Effects of Fine-Grinding Corn or Dried Distillers Grains with Solubles and Diet Form on Growth Performance and Caloric Efficiency of 25- to 50-lb Nursery Pigs[1,2]

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Summary

A total of 687 pigs (PIC 1050 barrows; initially 25.5 lb BW and 37 d of age) were used in a 21-d study to determine the effects of fine-grinding corn or dried distillers grains with solubles (DDGS) and diet form on nursery pig performance and caloric efficiency. Pens of pigs were balanced by initial BW and randomly allotted to 1 of 10 dietary treatments with 14 replications per treatment. There were 5 pigs per pen in two groups of nursery pigs. The 10 experimental diets included 4 corn-soybean meal–based diets consisting of: (1) corn ground to ~638 µ, in meal form; (2) treatment 1 in pellet form; (3) corn ground to ~325 µ, in meal form, and (4) treatment 3 in pellet form. The remaining 6 diets contained 30% DDGS. Diets 5 through 10 consisted of: (5) corn and DDGS ground to ~638 and 580 µ, in meal form; (6) diet 5 in pellet form; (7) corn and DDGS ground to ~638 and 391 µ, in meal form; (8) diet 7 in pellet form; (9) corn and DDGS ground to ~325 and 391 µ, in meal form; and (10) diet 9 in pellet form.

Overall (d 0 to 21), a corn particle size (regardless of DDGS addition) × diet form interaction was observed ($P < 0.01$) as a result of increased ADFI when corn was finely ground and fed in pellet form but decreased intake when corn was finely ground and fed in meal form. Pelleting diets decreased ($P < 0.001$) ADG, ADFI, and final BW but improved ($P < 0.001$) F/G and caloric efficiency on both an ME and NE basis. Fine-grinding corn decreased ($P < 0.04$) ADG as a result of numerically decreased ADFI ($P < 0.16$). Feeding 30% DDGS also decreased ($P < 0.01$) ADG, ADFI, and NE caloric efficiency and tended to decrease ($P < 0.07$) final BW. In conclusion, pelleting diets and fine-grinding ingredients reduced ADG as a result of decreased ADFI, but pelleting improved feed efficiency. Feeding 30% DDGS was detrimental to nursery pig growth performance.

Key words: DDGS, nursery pig, particle size, pelleting

Introduction

Feed processing and manufacturing technologies allow for more efficient nutrient utilization of grains used in swine diets. Two primary technologies help improve ingredient utilization: fine-grinding and pelleting. The primary grain source (i.e., corn or sorghum)

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typically is the only ingredient ground because other dietary ingredients arrive at the feed mill in processed form, and feed mills are not normally designed to grind non-cereal ingredients either pre- or post-mixing. Little is known about the effects of fine-grinding other ingredients in combination with the cereal grain source or the effect that the whole-diet particle size may have on nursery pig performance.

Previous research with pelleting corn-soybean meal–based diets has shown an improvement in ADG and feed efficiency of nursery pigs; however, few data are available on the interaction between pelleting high-fiber diets and particle size of ingredients on nursery pig performance. Therefore, the objective of this experiment was to determine the effects of fine-grinding corn, DDGS, or both and diet form (pellet vs. meal) on nursery pig growth performance.

Procedures

The protocol for this experiment was approved by the Kansas State University Institutional Animal Care and Use Committee. The study was conducted at the K-State Segregated Early Weaning Facility in Manhattan, KS. Pens (4 × 4 ft) had wire-mesh floors and deep pits for manure storage. Each pen was equipped with a 4-hole stainless steel dry self-feeder and a cup waterer for ad libitum access to feed and water. All pigs were fed common starter diets for approximately 18 d before the start of the experiment.

