Effects of withdrawing high-fiber ingredients before marketing on finishing pig growth performance, carcass characteristics, and intestinal weights

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ABSTRACT: Two experiments were conducted to determine the duration of high-fiber ingredient removal from finishing pig diets before marketing to restore carcass yield and carcass fat iodine value (**IV**), similar to pigs continuously fed a corn–soybean meal diet. In experiment 1, 288 pigs (initially 38.4 ± 0.3 kg body weight [BW]) were used in an 88-d study and fed either a low-fiber corn–soybean meal diet from day 0 to 88 or a high-fiber diet containing 30% corn distillers dried grains with solubles and 19% wheat middlings until day 20, 15, 10, 5, or 0 before slaughter and switched to the low-fiber corn–soybean meal diet thereafter. Diets were not balanced for net energy. From day 0 to 88, pigs continuously fed the high-fiber diet tended to have increased average daily feed intake (*P* = 0.072) and decreased G:F and carcass yield (*P* = 0.001) compared with pigs fed the low-fiber corn–soybean meal diet. Pigs continuously fed the high-fiber diet had greater (*P* < 0.010) IV of jowl, backfat, belly, and ham collar fat than those fed the low-fiber corn–soybean meal diet throughout. As days of withdrawal increased, pigs previously fed the high-fiber diet had increased carcass yield (quadratic; *P* = 0.039). Pigs continuously fed the high-fiber diet had heavier (percentage of hot carcass weight [HCW]) full large intestines (*P* = 0.003) than pigs fed the corn–soybean meal diet. Full large intestine weight decreased (linear; *P* = 0.018) as withdrawal time increased. Belly fat IV tended (linear; *P* = 0.080) to improve as withdrawal time increased. In experiment 2, a total of 1,089 pigs (initially 44.5 ± 0.1 kg BW) were used in a 96-d study with the same dietary treatments as in experiment 1, except pigs were fed the high-fiber diet until day 24, 19, 14, 9, or 0 before slaughter and then switched to the corn–soybean meal diet. Pigs fed the high-fiber diet throughout had decreased average daily gain and G:F (*P* = 0.001) compared with those fed the low-fiber corn–soybean meal diet. For pigs initially fed the high-fiber diet and then switched to the low-fiber corn–soybean meal diet, G:F tended to improve (linear; *P* = 0.070) as withdrawal period increased. Pigs fed the high-fiber diet throughout had decreased HCW (*P* = 0.001) compared with those fed the low-fiber corn–soybean meal diet and HCW marginally increased (quadratic; *P* = 0.077) as withdrawal period increased. In summary, switching pigs from a high-fiber diet to a corn–soybean meal diet for up to 24 d before market increased carcass yield (experiment 1) or HCW (experiment 2) with the improvement most prominent during the first 5 to 9 d after withdrawal.

Key words: energy, fat quality, fiber, intestinal weights, pigs, withdrawal

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INTRODUCTION

Different coproducts in diets fed to growing-finishing pigs have benefits and negative effects. For instance, in a review, Stein and Shurson (2009) report that up to 30% distillers dried grains with solubles **(DDGS)** can be fed without detrimental effects on growth performance but decreases carcass yield and increases iodine value (**IV**). Although there may be economic advantages to using by-product ingredients when they are cost-effective, it has been shown that high amounts of dietary fiber negatively affect carcass yield by increasing the weight of intestinal contents (Turlington, 1984).

Previous research has sought to better understand the effects of switching pigs from a high-fiber to low-fiber corn–soybean meal diet before slaughter on growth, carcass yield, and carcass fat quality (Nemechek et al., 2013; Asmus et al., 2014; Graham et al., 2014). Asmus et al. (2014) and Graham et al. (2014) observed that pigs switched from a high-fiber diet containing 30% DDGS and 19% wheat middlings approximately 3 wk before slaughter had similar carcass yield compared with those fed a corn–soybean meal diet throughout the entire finishing phase. Xu et al. (2010) also suggested that poor pork fat quality of pigs fed 30% DDGS could be improved in as little as 3 wk after withdrawing DDGS before slaughter. However, researchers have yet to investigate the potential changes in average daily gain (ADG), carcass yield, and IV within this critical, 3-wk window of time between diet change and slaughter.

Our hypothesis was that by switching pigs from a high-fiber diet to a corn–soybean meal-based diet at multiple time points within the last 3 wk before slaughter would reverse or mitigate the negative effects of feeding a high-fiber diet on carcass yield. Thus, using the dietary model introduced by Asmus et al. (2014), the objective of our studies was to determine optimal duration that finishing pigs should be switched from a high-fiber diet to a low-fiber corn–soybean meal diet before slaughter to optimize growth performance, carcass yield, and IV.

MATERIALS AND METHODS

General

All experimental procedures and animal care were approved by the Kansas State University Institutional Animal Care and Use Committee. Experiment 1 was conducted at the Kansas State University Swine Teaching and Research Center during the summer in Manhattan, KS. Pigs were housed in an enclosed environmentally regulated, mechanically ventilated barn containing 36 pens (2.44 × 3.05 m). The pens had adjustable gates facing the alleyway and allowed 0.93 m^2/pig. Each pen was equipped with a cup waterer and a single-sided, dry self-feeder (Farmweld, Teutopolis, IL) with two eating spaces to offer ad libitum access to feed and water. Pens were located over a completely slatted concrete floor with a manure storage pit underneath (1.20-m deep).

Experiment 2 was conducted in a commercial research facility during the winter in southwestern Minnesota. The facility was double-curtain sided with completely slatted concrete flooring. The barn contained 48 pens (3.05 × 5.49 m) equipped with a five-hole conventional dry self-feeder (Thorp Equipment, Thorp, WI) and a cup waterer providing ad libitum access to feed and water. Facilities in both experiments 1 and 2 were equipped with a computerized feeding system (FeedPro; Feedlogic Corp., Willmar, MN) that delivered and recorded daily additions of specific diets to each pen.

Animals and Diets

Pens of pigs were randomly allotted to one of six dietary feeding strategies consisting of a low-fiber (9% neutral detergent fiber [NDF]) corn–soybean meal-based control diet containing no DDGS or middlings fed from day 0 to 88 or a high-fiber (19% NDF) diet containing 30% DDGS and 19% middlings fed until day 20, 15, 10, 5, or 0 before slaughter after which they were switched to the low-fiber, corn–soybean meal-based diet for the remainder of the study. Dietary treatments were fed in four phases (Tables 1 and 2). All diets were fed in meal form and balanced to similar standardized ileal digestible **(SID)** Lys concentrations within each phase but were not balanced for energy. Diets were formulated to meet pigs' nutrient requirement suggested by NRC (2012). Nutrient values used in diet formulation for corn, soybean meal, and middlings were from the NRC (2012). For DDGS, amino acid (AA) concentration and SID AA values were from Stein (2007). The metabolizable energy (3,395 kcal/kg) values for corn were used for the energy values of DDGS, in accordance to Pedersen et al. (2007). The net energy (NE) (2,525 kcal/kg) values for DDGS were calculated based upon the oil content, as described by Graham et al. (2014).

