Kansas Agricultural Experiment Station Research Reports

Volume 1
Issue 7 *Swine Day*

Article 17

January 2015

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Recommended Citation

Bokelman, G. E.; De Jong, J. A.; Kalivoda, J. R.; Yoder, A.; Stark, C. R.; Woodworth, J. C.; and Jones, C. K. (2015) "Finely Grinding Cereal Grains in Pelleted Diets Offers Little Improvement in Nursery Pig Growth Performance," *Kansas Agricultural Experiment Station Research Reports*: Vol. 1: Iss. 7. https://doi.org/10.4148/2378-5977.1122

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Finely Grinding Cereal Grains in Pelleted Diets Offers Little Improvement in Nursery Pig Growth Performance

G. E. Bokelman[1], J. A. De Jong, J. R. Kalivoda[1], A. Yoder[1], C. R. Stark[1], J. C. Woodworth, and C. K. Jones[1]

Summary

Five experiments were conducted to determine the effects of corn particle size and diet form on nursery pig performance and feed preference. In Exp. 1, 192 nursery pigs (PIC 327 × 1050; initially 14.7 lb and 26 d of age) were used in a 35-d experiment. Pens of pigs were balanced by BW and allotted to 1 of 4 treatments with 6 pigs per pen and 8 pens per treatment. The same corn and soybean meal-based diet formulation was used for all treatments. The 2 × 2 factorial consisted of the main effects of corn particle size (400 vs. 700 μm) and diet form (mash vs. pelleted). Pigs fed mash diets had improved overall ADG and greater ADFI during all periods ($P < 0.05$) and particle size did not impact ($P > 0.10$) performance. In Exp. 2, a study utilized 96 pigs to evaluate feed preference of pigs consuming mash diets with either 400 or 700 μm corn. Pigs overwhelmingly ($P < 0.05$) preferred to consume 700 μm corn compared to 400 μm corn (79.3 vs. 20.7%).

In Exp. 3, 224 nursery pigs (PIC 327 × 1050; initially 24.1 lb and 40 d of age) were used in a 10-d experiment to determine the effects of corn particle size in pelleted diets on nursery pig performance. Experimental treatments were formed by grinding corn to 1 of 4 different particle sizes (250, 400, 550, or 700 μm). Particle size tended to affect ($P < 0.10$) ADG in a quadratic manner, but did not impact ($P > 0.10$) ADFI or F/G. Pigs fed pelleted diets from either 250 or 700 μm corn had poorer ADG than the intermediate treatments. Exp. 4 utilized 91 pigs to evaluate the preference of pigs consuming pelleted diets with either 250 or 700 μm corn from Exp. 3. Even in pelleted form, pigs preferred ($P < 0.05$) to consume diets manufactured with the coarser particle size corn (58.2 vs. 41.8%).

In Exp. 5, 180 nursery pigs (PIC 327 × 1050; initially 15.8 lb and 36 d of age) were used in a 35-d experiment to determine the effects of corn particle size and pelleting on nursery pig growth performance. The 2 × 2 factorial consisted of 2 corn particle sizes (500 μm vs. 750 μm) and two diet forms (mash vs. pelleted). Overall, reducing particle size from 750 to 500 μm did not affect growth performance ($P > 0.10$). Pelleting reduced ($P < 0.05$) feed intake, but did not affect ADG or F/G ($P > 0.10$). These studies

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suggest that there is little value to be gained by grinding corn to less than 700 microns if fed in pelleted form. Furthermore, our data suggest that, regardless if fed as mash or pellets, pigs prefer to consume diets manufactured with coarser ground corn if given the choice.