A total of 687 pigs in two consecutive groups (PIC 1050 barrows; initially 25.5 lb BW and 37 d of age) were used in a 21-d study. Pens of pigs were balanced by initial BW and randomly allotted to 1 of 10 dietary treatments with 14 replications per treatment and 5 pigs per pen. The 10 experimental diets included 4 corn-soybean meal–based diets consisting of: (1) corn ground to ~638 µ in meal form; (2) treatment 1 in pellet form; (3) corn ground to ~325 µ, in meal form; and (4) treatment 3 in pellet form. The remaining 6 diets contained 30% DDGS. Diets 5 through 10 consisted of: (5) corn and DDGS ground to ~638 and 580 µ, in meal form; (6) diet 5 in pellet form; (7) corn and DDGS ground to ~638 and 391 µ, in meal form; (8) diet 7 in pellet form, (9) corn and DDGS ground to ~325 and 391 µ, in meal form; and (10) diet 9 in pellet form.

All ingredients were ground and mixed at the K-State Grain Science and Industry Feed Mill. All 638-µ corn was ground by a 3-high roller mill (Model TP 912, Roskamp Manufacturing, Cedar Falls, IA). All finely ground ingredients were processed using a full-circle teardrop hammer mill (P-240D Pulverator, Jacobsen Machine Works, Minneapolis, MN) with a 1/16-in. screen. Diets were pelleted in a 30-horsepower pellet mill (30 HD Master Model, California Pellet Mill, San Francisco) with a 1/8-in.-thick die with 3/20-in. openings. Corn was from the same lot and was split at the mill to be ground through the hammer mill or roller mill.

All diets were formulated to meet or exceed the nutrient requirement estimates as defined by the NRC (1998; Table 1). Diets were not balanced for energy, so as DDGS increased in the diet, dietary energy increased slightly. All diets were formulated to a constant standardized ileal digestible (SID) lysine concentration.

Caloric efficiency of pigs were determined on both an ME and NE basis. Caloric efficiencies of pigs were determined using dietary ingredient values for ME (DDGS value used was equal to corn) from NRC (1998)[4] and for NE from INRA (2004)[5]. Caloric efficiency was calculated on a pen basis by multiplying total pen feed intake by the dietary energy level (kcal/lb) and dividing by total pen gain. Values from NRC (1998) were used because the NRC (2012) had not been published at the time of diet formulation. Pig weight and feed disappearance were measured on d 0, 7, 14, and 21 of the experiments to calculate ADG, ADFI, and F/G.

Multiple samples of each diet were collected from feeders, blended and subsampled, and submitted to Ward Laboratories, Inc. (Kearney, NE) for analysis of DM, CP, crude fat, crude fiber, ash, Ca, P, ADF, NDF, and NFE.

Bulk density was determined for all ingredients pre- and post-grind as well as for the complete diets. Particle size of the corn, soybean meal, DDGS, and complete meal diets also were determined using a standard method for determining particle size. Tyler sieves, with screen numbers 6, 8, 10, 14, 20, 28, 35, 48, 65, 100, 150, 200, 270, and a pan were used. A Ro-Tap shaker (W.S. Tyler, Mentor, OH) was used to sift the 100-g samples for 10 min. A geometric mean particle size (dgw) and the log-normal SD (sgw) were calculated by measuring the amount of grain remaining on each screen. For all diets in pelleted form, pellet durability index (PDI) and percentage fines were determined. Pellets were analyzed for PDI (ASAE, 1987) and modified PDI by altering the procedure by adding five 13-mm hexagonal nuts prior to tumbling. Percentage fines and angle of repose were also determined for all pellet and meal diets, respectively.

Data from both groups were combined and analyzed as a completely randomized design using the MIXED procedure of SAS (SAS Institute, Inc., Cary, NC) with pen as the experimental unit. Treatment was considered a fixed effect and group as a random effect in the statistical model. Contrasts were used to compare the effects of diet form, corn particle size, DDGS particle size, and diet type (corn soybean meal vs. high by-product). Results were considered significant at $P \leq 0.05$ and a trend at $P \leq 0.10$.

