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Effects of lowering dietary fiber before marketing on finishing pig growth performance, carcass characteristics, carcass fat quality, and intestinal weights[1,2]

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ABSTRACT: A total of 264 pigs (initially 41.0 kg BW) were used in a 90-d study to determine the effects of lowering dietary fiber before market on pigs fed high dietary fiber [provided by wheat middlings (midds) and distillers dried grains with solubles (DDGS)] on growth performance, carcass characteristics, carcass fat quality, and intestinal weights of growing-finishing pigs. Pens of pigs were randomly allotted by initial BW and sex to 1 of 6 treatments with 6 replications per treatment and 7 or 8 pigs per pen. A positive control (corn-soybean meal–based) diet containing no DDGS or midds (9.3% NDF) and a negative control diet with 30% DDGS and 19% midds (19% NDF) were fed throughout the entire trial (d 0 to 90). The other 4 treatments were arranged in a 2 × 2 factorial with the main effects of length of fiber reduction (23 or 47 d before marketing) and fiber level fed during the reduction period (low or medium). Pigs on these treatments were fed the negative control before the reduction treatment. The medium-fiber diet contained 15% DDGS and 9.5% midds (14.2% NDF) with the low-fiber diet was the positive control diet. Increasing the feeding duration of the low-fiber diets lowered overall ADFI (linear, P = 0.03) and improved G:F (linear, $P < 0.01$). Lowering the fiber level for the last 23 d did not influence growth performance; however, lowering the fiber level improved carcass yield (P = 0.002), with a greater response ($P < 0.001$) when the low-fiber diet was fed for 23 d. Jowl fat iodine value (IV) decreased when the longer lower fiber diets were fed (linear, $P < 0.01$) and was lower ($P < 0.001$) for pigs fed the low-fiber diet during the fiber reduction period than pigs fed the medium-fiber diet during the same time period; however, increasing the time lower fiber diets were fed from 23 to 47 d further reduced ($P < 0.01$) jowl IV. Increasing the duration that the control diet was fed by increasing the reduction time from 23 to 47 d increased ($P < 0.01$) backfat depth. Reducing the fiber level decreased full large intestine weight (linear, P = 0.005) with a greater response (P = 0.04) when the low-fiber diet was fed during the reduction period instead of the medium-fiber diet. In summary, lowering the fiber level before marketing can improve G:F, carcass yield, carcass IV, and reduce large intestine weight; however, the optimal duration of the fiber reduction period depends on the targeted response criteria.

Key words: distillers dried grains with solubles, fiber, finishing pig, growth, wheat middlings, yield

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INTRODUCTION

Considerable research has investigated dietary distillers dried grains with solubles (**DDGS**) and growth performance, with reports indicating that up to 30% DDGS can be fed without reducing pig performance (Senne et al., 1995; DeDecker et al., 2005). Research has also shown that carcass yield is reduced in pigs fed high levels of DDGS as reported by Linneen et al. (2008). Also, the unsaturated fat found in DDGS, mainly C 18:2, leads to reduced carcass fat quality (Whitney et al., 2006, Widmer et al., 2007). With soft and off-white fat being a main factor associated with price reductions of processed products such as bacon (Carr et al., 2005), some packers have begun setting price reductions for pigs that have increased iodine value (**IV**) of carcass fat.

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Wheat middlings (**midds**) are also among the cereal by-products commonly used in commercial pig feed (Cromwell et al., 2000). Salyer et al. (2012) determined that adding 20% dietary wheat midds decreased ADG and worsened G:F. Because of the lower ME content compared with corn, producers can expect reduced gains and poorer feed efficiency when midds are fed to finishing pigs (Shaw et al., 2002). Adding midds to the diet has been shown to decrease percentage carcass yield, HCW, and backfat depth (Salyer et al., 2012). Although midds are lower in fat content than DDGS, they are higher in fat than corn, and increases in IV have been reported with addition of midds to the diet (Shaw et al., 2002; Salyer et al., 2012).

Although reducing the level of DDGS in the diet before market has been successful in lowering IV and improving yield (Gaines et al., 2007; Jacela et al., 2009), no data on determining the length of time required and level of reduction needed to achieve desired endpoints for carcass yield and fat quality when pigs are fed DDGS and midds in combination have been published. Therefore, the objective of this study was to determine the effects of decreasing or fully removing DDGS and midds at different times before marketing on growth performance, carcass yield, carcass fat quality, and intestinal weights of growing-finishing pigs.

