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Short communication

Effects of diet form and corn particle size on growth performance and carcass characteristics of finishing pigs

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ABSTRACT

A total of 960 crossbred pigs, initially 34.3 ± 0.50 kg, were used in a 101-day trial to determine the effects of corn particle size and diet form on growth performance and carcass characteristics of finishing pigs. Pens were randomly allotted by initial weight to 1 of 6 experimental treatments with 8 pens per treatment and 20 pigs per pen. The 6 experimental treatments were arranged in a 2 × 3 factorial with main effects of final feed form (meal vs. pellet) and corn particle size (650 μm, 350 μm, or an equal blend of the 650 μm and 350 μm ground corn). The 650 μm corn was ground using a two-high roller mill, and the 350 μm corn was ground using a full circle hammer-mill equipped with a 1.59 mm screen. After all corn was ground, the diet containing the blend of particle sizes was manufactured by adding equal portions of the 2 at the mixer. Overall (day 0–101), linear particle size × diet form interactions were observed ($P < 0.05$) for average daily feed intake (ADFI) and gain:feed ratio (G:F), because ADFI decreased and G:F increased as particle size was reduced for pigs fed meal diets but was unchanged for pigs fed pelleted diets. Pigs fed pelleted diets had increased ($P < 0.05$) average daily gain (ADG) compared with pigs fed meal diets. As corn particle size decreased, ADG decreased (linear; $P < 0.05$). Pigs fed pelleted diets had increased ($P < 0.05$) hot carcass weight compared with pigs fed meal diets, but no other effects on carcass characteristics were observed. In summary, grinding corn finer than 650 μm decreased ADFI and improved G:F for pigs fed meal diets, but did not affect performance of pigs fed pelleted diets. Pigs fed pelleted diets had improved ADG compared with those fed meal-based diets. Thus, grinding corn finer than 650 μm improved feed efficiency for pigs fed meal diets, but provided no benefit in pelleted diets.

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1. Introduction

Pelleting swine diet is an effective processing method for improving growth performance of pigs. Consistent improvements in feed efficiency when feeding pelleted diets have been reported (Hanke et al., 1972; Medel et al., 2004; Nemechek et al., 2013) and are often accompanied by increased average daily gain (ADG; Wondra et al., 1995; Paulk et al., 2011). These

Abbreviations: ADFI, average daily feed intake; ADG, average daily gain; G:F, gain:feed ratio; PDI, pellet durability index; SID, standardized ileal digestible.

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improvements in growth performance may result from multiple factors including decreased feed wastage (Hanrahan, 1984), increased nutrient digestibility (Wondra et al., 1995), and improved palatability (Skoch et al., 1983).

Fine grinding is another feed processing method that improves feed efficiency. Wondra et al. (1995) observed improved feed efficiency as corn particle size decreased from 1000 to 400 μm. The improvements were attributed to increased nutrient digestibility. Other research conducted with cereal grain particle sizes ranging from 1200 to 600 μm has been conducted primarily with meal-based diets (Ohh et al., 1983; Seerley et al., 1988). There is much less information available on the impact of feeding pelleted diets containing corn ground finer than 700 μm in finishing pigs.

Therefore, the objective of the experiment was to determine the effect of corn particle size (650 μm, 350 μm, or an equal blend of the 650 μm and 350 μm ground corn) and diet form (meal vs. pellet) on finishing pig growth performance and carcass characteristics.

2. Materials and methods

All experimental procedures and animal care were approved by the Kansas State University Institutional Animal Care and Use Committee.

2.1. General

A total of 960 crossbred pigs (Pig Improvement Company [Hendersonville, TN] TR4 × Fast Genetics [Saskatoon, SK] × Pig Improvement Company Line 02, initially 34.3 ± 0.50 kg) were used in a 101-day trial. The study was conducted at the New Fashion Pork Research Facility (Round Lake, MN) in a commercial research-finishing barn located in northwest IA. The double-curtain-sided barn was tunnel-ventilated with completely slatted flooring and deep pits for manure storage. Each pen (2.4 m × 17.8 m) was equipped with a 5-hole stainless steel dry self-feeder and a cup waterer for ad libitum access to feed and water. Daily feed additions to each pen were made by a robotic feeding system (FeedPro; Feedlogic Corp., Willmar, MN) capable of providing and measuring feed deliveries for individual pens.

