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Effects of Pelleting and Diet Type on Growth Performance, Carcass Yield, and Iodine Value of Finishing Pigs[1,2]

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Summary

A total of 288 pigs (PIC 327 × 1050, initially 107.0 lb BW) were used in an 87-d trial to determine the effects of diet form and corn oil on growth performance, carcass yield, and iodine value (IV) of growing-finishing pigs. Treatments were arranged in a 2 × 3 factorial with the main effects of diet form and oil source. The 2 diet forms were meal or pellet. The 3 dietary formulations were: (1) corn-soybean meal–based control, (2) control with 30% dried distillers grains with solubles (DDGS) and 19% wheat middlings, and (3) control with 3% corn oil.

No diet form × diet formulation interactions were observed for growth performance, HCW, or carcass yield. Overall (d 0 to 87), pigs fed pelleted diets had increased ($P < 0.05$) ADG, decreased ($P < 0.05$) ADFI, and improved ($P < 0.05$) F/G compared with pigs fed meal diets. Diet form did not influence HCW or carcass yield. Pigs fed diets containing DDGS and wheat middlings had decreased ($P < 0.05$) ADG compared with pigs fed the control or corn oil diets. Feeding the corn oil diet resulted in decreased ($P < 0.05$) ADFI compared with pigs fed the diet with DDGS and wheat middlings, with pigs fed the control diet intermediate. Feed efficiency followed dietary energy, with pigs fed the corn oil diet having the best ($P < 0.05$) F/G, pigs fed DDGS and wheat middlings diet having the worst, and pigs fed the control intermediate. Pigs fed the diet with DDGS and wheat middlings had decreased ($P < 0.05$) HCW and carcass yield compared with pigs fed the control or corn oil treatments.

No interaction was detected between diet form and oil source for belly fat IV. Pigs fed pelleted diets had increased ($P < 0.05$) belly fat IV compared with those fed meal diets, regardless of diet formulation. Belly fat IV was greatest ($P < 0.05$) for pigs fed DDGS and wheat middlings, lowest for pigs fed the control, and intermediate for pigs fed the corn oil diets. An interactive effect between diet form and oil source was detected ($P < 0.05$) for shoulder fat IV, caused by an increase in shoulder fat IV from feeding pelleted diets for the control or corn oil treatments. Thus, with the exception of the lack of increase in IV in pigs fed the pelleted DDGS and wheat middlings diet, feeding pelleted diets increased carcass fat IV. Furthermore, we found no evidence that the source of fat (endogenous vs. supplemental) in pelleted diets affected the IV response to pelleting.

Key words: corn oil, DDGS, diet form, pelleting, finishing pig

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Introduction

Previous research has demonstrated that pelleting swine diets can improve ADG and feed efficiency in growing-finishing pigs. When carcass fat quality was evaluated, Nemechek et al. (2012[4]) reported that feeding pelleted diets increased carcass fat iodine value (IV) compared with feeding meal diets. This increase in carcass fat IV due to pelleting was greater when high-by-product (30% DDGS and 19% wheat middlings) diets were fed than when corn-soybean meal diets were fed. One hypothesis is that the pelleting process causes increased fat digestibility and results in an increase in the amount of dietary oil that is deposited as carcass fat. Kim et al. (2013[5]) reported that true ileal and total tract digestibility of acid-hydrolyzed ether extract was much greater for extracted corn oil than for the oil contained within DDGS (94.3 vs. 51.9%, respectively). We expected feeding pelleted diets to increase the digestibility at a greater rate from DDGS and wheat middlings than extracted corn oil. Thus, if the increases in IV caused by pelleting were a result of increased fat digestibility, we should observe a greater increase in IV when diets containing DDGS and wheat middlings are pelleted compared with a corn oil–supplemented diet with the same amount of fat. Therefore, the objective of this trial was to determine the effects of diet form and fat source on growth performance, carcass yield, and carcass fat IV of finishing pigs.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. The study was conducted at the K-State Swine Teaching and Research Center in Manhattan, KS. The facility was a totally enclosed, environmentally regulated, mechanically ventilated barn containing 36 pens (8 ft × 10 ft). The pens had adjustable gates facing the alleyway and allowed 10 ft^2/pig. Each pen was equipped with a cup waterer and a single-sided, dry self-feeder (Farmweld, Teutopolis, IL) with 2 eating spaces located in the fence line. Pens were located over a completely slatted concrete floor with a 4-ft pit underneath for manure storage. All pigs were provided ad libitum access to food and water.

A total of 288 pigs (PIC 327 × 1050, initially 107.0 lb BW) were used in an 87-d trial. Pens were randomly allotted to 1 of 6 experimental treatments with 6 pens per treatment and 8 pigs per pen (4 barrows and 4 gilts per pen). Treatments were arranged in a 2 × 3 factorial with the main effects of diet form and diet type (Tables 1 and 2). The 2 diet forms used were meal or pellet. The 3 dietary formulations were: (1) corn-soybean meal–based control, (2) control with 30% DDGS and 19% wheat middlings, and (3) control with 3% corn oil. The corn-soybean meal–based control provided a baseline, whereas the diet containing 30% DDGS and wheat middlings was a previously established diet that has been shown to cause predictable increases in IV. Based on research conducted by Benz et al. (2011[6]) with soybean oil, the third treatment diet was formulated to contain 3% corn oil in an effort to obtain similar carcass fat IV to pigs fed the diet containing DDGS and midds. Diets were fed in 4 phases from d 0 to 21, 21 to 45,

[4] Nemechek et al., Swine Day 2012, Report of Progress 1074, pp. 265–277.

[5] Kim, B.G., D.Y. Kil, and H.H. Stein. 2013. In growing pigs, the true ileal and total tract digestibility of acid hydrolyzed ether extract in extracted corn oil is greater than in intact sources of corn oil or soybean oil. J. Anim. Sci. 91:755-763.