MATERIALS AND METHODS

General

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. The study was conducted at the Kansas State Swine Teaching and Research Center in Manhattan, KS. The facility was a totally enclosed, environmentally regulated, mechanically ventilated facility containing 36 pens (2.4 × 3.1 m). The pens had adjustable gates facing the alleyway that allowed for 0.93 m^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 manure storage pit underneath (1.2-m deep). The facility was also equipped with a computerized feeding system (FeedPro; Feedlogic Corp., Willmar, MN) that delivered and recorded diets as specified. The equipment provided pigs with ad libitum access to feed and water.

Animals and Diets

A total of 264 pigs (327 × 1050, PIC [Hendersonville, TN]; initially 40.0 ± 1.1 kg) were used in a 90-d study. Pens of pigs (4 barrows and 4 gilts per pen or 3 barrows and 4 gilts per pen) were randomly allotted by initial weight to 1 of 6 dietary treatments with 6 replications per treatment. A positive control diet containing no DDGS or midds and a negative control diet containing 30% DDGS and 19% midds were fed for the duration of the study (d 0 to 90). The other 4 treatments were arranged in a 2 × 2 factorial with the main effects of length of fiber reduction (23 or 47 d before marketing corresponding to d 47 or 63 of the experiment) and fiber level fed during the reduction period (low or medium). Pigs on these treatments were fed the negative control (high-fiber) diet containing 30% DDGS and 19% wheat midds (19% NDF) before their reduction treatment. The medium-fiber diet fed during the reduction period contained 15% DDGS and 9.5% midds (14.2% NDF). The low-fiber diet fed during the reduction period was the positive control diet without DDGS or midds (9.3% NDF). Dietary treatments were corn-soybean meal–based and fed in 4 phases (Tables 1 and 2). All diets were fed in meal form and balanced to similar standardized ileal digestible (**SID**) Lys ratios within each phase, but diets were not isocaloric. Nutrient values used in diet formulation for corn, soybean meal, and midds were from the NRC (1998). For DDGS, AA concentration and SID AA values were from Stein (2007). Pedersen et al. (2007) demonstrated the ME of corn and DDGS are equal; thus, corn ME (3420 kcal/kg) from the NRC (1998) was used. Because of the high level of available P in DDGS and midds, no supplemental P was required in diets containing high levels of DDGS and midds. Phytase was added to all diets at a constant level of 0.13% of the diet, which provided 778.4 phytase units/kg of complete diet and a 0.12% P release.

Wheat midds and DDGS samples were collected at the time of feed preparation, and a composite sample was analyzed (Table 3) for moisture (934.01; AOAC International, 2006), CP (990.03; AOAC International, 2006), crude fat (920.39 A; AOAC International, 2006), crude fiber (978.10; AOAC International, 2006), ash (942.05; AOAC International, 2006), ADF, and NDF. Feed samples also were collected from each feeder during each phase and combined for a single composite sample by treatment for each phase to measure bulk density (Seedburo Model 8800; Seedburo Equipment, Chicago, IL; Table 4). Bulk density of a material represents the mass per unit volume (grams per liter).

Pens of pigs and feeders were weighed on d 0, 20, 43, 67, and 90 to calculate ADG, ADFI, and G:F. On d 90, all pigs were weighed individually, the second heaviest gilt in each pen (1 pig per pen and 6 pigs per treatment) was identified to be harvested at the Kansas State University Meats Lab, and all other pigs were then transported to a commercial packing plant (Triumph