Feed samples were collected for experiment 1 throughout the study at the time of feed delivery, and experiment 2 feed samples were collected for each phase and treatment. Feed samples were collected from a minimum of six feeders and combined into a composite sample. The complete feed samples, as well as samples of DDGS and middlings for each experiment collected at the time of feed manufacturing, were analyzed for dry matter (934.01; AOAC International, 2006), crude protein (990.03; AOAC International, 2006), ether extract (920.39 A; AOAC International, 2006), crude

Table 1. Composition of diets, experiment 1 (as-fed basis)[a]

Item Fiber level[b]	Phase 1 Low	Phase 1 High	Phase 2 Low	Phase 2 High	Phase 3 Low	Phase 3 High	Phase 4 Low	Phase 4 High
Ingredient, %								
Corn	73.70	34.87	78.91	39.98	82.63	43.55	84.95	45.77
Soybean meal, 46.5% CP	23.80	13.74	18.84	8.71	15.32	5.20	13.15	3.04
DDGS	—	30.00	—	30.00	—	30.00	—	30.00
Wheat middlings	—	19.00	—	19.00	—	19.00	—	19.00
Monocalcium P, 21% P	0.45	—	0.35	—	0.25	—	0.20	—
Limestone	1.05	1.30	1.00	1.28	0.98	1.29	0.93	1.28
Salt	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix[c]	0.15	0.15	0.13	0.13	0.10	0.10	0.08	0.08
Trace mineral premix[d]	0.15	0.15	0.13	0.13	0.10	0.10	0.08	0.08
L-Lys HCl	0.17	0.31	0.15	0.29	0.14	0.28	0.13	0.27
DL-Met	0.02	—	—	—	—	—	—	—
L-Thr	0.03	—	0.01	—	—	—	—	—
Phytase[e]	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Calculated analysis								
SID AA, %								
Lys	0.93	0.93	0.79	0.79	0.69	0.69	0.63	0.63
Ile:Lys	69	72	70	74	72	76	73	78
Met:Lys	30	34	30	37	32	40	33	43
Met + Cys:Lys	59	70	62	77	66	83	69	88
Thr:Lys	63	66	63	69	64	72	66	74
Trp:Lys	19	19	19	19	19	19	19	19
Val:Lys	78	88	81	94	85	99	87	103
Total Lys, %	1.04	1.09	0.89	0.94	0.78	0.83	0.72	0.77
SID Lys:ME, g/Mcal	2.82	2.88	2.39	2.44	2.08	2.13	1.90	1.94
ME, kcal/kg	3,296	3,232	3,307	3,240	3,316	3,245	3,324	3,249
NE, kcal/kg	2,474	2,388	2,507	2,419	2,533	2,441	2,549	2,455
Ca, %	0.59	0.58	0.53	0.56	0.49	0.55	0.46	0.54
STTD P, %[f]	0.26	0.30	0.20	0.29	0.17	0.24	0.16	0.27
Chemical analysis, %								
DM	89.92	90.76	89.53	90.52	89.70	90.51	89.95	91.01
CP	19.60	22.30	15.90	19.40	14.40	17.00	13.60	18.70
ADF	3.50	7.30	3.60	7.60	3.40	6.60	3.40	6.80
NDF	8.50	17.20	8.50	18.40	7.70	16.80	8.20	16.00
Ether extract	3.20	4.50	3.10	4.40	2.90	5.00	3.10	4.80
Ash	4.73	5.98	4.03	5.30	3.56	5.24	3.61	5.00

[a]Phase 1 diets were fed from day 0 to 22; phase 2, from day 22 to 42; phase 3, from day 42 to 63; and phase 4 from day 63 to 88.

[b]Each diet was fed in meal form.

[c]Provided per kilogram of premix: 4,409,200 IU vitamin A; 551,150 IU vitamin D_3; 17,637 IU vitamin E; 1,764 mg vitamin K; 3,307 mg riboflavin; 11,023 mg pantothenic acid; 19,841 mg niacin; and 15.4 mg vitamin B_{12}.

[d]Provided per kilogram of premix: 26.5 g Mn from manganese oxide; 110 g Fe from iron sulfate; 110 g Zn from zinc sulphate; 11 g Cu from copper sulfate; 198 mg I from calcium iodate; and 198 mg Se from sodium selenite.

[e]Phyzyme 600 (Danisco Animal Nutrition, St. Louis, MO) provided 780 phytase units (FTU)/kg, with a release of 0.11% standardized total tract digestible P.

[f]Standardized total tract digestible P.

CP, crude protein; DM, dry matter; ME, metabolizable energy; NE, net energy.

fiber (978.10; AOAC International, 2006), acid detergent fiber (ADF) and NDF (Van Soest et al.,1991). Pens of pigs and feeders were weighed approximately every 3 wk to determine ADG, average daily feed intake (ADFI), and G:F. During the high-fiber withdrawal period, all pens of pigs and feeders were weighed each time a treatment group switched diets.

Experiment 1

A total of 288 pigs (PIC 327 × 1050; PIC, Hendersonville, TN; initial body weight [BW] 38.4 ± 0.3 kg) were used in an 88-d experiment. Pens of pigs (four barrows and four gilts per pen) were randomly allotted to one of the six dietary withdrawal

Table 2. Composition of diets, experiment 2 (as-fed basis)[a]

Item	Fiber level[b]	Phase 1		Phase 2		Phase 3		Phase 4	
		Low	High	Low	High	Low	High	Low	High
Ingredient, %									
Corn		73.14	34.17	76.83	37.82	80.15	41.16	83.09	43.99
Soybean meal, 46.5% CP		24.55	14.68	20.97	11.10	17.78	7.82	14.90	5.04
DDGS		—	30.00	—	30.00	—	30.00	—	30.00
Wheat middlings		—	19.00	—	19.00	—	19.00	—	19.00
Monocalcium P, 21% P		0.60	—	0.55	—	0.45	—	0.40	—
Limestone		0.95	1.25	0.93	1.20	0.95	1.18	0.95	1.15
Salt		0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin and trace mineral premix[c]		0.10	0.10	0.10	0.10	0.08	0.08	0.08	0.08
L-Lys·SO_4		0.27	0.44	0.25	0.42	0.23	0.40	0.21	0.38
Methionine hydroxy analogue[d]		0.01	—	—	—	—	—	—	—
L-Thr		0.02	—	0.01	—	—	—	0.01	—
Phytase[e]		0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Calculated analysis									
SID AA, %									
Lys		0.95	0.95	0.85	0.85	0.76	0.76	0.68	0.68
Ile:Lys		69	74	70	75	71	77	72	79
Met:Lys		28	35	29	37	30	39	32	42
Met + Cys:Lys		58	66	60	70	63	75	66	80
Thr:Lys		62	65	62	67	63	69	65	71
Trp:Lys		19	19	19	19	19	19	19	19
Val:Lys		78	90	80	93	83	97	85	102
Total Lys, %		1.07	1.13	0.93	1.02	0.86	0.92	0.77	0.84
SID Lys:ME, g/Mcal		2.87	2.93	2.57	2.62	2.29	2.34	2.05	2.09
ME, kcal/kg		3,304	3,245	3,310	3,250	3,317	3,255	3,321	3,258
NE, kcal/kg		2,476	2,392	2,499	2,414	2,520	2,435	2,538	2,452
Ca, %		0.58	0.58	0.55	0.55	0.53	0.53	0.51	0.51
STTD P, %[f]		0.26	0.30	0.23	0.29	0.21	0.28	0.20	0.28
Chemical analysis, %									
DM		90.01	91.15	90.00	90.82	89.98	90.93	89.94	90.92
CP		18.20	24.60	17.10	22.40	15.40	19.80	13.50	18.20
ADF		3.70	7.90	3.60	7.50	3.60	6.60	3.10	6.70
NDF		7.20	18.50	6.60	15.70	7.20	16.50	6.70	17.40
Ether extract		3.60	6.70	3.00	6.50	3.00	5.50	3.00	5.70
Ash		3.96	4.68	3.91	4.34	4.06	5.12	3.71	4.04

[a]Phase 1 diets were fed from day 0 to 14; phase 2, from day 14 to 37; phase 3, from day 37 to 64; and phase 4 from day 64 to 96.