[6] Benz, J.M., M.D. Tokach, S.S. Dritz, J.L. Nelssen, J.M DeRouchey, R.C. Sulabo, and R.D. Goodband. 2011. Effects of choice white grease and soybean oil on growth performance, carcass characteristics, and carcass fat quality of growing-finishing pigs. J. Anim. Sci. 89:404–413.

45 to 70, and 70 to 87. Diets within phase were formulated to contain equal amounts of standardized ileal digestible lysine (SID Lys) with 0.98, 0.86, 0.77, and 0.69 SID Lys for Phases 1, 2, 3, and 4, respectively. Pigs and feeders were weighed approximately every 2 wk to calculate ADG, ADFI, and F/G. Diets were prepared and pelleted at Hubbard Feeds in Beloit, KS. Pelleted feed was processed with a Sprout Waldron Pellet Mill, model Ace 501, equipped with an 11/64-in.-diameter die. Prior to pelleting, diets were conditioned with steam at a temperature of 71°C for approximately 20 sec. After manufacturing, diets were delivered in bulk and fed through bulk bins using a computerized feeding system (FeedPro; Feedlogic Corp., Willmar, MN) that delivered and recorded diets as specified. Feed samples were taken at the feeder during each phase. Feed was analyzed for moisture, CP, ADF, NDF, crude fiber, crude fat, Ca, and P (Tables 3 and 4) at Ward Laboratories, Inc. (Kearney, NE). Pellet durability index (PDI) was determined using the standard tumbling-box technique, and modified PDI was done by adding 5 hexagonal nuts prior to tumbling. Percentage fines were also determined for all pelleted diets, with fines characterized as material that would pass through a #6 sieve (3,360-µm openings).

On d 87, all pigs were weighed individually, then transported to Farmland Foods (Milan, MO). Pigs were individually tattooed in sequential order to allow for carcass data collection at the packing plant and data retrieval by pig. Hot carcass weights were measured immediately after evisceration and were used to calculate percentage yield by dividing HCW at the plant by live weight at the farm before transport. Belly fat samples were collected from the ventral side of the belly along the navel edge between the 10th and 12th rib of each pig. Shoulder fat samples were collected approximately 2 in. dorsal to the medial ridge of the scapula. All fat samples were analyzed for fatty acid profiles and calculation of IV. Iodine value was calculated using the formula (AOCS, 1998[7]): [C16:1] × 0.95 + [C18:1] × 0.86 + [C18:2] × 1.732 + [C18:3] × 2.616 + [C20:1] × 0.785 + [C22:1] × 0.723.

Experimental data were analyzed using analysis of variance as a 2 × 3 factorial using the MIXED procedure of SAS (SAS Institute Inc., Cary, NC). Pen was the experimental unit for all data analysis. For HCW, carcass yield, and carcass fat IV, measurements were collected for each pig, then pen means were calculated and used in the model. All analysis included main effects of 2 diet forms and 3 diet types and their interactions as fixed effects. When a significant difference was found between diet types, differences were determined using the PDIFF statement in SAS. Significant differences were declared at $P \leq 0.05$ and trends at $P \leq 0.10$.

Results and Discussion

Pellet quality measurements

Standard PDI was greater than 88% during all phases for pelleted diets with modified PDI from 82.5 to 87.5% (Table 5). Percentage fines were low for all diets and phases, approximately 7 to 14.0% fines.

[7] AOAC. 1998. Official methods and recommended practices of AOCS. 5th ed. Am. Oil Chem. Soc., Champaign, IL.

Growth performance and carcass measurements

No diet form × diet formulation interactions were observed for growth performance, HCW, or carcass yield for the overall trial (Table 6).

Overall (d 0 to 87), pigs fed pelleted diets had increased ($P < 0.05$) ADG, decreased ($P < 0.05$) ADFI, and improved ($P < 0.05$) F/G compared with pigs fed meal diets (Table 7). The improvements in ADG and F/G were 3 and 6%, respectively. Pigs fed pelleted diets tended ($P < 0.10$) to have increased final BW, but diet form did not influence HCW or carcass yield. Pigs fed diets containing DDGS and wheat middlings had decreased ($P < 0.05$) ADG compared with pigs fed the control or corn oil diets. Feeding the corn oil diet resulted in decreased ($P < 0.05$) ADFI compared with feeding the DDGS and wheat middlings diet, with the control diet intermediate. Feed efficiency followed dietary energy, with pigs fed the corn oil diet having the best ($P < 0.05$) F/G, pigs fed the DDGS and wheat middlings diet having the worst ($P < 0.05$), and pigs fed the control intermediate. Pigs fed the diet with DDGS and wheat middlings had decreased ($P < 0.05$) HCW and carcass yield compared with pigs fed the control or corn oil treatments. These decreases in HCW and carcass yield when feeding high-fiber diets were expected and are consistent with previously reported data (Nemechek et al., 2012[8]; Coble et al., 2013[9]).

Belly fatty acid composition

Diet form × diet type interactions were detected ($P < 0.05$) for oleic acid (C18:1n9c), total C18:1, linoleic acid (C18:2n6c), total C18:2, total MUFA, and total PUFA (Table 8). These interactions were caused by the greater magnitude of decrease in C18:1 and increase in C18:2 fatty acids when pelleting the control diet than when pelleting the diet containing corn oil, with the diet containing DDGS and midds exhibiting an intermediate response to pelleting. There was also an interaction ($P < 0.05$) for myristic acid (C14:0) in which pelleting the control diet increased C14:0 concentration, but pelleting either of the other 2 treatment diets decreased C14:0 concentration, with the greatest decrease observed in pigs fed diets containing DDGS and midds.

Feeding pelleted diets also increased ($P < 0.05$) stearic (C18:0) and eicosenoic (C20:1) acids and decreased ($P < 0.05$) vaccenic acid (C18:1n7) compared with feeding meal diets (Table 9).