Foods LLC, St. Joseph, MO). The pigs selected for harvest at the Kansas State University Meats Lab were blocked within treatment and randomly allotted to a harvest order to equalize the withdrawal time from feed before slaughter within treatments. Feeders were removed from pens at 1800 h the night before harvest and harvest began at 0600 h the next morning. Hot carcass weights were measured immediately after evisceration. Following evisceration, the entire pluck (heart, lungs, liver, kidneys, spleen, stomach, cecum, large intestine, small intestine, and reproductive tract) was weighed, then, individual organs were weighed. After full organ weights were recorded, the stomach, cecum, and large intestine were physically stripped of contents and reweighed, then flushed with water, physically stripped of contents, and weighed again. Pigs harvested at the commercial packing plant were individually tattooed in sequential order by pen and gender to allow for carcass data collection at the packing plant and data retrieval by pen. Hot carcass weights were measured immediately after evisceration, and each carcass was evaluated for percentage yield, backfat, loin depth, and percentage lean. Percentage carcass yield was calculated by dividing HCW by live weight obtained before transport to the packing 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 7.1 cm from the dorsal midline. Fat-free lean index was calculated according to NPPC (1991) equations for lean containing 5% fat. Jowl samples were collected and analyzed by near infrared spectroscopy (Bruker Multi-Purpose Analyzer; Bruker Daltonics, Bremen, Germany) for fat IV using the equation of Cocciardi et al. (2009).

Statistical Analysis

Data were analyzed as a completely randomized design using the PROC MIXED procedure of SAS (SAS Inst. Inc., Cary, NC) with the pen as the experimental unit. The effects of the different withdrawal regimens of NDF level and withdrawal time were tested using preplanned contrasts. Linear and quadratic contrasts were used to determine the effects of duration of fiber reduction (0, 43, 67, or 90 d) before marketing and fiber level (from d 43 to 90 and 67 to 90). The interaction term between duration and level was evaluated and found to be not significant, so it was removed from the statistical model. Treatment means were determined by using least squares means. Differences between treatments were determined by using least squares means with results considered significant at $P \leq 0.05$ and a trend at $P \leq 0.10$.

Table 1. Phase 1 and 2 diet composition (as-fed basis)[1]

	Phase 1		Phase 2	
	Low fiber	High fiber	Low fiber	High fiber
Wheat middlings, %	0	19	0	19
DDGS,[2] %	0	30	0	30
Ingredient, %				
Corn	73.70	34.90	78.95	40.00
Soybean meal, 46.5% CP	23.80	13.75	18.85	8.70
DDGS	–	30.00	–	30.00
Wheat middlings	–	19.00	–	19.00
Monocalcium phosphate, 21% P	0.45	–	0.35	–
Limestone	1.05	1.30	1.00	1.28
Salt	0.35	0.35	0.35	0.35
Vitamin premix[3]	0.15	0.15	0.13	0.13
Trace mineral premix[4]	0.15	0.15	0.13	0.13
L-Lys×HCl	0.17	0.31	0.15	0.29
DL-Met	0.02	–	–	–
L-Thr	0.03	–	0.01	–
Phytase[5]	0.13	0.13	0.13	0.13
Total	100.0	100.0	100.0	100.0
Calculated analysis				
Standardized ileal digestible (SID) AA				
Lys, %	0.93	0.93	0.79	0.79
Met:Lys, %	30	34	30	37
Met + Cys:Lys, %	59	70	62	77
Thr:Lys, %	63	66	63	69
Trp:Lys, %	19	19	19	19
Total Lys, %	1.04	1.09	0.89	0.94
CP, %	17.52	20.83	15.62	18.91
SID Lys:ME, g/Mcal	2.79	2.84	2.36	2.41
ME, kcal/kg	3329	3265	3335	3269
Ca, %	0.59	0.58	0.53	0.56
Available P, %	0.27	0.39	0.25	0.38
Crude fiber, %	2.5	4.9	2.5	4.9
NDF, %	9.2	18.9	9.3	19.0

[1]Phase 1 diets were fed from approximately 41 to 59 kg; Phase 2 diets were fed from 59 to 82 kg.

[2]Distillers dried grains with solubles.

[3]Provided per kilogram of premix: 4409,200 IU vitamin A; 551,150 IU vitamin D_3; 17,637 IU vitamin E; 1764 mg vitamin K; 3307 mg riboflavin; 11,023 mg pantothenic acid; 19,841 mg niacin; and 15.4 mg vitamin B_{12}.

[4]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.