Pens were randomly allotted by initial weight to 1 of 6 experimental treatments with 8 pens per treatment and 20 pigs per pen. The 6 experimental treatments were arranged in a 2 × 3 factorial with main effects of final feed form (meal vs. pellet) and corn particle sizes (650 μm, 350 μm, or an equal blend of the 650 μm and 350 μm ground corn). Diets were fed in 4 phases, with Phase 1 through 4 fed from day 0 to 26, 26 to 46, 46 to 73, and 73 to 101, respectively (Table 1). Within each phase, the same corn-soybean meal–based diet containing 30% dried distillers grains with solubles (Phases 1 through 3) or 15% dried distillers grains with solubles (Phase 4) was used for all 6 experimental treatments.

All diets were prepared at New Fashion Pork's commercial feed mill in Estherville, IA. The 650 μm corn was ground using a two-high roller mill (RMS Roller Grinder, Tea, SD), and the 350 μm corn was ground using a full circle hammer-mill (Jacobsen Machine Works, Minneapolis, MN) equipped with a 1.59 mm screen. After all corn was ground, the diet containing the blend of the 650 μm and 350 μm ground corn was manufactured by adding equal portions of the 2 at the mixer. For all pelleted diets, the complete feed was pelleted with a CPM pellet mill (California Pellet Mill, San Francisco, CA) equipped with a 4.3 mm die. Pelleting temperature was 50 °C with a 1 min retention time.

Pigs were weighed and feed disappearance measured approximately every 2 weeks to calculate average daily gain (ADG), average daily feed intake (ADFI), and gain:feed ratio (G:F). On day 87 of the trial, pens were weighed and the 6 heaviest pigs (selected by the marketing serviceman) were removed and transported 560 km to Triumph Foods (St. Joseph, MO) for harvest. The remaining pigs were transported to Triumph Foods on day 101 for harvest. Carcass yield was calculated using live weight at the farm and hot carcass weight at the plant. At the plant, backfat and loin depth were measured.

Samples of corn and complete diets were collected at the feeder during each phase. Corn particle size of the diets containing a 50:50 mixture of 650 and 350 μm ground corns could not be determined; therefore, whole diet particle size was measured. Particle size of corn samples and diets in meal form was determined at the K-State Swine Laboratory using the ASAE (1996) standard method for determining particle size. Tyler sieves (numbers 6, 8, 10, 14, 20, 28, 35, 48, 65, 100, 150, 200, 270, and a pan) and a Ro-Tap shaker (W.S. Tyler, Mentor, OH) were used. The Ro-Tap was equipped with a hammer used to tap the sieve stack approximately 150 times per minute during the shaking process. One hundred-gram samples were sifted for 10 min without a flow agent, and the weight on each screen was used to calculate the mean particle size and standard deviation (Table 2). Pellet durability index (PDI) was determined using the standard tumbling-box technique (S269.4; ASAE, 1996). Percentage fines (ASAE, 1987) were also determined for all pelleted diets, with fines characterized as material that would pass through a #6 sieve (3360 μm openings). All pellet quality measurements were analyzed at the K-State Grain Sciences and Industry Feed Mill.

2.2. Statistical analysis

Experimental data were analyzed using analysis of variance as a 2 × 3 factorial in a completely randomized design using the MIXED procedure of SAS (SAS Inst., Inc., Cary, NC). Pen was the experimental unit for all data analysis. Data analysis included main effects of 2 diet forms and 3 corn particle sizes. Linear and quadratic effects of decreasing particle size were determined as well as interactive effects of corn particle size and diet form. Significant differences were declared at $P < 0.05$ and trends at $P < 0.10$.