[b]Each diet was fed in meal form.

[c]Provided per kilogram of premix: 4,509,410 IU vitamin A; 701,464 IU vitamin D_3; 24,050 IU vitamin E; 1,402 mg vitamin K; 3,006 mg riboflavin; 12,025 mg pantothenic acid; 18,038 mg niacin; and 15.0 mg vitamin B_{12}; 40 g Mn from manganese oxide; 90 g Fe from ferrous sulfate; 100 g Zn from zinc oxide; 10 g Cu from copper sulfate; 500 mg I from ethylenediamine dihydroiodide; and 300 mg Se from sodium selenite.

[d]Methionine hydroxy analogue (88% methionine; Novus International, St. Charles, MO).

[e]Optiphos 2000 (Enzyvia LLC, Sheridan, IN) provided 500 phytase units (FTU)/kg, with a release of 0.07% standardized total tract digestible P.

[f]Standardized total tract digestible P.

CP, crude protein; DM, dry matter; ME, metabolizable energy; NE, net energy.

strategies with average pig BW balanced across each treatment with six replications (pens) per treatment. On day 68, pens of pigs fed the high-fiber diet were realloted to withdrawal strategy, balancing on day 68 BW. This was done to ensure that any response criteria were not influenced by prior performance when all pigs were fed the same diet.

Before harvest, pigs were individually weighed and tattooed to allow calculation of carcass yield. One gilt per pen (six pigs per treatment) with similar BW was identified and transported 10 min to the Kansas State University Meat Laboratory, whereas all other pigs were transported 4.5 hr to a commercial packing plant (Triumph Food LLC, St. Joseph, MO). The gilts selected for harvest at the Kansas State University Meats Laboratory were blocked by treatment and then within a block, randomly assigned to a slaughter order to equalize withdrawal time before slaughter. Feeders were removed from the pens 12 hr before the harvest of sample pigs.

Following evisceration, the entire pluck (heart, kidneys, spleen, stomach, cecum, large intestine, small intestine, and reproductive tract) was collected, separated, and weighed. After the full organs were weighed, the stomach, cecum, and large intestine were physically stripped of digestive contents and flushed with water and weighed. Carcass quality measurements were taken 24 h after slaughter on the right side of the carcass, which was ribbed at the 10th rib. Marbling and color scores were determined for the loin according to the American Meat Science Association (AMSA, 2001) and the National Pork Producers Council (NPPC, 2000), and ultimate pH was measured using a portable HACCP compliant pH meter designed for meat (model HI 99163; Hanna Instruments, Smithfield, RI).

Fat samples that included adipose from all three fat layers were collected from the jowl, belly, backfat, and ham collar. Jowl fat samples were collected from the dorsal end of the carcass. Belly samples were taken from behind the second teat on the teat line. Backfat samples were taken at the 10th rib on the outer edge of the loin. Ham collar samples were collected from the middle portion of the ham collar.

Fatty acid analysis was determined by gas chromatography (model 14 A, Shimadzu, Tokyo, Japan) as described by Cromwell et al. (2011) for the DDGS and middlings, complete diets, and carcass fat samples at the University of Georgia Department of Animal and Dairy Sciences (Athens, GA). IV was calculated for the fat samples using the following equation (AOCS, 1998): IV = [C16:1] × 0.950 + [C18:1] × 0.860 + [C18:2] × 1.732 + [C18:3] × 2.616 + [C20:1] × 0.785 + [C20:4] × 3.201 + [C22:1] × 0.723 + [C22:5] × 3.697 + [C22:6] × 4.463, where brackets indicate concentration (%). Measurements of belly quality were also collected from the bellies cut from the left side of each carcass. Weight, length, width, and height were recorded for each belly. Also, a measure of belly flex, as described by Rentfrow et al. (2003), was used to determine the firmness of each belly. This was completed with both the skin-side up and skin-side down. The measurements were completed in a room that was maintained at 5°C.

Pigs harvested at the commercial packing plant were also slaughtered at approximately 0600 h, equalizing the 12 h feed withdrawal period across both groups. Hot carcass weights (HCWs) were measured immediately after evisceration, and each carcass evaluated for carcass yield, backfat depth, loin depth, percentage lean, and jowl IV. Carcass yield was calculated by dividing the HCW at the plant by the live weight at the farm before transport to the plant. Fat depth and loin depth were measured with an optical probe inserted between the third and fourth last rib (counting from the ham end of the carcass) at a distance approximately 7 cm from the dorsal midline.

Experiment 2

A total of 1,089 pigs (PIC 337 × 1050; PIC, Hendersonville, TN; initially 44.5 ± 0.1 kg) were used in this 96-d study, serving as a commercial field validation of results from for experiment 1. Pens of pigs (approximately the same number of barrows and gilts; 25 to 27 pigs per pen) were randomly allotted to one of six dietary withdrawal strategies with average pig BW balanced across each treatment with seven replications per treatment. Pigs were intended to have the same exact withdrawal timeline as experiment 1; however inclement weather shut down the packing plant and increased the original withdrawal schedule by 4 d such that pigs were switched to the low-fiber corn–soybean meal diet at day 24, 19, 14, 9, or 0 before slaughter. On day 64, the three heaviest pigs in each pen were weighed and sold according to standard farm procedures. After removing those pigs, pens of pigs on the high-fiber diets were realloted to withdrawal regimen, balancing on both days 0 and 64 BW. This was done to ensure that any response criteria were not influenced by prior performance when all pigs were fed the same diet. Before marketing, pigs were individually tattooed with a pen identification number to allow for carcass measurements to be collected on a pen basis.

On day 96, final pen weights were taken and pigs were transported 111 km to a commercial packing plant (JBS Swift and Company, Worthington, MN). HCW was measured immediately after evisceration and each carcass evaluated for carcass yield, backfat depth, loin depth, and percentage lean. Carcass yield was calculated by dividing the HCW at the plant by the live weight at the farm before transport to the plant. Fat depth and loin depth were measured with an optical probe inserted between the third and fourth last rib (counting from the ham end of the carcass) at a distance approximately 7 cm from the dorsal midline.

Statistical Analysis

Data from experiment 1 were analyzed using the PROC MIXED procedure in SAS (Version 9.3; SAS Institute Inc., Cary, NC) with pen serving as the experimental unit. Experiment 1 was analyzed as a completely randomized design with the fixed effect of feeding strategy, and experiment 2 was analyzed as a randomized complete-block design with the fixed effect feeding strategy and the random effect of weight block. Single degree of freedom contrast statements was used to determine the linear and quadratic effects of withdrawing the high-fiber diet before slaughter, and a contrast statement was used to compare data between continuously feeding the low-fiber corn–soy or high-fiber diet. In experiment 2, the interactive matrix language procedure of SAS was used to determine coefficients for unequally spaced treatments. In both experiments, backfat depth, loin depth, and lean percentage were adjusted to a common HCW for analysis. Results from the experiment were considered significant at $P \leq 0.05$ and a tendency between $P > 0.05$ and $P \leq 0.10$.