RESULTS AND DISCUSSION

Bulk density tests showed that adding dietary fiber from wheat midds and DDGS decreased diet bulk density, which agrees with work by Salyer et al. (2012) who found a substantial reduction when midds or DDGS were included in the diet. From d 0 to 43, no differences in growth performance were found when pigs were fed either the control or only high-fiber diet. (Tables 5 and 6) For the overall trial (d 0 to 90), however, as duration of dietary fiber reduction increased, ADFI decreased (P =

Table 2. Phase 3 and 4 diet composition (as-fed basis)[1]

	Phase 3			Phase 4		
	Low fiber	Medium fiber	High fiber	Low fiber	Medium fiber	High fiber
Wheat middlings, %	0	9.5	19	0	9.5	19
DDGS,[2] %	0	15	30	0	15	30
Ingredient, %						
Corn	82.65	63.30	43.55	84.95	65.60	45.80
Soybean meal, 46.5% CP	15.30	10.20	5.20	13.15	8.05	3.05
DDGS	–	15.00	30.00	–	15.00	30.00
Wheat middlings	–	9.50	19.00	–	9.50	19.00
Monocalcium P, 21% P	0.25	–	–	0.20	–	–
Limestone	0.98	1.10	1.29	0.93	1.05	1.28
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix[3]	0.10	0.10	0.10	0.08	0.08	0.08
Trace mineral premix[4]	0.10	0.10	0.10	0.08	0.08	0.08
L-Lys×HCl	0.14	0.21	0.28	0.13	0.20	0.27
Phytase[5]	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
Calculated analysis						
Standardized ileal digestible (SID) AA						
Lys, %	0.69	0.69	0.69	0.63	0.63	0.63
Met:Lys, %	32	36	40	33	38	43
Met + Cys:Lys, %	66	74	83	69	78	88
Thr:Lys, %	64	68	72	66	70	74
Trp:Lys, %	19	19	19	19	19	19
Total Lys, %	0.78	0.81	0.83	0.72	0.74	0.77
CP, %	14.28	15.92	17.57	13.46	15.10	16.75
SID Lys:ME, g/Mcal	2.06	2.08	2.10	1.88	1.90	1.92
ME, kcal/kg	3,344	3,313	3,271	3,348	3,318	3,274
Ca, %	0.49	0.49	0.55	0.46	0.46	0.54
Available P, %	0.22	0.27	0.38	0.21	0.27	0.37
Crude fiber, %	2.4	3.6	4.8	2.4	3.6	4.8
NDF, %	9.3	14.2	19.0	9.3	14.2	19.0

[1]Phase 3 diets were fed from approximately 82 to 105 kg; Phase 4 diets were fed from 105 to 127 kg.

[2]Distillers dried grains with solubles.

[3]Provided per kilogram of premix: 4409,200 IU vitamin A; 551,150 IU vitamin D_3; 17,637 IU vitamin E; 1764 mg vitamin K; 3307 mg riboflavin; 11,023 mg pantothenic acid; 19,841 mg niacin; and 15.4 mg vitamin B_{12}.

[4]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.

[5]Phyzyme 600 (Danisco Animal Nutrition, St Louis, MO) provided 778.4 phytase units/kg of feed and 0.11% available P released.

Table 3. Chemical analysis of distillers dried grains with solubles (DDGS) and wheat middlings (as-fed basis)

Item	DDGS	Wheat middlings
DM	90.2	88.8
CP	24.3 (27.2)[1]	16.6 (15.9)
Fat (oil)	12.3	4.0
Crude fiber	6.0 (7.7)	7.9 (7.0)
ADF	10.6 (9.9)	10.3 (10.7)
NDF	36.1 (25.3)	36.6 (35.6)
Ash	4.3	5.7

[1]Values in parentheses indicate those used in diet formulation.

Table 4. Bulk density of experimental diets (as-fed basis)[1]

	Treatments		
	Low fiber	Medium fiber	High fiber
Wheat middlings,%	0	9.5	19.0
DDGS,[3] %	0	15.0	30.0
Bulk density,[1,2] g/L			
Phase 1	653	–	488
Phase 2	669	–	488
Phase 3	647	609	515
Phase 4	636	547	493

[1]Diet samples collected from the tops of each feeder during each phase.

[2]Phase 1 was d 0 to 20; Phase 2 was d 20 to 43; Phase 3 was d 43 to 67; and Phase 4 was d 67 to 90.

[3]Distillers dried grains with solubles.