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

Item	Phase 1	Phase 2	Phase 3	Phase 4
Ingredient (g/kg)				
Corn	484.4	531.3	563.3	632.8
Soybean meal (465 g/kg CP)	178.8	133.6	103.9	184.2
Dried distillers grains with solubles	300.0	300.0	300.0	150.0
Beef tallow	15.0	15.0	15.0	15.0
Limestone	13.6	12.2	10.6	10.5
Salt	3.5	3.5	3.5	3.5
Vitamin-trace mineral premix[b]	1.0	1.0	0.75	0.50
L-Lys·HCl	3.7	3.4	3.1	2.8
L-Thr	–	–	–	0.50
Ractopamine HCl[c], 19.8 g/kg	–	–	–	0.25
Total	100.0	100.0	100.0	100.0
Calculated analysis				
Standardized ileal digestible (SID) amino acids				
Lys (g/kg)	10.1	8.8	7.8	9.0
Ile:Lys	68	70	72	68
Met:Lys	30	33	35	30
Met + Cys:Lys	58	62	67	58
Thr:Lys	60	62	65	65
Trp:Lys	17	17	17	18
Val:Lys	80	83	87	79
Total Lys (g/kg)	12.0	10.6	9.5	10.5
ME (kcal/kg)	3437	3446	3455	3,419
NE (kcal/kg)	2522	2553	2575	2,560
CP (g/kg)	213	195	183	185
Ca (g/kg)	5.8	5.2	4.5	4.6
P (g/kg)	4.3	4.1	4.0	3.9
Available P (g/kg)	3.2	3.1	3.0	3.2
Chemical analysis (g/kg)				
Dry matter	881	890	872	884
Crude protein	215	201	190	192
Ca	6.2	6.0	5.1	4.8
P	4.6	4.5	4.4	4.1

[a] Phase 1 diets were fed from day 0 to 26, phase 2 from day 26 to 46, phase 3 from day 46 to 73, and phase 4 from day 73 to 101.
[b] Provided per kilogram of premix: 3,968,324 IU vitamin A; 440,925 IU vitamin D_3; 22,046 IU vitamin E; 1874 mg vitamin K; 5512 mg riboflavin; 11,023 mg pantothenic acid; 16, 535 mg niacin; 16.5 mg vitamin B_{12}, 65 g Fe from iron sulfate, 75 g Zn from zinc sulfate and zinc oxide, 160 g Cu from tri-basic copper chloride, 4.5 g Mn from manganese sulfate, 200 mg I from calcium iodate, and 180 mg Se from sodium selenite.
[c] Paylean; Elanco Animal Health (Greenfield, IN).

3. Results

3.1. Particle size and pellet quality measurements

Particle size of corn was similar to expectations with corn targeted at 650 μm ranging from 616 to 681 μm and corn targeted at 350 μm ranging from 336 to 359 μm across the different dietary phases (Table 2). The complete feed particle size of diets containing the 50:50 blends of 650 and 350 μm corn were intermediate between high- and low-particle size corn diets, which was expected. High-quality pellets were produced as reflected by the PDI being greater than 90% and the percentage fines 20% or less for all diets and phases.

3.2. Growth performance and carcass measurements

Overall (day 0–101), linear particle size × diet form interactions were observed ($P < 0.05$) for ADFI and G:F (Table 3). This was a result of decreased ADFI and increased G:F as particle size was decreased for pigs fed meal diets but there were no changes observed for pigs fed pelleted diets. There was no particle size × diet form interaction observed for ADG; pigs fed pelleted diets had increased ($P < 0.05$) ADG compared with those fed meal diets. However, as corn particle size decreased, so did ADG.

For carcass characteristics, pigs fed pelleted diets had increased ($P < 0.05$) hot carcass weight compared with pigs fed meal diets. However, there were no other effects on carcass traits observed.

4. Discussion

Reducing cereal grain particle size in livestock diets has been widely implemented for many years. Early particle size reduction research was conducted with cereal grain particle sizes ranging from 1200 to 600 μm and was limited primarily

Table 2
Analysis of pellet quality and particle size[a].