RESULTS

Diet and Ingredient Analysis

For experiments 1 and 2, analyzed nutrient compositions of DDGS and middlings were similar to the values used in diet formulation (Table 3). However, the DDGS source used in experiment 2 had greater oil content than the DDGS used in experiment 1. Proximate analysis of the diets also resulted in values similar to those intended in diet formulation. For experiment 1, the fatty acid analysis of the high-fiber diet indicated increased amounts of palmitic acid (C16:0) and palmitoleic acid (C16:1) and decreased amounts of stearic acid (C18:0; Table 4) in each phase. The iodine value product (**IVP**) for the complete diets was similar across phases, with the high-fiber diet having analyzed IVP values averagely 34% greater than the low-fiber corn–soybean meal diet.

Table 3. Chemical analysis of DDGS and wheat middlings

	DDGS		Wheat middlings	
Item, %	Experiment 1	Experiment 2	Experiment 1	Experiment 2
DM	91.45	90.35	90.22	90.72
CP	27.5 (27.2)[a]	29.4 (27.3)[a]	15.0 (15.9)	15.5 (15.9)
Ether extract	8.0	11.2	3.7	4.4
Crude fiber	7.3 (7.7)	7.4 (8.9)	7.8 (7.0)	8.4 (7.0)
ADF	12.4 (9.9)	9.1 (12.0)	12.2 (10.7)	11.9 (10.7)
NDF	28.9 (25.3)	22.4 (30.4)	34 (35.6)	34.6 (35.6)
Ash	4.64	3.89	5.55	4.97

[a]Values in parenthesis indicate those used in diet formulation.
CP, crude protein; DM, dry matter.

Experiment 1

From day 0 to 63, pigs fed the high-fiber diet tended to have decreased ADG ($P = 0.066$) and G:F ($P = 0.001$) compared with pigs fed the low-fiber corn–soybean meal diet (Table 5). From day 63 to 88, pigs fed the high-fiber diet throughout the growing-finishing period tended to have increased ADG ($P = 0.056$) and ADFI ($P = 0.001$) compared with pigs fed the low-fiber corn–soybean meal diet, which resulted in no difference in G:F. For pigs switched from the high-fiber diet to the low-fiber corn–soybean meal diet, there were no differences in ADG or G:F; however, ADFI increased and then decreased (quadratic; $P = 0.049$) as days of fiber withdrawal before slaughter increased. Overall (day 0 to 88), pigs fed the high-fiber diet throughout the growing-finishing period tended to have increased ADFI ($P = 0.072$) compared with pigs fed the low-fiber corn–soybean meal diet. Length of withdrawal from the high-fiber diet before slaughter did not influence overall ADG or G:F.

Percentage carcass yield and backfat depth decreased ($P = 0.001$), whereas percentage lean ($P = 0.069$) tended to increase, for pigs fed the high-fiber diet throughout the growing-finishing period compared with those fed the low-fiber corn–soybean meal diet (Table 6). As high-fiber diet withdrawal for pigs increased, percentage carcass yield improved (quadratic; $P = 0.039$). Pigs fed the high-fiber diet throughout the growing-finishing period tended ($P = 0.059$) to have increased belly width compared with those fed the low-fiber corn–soybean meal diet. In addition, belly firmness decreased both when measured skin-side up ($P = 0.013$) and skin-side down ($P = 0.002$) for pigs fed the high-fiber diet throughout the growing-finishing period

Table 4. Fatty acid analysis of ingredients and diets, experiment 1 (dry matter basis)[a]

		Phase 1		Phase 2		Phase 3		Phase 4		Ingredients	
Item	Fiber level:	Low[b]	High[c]	Low	High	Low	High	Low	High	DDGS[d]	Midds[e]
Fatty acids, % of analyzed dietary lipids											
Myristic acid (C14:0)	0.04	0.09	0.07	0.08	0.12	0.07	0.03	0.08	0.07	0.14	
Palmitic acid (C16:0)	14.93	16.03	15.22	15.29	14.47	14.80	15.14	15.49	15.80	16.17	
Palmitoleic acid (C16:1)	0.03	0.13	0.11	0.15	0.11	0.14	0.03	0.16	0.22	0.15	
Stearic acid (C18:0)	2.88	2.41	2.79	2.30	2.34	2.16	2.47	2.10	2.52	1.37	
Oleic acid (C18:1 *cis*-9)	23.03	24.14	25.53	25.21	26.33	25.94	25.08	24.31	26.02	19.21	
Linoleic acid (C18:2n-6)	55.09	53.96	52.45	53.28	53.44	53.88	53.77	54.58	52.25	57.11	
α-linolenic acid (C18:3n-3)	2.87	2.52	2.69	2.36	2.13	2.03	2.51	2.30	1.50	4.36	
Arachidic acid (C20:0)	0.39	0.36	0.27	0.39	0.42	0.40	0.14	0.35	0.40	0.24	
Gadoleic acid (C20:1)	0.10	0.26	0.12	0.37	0.28	0.35	0.06	0.29	0.27	0.73	
Other fatty acids	0.63	0.10	0.72	0.56	0.38	0.23	0.77	0.34	0.94	0.52	
Total SFA[f]	18.24	18.90	18.42	18.17	17.35	17.51	17.78	18.09	18.92	18.08	
Total MUFA[g]	23.17	24.53	25.76	25.73	26.71	26.44	25.16	24.77	26.52	20.09	
Total PUFA[h]	57.96	56.48	55.14	55.64	55.57	55.91	56.28	56.88	53.75	61.47	
UFA:SFA ratio[i]	4.45	4.29	4.39	4.48	4.74	4.70	4.58	4.51	4.24	4.51	
PUFA:SFA ratio[j]	3.18	2.99	2.99	3.06	3.20	3.19	3.17	3.14	2.84	3.40	
Analyzed ether extract, %	3.20	4.50	3.10	4.40	2.90	5.00	3.10	4.80	8.00	3.70	
IV,[k] g/100g	122.8	121.1	120	120.6	121.1	121.4	121.4	121.8	117.2	127.6	
Analyzed IVP[l]	39.3	54.5	37.2	53.1	35.1	60.7	37.6	58.5	93.8	47.2	

[a]Values represent the mean of composite samples that were analyzed in duplicate.

[b]Refers to low-fiber diet without DDGS or wheat middlings (midds).

[c]Refers to high-fiber diet with 30% DDGS and 19% midds.

[d]DDGS.

[e]Wheat middlings.

[f]Total SFA = ([C8:0] + [C10:0] + [C12:0] + [C14:0] + [C16:0] + [C18:0] + [C20:0] + [C22:0] + [C24:0]); brackets indicate concentration.

[g]Total MUFA = ([C14:1] + [C16:1] + [C18:1*cis*-9] + [C18:1n-7] + [C20:1] + [C24:1]); brackets indicate concentration.

[h]Total PUFA = ([C18:2n-6] + [C18:3n-3] + [C18:3n-6] + [C20:4n-6]); brackets indicate concentration.

[i]Unsaturated FA:SFA = (total MUFA+PUFA)/total SFA.

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

[k]Calculated as IV = [C16:1] × 0.950 + [C18:1] × 0.860 + [C18:2] × 1.732 + [C18:3] × 2.616 + [C20:1] × 0.785 + [C20:4] × 3.201 + [C22:1] × 0.723 + [C22:5] × 3.697 + [C22:6] × 4.463; brackets indicate concentration.

[l]IV product of dietary lipids calculated from the IV × % analyzed ether extract × 0.10 (NRC, 2012).

MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; UFA, unsaturated fatty acid.

compared with pigs fed the low-fiber corn–soybean meal diet continuously.

IV was greater (P = 0.010) in the jowl, backfat, belly, and ham collar fat of pigs fed the high-fiber diet compared with the corn–soybean meal diet (Table 6). As withdrawal days increased, belly fat IV tended (linear; P = 0.080) to decrease. Backfat IV also decreased for pigs with 15 or fewer withdrawal days, but unexpectedly increased (quadratic; P = 0.040) for pigs with a 20-d withdrawal time.

When organ mass was expressed as a percentage of BW, the whole intestine tended to be greater (P = 0.055) and full large intestine mass increased (P = 0.002) in pigs fed the high-fiber diet throughout the growing-finishing period compared with pigs fed the low-fiber corn–soybean meal diet (Table 7). The percentage mass for the spleen was also decreased (P = 0.040) in pigs fed the high-fiber diet compared with the low-fiber diet. Furthermore, as withdrawal days increased, the percentage of whole intestinal and full large intestine mass decreased

Table 5. Effect of dietary fiber withdrawal before market on growth performance of finishing pigs, experiment 1[a]

		High-fiber diet withdrawal before market,[c] d						Probability, *P*		
								Low fiber vs. 0-d withdrawal	Duration	
Item	Low fiber[b]	20[d]	15	10	5	0	SEM		Linear	Quadratic
BW, kg										
d 0	38.3	38.3	38.4	38.5	38.3	38.6	1.08	0.825	0.894	0.992
d 63	105.0	102.8	102.9	102.9	103.0	102.9	1.74	0.399	0.967	0.969
d 88	126.0	124.9	126.0	125.2	125.8	125.7	1.93	0.904	0.834	0.895
d 0 to 63										
ADG, kg	1.06	1.02	1.02	1.02	1.02	1.02	0.015	0.066	—	—
ADFI, kg	2.76	2.76	2.80	2.82	2.81	2.80	0.045	0.535	—	—
G:F	0.385	0.371	0.366	0.364	0.363	0.365	0.003	0.001	—	—
d 63 to 88										
ADG, kg	0.84	0.87	0.92	0.89	0.91	0.91	0.025	0.056	0.328	0.482
ADFI, kg	2.87	3.06	3.23	3.17	3.30	3.16	0.056	0.001	0.143	0.049
G:F	0.293	0.283	0.285	0.281	0.277	0.287	0.006	0.498	0.948	0.436
d 0 to 88										
ADG, kg	1.00	0.98	1.00	0.99	0.99	0.99	0.014	0.613	0.707	0.655
ADFI, kg	2.79	2.85	2.93	2.92	2.95	2.90	0.043	0.072	0.331	0.197
G:F	0.358	0.344	0.340	0.339	0.336	0.341	0.003	0.001	0.287	0.147

[a]A total of 280 pigs [PIC 327 × 1050, PIC (Hendersonville, TN); initial BW = 38.4 ± 0.3 kg] were used in this 88-d study; 6 pens per treatment and 8 pigs per pen.

[b]Refers to low-fiber diet without DDGS or wheat middlings (midds).

[c]Refers to high-fiber diet with 30% DDGS and 19% midds.

[d]Refers to the number of days pigs were switched from the high-fiber diet to the low-fiber diet before market.

SEM, standard error of the mean.

(linear; $P < 0.05$). Full large intestine weight tended to be reduced (quadratic; $P = 0.063$) as days of withdrawal increased, indicating that much of the change in full intestine weight occurred in the first 5 d of withdrawal.

Experiment 2

From day 0 to 64, pigs fed the high-fiber diet had decreased ADG ($P = 0.001$), ADFI ($P = 0.016$), and G:F ($P = 0.023$) compared with pigs fed the low-fiber corn–soybean meal diet (Table 8). As a result, pigs fed the high-fiber diet weighed approximately 3.5 kg less ($P = 0.001$) than those fed the low-fiber corn–soybean meal diet on day 64. From day 64 to 96, there was no difference in ADG or ADFI between pigs fed the high-fiber or low-fiber corn–soybean meal diets throughout the growing-finishing period; however, G:F ($P = 0.053$) and final BW ($P = 0.001$) decreased for pigs fed the high-fiber diet throughout the growing-finishing period compared with the low-fiber corn–soybean meal diet. There were no differences in ADG, ADFI, G:F, or final BW for pigs fed the high-fiber diet with different withdrawal regimens. Overall (d 0 to 96), pigs continuously fed the high-fiber diet had decreased ($P < 0.05$) ADG and G:F compared with pigs fed the low-fiber corn–soybean meal diet, decreasing final BW ($P = 0.001$) by 4.2 kg. For pigs initially fed the high-fiber diet and then switched to the low-fiber corn–soybean meal diet, ADG and ADFI were not different between withdrawal days; however, G:F tended to improve (linear; $P = 0.070$) as withdrawal days increased from 0 to 24 d, with the pigs withdrawn 19 and 24 days before harvest being the most efficient.

Pigs fed the high-fiber diet throughout the growing-finishing period had a 4.3 kg lighter HCW ($P = 0.001$) compared with pigs fed the low-fiber corn–soybean meal diet although percentage carcass yield was unaffected by dietary treatment. Nevertheless, pigs switched from the high-fiber diet tended to have greater HCW (linear; $P = 0.052$) as withdrawal days increased. Backfat and loin depth were both decreased ($P < 0.05$) in pigs continuously fed the high-fiber diet compared with pigs fed the low-fiber corn–soybean meal diet. Loin depth increased (quadratic; $P = 0.042$) as withdrawal time increased.

DISCUSSION

Previous researches (Xu et al., 2010; Asmus et al., 2014; Graham et al., 2014) have demonstrated that 21 d

Table 6. Effect of dietary fiber withdrawal before market on carcass characteristics of finishing pigs, experiment 1[a]

		High-fiber diet withdrawal before market,[c] d						Probability, P		
								Low fiber vs. 0-d withdrawal	Duration	
Item	Low fiber[b]	20[d]	15	10	5	0	SEM		Linear	Quadratic
Carcass characteristics										
HCW, kg	92.2	91.0	91.4	91.1	90.7	89.3	1.39	0.140	0.334	0.488
Carcass yield,[e] %	72.7	72.5	72.5	72.2	72.0	71.2	0.21	0.001	0.001	0.039
Backfat depth,[f] mm	19.8	17.2	17.6	17.9	17.5	16.4	0.65	0.001	0.421	0.129
Loin depth,[f] mm	59.2	59.8	59.9	57.8	60.2	58.0	0.91	0.349	0.248	0.987
Lean,[f] %	52.7	53.7	53.3	53.0	53.7	53.6	0.33	0.069	0.859	0.240
Loin characteristics[g]										
Loin marbling	1.50	1.33	1.30	1.25	1.08	1.25	0.168	0.258	0.440	0.628
Loin color	2.25	2.17	2.00	2.42	1.67	2.17	0.221	0.772	0.609	0.828
Ultimate pH	5.49	5.51	5.52	5.48	5.48	5.50	0.033	0.670	0.595	0.591
Belly characteristics										
Weight, kg	4.94	5.05	5.19	4.95	5.19	5.30	0.235	0.257	0.480	0.618
Length, cm	59.8	58.6	59.9	57.0	59.4	60.4	0.92	0.618	0.241	0.142
Width, cm	22.7	23.6	23.4	23.5	23.3	24.3	0.65	0.059	0.483	0.318
Height, cm	3.85	3.84	3.88	3.77	3.88	3.66	0.167	0.402	0.486	0.594
Belly firmness[h]										
Skin-up, cm	13.11	7.07	7.56	8.90	8.22	7.65	1.592	0.013	0.697	0.455
Skin-down, cm	19.33	11.12	10.44	12.30	10.55	10.48	1.960	0.002	0.841	0.726
IV,[i] g/100 g										
Jowl	65.0	72.1	68.9	71.1	71.7	72.4	1.143	0.010	0.300	0.120
Backfat	61.8	71.2	66.4	69.0	69.5	72.1	1.716	0.010	0.330	0.040
Belly	60.2	65.1	65.2	67.8	67.3	68.6	1.682	0.010	0.080	0.907
Ham collar	64.3	69.4	71.7	70.2	71.8	72.1	1.349	0.001	0.169	0.837

[a]A total of 280 pigs (PIC 327 × 1050; PIC, Hendersonville, TN; initially 38.4 ± 0.3 kg) were used in this 88-d study; 6 pens per treatment and 8 pigs per pen.