Table 5. Effect of dietary fiber level before marketing on finishing pig growth performance[1]

	Treatment						SEM
	1	2	3	4	5	6	
d 0 to 43:	Low[2]	High[3]	High	High	High	High	
d 43 to 67:	Low	Low	Medium[4]	High	High	High	
d 67 to 90:	Low	Low	Medium	Low	Medium	High	
Item							
BW, kg							
d 0	41.0	41.1	41.0	41.0	40.9	41.0	0.8
d 20	61.3	60.7	60.7	60.8	60.5	60.7	1.0
d 43	81.7	80.5	80.6	80.7	80.7	80.7	1.4
d 67	101.1	101.6	102.5	101.3	101.2	101.5	1.3
d 90	120.6	122.1	122.8	121.9	121.5	121.6	1.4
d 0 to 43							
ADG, kg	0.95	0.92	0.92	0.92	0.92	0.92	0.02
ADFI, kg	2.41	2.42	2.39	2.42	2.42	2.43	0.05
G:F	0.39	0.38	0.39	0.38	0.38	0.38	0.01
d 43 to 67							
ADG, kg	0.81	0.88	0.91	0.86	0.85	0.87	0.02
ADFI, kg	2.64	2.79	2.85	2.86	2.85	2.87	0.07
G:F	0.31	0.32	0.32	0.30	0.30	0.30	0.01
d 67 to 90							
ADG, kg	0.85	0.89	0.88	0.90	0.88	0.87	0.02
ADFI, kg	2.80	2.83	2.94	3.02	3.03	3.05	0.06
G:F	0.30	0.31	0.30	0.30	0.29	0.29	0.01
d 43 to 90							
ADG, kg	0.83	0.88	0.90	0.88	0.87	0.87	0.01
ADFI, kg	2.72	2.81	2.90	2.93	2.94	2.96	0.06
G:F	0.30	0.31	0.31	0.30	0.30	0.29	0.01
d 0 to 90							
ADG, kg	0.89	0.90	0.91	0.90	0.89	0.89	0.01
ADFI, kg	2.57	2.62	2.64	2.69	2.69	2.70	0.05
G:F	0.35	0.34	0.34	0.33	0.33	0.33	0.01

[1]A total of 264 pigs [327 × 1050, PIC (Hendersonville, TN); initial BW = 41.0 ± 1.1 kg] were used in this 90-d study; 6 pens per treatment and 7 or 8 pigs per pen.

[2]Refers to low-fiber corn-soybean meal–based diet without distillers dried grains with solubles (DDGS) or wheat middlings (midds).

[3]Refers to high-fiber diet with 30% DDGS and 19.0% midds.

[4]Refers to medium-fiber diet with 15% DDGS and 9.5% midds.

Table 6. Main effects of dietary fiber level before marketing on finishing pig growth performance[1]

	P-value						
	Duration[2]		Fiber level, d 43 to 90[3]		Fiber level, d 67 to 90[4]		Low vs. medium fiber[5]
Item	Linear	Quadratic	Linear	Quadratic	Linear	Quadratic	
BW, kg							
d 0			0.99	0.92	0.96	0.91	
d 20			0.98	0.98	0.91	0.82	
d 43			0.92	0.98	1.00	0.99	
d 67			0.98	0.57	0.89	0.89	
d 90	0.64	0.43	0.81	0.58	0.89	0.90	
d 0 to 43							
ADG, kg			0.92	0.93	0.91	0.98	
ADFI, kg			0.92	0.49	0.94	0.89	
G:F			0.95	0.34	0.99	0.81	
d 43 to 67							
ADG, kg			0.64	0.04	0.59	0.66	
ADFI, kg			0.42	0.75	0.91	0.92	
G:F			0.20	0.14	0.75	0.95	
d 67 to 90							
ADG, kg	0.30	0.24	0.65	0.92	0.45	1.00	
ADFI, kg	0.001	0.81	0.008	0.99	0.63	0.98	
G:F	0.06	0.12	0.005	0.94	0.24	0.99	
d 43 to 90							
ADG, kg	0.04	0.02	0.56	0.28	0.79	0.82	0.82
ADFI, kg	0.003	0.61	0.07	0.86	0.76	0.94	0.42
G:F	0.09	0.08	0.01	0.35	0.57	0.96	0.54
d 0 to 90							
ADG, kg	0.65	0.36	0.76	0.47	0.91	0.90	0.83
ADFI, kg	0.03	0.86	0.22	0.74	0.82	0.86	0.83
G:F	0.004	0.43	0.03	0.16	0.62	0.86	0.99

[1]A total of 264 pigs [327 × 1050, PIC (Hendersonville, TN); initial BW = 41.0 ± 1.1 kg] were used in a 90-d study; 6 pens per treatment and 7 or 8 pigs per pen.