For diet types, pigs fed the control diet had increased ($P < 0.05$) palmitic (C16:0) and reduced ($P < 0.05$) eicosenoic (C20:1) acid concentrations compared with pigs fed the DDGS and midds or corn oil diets. Compared with pigs fed the control diet, pigs fed the diet containing DDGS and midds had decreased ($P < 0.05$) stearic acid (C18:0) and total SFA, with those fed the diet containing corn oil intermediate ($P < 0.05$). Pigs fed diets with DDGS and midds had increased ($P < 0.05$) margaric (C17:0) and α-linolenic (C18:3n3) acid concentrations compared with pigs fed either of the other 2 diet types. No interaction was observed between diet form and oil source for belly fat IV. Feeding pelleted diets increased ($P < 0.05$) belly fat IV, and there was no evidence that the increase was influenced by diet type. Similarly, in a previous experiment feeding pelleted diets increased belly fat IV (Nemechek et al., 2012[8]). However, the increase in belly fat

[8] Nemechek et al., Swine Day 2012, Report of Progress 1074, pp. 265–277.
[9] Coble et al., Swine Day 2013, Report of Progress 1092, pp. 205–214.

IV from pelleting was greater for pigs fed diets containing DDGS and wheat middlings than those fed a corn-soybean meal diet. Belly IV was greatest ($P < 0.05$) for pigs fed diets with DDGS and midds and lowest for pigs fed the control. Belly IV for pigs fed diets with corn oil were intermediate but were numerically closer to the belly IV for pigs fed the DDGS and midds.

Shoulder fatty acid composition

Similar to belly fat, there were diet form × diet type interactions ($P < 0.05$) for several fatty acids (C16:0, C18:1, C18:2, C20:1; Table 10). Pelleting the control diet resulted in a greater increase in unsaturated fatty acids and a reduction in saturated fatty acids compared with pelleting the diet containing corn oil, with the response to pelleting the diet containing wheat middlings and DDGS intermediate. These changes in individual fatty acids led to interactions ($P < 0.05$) between diet form and diet type for total MUFA, PUFA, PUFA:SFA, and IV, with tendencies for interactions ($P < 0.10$) for total SFA and UFA:SFA.

For main effects of diet type, pigs fed the control diet had increased ($P < 0.05$) myristic acid compared with pigs fed the diets containing corn oil or DDGS and midds (Table 11). Feeding the corn oil diet resulted in decreased ($P < 0.05$) vaccenic (C18:1n7) and α-linolenic (C18:3n3) acid concentrations compared with pigs fed the control diet, with pigs fed the diet containing DDGS and midds intermediate. Pigs fed corn oil had decreased ($P < 0.05$) stearic acid (C18:0) concentration compared with pigs fed the control diet, with further decrease ($P < 0.05$) when pigs were fed the diet containing DDGS and midds. For main effects of diet form, pigs fed meal diets had increased ($P < 0.05$) myristic acid (C14:0) concentrations compared with pigs fed pelleted diets.

A diet form × oil source interaction was detected ($P < 0.05$) for shoulder fat IV, a result of pigs fed the control or corn oil diets having higher shoulder fat IV when diets were fed as pellets rather than in meal form. However, pigs fed the DDGS and midds diet had a slight numeric decrease in shoulder fat IV when fed pelleted diets compared with meal.

Conclusions

Pigs fed diets with DDGS and wheat middlings had poorer growth performance, decreased HCW, and reduced carcass yield compared with pigs fed the control or corn oil diets, with pigs fed corn oil having the greatest improvements in F/G. Feeding pelleted diets increased ADG, decreased ADFI, and improved F/G. Diet form did not influence HCW or carcass yield. Belly fat IV was greater for pigs fed pelleted diets, regardless of diet formulation. Pigs fed the control or corn oil diets had increased shoulder IV when diets were fed in pelleted form compared with meal form. The lack of increase in shoulder IV from feeding pelleting diets containing DDGS and wheat middlings was unexpected. With this exception, feeding pelleted diets increased carcass fat IV, which is consistent with our previous experiment; furthermore, it does not appear that the source of fat (endogenous from the ingredient vs. supplemental) in pelleted diets impacted the carcass fat IV response to pelleting.

Table 1. Diet composition (as-fed basis)

	Phase 1[1]			Phase 2[2]		
Item	Control	DDGS[3] + midds	Corn oil	Control	DDGS + midds	Corn oil
Ingredient, %						
Corn	72.01	33.03	68.84	77.57	37.46	74.25
Soybean meal, 46.5% CP	25.56	15.70	25.64	20.17	11.36	20.40
DDGS	---	30.00	---	---	30.00	---
Wheat middlings	---	19.00	---	---	19.00	---
Corn oil	---	---	3.00	---	---	3.00
Monocalcium P, 21% P	0.45	---	0.52	0.37	---	0.44
Limestone	1.05	1.30	1.05	1.00	1.28	1.00
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.150	0.150	0.150	0.125	0.125	0.125
Trace mineral premix	0.150	0.150	0.150	0.125	0.125	0.125
L-lysine HCl	0.220	0.310	0.225	0.235	0.293	0.235
Methionine hydroxyl analog	0.020	---	0.028	0.013	---	0.015
L-threonine	0.030	---	0.040	0.035	---	0.040
Phytase[4]	0.012	0.012	0.012	0.015	0.015	0.015
Total	100.0	100.0	100.0	100.0	100.0	100.0
Standardized ileal digestible, %						
Lysine	0.98	0.98	0.98	0.86	0.86	0.86
Isoleucine:lysine	67	71	66	65	72	65
Methionine:lysine	28	33	29	29	35	29
Met & Cys:lysine	55	62	55	56	67	56
Threonine:lysine	60	62	61	61	63	61
Tryptophan:lysine	19	19	19	18	18	18
Valine:lysine	74	85	73	74	88	73
Total lysine, %	1.11	1.19	1.11	0.98	1.05	0.97
ME, kcal/lb	1,496	1,467	1,566	1,501	1,470	1,571
CP, %	18.4	21.7	18.1	16.3	20.0	16.1
Ca, %	0.55	0.57	0.56	0.50	0.55	0.52
P, %	0.47	0.56	0.47	0.42	0.54	0.43
Available P, %	0.29	0.37	0.30	0.26	0.37	0.28

[1] Phase 1 diets were fed from d 0 to 21.
[2] Phase 2 diets were fed from d 21 to 45.
[3] Dried distillers grains with solubles.
[4] Natuphos 2500 (BASF Corp., Mt. Olive, NJ) provided 136 phytase units (FTU)/lb, with a release of 0.10% available P.