[b]Refers to low-fiber diet without DDGS or wheat middlings (midds).

[c]Refers to high-fiber diet with 30% DDGS and 19% midds.

[d]Refers to the number of days pigs were switched from the high-fiber diet to the low-fiber diet before market.

[e]Carcass yield calculated by dividing HCW by live weight obtained at the farm before transportation to the packing plant.

[f]Adjusted by using HCW as a covariate.

[g]Measurements taken on a subsample (1 pig/pen) at the Kansas State University Meats Laboratory.

[h]Values represent the distance from each end of the belly when centered upon a fulcrum point.

[i]IV was calculated for the fat samples using the following equation (AOCS, 1998): IV = [C16:1] × 0.950 + [C18:1] × 0.860 + [C18:2] × 1.732 + [C18:3] × 2.616 + [C20:1] × 0.785 + [C20:4] × 3.201 + [C22:1] × 0.723 + [C22:5] × 3.697 + [C22:6] × 4.463, where brackets indicate concentration (%).

SEM, standard error of the mean.

of returning to a corn–soybean meal diet was sufficient to restore carcass yield and pork fat quality compared with feeding high-fiber diets throughout. The present study focused on examining the different durations of switching pigs from high-fiber to low-fiber diets during the last 3 wk of growth before slaughter.

The reduction in ADG and G:F shown in experiments 1 (d 0 to 63) and 2 (d 0 to 96) for pigs fed the high-fiber diet compared with those fed the low-fiber corn–soybean meal diet can be explained by the lower NE content of high-fiber diets. Similar observations were reported by others

Table 7. Effect of dietary fiber withdrawal before market on organ weights of finishing pigs, %, experiment 1[a,b]

								Probability, *P*			
	Low	High-fiber diet withdrawal before market,[d] d						Low fiber vs. 0-d		Duration	
Item	fiber[c]	20[e]	15	10	5	0	SEM	withdrawal		Linear	Quadratic
Full pluck	10.95	10.76	11.44	11.46	11.14	11.75	0.378	0.146		0.176	0.740
Whole intestine	7.20	6.92	7.61	7.46	7.33	8.04	0.295	0.055		0.047	0.966
Stomach											
Full	0.99	0.90	0.89	1.09	0.94	1.03	0.086	0.740	0.250		0.683
Rinsed	0.73	0.73	0.74	0.76	0.76	0.78	0.035	0.382	0.313		0.938
Cecum											
Full	0.60	0.58	0.71	0.69	0.67	0.74	0.062	0.138	0.169		0.552
Rinsed	0.25	0.23	0.26	0.23	0.25	0.25	0.013	0.709	0.375		0.557
Large intestine											
Full	2.37	2.38	2.69	2.34	2.53	3.26	0.188	0.002	0.013		0.063
Rinsed	1.47	1.41	1.59	1.45	1.47	1.52	0.059	0.527	0.571		0.637
Small intestine											
Full	2.64	2.41	2.71	2.66	2.54	2.42	0.136	0.273	0.746		0.093
Heart	0.38	0.38	0.37	0.40	0.40	0.38	0.030	0.939	0.720		0.624
Lungs	0.88	0.95	0.89	0.96	0.79	0.85	0.051	0.688	0.090		0.984
Liver	1.52	1.59	1.61	1.67	1.60	1.52	0.059	0.984	0.422		0.144
Kidneys	0.31	0.34	0.35	0.36	0.32	0.35	0.018	0.153	0.660		0.838
Spleen	0.21	0.21	0.18	0.21	0.17	0.17	0.015	0.040	0.054		0.872
Reproductive tract	0.39	0.38	0.41	0.39	0.52	0.37	0.053	0.743	0.624		0.252

[a]A total of 36 pigs (PIC 327 × 1050; PIC, Hendersonville, TN; initially 38.4 ± 0.3 kg) were used in this 88-d study; 6 pens per treatment and 1 pig per pen.

[b]All values are a percentage of live weight (i.e., [reproductive tract/live weight] × 100).

[c]Refers to low-fiber diet without DDGS or wheat middlings (midds).

[d]Refers to high-fiber diet with 30% DDGS and 19% midds.

[e]Refers to the number of days pigs were switched from the high-fiber diet to the low-fiber diet before market.

SEM, standard error of the mean.

whom have fed similar diets with DDGS and middlings (Nemechek et al., 2013; Asmus et al., 2014; Graham et al., 2014). The difference in the ADG response between experiments 1 and 2 is related to the difference in ADFI. Pigs fed at the university in experiment 1 were able to increase feed intake to compensate for the lower energy density of high-fiber diets; in contrast, those fed at the commercial research facility in experiment 2 had limited ability to increase ADFI because of the high stocking density. Interestingly, in experiment 1, increased feed intake was observed from day 63 to 88 for pigs receiving withdrawal treatments compared with those fed low-fiber corn–soybean meal throughout. It is possible that pigs previously fed high-fiber, low bulk density diet had extended gut capacity, especially during the late finishing period and thus consumed more feed regardless of diet types.

As expected, in both experiments 1 and 2, there was a reduction in carcass yield because of the reduction in HCW when pigs were fed the high-fiber diet compared with the low-fiber corn–soybean meal diet, which is consistent with published literature (Whitney et al., 2006; Salyer et al., 2012; Tsai et al., 2014). Other researchers (Turlington, 1984; Anugwa et al., 1989) also reported reduced carcass yield in pigs fed high-fiber ingredients. It has been suggested that elevated NDF content in diet increases the weight of both intestinal content and intestinal tissue in colon and cecum and results in decreased carcass yield (Turlington, 1984). In this study, increased full large intestinal weight was observed for pigs fed high-fiber diet compared with those fed low-fiber corn–soybean meal diet; however, this difference was not observed for empty large intestinal weights. Similarly, Stewart et al. (2013) reported an increase in full viscera weight in pigs fed either 30% middlings or 30% soybean hulls compared with pigs fed a low-fiber corn–soybean meal diet, whereas empty viscera was not affected by dietary treatments.