Results and Discussion

Nutrient chemical analysis of corn, soybean meal, and DDGS used were verified to be similar to those used in formulation (Table 2). The minor differences were not expected to influence the results of the experiment. Nutrient analysis of treatment diets (Table 3) showed that the concentrations were similar to formulated values. The only exception was ADF and NDF, which were all slightly lower than formulated values. As expected, as the portion of the diet that was ground increased, the particle size of the diet decreased, which led to an increase in the diet angle of repose (Table 4). Bulk densities of meal diets were all relatively similar. Diets that were pelleted were higher in bulk density compared with the meal diets. Across all treatments, PDI and modified PDI, percentage fines, mill throughput, and hot pellet temperature were all similar.

Overall (d 0 to 21), a corn particle size (regardless of DDGS addition) × diet form interaction was observed ($P < 0.01$) as a result of increased ADFI when corn was finely

[4] NRC. 1998. Nutrient Requirements of Swine, 10th ed. Natl. Acad. Press, Washington DC.

[5] INRA (Institut National de la Recherche Agronomique). 2004. Tables of composition and nutritional value of feed materials, Sauvant, D., J-M. Perez, and G. Tran, Eds. Wageningen Academic Publishers, The Netherlands and INRA, Paris, France.

ground and fed in pellet form, but intake decreased when corn was finely ground and fed in meal form. Pelleting the diets decreased (*P* < 0.001) ADG, ADFI, and final BW and improved (*P* < 0.001) F/G and caloric efficiency on both an ME and NE basis. Fine-grinding corn decreased (*P* < 0.04) ADG as a result of numerically decreased ADFI (*P* < 0.016). Also, feeding 30% DDGS decreased *(P* < 0.01) ADG and ADFI, resulted in poorer NE caloric efficiency, and tended to decrease (*P* < 0.07) final BW (Tables 5 and 6).

Why pelleting and fine-grinding had few positive, and even some negative, effects on nursery pig performance in the current experiment is not clear. Some reasons could include decreased palatability of finely ground ingredients, limited or no benefit to grinding grain finer than 600 µ for nursery pigs, or limited biological benefits of fine-grinding other ingredients for nursery pigs. The lack of growth improvement with pelleting may have been a result of increased pellet hardness supported by high measured PDI values. The negative effects of DDGS on nursery pig growth performance also were not expected.

More research clearly needs to be conducted to determine the optimum particle size of cereal grains and complete diets when fed to nursery pigs as well as the effects of pellet hardness on nursery pig performance.

Table 1. Diet composition (as-fed basis)[1]

	DDGS, %[2]	
Item	0	30
Ingredient, %		
Corn	63.23	39.14
Soybean meal (46.5% CP)	32.83	27.39
DDGS	---	30.00
Monocalcium phosphate (21% P)	1.63	0.93
Limestone	0.98	1.35
Salt	0.35	0.35
Vitamin premix	0.25	0.25
Trace mineral premix	0.15	0.15
L-lysine HCl	0.33	0.40
DL-methionine	0.14	---
L-threonine	0.13	0.05
Phytase[3]	0.13	0.13
Total	100.00	100.00
Calculated analysis		
Standardized ileal digestible (SID) amino acids		
Lysine, %	1.28	1.28
Ise:lysine	61	66
Leu:lysine	129	160
Methionine:lysine	34	28
Met & Cys:lysine	58	58
Threonine:lysine	63	63
Tryptophan:lysine	17.5	17.5
Valine:lysine	68	77
Total lysine, %	1.42	1.47
ME, kcal/lb[4]	1,496	1,501
NE, kcal/lb[5]	1,067	1,086
SID lysine:ME, g/Mcal	3.88	3.87
CP, %	21.1	24.6
Crude fiber, %	2.7	1.9
NDF, %	10	17.6
ADF, %	3.9	7.5
Ca, %	0.80	0.80
P, %	0.74	0.71
Available P, %	0.42	0.42