Key words: mash, nursery pig, particle size, performance, pelleting

Introduction

Grinding cereal grains prior to their inclusion in a swine diet is important to maximize nutritive value. Whether ground by a hammermill or roller mill, reducing particle size is expected to improve feed efficiency of a diet by 1.0 to 1.2% for every 100 micron reduction in corn particle size. However, manufacturing and feeding diets with small particle size can be challenging. Achieving the smaller particle size requires greater electrical energy and may slow mill throughput. In addition, dust, feed bridging, out-of-feed events, and gastric ulcers may all result from feeding diets manufactured from grain with a small particle size. Pelleting can help overcome some of these disadvantages, but the process requires even more electrical energy and expensive equipment, thus increasing overall feed costs. The return on investment from pelleting comes from improved growth performance, less feed waste, and greater feed efficiency; however, the magnitude of these improvements depends on other factors, including the grain particle size. While pelleting diets manufactured with finely ground grain is a common practice in the swine industry, a search of the peer-reviewed data shows surprisingly little research to quantify the effects of varying particle sizes in pelleted diets in nursery pigs of modern genotypes. The objectives of these experiments were to: 1) quantify growth performance differences in nursery pigs due to diet form (mash vs. pelleted) and corn particle size, and 2) determine pig consumption preference when given the choice of diets manufactured with corn ground to different particle sizes.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in these experiments. These studies were conducted at the Kansas State University Swine Teaching and Research Facility in Manhattan, KS.

In Exp. 1, 192 nursery pigs (PIC 327 × 1050; initially 14.7 lb and 26 d of age) were utilized to evaluate the effects of particle size and diet form on swine growth performance. Pigs were weaned and fed a common diet for 5 d, balanced by initial BW, and randomly allotted to 1 of 4 treatments, with 6 pigs per pen and 8 pens per treatment. Each pen contained 1 nipple waterer and 1 self-feeder to allow for ad libitum access to water and feed. The 4 experimental treatments were created utilizing the same basal formulation and arranged in a 2 × 2 factorial design with the main effects of feed form (meal vs. pellet) and corn particle size (400 vs. 700 µm; Table 1). All feed was manufactured at the O. H. Kruse Feed Technology Innovation Center at Kansas State University. Corn was ground using a triple-pair roller mill (RMS Roller-Grinder, Harrisburg, SD) and analyzed for particle size according to ASAE Method S319.4 with a 15-min tap time and 1.0 g fumed silica included as a flow agent. Actual corn micron sizes were 387 and 477 vs. 703 and 725 µm for phases 1 and 2 of each treatment, respectively (Table 2). Pelleted diets were pelleted at 176°F for 45 s using a CPM pellet mill (California Pellet

Mill, Crawfordsville, IN) and analyzed for pellet durability index (PDI) according to ASAE Method S269.4 with a modification to include five ½-in. hexagonal nuts. Diets were fed in 2 phases: Phase 1 from d 0 to 14, and Phase 2 from d 14 to 35. Pigs and feeders were weighed on d 0, 14, and 35 to determine ADG, ADFI, and F/G.

A separate 10-d study utilized 96 pigs (PIC 327 × 1050; initially 13.9 lb and 26 d of age) to evaluate the preference of pigs consuming mash diets manufactured with either the 400 or 700 µm corn from Exp. 1. There were 12 pens utilized and 8 pigs per pen. Each pen was equipped with two identical 4-hole dry self-feeders and a nipple waterer to allow for ad libitum access to feed from either treatment. Feeder location was changed daily to prevent a location bias of the feeder within the pen. Preference was measured by feed disappearance from an individual feeder. Feeders were weighed on d 0 and 10 to determine feed disappearance and ADFI per feeder.