The 30% heavier full large intestinal (as a percentage of HCW) weights in experiment 1 were the

Table 8. Effect of dietary fiber withdrawal before market on growth performance of finishing pigs, experiment 2[a]

								Probability, *P*		
		High-fiber diet withdrawal before market,[c] d						Low fiber vs. 0-d withdrawal	Duration	
Item	Low fiber[b]	24[d]	19	14	9	0	SEM		Linear	Quadratic
BW, kg										
d 0	44.5	44.5	44.5	44.6	44.6	44.5	0.94	1.000	0.885	0.921
d 64	105.3	101.7	101.5	101.7	101.6	101.8	1.47	0.001	0.850	0.734
d 96	132.5	129.3	129.5	129.1	128.3	128.3	1.58	0.001	0.233	0.797
d 0 to 64										
ADG, kg	0.95	0.90	0.89	0.89	0.89	0.89	0.013	0.001	—	—
ADFI, kg	2.55	2.44	2.44	2.45	2.45	2.49	0.031	0.016	—	—
G:F	0.372	0.367	0.365	0.364	0.364	0.359	0.004	0.023	—	—
d 64 to 96										
ADG, kg	0.85	0.87	0.86	0.87	0.83	0.84	0.019	0.720	0.199	0.982
ADFI, kg	2.83	2.97	2.92	2.97	2.92	2.93	0.055	0.185	0.611	0.954
G:F	0.302	0.292	0.295	0.292	0.284	0.289	0.005	0.053	0.262	0.981
d 0 to 96										
ADG, kg	0.92	0.89	0.88	0.88	0.87	0.88	0.010	0.001	0.285	0.786
ADFI, kg	2.64	2.60	2.59	2.61	2.60	2.62	0.035	0.683	0.526	0.656
G:F	0.348	0.340	0.340	0.339	0.336	0.335	0.003	0.001	0.070	0.791
Carcass characteristics										
HCW, kg	99.1	95.8	96.6	96.2	95.5	94.8	0.91	0.001	0.052	0.077
Carcass yield, %	74.9	74.1	74.6	74.5	74.4	73.9	0.50	0.194	0.723	0.275
Backfat depth,[e] mm	17.9	16.7	17.1	16.6	16.3	16.4	0.42	0.018	0.206	0.790
Loin depth,[e] mm	66.5	64.9	65.6	65.5	65.9	63.9	0.77	0.019	0.388	0.042
Lean,[e] %	55.9	56.5	56.3	56.6	56.9	56.5	0.30	0.141	0.390	0.752

[a]A total of 1,089 pigs (PIC 337 × 1050, PIC, Hendersonville, TN; initially 44.5 ± 0.1 kg) were used in this 96-d study; 7 pens per treatment and 25 to 27 pigs per pen.

[b]Refers to low-fiber diet without DDGS or wheat middlings (midds).

[c]Refers to high-fiber diet with 30% DDGS and 19% midds.

[d]Refers to the number of days pigs were switched from the high-fiber diet to the low-fiber diet before market.

[e]Adjusted by using HCW as a covariate.

SEM, standard error of the mean.

reason for the observed reduction in carcass yield in pigs fed the high-fiber diet compared with those fed the low-fiber corn–soybean meal diet. In the present experiments, pigs were withdrawn from feed for approximately 12 hr before harvesting, thus residual digestive contents in the lower digestive tract was present and influenced by diet type. This is consistent with both Asmus et al. (2014) and Graham et al. (2014) who reported a 25% and 19% increase, respectively, in large intestine weights of pigs fed the high-fiber diet compared with those fed the low-fiber corn–soybean meal diet throughout. In addition, lower final BW of pigs fed low-fiber diet might have also contributed to a decreased carcass yield. As BW increases, carcass has a greater allometric growth coefficient than the whole body (Gu et al., 1992). In a review by Wu et al. (2017), carcass yield increased by approximately 0.4% for every 10-kg increase in final BW.

Asmus et al. (2014) and Graham et al. (2014) switched pigs from the high-fiber diet to the low-fiber corn–soybean meal diet approximately 3 wk before slaughter, and carcass yield was restored to values similar to that of those fed the low-fiber corn–soybean meal diet. Further, both of the previously mentioned studies reported reductions in full large intestinal weight of at least 18% for pigs switched to a low-fiber corn–soybean meal diet approximately 3 wk before slaughter compared with those fed the high-fiber diet throughout. Our results demonstrate that full large intestinal weights can be decreased by almost 1 kg in as few as 5 d when pigs are switched to a low-fiber corn–soybean meal diet. These results correspond to the observation that the improvement in carcass yield was most prominent during the first 5 d (experiment 1) after withdrawing the high-fiber diet, which resulted in a quadratic response of carcass yield to the increase of withdraw time.

The reduction in backfat depth in pigs fed the high-fiber diet compared with the low-fiber corn–soybean meal diet is consistent between both of the current experiments and other studies where low-energy diets were fed (Pond et al., 1988; Hinson et al., 2011). It is possible that the NE content of high-fiber diet used in these studies were slightly overestimated, resulting in a decreased energy intake, even with greater ADFI, of pigs fed the high-fiber diets compared with those fed the corn–soybean meal diets. It is also possible that reduced backfat depth and increased percent lean were the consequences of a greater Lys:NE ratio in the high-fiber diets.

Belly firmness was reduced both when measured skin-up and skin-down when pigs were fed the high-fiber diet compared with the low-fiber corn–soy. This is consistent with others who have shown a decrease in belly firmness as the amount of DDGS in the diet increases, as a result of the increased concentrations of unsaturated fatty acids in those diets (Whitney et al., 2006; Cromwell et al., 2011). This is also consistent with the increased carcass leanness of the high-fiber fed pigs as with less energy intake, there would be less energy available for de novo (saturated) fat synthesis.

In experiment 1, pigs fed the corn–soybean meal diet had decreased jowl, backfat, belly, and ham collar IV compared with those fed the high-fiber diet throughout. As with belly firmness, the likelihood for increased energy available for more de novo fatty acid synthesis would lead to a more saturated fatty acid (SFA) profile of pigs fed the corn–soybean meal-based diets. The increase in IV of the four fat depots evaluated in pigs fed the high-fiber diet, because of the elevated level of unsaturated fatty acids in the DDGS, is consistent with previous research (Pompeau et al., 2013). Similar to others, these data demonstrate that the increase in IV is a result of the decrease in SFA and increase in polyunsaturated fatty acid. The trend for the reduction in jowl IV as the period of withdrawal from the high-fiber diet increases observed in this study is similar to Asmus et al. (2014) and Graham et al. (2014). However, previous data indicate that the rate of change among the different fat depots is slightly different, with the jowl less responsive to withdrawal periods relative to the other depots (Wiegand et al., 2011). Backfat IV decreased with increasing withdrawal days, which is consistent with it being relatively more responsive to changes in diet (Wiegand et al., 2011). However, for some unknown reason, IV of pigs given the 20-d withdrawal period was greater than those given 15-, 10-, or 5-d withdrawal days.

In summary, reducing the dietary fiber level in finishing swine diets for up to 24 d before slaughter is beneficial to increase gain, HCW, and carcass yield, and the improvement is most prominent during the first 5 to 9 d after withdrawal. Furthermore, reducing high-fiber diets that contain increased amounts of unsaturated fatty acids can improve carcass fat IV; however, none of the withdrawal strategies in this trial were successful at restoring carcass fat IV to levels similar to pigs fed the low-fiber corn–soybean meal diet. This is an important finding, which will allow producers and nutritionists to make more knowledgeable decisions when marketing pigs based on the diet type being used.

LITERATURE CITED

AMSA. 2001. Meat evaluation handbook. Savoy, IL: American Meat Science Association.