[2]Effect of duration (0, 43, 67, or 90 d) of fiber reduction regardless of fiber level fed during reduction period.

[3]Effect of fiber level (high, medium, low) fed from d 43 to 90 (last 47 d before market; treatments 2, 3, and 6).

[4]Effect of fiber level (high, medium, low) fed from d 67 to 90 (last 23 d before market; treatments 4, 5, and 6).

[5]Effect of low vs. medium fiber after pigs were fed high fiber from d 0 to 43 (treatments 2 and 4 vs. 3 and 5).

0.03) and G:F improved (*P* = 0.004) with no change in ADG. The decreased ADFI was driven by lowered ADFI from d 43 to 90 (*P* = 0.003) when the dietary fiber levels reductions occurred. Interestingly, when pigs were switched from the high-fiber (low-energy) diet to the control (high-energy) diet, they numerically increased ADFI within that time period. This increase in feed intake could be driven by the differences in diet bulk density; thus, when pigs were switched to the low-fiber diet, they consumed the same volumetric amount of feed for a period of time but the actual intake in kilograms was greater. Increased feed intake in pigs fed the high-fiber diet disagrees with work by Fu et al. (2004) and Linneen et al. (2008), which showed linear decreases in ADFI when increasing levels of DDGS (up to 30%) were fed. However, their diets did not contain wheat midds, which are of lower energy and could contribute to the need for increased daily feed intake to meet their energy requirement. Another possibility is that ADFI was affected in their studies because pigs' reduced preference for diets containing high levels of DDGS (Hastad et al., 2004).

However, lowering the fiber level for only 23 d (d 43 to 90) before market did not alter ADFI or G:F, which differs from work by Jacela et al. (2009), who observed a tendency for improved feed efficiency when DDGS were removed from the diet and pigs were fed a corn-soybean meal–based diet before marketing. Although ADG did not differ from d 67 to 90, the improvements from d 43 to 67 were large enough to result in improved (quadratic, *P* = 0.04) ADG for the entire fiber reduction duration (d 43 to 90; quadratic, *P* = 0.02). This ADG effect was driven by the increased ADFI, and resulted in a tendency (*P* = 0.09) for improved G:F. Jacela et al. (2009) also showed a tendency for improved ADG and G:F when DDGS were removed from the diet for a longer amount of time, but this result differs from other research with DDGS withdrawal (Gaines et al., 2007; Xu et al., 2010) showing no differences in ADFI or feed

Table 7. Effect of dietary fiber level before marketing on finishing pig carcass characteristics[1]

	Treatment						SEM
	1	2	3	4	5	6	
d 0 to 43	Low[2]	High[3]	High	High	High	High	
d 43 to 67	Low	Low	Medium[4]	High	High	High	
Item d 67 to 90:	Low	Low	Medium	Low	Medium	High	
Carcass yield,[5] %	73.2	72.9	71.6	73.0	72.4	71.7	0.3
HCW, kg	88.3	89.0	88.0	88.9	88.0	87.0	1.2
Backfat depth,[6] mm	18.8	18.4	17.5	18.3	18.9	16.8	0.5
Loin depth,[6] mm	58.4	59.8	58.6	59.2	57.1	59.3	1.1
Lean,[6] %	53.0	53.4	53.6	53.3	52.7	54.0	0.3
Jowl iodine value	68.4	70.6	75.8	74.8	76.6	78.5	0.9

[1]A total of 264 pigs [327 × 1050, PIC (Hendersonville, TN); initial BW = 41.0 ± 1.1 kg] were used in this 90-d study; 6 pens per treatment and 7 or 8 pigs per pen.

[2]Refers to low fiber corn-soybean meal–based diet without distillers dried grains with solubles (DDGS) or wheat middlings (midds).

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

[4]Refers to medium-fiber diet with 15% DDGS and 9.5% midds.

[5]Percentage yield was calculated by dividing HCW by live weight obtained at the farm before transport to the packing plant.

[6]Adjusted by using HCW as a covariate.

efficiency regardless of the reduction strategy. The difference could be partly explained by the fact that the high-fiber diets used in our study also included wheat midds, which resulted in the diets lower in energy, thus, requiring a greater ADFI to meet energy requirements.