In Exp. 3, a total of 224 nursery pigs (PIC 327 × 1050; initially 24.1 lb and 40 d of age) were utilized in a 10-d experiment to determine the effects of corn particle size in pelleted diets on late nursery pig growth performance. Pigs were weaned and placed on common Phase 1 and Phase 2 diets. On d 19 post-weaning, pigs were balanced by initial BW and randomly allotted to 1 of 4 treatments with 7 pigs per pen and 8 pens per treatment. Each pen contained 1 nipple waterer and 1 self-feeder to allow for ad libitum access to water and feed. The same basal diet formulation was utilized for all diets, with experimental treatments created by including corn ground to four different mean particle sizes (approximately 250, 400, 550, or 700 µm; Table 3). All feed was manufactured at the O. H. Kruse Feed Technology Innovation Center at Kansas State University. Corn was ground using a hammermill (Bliss Industries, LLC, Ponca City, OK) and analyzed for particle size as described in Exp. 1. To achieve the intended corn micron size in a consistent manner, corn was blended to achieve similar particle size separation between treatments. The treatment of corn ground to 250 µm corn contained only corn ground through a #4 screen. The treatment of corn ground to 700 µm corn contained only corn ground through a #24 screen. The treatment of corn ground to 400 µm contained 66% corn from a #4 screen and 33% corn from a #24 screen. The treatment of corn ground to 550 µm corn contained 66% corn from a #24 screen and 33% corn from a #4 screen. Actual corn micron sizes were 212, 422, 509, and 739 µm (Table 4). Diets were pelleted as described in Exp. 1 and PDI was determined using a Holmen NHP100 (Tekpro Limited, Norfolk, United Kingdom; Table 4) for 60 seconds. Percentage fines were also determined on each sample. Fines were characterized as material that would pass through a #6 Tyler Sieve (3,360-µm opening) after 15 sec of manual shaking. Diets were fed for 10 d, and pigs and feeders were weighed on d 0 and 10 determine ADG, ADFI, and F/G.

Exp. 4 was a separate 10-d study utilizing 91 pigs (PIC 327 × 1050; initially 23.7 lb and 40 d of age) to evaluate the preference of pigs consuming pelleted diets manufactured with either 250 or 700 µm corn from Exp. 3. Twelve pens were utilized with 7 or 8 pigs per pen. Each pen was equipped with two identical 4-hole dry self-feeders and a nipple waterer to allow for ad libitum access to feed from either treatment. Feeder location was changed daily to prevent a location bias of the feeder within the pen. Preference was measured by feed disappearance from an individual feeder. Feeders were weighed on d 0 and 10 to determine feed disappearance and ADFI per feeder.

In Exp. 5 a total of 180 pigs (PIC 327 × 1050; initially 15.8 lb and 36 d of age) were used in a 35-d growth trial to evaluate the effects of particle size and diet form on swine growth performance. Pigs were weaned on d 26 of age, blocked by initial BW, and fed a pelleted acclimation Phase 1 diet for 5 d. On d 0 of the experiment, pigs were randomly assigned to pens in a randomized complete block design with 5 pigs per pen and 9 replications per treatment. Each pen contained 1 nipple waterer and 1 self-feeder to allow for ad libitum access to water and feed. The 4 experimental treatments were created utilizing the same basal formulation and arranged in a 2 × 2 factorial design with the main effects of feed form (meal vs. pellet) and corn particle size (500 µm vs. 750 µm; Table 5). All feed was manufactured at the O. H. Kruse Feed Technology Innovation Center at Kansas State University. The same basal diet formulation was used for all diets. Corn was ground using a hammermill (Bliss Industries, LLC, Ponca City, OK) and analyzed for particle size as described in Exp. 1 (Table 6). Diets were pelleted and analyzed for PDI as described in Exp. 1. Experimental diets were fed in two phases: d 0 to 14 and d 14 to 35.

Data were analyzed using PROC GLIMMIX in SAS (SAS Institute, Inc., Cary, NC). Growth performance data were analyzed with pen as the experimental unit. In Exp. 1 and 5, particle size and feed form, as well as their interaction, were considered main effects. In Exp. 2, 3, and 4, treatment served as a fixed effect. Linear and quadratic effects of particle size were determined utilizing orthogonal contrasts. Results were considered significant if $P < 0.05$ and trends if $P < 0.10$.