Item	Corn particle size					
	650 μm		50:50 blend		350 μm	
	Meal	Pellet	Meal	Pellet	Meal	Pellet
Corn particle size						
Phase 1						
Mean (μm)	675		–	–	350	
Standard deviation (μm)	1.91		–	–	1.77	
Phase 2						
Mean (μm)	616		–	–	336	
Standard deviation (μm)	2.08		–	–	1.89	
Phase 3						
Mean (μm)	681		–	–	359	
Standard deviation (μm)	1.90		–	–	1.70	
Phase 4						
Mean (μm)	656		–	–	355	
Standard deviation (μm)	2.12		–	–	1.76	
Diet particle size (μm)						
Phase 1						
Mean (μm)	610	–	541	–	480	–
Standard deviation (μm)	2.18	–	2.21	–	2.31	–
Phase 2						
Mean (μm)	595	–	483	–	425	–
Standard deviation (μm)	2.12	–	2.26	–	2.31	–
Phase 3						
Mean (μm)	611	–	483	–	455	–
Standard deviation (μm)	2.20	–	2.29	–	2.33	–
Phase 4						
Mean (μm)	622	–	500	–	496	–
Standard deviation (μm)	2.17	–	2.25	–	2.35	–
Standard pellet durability index (%[b])						
Phase 1	–	92.8	–	94.1	–	96.0
Phase 2	–	97.6	–	93.2	–	94.5
Phase 3	–	94.1	–	91.7	–	95.8
Phase 4	–	96.8	–	92.4	–	97.8
Fines (%)						
Phase 1	–	9.2	–	11.7	–	11.3
Phase 2	–	9.7	–	10.5	–	8.8
Phase 3	–	18.2	–	11.9	–	10.7
Phase 4	–	20.0	–	8.6	–	11.2

[a] A composite sample of 3 subsamples was used for analysis.
[b] Pellet durability index was determined using the standard tumbling-box technique (S269.4; ASAE, 1996).

in diets fed in meal form (Ohh et al., 1983; Seerley et al., 1988). With advancements in feed processing technology, current feed manufacturers can more efficiently reduce grain to much finer particle sizes (300–400 μm).

In this study, particle size linear × diet form interactions for ADFI and G:F were observed. This appeared to be the result of pigs fed meal diets having decreased feed intake as corn particle size decreased; however, pigs fed pelleted diets had similar ADFI, regardless of corn particle size. As for G:F, a similar pattern was observed; fine grinding improved G:F in meal diets but did not affect G:F of pigs fed pelleted diets.

We believe that this ADFI interaction is likely due to decreased palatability of the meal diets containing finer particle size corn. Wondra et al. (1995) also found that finishing pigs fed meal diets with 400 μm corn had decreased ADFI compared to pigs fed diets with 800 μm corn. Similarly, De Jong et al. (2013) reported that reducing complete diet particle size from 596 to 360 μm resulted in a decrease in ADFI when diets were fed in meal form, but pigs fed pelleted diets, regardless of particle size, had similar ADFI.

Previous research has shown that decreasing cereal grain particle size in meal diets improves feed efficiency of finishing pigs (Ohh et al., 1983; Hedde et al., 1985; Mavromchalis et al., 2000). These results agree with the current experiment for pigs fed meal diets. However, grinding corn finer than 650 μm for pelleted diets provided no additional benefit to G:F. Thus, the improvements in feed efficiency from particle size reduction and pelleting were not additive.

A possible explanation for the feed efficiency interaction found in the current experiment may be that additional particle size reduction occurs during the pelleting process. Diets are subjected to extreme force and pressure as the feed is driven through the pellet mill die, which may cause the particle size of larger material to be reduced further.

In contrast to the current results, Wondra et al. (1995) reported that feed efficiency improved linearly for pigs fed pelleted diets as corn particle size was reduced (1000, 800, 600, and 400 μm). However, in their research, pellet quality was much

Table 3
The effect of corn particle size and diet form on finishing pig performance[a].