Table 2. Diet composition (as-fed basis)

Item	Phase 3[1] Control	Phase 3[1] DDGS[3] + midds	Phase 3[1] Corn oil	Phase 4[2] Control	Phase 4[2] DDGS + midds	Phase 4[2] Corn oil
Ingredient, %						
Corn	81.04	40.70	77.72	83.98	43.80	80.62
Soybean meal, 46.5% CP	16.81	8.16	17.04	13.86	5.13	14.17
DDGS	---	30.00	---	---	30.00	---
Wheat middlings	---	19.00	---	---	19.00	---
Corn oil	---	---	3.00	---	---	3.00
Monocalcium P, 21% P	0.34	---	0.42	0.45	---	0.49
Limestone	0.98	1.29	0.98	0.93	1.28	0.93
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.100	0.100	0.100	0.075	0.075	0.075
Trace mineral premix	0.100	0.100	0.100	0.075	0.075	0.075
L-lysine HCl	0.225	0.278	0.225	0.215	0.270	0.213
Methionine hydroxyl analog	0.010	---	0.010	---	---	0.010
L-threonine	0.038	---	0.043	0.050	---	0.055
Phytase[4]	0.018	0.018	0.018	0.021	0.021	0.021
Total	100.0	100.0	100.0	100.0	100.0	100.0
Standardized ileal digestible, %						
Lysine	0.77	0.77	0.77	0.69	0.69	0.69
Isoleucine:lysine	66	74	65	66	75	66
Methionine:lysine	30	37	29	30	40	31
Met & Cys:lysine	59	71	58	60	75	61
Threonine:lysine	62	65	62	65	67	66
Tryptophan:lysine	18	18	18	18	18	18
Valine:lysine	75	92	74	77	96	76
Total lysine, %	0.88	0.96	0.88	0.79	0.87	0.79
ME, kcal/lb	1,504	1,472	1,574	1,505	1,474	1,575
CP, %	14.9	18.7	14.8	13.8	17.5	13.6
Ca, %	0.48	0.54	0.49	0.47	0.53	0.48
P, %	0.40	0.53	0.41	0.41	0.52	0.41
Available P, %	0.25	0.36	0.27	0.27	0.36	0.28

[1] Phase 3 diets were fed from d 45 to 70.
[2] Phase 4 diets were fed from d 70 to 87.
[3] Dried distillers grains with solubles.
[4] Natuphos 2500 (BASF Corp., Mt. Olive, NJ) provided 136 phytase units (FTU)/lb, with a release of 0.10% available P.

Table 3. Chemical analysis of diets[1]

	Phase 1[2]						Phase 2[3]					
Diet form:	Meal			Pellet			Meal			Pellet		
Item / Diet type:	Control	DDGS[4] + midds	Corn oil	Control	DDGS + midds	Corn oil	Control	DDGS + midds	Corn oil	Control	DDGS + midds	Corn oil
DM, %	89.47	90.73	89.62	89.18	88.94	89.33	89.60	90.63	89.47	89.46	88.64	89.13
CP, %	17.7	18.4	18.0	18.8	23.0	18.1	18.1	18.6	17.4	16.9	21.6	17.0
ADF, %	2.7	7.1	2.6	3	7.3	3.1	3.2	7.3	3.3	2.9	6.4	3.2
NDF, %	7.6	17.7	6.6	6.7	16.6	6.6	5.9	18.0	6.7	5.1	14.0	5.3
Crude fiber, %	2.0	4.7	2.0	1.8	4.5	2.0	2.1	4.8	2.1	1.8	4.0	2.0
Crude fat, %	1.6	4.3	3.5	1.4	3.4	3.7	1.5	4.3	3.7	1.5	3.2	3.1
Ca, %	0.98	0.45	0.83	0.58	0.62	0.64	0.62	0.58	0.54	0.65	0.60	0.53
P, %	0.49	0.65	0.51	0.48	0.66	0.49	0.46	0.66	0.44	0.44	0.62	0.42

[1] A composite sample consisting of 6 subsamples was used for analysis.
[2] Phase 1 diets were fed from d 0 to 21.
[3] Phase 2 diets were fed from d 21 to 45.
[4] Dried distillers grains with solubles.

Table 4. Chemical analysis of diets[1]

	Phase 3[2]						Phase 4[3]					
Diet form:	Meal			Pellet			Meal			Pellet		
Item / Diet type:	Control	DDGS[4] + midds	Corn oil	Control	DDGS + midds	Corn oil	Control	DDGS + midds	Corn oil	Control	DDGS + midds	Corn oil
DM, %	89.09	90.58	89.41	88.77	90.16	88.93	89.85	90.15	89.81	89.74	91.89	90.61
CP, %	17.1	21	15.3	16.3	20.8	15.9	14.2	22.3	14.0	14.5	18.4	14.3
ADF, %	2.8	7.6	3.0	3.4	5.9	2.8	3.4	8.2	2.8	3.3	6.5	2.6
NDF, %	6.4	16	6.4	5.9	14.4	6.6	6.7	16.8	6.3	5.1	16.5	5.1
Crude fiber, %	1.7	4.2	2.0	1.8	3.5	1.9	2.1	4.8	2.1	1.6	4.3	1.5
Crude fat, %	2.0	4.6	4.2	1.6	4.4	3.8	2.0	3.7	3.2	1.9	4.7	3.5
Ca, %	0.38	0.47	0.61	0.45	0.61	0.55	0.90	0.88	1.19	0.98	0.56	0.56
P, %	0.49	0.66	0.49	0.46	0.66	0.44	0.47	0.58	0.51	0.44	0.64	0.40

[1] A composite sample consisting of 6 subsamples was used for analysis.
[2] Phase 3 diets were fed from d 45 to 70.
[3] Phase 4 diets were fed from d 70 to 87.
[4] Dried distillers grains with solubles.