Results and Discussion

In Exp. 1, there was a particle size × feed form interaction for F/G from d 14 to 35 and d 0 to 35 ($P < 0.05$; Table 7). Pigs fed pelleted diets manufactured from 700 µm ground corn had improved ($P < 0.05$) F/G from d 14 to 35 and d 0 to 35 compared to pigs fed pelleted diets manufactured from 400 µm ground corn, with mash treatments intermediate. There were no particle size × feed form interactions for ADG or ADFI (Table 8), nor were any effects of corn particle size observed on any measured response criteria. The lack of feed efficiency response from the decrease in particle size was surprising considering that previous research had reported a near linear improvement in feed efficiency with decreasing particle size. While we were surprised to find no overall improvement from the main effect of particle size, the negative effect of pelleting on ADG was even more unexpected. Pigs fed pelleted diets had poorer ($P < 0.05$) ADG than those fed mash diets from d 14 to 35 and d 0 to 35. These differences were largely driven by ADFI, which was greater in mash diets across all phases ($P < 0.05$). Therefore, F/G was improved by 11% from pelleting from d 0 to 14, but no differences were observed from d 14 to 35. This resulted in a tendency ($P < 0.10$) for improved F/G from pelleting overall. Still, this improvement in feed efficiency did not overcome the reductions in ADG observed in pigs fed pelleted diets, so those fed mash diets tended ($P < 0.10$) to be heavier by the end of the 35-d experiment.

When pigs were allowed to choose to consume either the mash diet manufactured from 400 or 700 µm corn, they clearly preferred diets manufactured from corn with the coarser particle size ($P = 0.001$; Table 9), with nearly 80% of the total feed consumed from the coarser particle size diet (0.31 vs. 1.19 lb/d for 400 vs. 700µm, respectively).

Fine grinding corn in mash diets is known to create feed flow issues, but feeders were managed closely during the course of this experiment to prevent differences in quantity of feed in the pan. This preference data suggest that fine grinding corn in nursery pig diets may also have negative implications on feed intake.

Because of the unexpected findings from Exp. 1, we further evaluated the effect of reducing particle size in pelleted diets, particularly evaluating even finer particle grain sizes. Again, reducing particle size in pelleted diets did not affect F/G ($P > 0.10$). These findings confirm our initial results and suggest the reduction in particle size does not always linearly influence F/G. Numerically, experimental results were variable, but a tendency was observed for decreased particle size in pelleted diets to affect ($P < 0.10$) ADG in a quadratic manner (Table 10). Notably, there were marked differences in PDI across different treatments, with the PDI from diets manufactured from 250 or 700 µm corn being greater than those manufactured with corn from the intermediate particle sizes (PDI = 68.3, 50.8, 43.2 and 68.9, respectively). It is important to understand that these PDI values are all strikingly low, especially compared to the range from 84.9 to 89.0 observed in Exp. 1. These PDI values were obtained from analysis using the Holmen NHP 100 method compared to the modified tumbling box method utilized in Exp. 1. Thus, a slight change in PDI due to different analytical methods may explain some of the differences across trials, but not to the extent observed. Still, one would expect that poor pellet quality would be associated with poor feed efficiency, but that was not observed in this study.

We can evaluate effects between particle sizes in pelleted diets further through the preference experiment between diets manufactured with 250 or 700 µm ground corn because those treatments had similar PDI. In agreement with Exp. 2, pigs preferred to consume diets manufactured with the coarser particle size corn (P =0.011; Table 11). However, the percentage of preference of the pelleted diets was not as extreme as that observed when the diets were in mash form (31.8 vs. 58.2% ADFI for 250 vs. 700 µm corn, respectively). While the first experiment alluded to fine particle size playing a role in feeding preference, it was interesting to see the effect remained, although in a diluted manner, when the diets were pelleted. This shows that pigs can still detect a particle size difference, even when diet form is altered.

