the Chick Experiment, %[a]

Ingredient	Simple	Complex
Corn	54.94	48.28
Soybean meal (46.5% CP)	39.30	35.90
Meat and bone meal	--	4.00
Feather meal	--	1.00
Tallow	1.00	6.00
DL-methionine	.30	.30
Monocalcium phosphate	2.02	2.05
Limestone	1.14	1.17
Salt	.40	.40
Vitamin and mineral premixes	.75	.75
Copper sulfate	.05	.05
Antibiotic[b]	.10	.10
Total	100.00	100.00

[a]Diets were formulated to 1.32% lysine, .61% methionine, 1.1% Ca, and .5% available P.
[b]Provided 110 g/ton of chlortetracycline.

Table 3. Characteristics of Corn and Diets for the Pig Experiment

	Simple		Complex	
Item	1,000	500	1,000	500
Grain characteristics				
Geometric mean particle size, μm	938	565	--[a]	--
Standard deviation of the particle size	2.4	1.9	--	--
Surface area, cm^2/g	70.7	97.2	--	--
Diet characteristics				
Pellet durability index				
d 0 to 10	98.9	99.1	98.8	98.9
d 10 to 24	97.7	98.4	98.8	98.8

[a]The same corn was used for simple and complex diets.

Table 4. Growth Performance of Weanling Pigs Fed Simple and Complex Diets with Corn Milled to 1,000 and 500 μm[a]

	Simple		Complex			Contrasts[b]		
Item	1,000	500	1,000	500	CV	1	2	3
d 0 to 10								
ADG, lb	.61	.70	.71	.72	9.7	.04	.06	--[c]
ADFI, lb	.64	.72	.77	.73	7.6	.006	--	.02
F/G	1.05	1.03	1.09	1.01	7.0	--	.11	--
d 10 to 24								
ADG, lb	1.07	1.14	1.18	1.18	5.4	.01	--	.12
ADFI, lb	1.53	1.58	1.61	1.57	6.5	--	--	--
F/G	1.43	1.39	1.36	1.33	3.4	.006	.09	--
d 0 to 24								
ADG, lb	.87	.96	.98	.99	5.5	.005	.04	.07
ADFI, lb	1.16	1.22	1.26	1.22	6.2	.15	--	.14
F/G	1.33	1.27	1.29	1.23	3.1	.01	.007	--
Apparent digestibility, %								
d 9								
DM	85.2	87.3	86.7	88.6	1.3	.01	.001	--
N	80.2	83.7	84.1	84.9	2.4	.01	.02	.13
GE	85.0	87.1	86.7	88.4	1.4	.01	.001	--
d 23								
DM	87.4	88.0	87.9	88.8	.8	.06	.02	--
N	83.8	84.8	84.5	84.6	1.5	--	--	--
GE	88.1	89.0	88.1	89.5	.9	--	.003	--

[a]One hundred ninety-two weanling pigs (initially 11.7 lb and 21 d of age, with eight pigs per pen and six pens per treatment) were used.
[b]Contrasts were: 1) simple vs complex diet formulation; 2) 1,000 vs 500 μm particle size; 3) simple vs complex × 1,000 vs 500 μm.
[c]Dashes indicate P > .15.

Table 5. Effects of Diet Complexity, Physical Form, and Particle Size on Growth Performance of Broiler Chicks[a]

	Simple				Complex					Contrasts[b]						
	Meal		Crumble		Meal		Crumble									
Item	1,000	500	1,000	500	1,000	500	1,000	500	CV	1	2	3	4	5	6	7
Gain, lb	1.05	1.06	1.14	1.11	1.09	1.14	1.09	1.12	5.2	.12	.007	--[c]	--	.02	.001	--
Feed intake, lb	1.50	1.45	1.57	1.54	1.49	1.53	1.45	1.50	3.9	.11	.03	--	--	.001	.001	--
F/G	1.43	1.37	1.38	1.39	1.37	1.34	1.33	1.34	3.6	.001	.09	.14	.005	--	--	--

[a]A total of 480 broiler chicks (initially 94 g initial wt, with five birds per cage and 12 cages per treatment) were used in a 14-d growth assay.
[b]Contrasts were: 1) simple vs complex; 2) meal vs crumble; 3) 1,000 vs 500 μm; 4) complexity × form; 5) complexity × particle size; 6) form × particle size; 7) complexity × form × particle size.
[c]Dashes indicate P > .15.