Table 5. Analysis of pellet quality[1]

	Diet type		
Item	Control[2]	DDGS + midds[3]	Corn oil[4]
Standard pellet durability index, %[5]			
Phase 1	93.6	92.0	91.5
Phase 2	94.2	90.4	88.9
Phase 3	94.1	89.9	90.5
Phase 4	90.0	94.3	92.7
Modified pellet durability index[6]			
Phase 1	85.5	84.2	84.8
Phase 2	86.4	84.1	82.5
Phase 3	86.0	84.9	84.0
Phase 4	83.0	87.5	83.0
Fines, %			
Phase 1	10.2	12.4	14.0
Phase 2	11.9	12.7	7.6
Phase 3	7.2	8.8	6.9
Phase 4	7.3	13.6	8.5

[1] A representative feed sample was taken at the feeder during each phase and analyzed in duplicate for each pellet quality measurement.
[2] Corn-soybean meal–based diet with 0% dried distillers grains with solubles (DDGS), 0% wheat middlings, and 0% corn oil.
[3] Control diet with 30% DDGS and 19% wheat middlings.
[4] Control diet with 3% corn oil.
[5] Pellet durability index was determined using the standard tumbling-box technique.
[6] Procedure was altered by adding 5 hexagonal nuts prior to tumbling.

Table 6. Interactive effects of diet form and diet type on growth, carcass yield, and iodine value of finishing pigs[1]

Diet form:	Meal			Pellet				Probability, $P <$		
Diet type:	Control[2]	DDGS + midds[3]	Corn oil[4]	Control	DDGS + midds	Corn oil	SEM	Diet form × type	Diet form	Diet type
Initial BW, lb	107.0	107.0	107.0	107.0	107.0	107.0	2.295	0.998	0.997	0.996
d 0 to 87										
ADG, lb	2.08	2.00	2.10	2.12	2.07	2.15	0.029	0.706	0.038	0.009
ADFI, lb	5.81	5.86	5.56	5.48	5.79	5.37	0.092	0.372	0.016	0.002
F/G	2.79	2.94	2.65	2.60	2.80	2.50	0.037	0.760	0.001	0.001
Final BW, lb	288.4	280.6	289.8	290.4	286.8	296.6	3.550	0.747	0.076	0.028
HCW, lb	217.3	207.1	217.4	216.5	211.5	224.0	2.708	0.366	0.132	0.001
Carcass yield, %	75.37	73.82	75.01	74.53	73.75	75.54	0.309	0.163	0.619	0.001

[1] A total of 288 pigs (PIC 327 × 1050, initially 107.0 lb BW) were used with 8 pigs per pen and 6 pens per treatment.
[2] Corn-soybean meal–based diet with 0% dried distillers grains with solubles (DDGS), 0% wheat middlings, and 0% corn oil.
[3] Control diet with 30% DDGS and 19% wheat middlings.
[4] Control diet with 3% corn oil.

Table 7. Main effects of diet form and diet type on growth, carcass yield, and iodine value of finishing pigs[1]

	Diet form			Diet type				Probability, $P <$	
	Meal	Pellet	SEM	Control[2]	DDGS + midds[3]	Corn oil[4]	SEM	Diet form	Diet type
Initial BW, lb									
d 0 to 87	2.06	2.11	0.017	2.10[b]	2.03[a]	2.13[b]	0.020	0.038	0.009
ADG, lb	5.74	5.55	0.053	5.65[ab]	5.83[b]	5.47[a]	0.065	0.016	0.002
ADFI, lb	2.79	2.63	0.021	2.70[b]	2.87[c]	2.57[a]	0.026	0.001	0.001
F/G	107.0	107.0	1.325	107.0	107.0	107.0	1.623	0.997	0.996
Final BW, lb	286.2	291.3	1.936	289.4[ab]	283.7[a]	293.2[b]	2.372	0.076	0.028
HCW, lb	213.9	217.3	1.551	216.9[b]	209.3[a]	220.1[b]	1.899	0.132	0.001
Carcass yield, %	74.73	74.60	0.178	74.95[b]	73.78[a]	75.27[b]	0.218	0.619	0.001

[a,b,c] Means for diet type with different superscripts within row significantly differ, $P < 0.05$.
[1] A total of 288 pigs (PIC 327 × 1050, initially 107.0 lb BW) were used with 8 pigs per pen and 18 pens per treatment for diet form and 12 pigs per pen for diet type.
[2] Corn-soybean meal-based diet with 0% dried distillers grains with solubles (DDGS), 0% wheat middlings, and 0% corn oil.
[3] Control diet with 30% DDGS and 19% wheat middlings.
[4] Control diet with 3% corn oil.

Table 8. Interactive effects of diet form and diet type on belly fatty acid profile[1]