To further evaluate the variability in results from Exp. 1 and 3, as well as address potential differences in particle size and feed form using a hammermill, a 35-d growth experiment was conducted as Exp. 5. While a roller mill was used to grind grain by shear for Exp. 1, this experiment utilized a hammermill to reach target particle sizes of 507 and 734 µm in ground corn. In this experiment, an interaction between particle size and diet form affected F/G from d 0 to 14 (Table 12), as pigs fed pellets with coarsely ground corn again had better F/G than those fed pellets with finely ground corn or coarsely ground corn in mash diets ($P < 0.05$). This was not due to PDI, because pellet quality was consistent across treatments within phases. Additionally, the interaction tended to affect ADG from d 0 to 14 and overall, as pigs fed finely ground corn in mash diets had greater ADG than those fed finely ground corn in pelleted diets ($P < 0.10$). A tendency for an interaction was observed for ADFI from d 14 to 35, as pigs fed finely ground corn in mash diets had greater feed disappearance than those fed finely ground corn in pelleted diets ($P < 0.10$) with the diets containing course ground corn being similar, regardless of form. Similar to Exp. 1, pelleting reduced ($P < 0.05$) feed intake during each phase, potentially due to less feed waste than in the mash diet. Reducing particle size from 750 to 500 µm again did not affect growth performance (Table 13). Contrary to Exp. 1, no effect of pelleting was observed on overall ADG or F/G. This is interesting because past research overwhelmingly suggests that pelleting improves growth rate and feed efficiency in nursery pigs. While these findings are unexpected, the lack of feed efficiency effect is similar to recently published research in both nursery and finishing pigs, yet contradictory to others that suggest there is little advantage of pelleting diets with a fine particle size. Potentially, the digestibility of the diet is already maximized by pelleting; therefore, further reducing particle size does not result in greater digestibility. More research is needed to evaluate the physiological causes of this effect.

In general, this series of 5 experiments suggests pigs fed pelleted diets had reduced ADG and ADFI than those fed mash diets. We observed mixed effects regarding the effect of particle size, with no effect in mash diets and a quadratic effect in pelleted diets. The best feed efficiency was achieved when pigs were fed pelleted diets manufactured from 700 µm corn. Finally, pigs preferred to consume a coarser corn particle size, particularly when the diet was fed in mash form.

Table 1. Composition of experimental diets (Exp. 1 and 2; as-fed basis)

	Phase[1]	
Item	2	3
Ingredient, %		
Corn	55.57	64.23
Soybean meal, 46.5%	27.15	30.40
Select menhaden fish meal	3.00	---
Spray dried whey	10.00	---
Soy oil	2.00	2.00
Monocalcium P, 21% P	0.65	1.05
Limestone	0.39	1.00
Salt	0.35	0.35
L-lysine HCl	0.24	0.31
DL-methionine	0.12	0.12
L-threonine	0.11	0.12
Trace mineral premix	0.15	0.15
Vitamin premix	0.25	0.25
Phytase[2]	0.02	0.02
Total	100.00	100.00
Calculated analysis		
Standard ileal digestible (SID) amino acids, %		
Lys	1.25	1.20
Iso:lys	62	62
Leu:lys	129	131
Met:lys	34	33
Met & cys:lys	58	58
Thr:lys	64	63
Trp:lys	17.5	17.5
Val:lys	69	69
SID Lys:ME, g/Mcal	3.67	3.51
ME, kcal/lb	1,545	1,550
Total lys, %	1.38	1.33
CP, %	20.8	20.0
Ca, %	0.8	0.7
P, %	0.64	0.61
Available P, %	0.50	0.43

[1] Phase 2 diets were fed from approximately 14 to 21 lb (d 0 to 14); Phase 3 diets were fed from approximately 21 to 45 lb (d 14 to 35).
[2] Phyzyme 600 (Danisco Animal Nutrition, St. Louis, MO) provided a release of 0.11% available P.

Table 2. Physical analysis of corn and diets (Exp. 1 and 2)[1]

	Phase[2]	
Item	2	3
Particle size[3]		
400 µm corn		
Geometric mean, µm	387	477
Standard deviation	2.46	2.40
700 µm corn		
Geometric mean, µm	703	825
Standard deviation	2.48	2.09
Pelleted diet durability index[4]		
400 µm corn diets	89.0	88.8
700 µm corn diets	84.9	85.2

[1] A composite sample of 2 subsamples was utilized for analysis.
[2] Phase 2 diets were fed from approximately 14 to 21 lb (d 0 to 14); Phase 3 diets were fed from approximately 21 to 45 lb (d 14 to 35).
[3] Determined according to ASAE S319.3, 2003 using 0.5 g of flow agent and sifted for 15 minutes.
[4] Determined according to ASAE S269.4, 2003 with a modification to include five ½-in. hex nuts in the tumbling chamber.