Reducing the fiber level in the diet improved carcass yield (linear, $P = 0.004$) with a greater response ($P < 0.001$) when the low-fiber diet was fed for 23 d (Tables 7 and 8) with the medium-fiber diet being intermediate. Gaines et al. (2007) reported improvements in yield when DDGS were reduced for 3 or 6 wk before harvest, which agrees with our findings. However, Gaines et al. (2007) reported that the 6-wk, but not the 3-wk, reduction strategy was able to fully recover the

Table 9. Effect of dietary fiber level before marketing on finishing pig intestinal and organ weights, kg[1]

	Treatment						SEM
	1	2	3	4	5	6	
d 0 to 43	Low[2]	High[3]	High	High	High	High	
d 43 to 67	Low	Low	Medium[4]	High	High	High	
d 67 to 90	Low	Low	Medium	Low	Medium	High	
Item							
Full pluck	12.14	12.86	13.02	12.43	12.69	13.07	0.41
Whole intestine	7.52	8.03	8.37	7.65	8.02	8.45	0.32
Stomach							
Full	0.87	0.98	0.98	1.02	0.95	0.95	0.07
Stripped	0.63	0.67	0.67	0.67	0.66	0.68	0.02
Rinsed	0.63	0.63	0.63	0.64	0.64	0.66	0.02
Cecum							
Full	0.72	0.58	0.86	0.68	0.74	0.77	0.09
Stripped	0.27	0.25	0.28	0.23	0.25	0.25	0.01
Rinsed	0.25	0.23	0.25	0.23	0.25	0.25	0.01
Large intestine							
Full	2.98	3.23	3.72	3.04	3.40	3.95	0.21
Stripped	1.54	1.54	1.66	1.48	1.55	1.79	0.08
Rinsed	1.44	1.47	1.55	1.39	1.45	1.62	0.06
Small intestine							
Full	2.75	3.09	2.75	2.56	2.76	2.67	0.13
Heart	0.45	0.42	0.42	0.42	0.43	0.42	0.01
Lungs	0.61	0.64	0.56	0.56	0.62	0.59	0.03
Liver	1.78	1.80	1.73	1.81	1.76	1.92	0.06
Kidneys	0.36	0.37	0.42	0.37	0.39	0.39	0.02
Spleen	0.17	0.20	0.22	0.20	0.19	0.19	0.01
Reproductive tract	0.55	0.60	0.53	0.57	0.52	0.54	0.08

[1]A total of 264 pigs [327 × 1050, PIC (Hendersonville, TN); initial BW = 41.0 ± 1.1 kg] were used in this 90-d study; 6 pens per treatment and 7 or 8 pigs per pen.

[2]Refers to low-fiber corn-soybean meal–based diet without distillers dried grains with solubles (DDGS) or wheat middlings (midds).

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

[4]Refers to medium-fiber diet with 15% DDGS and 9.5% midds.

Table 8. Main effects of dietary fiber level before marketing on finishing pig carcass characteristics[1]

	P-value						
	Duration[2]		Fiber level, d 43 to 90[3]		Fiber level, d 67 to 90[4]		Low vs. medium fiber[5]
Item	Linear	Quadratic	Linear	Quadratic	Linear	Quadratic	
Carcass yield %	0.002	0.85	0.004	0.03	0.002	0.97	0.001
HCW, kg	0.49	0.38	0.23	0.98	0.26	0.98	0.43
Backfat depth, mm	0.01	0.22	0.02	0.80	0.03	0.02	0.74
Loin depth,[7] mm	0.71	0.94	0.74	0.46	0.95	0.12	0.14
Lean,[7] %	0.11	0.45	0.27	0.73	0.18	0.02	0.46
Jowl iodine value	0.001	0.91	0.001	0.27	0.01	0.94	0.001

[1]A total of 264 pigs [327 × 1050, PIC (Hendersonville, TN); initial BW = 41.0 ± 1.1 kg] were used in a 90-d study; 6 pens per treatment and 7 or 8 pigs per pen.

[2]Effect of duration (0, 43, 67, or 90 d) of fiber reduction regardless of fiber level fed during reduction period.

[3]Effect of fiber level (low, medium, high) fed from d 43 to 90 (last 47 d before market; treatments 2, 3, and 6).