Item Diet type:	Meal: Control[2]	Meal: DDGS + midds[3]	Meal: Corn oil[4]	Pellet: Control	Pellet: DDGS + Midds	Pellet: Corn oil	SEM	Probability, $P <$: Diet form × type	Probability, $P <$: Meal vs. pellet	Probability, $P <$: Diet type
Myristic acid (C14:0), %	1.39	1.39	1.36	1.41	1.30	1.33	0.020	0.028	0.034	0.022
Palmitic acid (C16:0), %	23.62	22.16	22.48	23.20	22.27	22.27	0.152	0.239	0.177	0.001
Palmitoleic acid (C16:1), %	3.29	2.95	2.65	2.76	2.46	2.47	0.076	0.056	0.001	0.001
Margaric acid (C17:0), %	0.24	0.27	0.21	0.22	0.27	0.19	0.016	0.545	0.239	0.001
Stearic acid (C18:0), %	10.44	9.07	9.65	10.91	9.24	9.66	0.116	0.148	0.032	0.001
Oleic acid (C18:1n9c), %	46.66	42.56	42.55	44.99	41.66	42.31	0.239	0.019	0.001	0.001
Vaccenic acid (C18:1n7), %	0.93	0.84	0.63	0.73	0.64	0.61	0.048	0.130	0.001	0.001
Total C18:1 fatty acids[5], %	47.61	43.40	43.11	45.69	42.25	42.88	0.265	0.013	0.001	0.001
Linoleic acid (C18:2n6c), %	11.31	18.30	18.15	13.62	19.64	18.87	0.268	0.020	0.001	0.001
Total C18:2 fatty acids[6], %	11.94	19.13	18.93	14.31	20.53	19.68	0.274	0.021	0.001	0.001
α-Linolenic acid (C18:3n3), %	0.70	0.72	0.65	0.66	0.69	0.64	0.022	0.765	0.171	0.037
Eicosenoic acid (C20:1), %	0.43	0.71	0.69	0.53	0.77	0.73	0.016	0.181	0.001	0.001
Total SFA[7], %	35.69	32.89	33.70	35.74	33.07	33.45	0.202	0.545	0.958	0.001
Total MUFA[8], %	51.33	47.05	46.45	48.99	45.48	46.08	0.318	0.014	0.001	0.001
Total PUFA[9], %	12.60	19.77	19.49	14.92	21.16	20.23	0.263	0.019	0.001	0.001
UFA:SFA[10]	1.79	2.03	1.96	1.79	2.02	1.98	0.017	0.486	0.885	0.001
PUFA:SFA[11]	0.35	0.60	0.58	0.42	0.64	0.61	0.009	0.096	0.001	0.001
Iodine value, mg/g[12]	66.74	75.40	74.31	68.65	76.45	75.26	0.300	0.229	0.001	0.001

[1] All items calculated as a percentage of the total fatty acid content. Fat samples were collected and analyzed by individual pig and used to calculate means per pen.
[2] Corn-soybean meal-based control diet with 0% dried distillers grains with solubles (DDGS), 0% wheat middlings, and 0% corn oil.
[3] Control diet with 30% DDGS and 19% wheat middlings.
[4] Control diet with 3% corn oil.
[5] Total C18:1 fatty acids = [% C18:1n9c] + [% C18:1n7]
[6] Total C18:2 fatty acids = [% C18:2n6t] + [% C18:2n6c] + [% C18:2, 9c11t] + [% 18:2, 10t12c] + [% C18:2, 9c11c] + [C18:2, 9t11t].
[7] Total saturated fatty acids = [% C14:0] + [% C15:0] + [% C16:0] + [% C17:0] + [% C18:0] + [% C20:0] + [% C21:0] + [% C22:0] + [% C 24:0].
[8] Total monounsaturated fatty acids = [% C14:1] + [% C15:1] + [% C16:1] + [% C17:1] + [% C18:1n9t] + [% C18:1n9c] + [% C18:1n7] + [% C20:1] + [% C24:1].
[9] Total polyunsaturated fatty acids = [% C18:2n6t] + [% C18:2n6c] + [% C18:2 9c, 11t] + [% C18:2 10t, 12c] + [% C18:2 9c, 11c] + [% C18:2 9t, 11t] + [% C18:3n6] + [% C18:3n3].
[10] UFA:SFA = [total MUFA + total PUFA] / total SFA.
[11] PUFA:SFA = total PUFA / total SFA.
[12] Iodine value = [% C16:1] × 0.95 + [% C18:1] × 0.86 + [% C18:2] × 1.732 + [% C18:3] × 2.616 + [% C20:1] × 0.785.

Table 9. Main effects of diet form and diet type on belly fatty acid profile[1]

	Diet form			Diet type				Probability, $P <$	
Item	Meal	Pellet	SEM	Control[2]	DDGS + midds[3]	Corn oil[4]	SEM	Meal vs. pellet	Diet type
Myristic acid (C14:0), %	1.38	1.35	0.012	1.40[b]	1.35[a]	1.35[a]	0.014	0.034	0.022
Palmitic acid (C16:0), %	22.75	22.58	0.088	23.41[b]	22.21[a]	22.37[a]	0.107	0.177	0.001
Palmitoleic acid (C16:1), %	2.96	2.56	0.044	3.03[b]	2.70[a]	2.56[a]	0.054	0.001	0.001
Margaric acid (C17:0), %	0.24	0.23	0.009	0.23[a]	0.27[b]	0.20[a]	0.011	0.239	0.001
Stearic acid (C18:0), %	9.72	9.94	0.067	10.67[c]	9.16[a]	9.66[b]	0.082	0.032	0.001
Oleic acid (C18:1n9c), %	43.92	42.99	0.138	45.83[b]	42.11[a]	42.43[a]	0.169	0.001	0.001
Vaccenic acid (C18:1n7), %	0.80	0.66	0.028	0.83[b]	0.74[b]	0.62[a]	0.034	0.001	0.001
Total C18:1 fatty acids[5], %	44.71	43.61	0.153	46.65[b]	42.83[a]	42.99[a]	0.188	0.001	0.001
Linoleic acid (C18:2n6c), %	15.92	17.38	0.155	12.47[a]	18.97[b]	18.51[b]	0.190	0.001	0.001
Total C18:2 fatty acids[6], %	16.67	18.17	0.158	13.12[a]	19.83[b]	19.30[b]	0.194	0.001	0.001
α-Linolenic acid (C18:3n3), %	0.69	0.67	0.013	0.68[a]	0.71[b]	0.65[a]	0.016	0.171	0.037
Eicosenoic acid (C20:1), %	0.61	0.68	0.009	0.48[b]	0.74[a]	0.71[a]	0.011	0.001	0.001
Total SFA[7], %	34.10	34.09	0.116	35.71[c]	32.98[a]	33.58[b]	0.142	0.958	0.001
Total MUFA[8], %	48.28	46.85	0.184	50.16[b]	46.27[a]	46.27[a]	0.225	0.001	0.001
Total PUFA[9], %	17.29	18.77	0.152	13.76[a]	20.46[c]	19.86[b]	0.186	0.001	0.001
UFA:SFA[10]	1.93	1.93	0.010	1.79[a]	2.02[c]	1.97[b]	0.012	0.885	0.001
PUFA:SFA[11]	0.51	0.55	0.005	0.39[a]	0.62[c]	0.59[b]	0.006	0.001	0.001
Iodine value, mg/g[12]	72.15	73.45	0.173	67.70[a]	75.93[c]	74.79[b]	0.212	0.001	0.001