Table 3. Composition of experimental diets (Exp. 3 and 4; as-fed basis)[1]

Item	
Ingredient, %	
Corn	64.23
Soybean meal, 46.5%	30.40
Soybean oil	2.00
Monocalcium P, 21% P	1.05
Limestone	1.00
Salt	0.35
L-lysine HCl	0.31
DL-methionine	0.12
L-threonine	0.12
Trace mineral premix	0.15
Vitamin premix	0.25
Phytase[2]	0.02
Total	100.00
Calculated analysis	
Standard ileal digestible (SID) amino acids, %	
Lys	1.20
Iso:lys	62
Leu:lys	131
Met:lys	33
Met & cys:lys	58
Thr:lys	63
Trp:lys	17.5
Val:lys	69
SID Lys:ME, g/Mcal	3.51
ME, kcal/lb	1,545
Total lys, %	1.33
CP, %	20.3
Ca, %	0.70
P, %	0.61
Available P, %	0.43

[1] Diets were fed from approximately 24 to 33 lb.
[2] Phyzyme 600 (Danisco Animal Nutrition, St. Louis, MO) provided a release of 0.11% available P.

Table 4. Physical analysis of corn and diets (Exp. 3 and 4)[1]

Item	Particle size[2]		Pelleted durability index[3]
	Geometric mean, µm	Geometric standard deviation	
250 µm	212	2.52	68.3
400 µm	422	2.55	50.8
550 µm	509	2.80	43.2
700 µm	739	2.48	68.9

[1] Represents a mean of 3 samples.
[2] Determined according to ASAE S319.3, 2003 using 0.5 g of flow agent and sifted for 15 minutes.
[3] Determined using a Holmen NHP 100 (TekPro; Norfolk, GBR) with 100 g of sample for 60 seconds.

Table 5. Composition of experimental diets (Exp. 5; as-fed basis)[1]

	Phase[1]	
Item	2	3
Ingredient, %		
Corn	55.57	64.23
Soybean meal, 46.5%	27.15	30.40
Select menhaden fish meal	3.00	---
Spray dried whey	10.00	---
Soy oil	2.00	2.00
Monocalcium P, 21% P	0.65	1.05
Limestone	0.39	1.00
Salt	0.35	0.35
L-lysine HCl	0.24	0.31
DL-methionine	0.12	0.12
L-threonine	0.11	0.12
Trace mineral premix	0.15	0.15
Vitamin premix	0.25	0.25
Phytase[2]	0.02	0.02
Total	100.00	100.00
Calculated analysis		
Standard ileal digestible (SID) amino acids, %		
Lys	1.25	1.20
Iso:lys	62	62
Leu:lys	129	131
Met:lys	34	33
Met & cys:lys	58	58
Thr:lys	64	63
Trp:lys	17.5	17.5
Val:lys	69	69
SID Lys:ME, g/Mcal	3.67	3.51
ME, kcal/lb	1,548	1,550
Total lys, %	1.38	1.33
CP, %	20.8	20.3
Ca, %	0.8	0.7
P, %	0.64	0.61
Available P, %	0.50	0.43

[1] Phase 2 diets were fed from approximately 16 to 29 lb (d 0 to 14); Phase 3 diets were fed from approximately 29 to 59 lb (d 14 to 35).
[2] HiPhos 2700 (DSM Nutritional Products, Inc., Parsippany, NJ), provided an estimated release of 0.10% available P.

Table 6. Physical analysis of corn and diets (Exp. 5)[1]

Item	Particle size[1]		
	Geometric mean, µm	Geometric standard deviation	Pelleted durability index[2]
500 µm			
Phase 2	512	2.41	85.3
Phase 3	469	2.33	66.2
750 µm			
Phase 2	764	2.49	90.7
Phase 3	770	2.51	78.9

[1] Determined according to ASAE S319.3, 2003 using 0.5 g of flow agent and sifted for 15 minutes.
[2] Determined according to ASAE S269.4, 2003 with a modification to include five ½-in. hex nuts in the tumbling chamber.