	Corn particle size							Probability (P<)				
	650 µm		50:50 blend[b]		350 µm			Diet form × particle size		Particle size		
Diet form	Meal	Pellet	Meal	Pellet	Meal	Pellet	SEM	Linear	Quadratic	Linear	Quadratic	Diet form
Day 0–101												
ADG (kg)	0.90	0.94	0.89	0.93	0.86	0.92	0.010	0.578	0.722	0.013	0.582	0.001
ADFI (kg[c])	2.41	2.35	2.37	2.37	2.26	2.35	0.065	0.021	0.823	0.018	0.283	0.601
G:F[d]	0.372	0.399	0.375	0.392	0.382	0.391	0.020	0.004	0.889	0.766	0.326	0.001
Weight (kg)												
Day 0	34.4	34.4	34.3	34.3	34.4	34.4	0.449	0.995	0.997	0.995	0.985	0.996
Day 101	120.7	125.0	120.1	124.4	118.2	122.6	2.860	0.496	0.960	0.166	0.328	0.002
Carcass characteristics[e]												
Hot carcass weight (kg)	88.6	93.1	89.5	92.3	87.7	90.4	0.915	0.339	0.630	0.058	0.235	0.001
Carcass yield (%)	74.1	74.5	74.3	74.4	74.6	74.3	0.402	0.676	0.408	0.942	0.771	0.802
Backfat (mm)	18.3	18.8	18.3	18.4	18.3	18.9	0.386	0.208	0.746	0.165	0.351	0.116
Loin depth (cm)	6.65	6.63	6.55	6.70	6.60	6.53	1.035	0.624	0.292	0.338	0.827	0.131

[a] A total of 960 pigs (Pig Improvement Company [Hendersonville, TN] TR4 × Fast Genetics [Saskatoon, SK] × Pig Improvement Company Line 02) were used in a 101-day trial with 8 pens per treatment and 20 pigs per pen. Average daily gain (ADG), average daily feed intake (ADFI), and Gain:feed ratio (G:F) are reported.
[b] Equal blend of the 650 and 350 µm ground corn.
[c] Linear effect of particle size within meal diets, $P < 0.001$. Linear effect of particle size within pelleted diets, $P > 0.960$.
[d] Linear effect of particle size within meal diets, $P < 0.022$. Linear effect of particle size within pelleted diets, $P < 0.058$.
[e] The 6 largest pigs were marketed from each pen on day 87. All remaining pigs were marketed from each pen on day 101. Means represent data collected from all pigs marketed on days 87 and 101. Carcass characteristics other than yield were adjusted by using hot carcass weight as a covariate.

poorer than in the experiment herein. Those authors reported that PDI improved from 78.8 to 86.4% as corn particle size decreased from 1000 to 400 µm, respectively. Stark et al. (1993) and Nemechek et al. (2012) found that pellet quality affected the feed efficiency response to pelleting. Therefore, the improvements in feed efficiency observed by Wondra et al. (1995) may be due to improved pellet quality and not a direct effect of particle size.

Improvements observed in ADG from pigs fed pelleted diets in the current experiment are similar to those reported in previous research (Hanke et al., 1972; Paulk et al., 2011; Nemechek et al., 2013). However, the effect of particle size on daily weight gain of pigs has also varied among experiments. Hedde et al. (1985) reported that feeding fine-ground corn increased ADG of finishing pigs, while others have found that grain particle size did not influence ADG (Ohh et al., 1983; Wu and Allee, 1984; Bokelman et al., 2014). We found that ADG decreased in meal diets as corn particle size decreased, which is in agreement with De Jong et al. (2014). The decreased gain can be explained by the reduced feed intake in pigs fed diets with fine corn particle sizes.

5. Conclusion

In summary, pigs fed pelleted diets had improved average daily gain compared with those fed meal diets. Feed efficiency improved as corn particle size decreased for pigs fed meal diets but not for those fed pelleted diets, suggesting that grinding corn finer than 650 µm for pelleted diets conferred no benefit.

Conflict of interest

The authors declare that there are no conflicts of interest.

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