[1] All items calculated as a percentage of the total fatty acid content. Fat samples were collected and analyzed by individual pig and used to calculate means per pen.
[2] Corn-soybean meal–based control diet with 0% dried distillers grains with solubles (DDGS), 0% wheat middlings, and 0% corn oil.
[3] Control diet with 30% DDGS and 19% wheat middlings.
[4] Control diet with 3% corn oil.
[5] Total C18:1 fatty acids = [% C18:1n9c] + [% C18:1n7].
[6] Total C18:2 fatty acids = [% C18:2n6t] + [% C18:2n6c] + [% C18:2, 9c11t] + [% 18:2, 10t12c] + [% C18:2, 9c11c] + [C18:2, 9t11t].
[7] Total saturated fatty acids = [% C14:0] + [% C15:0] + [% C16:0] + [% C17:0] + [% C18:0] + [% C20:0] + [% C21:0] + [% C22:0] + [% C 24:0].
[8] Total monounsaturated fatty acids = [% C14:1] + [% C15:1] + [% C16:1] + [% C17:1] + [% C18:1n9t] + [% C18:1n9c] + [% C18:1n7] + [% C20:1] + [% C24:1].
[9] Total polyunsaturated fatty acids = [% C18:2n6t] + [% C18:2n6c] + [% C18:2 9c, 11t] + [% C18:2 10t, 12c] + [% C18:2 9c, 11c] + [% C18:2 9t, 11t] + [% C18:3n6] + [% C18:3n3].
[10] UFA:SFA = [total MUFA + total PUFA] / total SFA.
[11] PUFA:SFA = total PUFA / total SFA.
[12] Iodine value = [% C16:1] × 0.95 + [% C18:1] × 0.86 + [% C18:2] × 1.732 + [% C18:3] × 2.616 + [% C20:1] × 0.785.
[a,b,c] Within a row, means without a common superscript differ ($P < 0.05$)

Table 10. Interactive effects of diet form and diet type on shoulder fatty acid profile[1]

	Diet form							Probability, $P <$		
	Meal			Pellet						
Item Diet type:	Control[2]	DDGS + midds[3]	Corn oil[4]	Control	DDGS + midds	Corn oil	SEM	Diet form × type	Meal vs. pellet	Diet type
Myristic acid (C14:0), %	1.35	1.28	1.25	1.29	1.22	1.19	0.021	0.956	0.002	0.001
Palmitic acid (C16:0), %	23.82	22.46	22.54	22.96	23.23	22.64	0.244	0.008	0.974	0.008
Palmitoleic acid (C16:1), %	2.58	2.21	2.04	2.13	1.96	1.84	0.058	0.100	0.001	0.001
Margaric acid (C17:0), %	0.28	0.33	0.27	0.30	0.27	0.24	0.013	0.028	0.064	0.004
Stearic acid (C18:0), %	11.64	10.04	10.45	11.81	10.10	10.49	0.196	0.940	0.579	0.001
Oleic acid (C18:1n9c), %	44.45	40.69	40.74	42.36	39.96	40.20	0.307	0.035	0.001	0.001
Vaccenic acid (C18:1n7), %	0.55	0.51	0.42	0.65	0.47	0.37	0.070	0.469	0.891	0.020
Total C18:1 fatty acids[5], %	44.87	41.05	40.93	42.76	40.25	40.37	0.301	0.033	0.001	0.001
Linoleic acid (C18:2n6c), %	12.96	19.65	19.71	16.08	20.01	20.38	0.246	0.001	0.001	0.001
Total C18:2 fatty acids[6], %	13.68	20.55	20.55	16.89	20.96	21.32	0.245	0.001	0.001	0.001
α-Linolenic acid (C18:3n3), %	0.74	0.73	0.69	0.75	0.70	0.67	0.018	0.461	0.366	0.005
Eicosenoic acid (C20:1), %	0.51	0.81	0.81	0.68	0.86	0.85	0.018	0.002	0.001	0.001
Total SFA[7], %	37.09	34.10	34.51	36.37	34.82	34.56	0.282	0.052	0.946	0.001
Total MUFA[8], %	47.96	44.07	43.78	45.57	43.07	43.06	0.329	0.038	0.001	0.001
Total PUFA[9], %	14.55	21.46	21.40	17.73	21.72	22.12	0.244	0.001	0.001	0.001
UFA:SFA[10]	1.69	1.92	1.89	1.74	1.86	1.89	0.023	0.060	0.910	0.001
PUFA:SFA[11]	0.39	0.63	0.62	0.49	0.62	0.64	0.010	0.001	0.001	0.001
Iodine value, mg/g[12]	67.39	75.96	75.53	70.73	75.42	76.14	0.355	0.001	0.001	0.001