Table 7. Influence of corn particle size and diet form on nursery pig growth performance (Exp. 1)[1]

	Particle size, µm					
	400 µm		700 µm			P =
Diet form:	Mash	Pellet	Mash	Pelleted	SEM	Particle size × diet form
d 0 to 14						
ADG, lb	0.51	0.53	0.48	0.51	0.421	0.883
ADFI, lb	0.88	0.81	0.88	0.73	0.253	0.364
F/G	1.74	1.54	1.82	1.43	0.548	0.244
d 14 to 35						
ADG, lb	1.23	1.06	1.21	1.08	0.873	0.603
ADFI, lb	1.94	1.74	1.96	1.65	0.441	0.242
F/G	1.57[ab]	1.65[b]	1.62[ab]	1.53[a]	0.437	0.048
d 0 to 35						
ADG, lb	0.95	0.86	0.92	0.86	0.650	0.803
ADFI, lb	1.54	1.39	1.54	1.28	0.252	0.167
F/G	1.63[b]	1.62[b]	1.67[b]	1.49[a]	0.334	0.031
BW, lb						
d 0	14.63	14.74	14.83	14.63	0.948	0.790
d 14	21.23	21.69	21.23	21.25	0.793	0.804
d 35	47.10	43.82	46.55	44.79	0.867	0.574

[1] A total of 192 pigs (PIC 327 × 1050) were used with 8 pens per treatment and 6 pigs per pen.
[ab] Letters within a row that do not share a common superscript differ $P < 0.05$.

Table 8. Main effects of corn particle size and diet form on nursery pig growth performance (Exp. 1)[1]

	Particle size, µm			Diet form			$P =$	
Item	400	700	SEM	Mash	Pellet	SEM	Particle size	Diet form
d 0 to 14								
ADG, lb	0.53	0.51	0.018	0.51	0.53	0.019	0.421	0.410
ADFI, lb	0.84	0.79	0.028	0.88	0.77	0.025	0.253	0.009
F/G	1.58	1.57	0.031	1.74	1.46	0.033	0.548	< 0.001
d 14 to 35								
ADG, lb	1.14	1.14	0.024	1.21	1.06	0.024	0.873	< 0.001
ADFI, lb	1.85	1.80	0.038	1.96	1.69	0.035	0.441	< 0.001
F/G	1.62	1.58	0.023	1.62	1.60	0.024	0.437	0.806
d 0 to 35								
ADG, lb	0.90	0.88	0.024	0.95	0.86	0.022	0.650	0.006
ADFI, lb	1.45	1.41	0.028	1.54	1.34	0.027	0.252	< 0.001
F/G	1.61	1.60	0.020	1.63	1.56	0.020	0.334	0.062
BW, lb								
d 0	14.70	14.74	0.436	14.74	14.70	0.434	0.948	0.948
d 14	21.45	21.23	0.584	21.3	21.5	0.587	0.793	0.775
d 35	45.45	45.67	0.945	46.82	44.31	0.943	0.867	0.071

[1] A total of 192 pigs (PIC 327 × 1050) were used in a 35-d trial with 8 pens per treatment, and 6 pigs per pen.

Table 9. Preference of meal diets based on corn ground to two particle sizes (Exp. 2)[1,2]

	Corn particle size, µm			
Item	400	700	SEM	$P =$
ADFI, lb	0.31	1.19	0.072	0.001
ADFI, %	20.7	79.3	---	---

[1] A total of 96 pigs (initially 13.9 lb) were used in a 10-d experiment with 12 pens per treatment and 8 pigs per pen.
[2] Two feeders each containing the same formulated diet but manufactured with either 400 µm or 700 µm corn were provided per pen. Intake was determined by feed disappearance from each feeder.

Table 10. Effects of corn particle size in pelleted diets on nursery pig growth performance (Exp. 3)[1]

	Corn particle size, µm					*P* =		
Item	250	400	550	700	SEM	Treatment	Linear	Quadratic
d 0 to 10								
ADG, lb	1.01	1.08	1.06	1.01	0.07	0.302	0.589	0.084
ADFI, lb	1.61	1.56	1.63	1.58	0.04	0.594	0.956	0.733
F/G	1.59	1.45	1.54	1.57	0.04	0.145	0.662	0.101
BW, lb								
d 0	24.42	23.63	24.55	23.87	0.89	0.856	0.859	0.956
d 10	33.57	33.31	34.03	32.91	0.94	0.864	0.762	0.650

[1]A total of 224 pigs (PIC 327 × 1050) were used with 8 pens per treatment and 7 pigs per pen.