[1] Experimental diets were fed from d 0 to 21.
[2] Dried distillers grains with solubles.
[3] Phyzyme 600 (Danisco Animal Nutrition, St. Louis, MO) provided 340.5 phytase units (FTU)/lb, with a release of 0.12% available P.
[4] NRC. 1998. Nutrient Requirements of Swine, 10th ed. Natl. Acad. Press, Washington DC.
[5] INRA (Institut National de la Recherche Agronomique). 2004. Tables of composition and nutritional value of feed materials, Sauvant, D., J-M. Perez and G. Tran, Eds. Wageningen Academic Publishers, The Netherlands and INRA, Paris, France.

Table 2. Chemical analysis of ingredients (as-fed basis)[1]

Item	DDGS[2]	Soybean meal[3]	Corn[3]
DM, %	91.16	89.34	89.06
CP, %	31.2 (27.2)	44.8 (46.5)	9.3 (8.50)
ADF, %	10.6	6.1	2.5
NDF, %	25.4	7.5	5.9
Crude fiber, %	7.3(7.3)	3.5(3.9)	2(2.2)
Crude fat, %	9.4	1.6	3.2
NFE, %	38.3	33	73.2
Ca, %	0.09 (0.03)	0.51 (0.03)	0.06 (0.03)
P, %	0.91 (0.71)	0.66 (0.69)	0.26 (0.28)
Ash, %	4.87	6.5	1.39
Starch	3.1	4.3	61.9
Particle size, μ[4]	580; 391	780	638; 325
Particle size, SD[5]	1.90; 1.86	2.13	2.18; 2.21
Bulk density, lb/bu[6]	48.2	55.1	49.6

[1] All values are averages of the ingredients used for the 2 groups used in this experiment.
[2] Dried distillers grains with solubles. Values in parentheses for DDGS are taken from Stein (2007).
[3] Values in parentheses from NRC (1998).
[4] Values listed first are initial particle sizes; values listed second are particle sizes post–hammer mill grinding.
[5] Values listed first are roller mill–ground SD; values listed second are hammer mill–ground SD.
[6] Bulk density was determined from hammer mill–ground samples for DDGS and corn.

Table 3. Chemical analysis of diets (as-fed basis)[1,2]

	Control[2]	30% DDGS[3]
DM, %	90.81	91.93
CP, %	21.3	25.6
ADF, %	3.8	6.2
NDF, %	6.3	12.9
Crude fiber, %	2.1	3.5
Crude fat, %	2.3	4.0
NFE, %	59.5	52.5
Ca, %	0.97	1.04
P, %	0.71	0.75
Ash, %	5.8	6.4

[1] A composite sample consisting of 6 subsamples from each of 2 groups within each experiment.
[2] Control diet was a corn-soybean meal–based diet.
[3] Dried distillers grains with solubles.

Table 4. Analysis of diets

Item	Treatment:	1	2	3	4	5	6	7	8	9	10
	Diet:[1]	C	C	C	C	DDGS	DDGS	DDGS	DDGS	DDGS	DDGS
	Ingredient processed:[2]	---	---	Corn	Corn	---	---	DDGS	DDGS	Both	Both
	Diet form:	Meal	Pellet	Meal	Pellet	Meal	Pellet	Meal	Pellet	Meal	Pellet
Diet particle size, µ		724	---	619	---	709	---	703	---	550	---
Bulk density, lb/bu		54.0	55.6	49.0	57.4	51.4	53.7	52.1	53.9	53.4	53.2
Angle of repose, °		50.1	---	52.8	---	50.9	---	51.0	---	55.3	---
Standard pellet durability index		---	96.0	---	94.6	---	93.3	---	96.9	---	95.4
Modified pellet durability index		---	91.2	---	92.3	---	90.3	---	92.5	---	92.8
Fines, %		---	6.4	---	8.0	---	4.5	---	5.0	---	1.2
Production rate, lb/h		---	2,564		2,839		2,421		2,784		2,828
Hot pellet temperature, °F		---	190	---	192	---	190	---	190	---	190

[1] C = Control diet was a corn-soybean meal–based diet. DDGS = 30% dried distillers grains with solubles.
[2] Corn ground to ~638 µ and fine-ground to ~325 µ. DDGS received at ~580 µ and fine-ground to ~391 µ .