Anugwa, F. O. I., V. H. Varel, J. S. Dickson, W. G. Pond, and L. P. Krook. 1989. Effects of dietary fiber and protein concentration on growth, feed efficiency, visceral organ weights, and large intestine microbial populations of swine. J. Nutr. 119:879–866.

AOAC International. 2006. Official methods of analysis. 18th ed. Arlington, VA: Assoc. Off. Anal. Chem..

AOCS. 1998. Official methods and recommended practices of the AOCS. 5th ed. Champaign, IL: Am. Oil Chem. Soc.

Asmus, M. D., J. M. DeRouchey, M. D. Tokach, S. S. Dritz, T. A. Houser, J. L. Nelssen, and R. D. Goodband. 2014. Effects of lowering dietary fiber before marketing on finishing pig growth performance, carcass characteristics, carcass fat quality, and intestinal weights. J. Anim. Sci. 92:119–128. doi: 10.2527/jas.2013–6679.

Cromwell, G. L., M. J. Azain, O. Adeola, S. K. Baidoo, S. D. Carter, T. D. Crenshaw, S. W. Kim, D. C. Mahan, P. S. Miller, and M. C. Shannon. 2011. Corn distillers dried grains with solubles in diets for growing-finishing pigs: a cooperative study. J. Anim. Sci. 89:2801–2811. doi: 10.2527/jas.2010–3704.

Graham, A. B., R. D. Goodband, M. D. Tokach, S. S. Dritz, J. M. DeRouchey, and S. Nitikanchana. 2014. The interactive effects of high-fat, high-fiber diets and ractopamine HCl on finishing pig growth performance, carcass characteristics, and carcass fat quality. J. Anim. Sci. 92:4585–4597. doi: 10.2527/jas.2013–7434.

Gu, Y., A. Schinckel, and T. Martin. 1992. Growth, development, and carcass composition in five genotypes of swine. J. Anim. Sci. 70:1719–1729. doi:10.2527/1992.7061719x

Hinson, R. B., B. R. Wiegand, M. J. Ritter, G. L. Allee, and S. N. Carr. 2011. Impact of dietary energy level and ractopamine on growth performance, carcass characteristics, and meat quality of finishing pigs. J. Anim. Sci. 89:3572–3579. doi: 10.2527/jas.2010–3302.

Nemechek, J. E., M. D. Tokach, J. M. DeRouchey, S. S. Dritz, R. D. Goodband, and J. L. Nelssen. 2013. Effects of diet form and fiber level before marketing on growth performance, carcass yield, and iodine value of finishing pigs. J. Anim. Sci. 91(Suppl. 2):24. doi: 10.2527/jas.2015–9149.

NPPC. 2000. Pork composition and quality assessment procedures. Des Moines, IA: National Pork Producers Council.

NRC. 2012. Nutrient Requirements of Swine. 11th rev. ed. Washington, DC: Natl. Acad. Press.

Pedersen, C., M. G. Boersma, and H. H. Stein. 2007. Digestibility of energy and phosphorus in 10 samples of distillers dried grains with solubles fed to growing pigs. J. Anim. Sci. 85:1168–1176. doi:10.2527/jas.2006–252.

Pompeau, D., B. R. Wiegand, H. L. Evans, J. W. Rickard, G. D. Gerlemann, R. B. Hinson, S. N. Carr, M. J. Ritter, R. D. Boyd, and G. L. Allee. 2013. Effect of corn dried distillers grains with solubles, conjugated linoleic acid, and ractopamine (Paylean) on growth performance and fat characteristics of late finishing pigs. J. Anim. Sci. 91:793–803. doi: 10.2527/jas.2012–5257.

Pond, W. G., H. G. Jung, and V. H. Varel. 1988. Effect of dietary fiber on young adult genetically lean, obese, and contemporary pigs: body weight, carcass measurements, organ weights and digesta content. J. Anim. Sci. 66:699–706. doi:10.2527/jas1988.663699x.

Rentfrow, G., C. A. Stahl, K. R. Maddock, M. C. Linville, G. Allee, T. E. Sauber, and E. P. Berg. 2003. The influence of diets containing conventional corn, conventional corn and choice white grease, high oil corn, and high oleic corn on belly/bacon quality. Meat Sci. 64:459–466. doi: 10.1016/S0309-1740(02)00215-2.

Salyer, J. A., J. M. DeRouchey, M. D. Tokach, S. S. Dritz, R. D. Goodband, J. L. Nelssen, and D. B. Petry. 2012. Effects of dietary wheat middlings, distillers dried grains with solubles, and choice white grease on growth performance, carcass characteristics, and carcass fat quality of finishing pigs. J. Anim. Sci. 90:2620–2630. doi: 10.2527/jas.2011–4472.

Stein, H. H. 2007. Feeding distillers dried grains with solubles (DDGS) to swine. Swine Focus #001. Urbana: Univ of Ill. At Urbana-Champaign.

Stein, H. H. and G. C. Shurson. 2009. Board-invited review: The use and application of distillers dried grains with solubles in swine diets. J. Anim. Sci. 87:1292–1303. doi:10.2527/jas.2008–1290.

Stewart, L. L., D. Y. Kil, F. Ji, R. B. Hinson, A. D. Beaulieu, G. L. Allee, J. F. Patience, J. E. Pettigrew, and H. H. Stein. 2013. Effects of dietary soybean hulls and wheat middlings on body composition, nutrient and energy retention and the net energy of diets and ingredients fed to growing and finishing pigs. J. Anim. Sci. 91:2756–2765. doi: 10.2527/jas.2012–5147.

Tsai, T. C., H. J. Kim, J. R. Bergstom, J. J. Chewning, J. K. Apple, and C. V. Maxwell. 2014. Effect of wheat middling and multiple enzyme products on growth performance and carcass characteristics in nursery and finisher pigs. J. Anim. Sci. 92(Suppl. 2):55.

Turlington, W. H. 1984. Interactive effects of dietary fiber levels and environmental temperature on growing pigs [MS thesis]. Lexington: University of Kentucky.

Van Soest, P. J., J. B. Robertson, and B. A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583–3597. doi: 10:3168/jds.S0022-0302(91)78551–2.

Whitney, M. H., G. C. Shurson, L. J. Johnston, D. M. Wulf, and B. C. Shanks. 2006. Growth performance and carcass characteristics of grower-finisher pigs fed high-quality corn distillers dried grain with solubles originating from a modern Midwestern ethanol plant. J. Anim. Sci. 84:3356–3363. doi:10.2527/jas.2006–099.

Wiegand, B. R., R. B. Hinson, M. J. Ritter, S. N. Carr, and G. L. Allee. 2011. Fatty acid profiles and iodine value correlations between 4 carcass fat depots from pigs fed varied combinations of ractopamine and energy. J. Anim. Sci. 89: 3580–3586. doi: 10.2527/jas.2010–3303.

Wu, F., K. R. Vierck, J. M. DeRouchey, T. G. O'Quinn, M. D. Tokach, R. D. Goodband, S. S. Dritz, and J. C. Woodworth. 2017. A review of heavy weight market pigs: Status of knowledge and future needs assessment. Transl. Anim. Sci. 1:1–15. doi:10.2527/ tas2016.0004.

Xu, G., S. K. Baidoo, L. J. Johnston, D. Bibus, J. E. Cannon, and G. C. Shurson. 2010. Effects of feeding diets containing in- creasing content of corn distillers dried grains with solubles to grower- nisher pigs on growth performance, carcass composi- tion, and pork fat quality. J. Anim. Sci. 88:1398–1410. doi:10.2527/jas.2008–1403.