Table 11. Preference of pelleted diets based on corn ground to two particle sizes (Exp. 4)[1,2]

	Corn particle size, µm			
Item	250 µm	700 µm	SEM	*P* =
ADFI, lb	0.44	0.62	0.053	0.011
ADFI, %	41.8	58.2	---	---

[1]A total of 91 pigs (PIC 327 × 1050; initially 23.7 lb. and 40 d of age) were used in a 10-d study with 12 pens per treatment and 7 or 8 pigs per pen.
[2]Two feeders each containing the same formulated diet but manufactured with either 250 µm or 700 µm corn were provided per pen. Intake was determined by feed disappearance from each feeder.

Table 12. Interactive means of feed efficiency for particle size and diet form (Exp. 5)[1]

	Corn particle size, µm					$P =$
	500 µm		750 µm			Particle size
Diet form:	Mash	Pelleted	Mash	Pelleted	SEM	× diet form
d 0 to 14						
ADG, lb	1.01	0.88	0.95	0.95	0.026	0.064
ADFI, lb	1.41	1.28	1.39	1.32	0.035	0.650
F/G	1.39[a]	1.45[b]	1.47[b]	1.40[a]	0.035	0.044
d 14 to 35						
ADG, lb	1.50	1.45	1.41	1.47	0.081	0.378
ADFI, lb	2.60	2.38	2.49	2.46	0.059	0.082
F/G	1.74	1.64	1.77	1.67	0.055	0.803
d 0 to 35						
ADG, lb	1.17	1.06[y]	1.08	1.12	0.046	0.103
ADFI, lb	1.80	1.63	1.74	1.67	0.044	0.245
F/G	1.55	1.54	1.61	1.49	0.040	0.206
BW, lb						
d 0	15.95	15.88	15.75	15.71	0.343	0.988
d 14	29.68	28.47	28.75	28.89	0.678	0.262
d 35	60.68	58.89	58.83	59.22	1.071	0.256

[1] A total of 180 pigs (PIC 327 × 1050) were used with 9 pens per treatment and 5 pigs per pen.
[ab]Letters within a row that do not share a common superscript differ $P < 0.05$.

Table 13. Main effects of corn particle size and diet form on nursery pig growth performance (Exp. 5)[1]

	Particle size, µm			Diet form			$P =$	
Item	500	750	SEM	Mash	Pellet	SEM	Particle size	Diet form
d 0 to 14								
ADG, lb	0.95	0.95	0.024	0.97	0.92	0.026	0.892	0.110
ADFI, lb	1.34	1.34	0.035	1.39	1.30	0.037	0.940	0.045
F/G	1.42	1.42	0.034	1.43	1.40	0.036	0.644	0.645
d 14 to 35								
ADG, lb	1.47	1.43	0.080	1.45	1.45	0.083	0.983	0.578
ADFI, lb	2.49	2.46	0.061	2.55	2.42	0.058	0.78	0.042
F/G	1.69	1.72	0.057	1.76	1.67	0.053	0.556	0.140
d 0 to 35								
ADG, lb	1.10	1.10	0.046	1.12	1.08	0.044	0.827	0.337
ADFI, lb	1.72	1.72	0.046	1.76	1.65	0.042	0.982	0.020
F/G	1.56	1.56	0.043	1.57	1.53	0.040	0.878	0.224
BW, lb								
d 0	15.91	15.73	0.345	15.84	15.80	0.343	0.525	0.860
d 14	29.08	28.82	0.679	29.22	28.69	0.677	0.660	0.365
d 35	59.80	59.03	1.070	59.75	59.07	1.072	0.440	0.478

[1] A total of 180 pigs (PIC 327 × 1050 at 36 d of age) were used with 9 pens per treatment and 5 pigs per pen.