Table 5. Effects of fine-grinding corn and/or dried distillers grains with solubles (DDGS) and diet forms on 25- to 50-lb nursery pig performance[1]

Item	Treatment:	1	2	3	4	5	6	7	8	9	10	
	Diet:[2]	C	C	C	C	DDGS	DDGS	DDGS	DDGS	DDGS	DDGS	
	Ingredient processed:[3]	---	---	Corn	Corn	---	---	DDGS	DDGS	Both	Both	
	Diet form:	Meal	Pellet	Meal	Pellet	Meal	Pellet	Meal	Pellet	Meal	Pellet	SEM
d 0 to 21												
ADG, lb		1.37	1.31	1.30	1.23	1.30	1.20	1.31	1.18	1.27	1.25	0.05
ADFI, lb		2.18	1.98	2.05	1.93	2.11	1.84	2.10	1.84	2.04	1.93	0.08
F/G		1.59	1.51	1.58	1.58	1.63	1.53	1.61	1.56	1.61	1.55	0.02
Caloric efficiency[4]												
ME		2,384	2,255	2,368	2,359	2,445	2,300	2,414	2,342	2,417	2,328	34.5
NE		1,700	1,609	1,689	1,683	1,770	1,664	1,747	1,695	1,749	1,684	24.9
Wt, lb												
d 0		25.59	25.58	25.56	25.57	25.61	25.56	25.55	25.54	25.58	25.54	0.69
d 21		53.66	52.54	52.16	50.69	52.18	50.98	52.46	49.94	51.76	51.06	1.14

[1] A total of 687 pigs (initially 25.5 lb BW and 37 d of age) were used in a 21-d study with 5 pigs/pen and 14 pens/treatment.
[2] C = Control diet was a corn-soybean meal–based diet. DDGS = 30% dried distillers grains with solubles.
[3] Corn ground to ~638 µ and fine-ground to ~325 µ. DDGS received at ~580 µ and fine-ground to ~391 µ.
[4] Caloric efficiency is expressed as kcal/lb of gain.

Table 6. Effects of fine-grinding corn and/or dried distillers grains with solubles (DDGS) and diet form on 25- to 50-lb nursery pig performance

Item	Diet: Contrast:	Probability, $P <$ Corn µ × diet form[1,2]	Diet form[3]	Corn µ[4]	DDGS µ[5]	Diet[6]
d 0 to 21						
ADG, lb		0.15	0.001	0.04	0.95	0.001
ADFI, lb		0.01	0.001	0.16	0.95	0.008
F/G		0.13	0.001	0.43	0.87	0.19
Caloric efficiency[7]						
ME		0.14	0.001	0.42	0.88	0.13
NE		0.14	0.001	0.44	0.87	0.01
Wt, lb						
d 21		0.62	0.008	0.21	0.64	0.07

[1] Interactive effects of corn particle size and diet form.
[2] No interactive effects ($P > 0.20$) of diet × diet form, or DDGS µ × diet form.
[3] Pellet vs. meal (treatments 1, 3, 5, 7, and 9 vs. 2, 4, 6, 8, and 10).
[4] Corn particle size effect (treatments 1, 2, 7, and 8 vs. 3, 4, 9, and 10).
[5] DDGS particle size effect (treatments 5 and 6 vs. 7 and 8).
[6] DDGS effect (treatments 1 and 2 vs. 5 and 6).
[7] Caloric efficiency is expressed as kcal/lb gain.