[1] All items calculated as a percentage of the total fatty acid content. Fat samples were collected and analyzed by individual pig and used to calculate means per pen.
[2] Corn-soybean meal–based control diet with 0% dried distillers grains with solubles (DDGS), 0% wheat middlings, and 0% corn oil.
[3] Control diet with 30% DDGS and 19% wheat middlings.
[4] Control diet with 3% corn oil.
[5] Total C18:1 fatty acids = [% C18:1n9c] + [% C18:1n7].
[6] Total C18:2 fatty acids = [% C18:2n6t] + [% C18:2n6c] + [% C18:2, 9c11t] + [% 18:2, 10t12c] + [% C18:2, 9c11c] + [C18:2, 9t11t].
[7] Total saturated fatty acids = [% C14:0] + [% C15:0] + [% C16:0] + [% C17:0] + [% C18:0] + [% C20:0] + [% C21:0] + [% C22:0] + [% C 24:0].
[8] Total monounsaturated fatty acids = [% C14:1] + [% C15:1] + [% C16:1] + [% C17:1] + [% C18:1n9t] + [% C18:1n9c] + [% C18:1n7] + [% C20:1] + [% C24:1].
[9] Total polyunsaturated fatty acids = [% C18:2n6t] + [% C18:2n6c] + [% C18:2 9c, 11t] + [% C18:2 10t, 12c] + [% C18:2 9c, 11c] + [% C18:2 9t, 11t] + [% C18:3n6] + [% C18:3n3].
[10] UFA:SFA = [total MUFA + total PUFA] / total SFA.
[11] PUFA:SFA = total PUFA / total SFA.
[12] Iodine value = [% C16:1] × 0.95 + [% C18:1] × 0.86 + [% C18:2] × 1.732 + [% C18:3] × 2.616 + [% C20:1] × 0.785.

Table 11. Main effects of diet form and diet type on shoulder fatty acid profile[1]

	Diet form			Diet type				Probability, *P* <	
Item	Meal	Pellet	SEM	Control[2]	DDGS + midds[3]	Corn oil[4]	SEM	Meal vs. pellet	Diet type
Myristic acid (C14:0), %	1.29	1.23	0.012	1.32^{b}	1.25^{a}	1.22^{a}	0.015	0.002	0.001
Palmitic acid (C16:0), %	22.94	22.95	0.141	23.39^{b}	22.85^{a}	22.59^{a}	0.172	0.974	0.008
Palmitoleic acid (C16:1), %	2.27	1.98	0.033	2.36^{c}	2.08^{b}	1.94^{a}	0.041	0.001	0.001
Margaric acid (C17:0), %	0.29	0.27	0.008	0.29^{b}	0.30^{b}	0.25^{a}	0.010	0.064	0.004
Stearic acid (C18:0), %	10.71	10.80	0.113	11.72^{c}	10.07^{a}	10.47^{b}	0.138	0.579	0.001
Oleic acid (C18:1n9c), %	41.96	40.84	0.177	43.41^{b}	40.32^{a}	40.47^{a}	0.217	0.001	0.001
Vaccenic acid (C18:1n7), %	0.49	0.50	0.040	0.60^{b}	0.49^{ab}	0.39^{a}	0.049	0.891	0.020
Total C18:1 fatty acids[5], %	42.28	41.13	0.174	43.81^{a}	40.65^{b}	40.65^{b}	0.213	0.001	0.001
Linoleic acid (C18:2n6c), %	17.44	18.82	0.142	14.52^{a}	19.83^{b}	20.04^{b}	0.174	0.001	0.001
Total C18:2 fatty acids[6], %	18.26	19.72	0.142	15.28^{a}	20.75^{b}	20.93^{b}	0.174	0.001	0.001
α-Linolenic acid (C18:3n3), %	0.72	0.71	0.010	0.75^{b}	0.72^{ab}	0.68^{a}	0.013	0.366	0.005
Eicosenoic acid (C20:1), %	0.71	0.80	0.011	0.60^{a}	0.83^{b}	0.83^{b}	0.013	0.001	0.001
Total SFA[7], %	35.23	35.25	0.163	36.73^{b}	34.46^{a}	34.53^{a}	0.200	0.946	0.001
Total MUFA[8], %	45.27	43.90	0.190	46.77^{b}	43.57^{a}	43.42^{a}	0.233	0.001	0.001
Total PUFA[9], %	19.13	20.52	0.141	16.14^{a}	21.59^{b}	21.76^{b}	0.172	0.001	0.001
UFA:SFA[10]	1.83	1.83	0.013	1.71^{a}	1.89^{b}	1.89^{b}	0.016	0.91	0.001
PUFA:SFA[11]	0.55	0.58	0.006	0.44^{a}	0.63^{b}	0.63^{b}	0.007	0.001	0.001
Iodine value, mg/g[12]	72.96	74.10	0.205	69.06^{a}	75.69^{b}	75.83^{b}	0.251	0.001	0.001

[1] All items calculated as a percentage of the total fatty acid content. Fat samples were collected and analyzed by individual pig and used to calculate means per pen.

[2] Corn-soybean meal-based control diet with 0% dried distillers grains with solubles (DDGS), 0% wheat middlings, and 0% corn oil.

[3] Control diet with 30% DDGS and 19% wheat middlings.

[4] Control diet with 3% corn oil.

[5] Total C18:1 fatty acids = [% C18:1n9c] + [% C18:1n7].

[6] Total C18:2 fatty acids = [% C18:2n6t] + [% C18:2n6c] + [% C18:2, 9c11t] + [% 18:2, 10t12c] + [% C18:2, 9c11c] + [C18:2, 9t11t].

[7] Total saturated fatty acids = [% C14:0] + [% C15:0] + [% C16:0] + [% C17:0] + [% C18:0] + [% C20:0] + [% C21:0] + [% C22:0] + [% C 24:0].

[8] Total monounsaturated fatty acids = [% C14:1] + [% C15:1] + [% C16:1] + [% C17:1] + [% C18:1n9t] + [% C18:1n9c] + [% C18:1n7] + [% C20:1] + [% C24:1].

[9] Total polyunsaturated fatty acids = [% C18:2n6t] + [% C18:2n6c] + [% C18:2 9c, 11t] + [% C18:2 10t, 12c] + [% C18:2 9c, 11c] + [% C18:2 9t, 11t] + [% C18:3n6] + [% C18:3n3].

[10] UFA:SFA = [total MUFA + total PUFA] / total SFA.

[11] PUFA:SFA = total PUFA / total SFA.

[12] Iodine value = [% C16:1] × 0.95 + [% C18:1] × 0.86 + [% C18:2] × 1.732 + [% C18:3] × 2.616 + [% C20:1] × 0.785.

[a,b,c] Within a row, means without a common superscript differ ($P < 0.05$).