[4]Effect of fiber level (low, medium, high) fed from d 67 to 90 (last 23 d before market; treatments 4, 5, and 6).

[5]Effect of low vs. medium fiber after pigs were fed high fiber from d 0 to 43 (treatments 2 and 4 vs. 3 and 5).

[6]Percentage yield was calculated by dividing HCW by live weight obtained at the farm before transport to the packing plant.

[7]Adjusted by using HCW as a covariate.

Table 10. Main effects of dietary fiber level before marketing on finishing pig intestinal and organ weights,[1] kg

	P-value						
	Duration[2]		Fiber level, d 43 to 90[3]		Fiber level, d 67 to 90[4]		Low vs. medium fiber[5]
Item	Linear	Quadratic	Linear	Quadratic	Linear	Quadratic	
Full pluck	0.16	0.71	0.74	0.92	0.28	0.91	0.62
Whole intestine	0.08	0.94	0.36	0.74	0.09	0.95	0.27
Stomach							
Full	0.32	0.28	0.76	0.86	0.52	0.71	0.65
Stripped	0.12	0.74	0.66	0.80	0.74	0.57	0.81
Rinsed	0.36	0.58	0.36	0.69	0.65	0.69	1.00
Cecum							
Full	0.73	0.69	0.13	0.12	0.46	0.89	0.07
Stripped	0.38	0.79	0.70	0.12	0.33	0.57	0.08
Rinsed	0.93	0.68	0.39	0.32	0.28	0.26	0.05
Large intestine							
Full	0.01	0.44	0.02	0.61	0.01	0.72	0.05
Stripped	0.07	0.11	0.03	0.95	0.01	0.38	0.22
Rinsed	0.13	0.29	0.11	0.92	0.02	0.51	0.27
Small intestine							
Full	0.50	0.26	0.03	0.43	0.58	0.38	0.58
Heart	0.07	0.38	0.91	0.87	0.84	0.73	0.85
Lungs	0.65	0.78	0.34	0.12	0.42	0.28	0.71
Liver	0.15	0.13	0.18	0.10	0.22	0.16	0.33
Kidneys	0.39	0.36	0.44	0.03	0.53	0.59	0.03
Spleen	0.19	0.03	0.54	0.13	0.54	0.90	0.66
Reproductive tract	0.92	0.82	0.58	0.69	0.81	0.73	0.47

[1]A total of 264 pigs [327 × 1050, PIC (Hendersonville, TN); initial BW = 41.0 ± 1.1 kg] were used in a 90-d study.

[2]Effect of duration (0, 43, 67 or 90 d) of fiber reduction regardless of fiber level fed during reduction period.

[3]Effect of fiber level (low, medium, high) fed from d 43 to 90 (last 47 d before market; treatments 2, 3, and 6).

[4]Effect of fiber level (low, medium, high) fed from d 67 to 90 (last 23 d before market; treatments 4, 5, and 6).

[5]Effect of low vs. medium fiber after pigs were fed high fiber from d 0 to 43 (treatments 2 and 4 vs. 3 and 5).

yield loss, whereas in our study, the entire loss in yield was recovered by the 3-wk (23-d) reduction period. Conversely, Xu et al. (2010) reported no differences in yield when pigs were removed from 15 or 30% DDGS at 3, 6, or 9 wk before harvest.

Increasing the duration of feeding the low-fiber diets, by extending the fiber reduction time, increased ($P = 0.01$) backfat depth and numerically reduced percentage lean ($P = 0.11$). This result is supported by Jacela et al. (2009) who reported an increase in backfat depth when pigs were switched from high-DDGS diets and fed corn-soybean meal diets. Conversely, Xu et al. (2010) reported no differences in backfat depth or percentage lean regardless of DDGS inclusion or fiber reduction strategy. The change in backfat depth in our study was expected because our lower energy, high-fiber diets contained wheat midds, which have been shown to reduce backfat depth (Salyer et al., 2012).

In our study, as expected, jowl fat IV decreased as fiber reduction time increased (linear, $P < 0.01$) and was lower ($P < 0.001$) in pigs fed the low-fiber diet during the reduction period than pigs fed the medium-fiber diet. This further improvement as reduction time increased from 23 to 47 d agrees with other published data (Jacela et al., 2009), but the 23-d reduction time improved IV only by 37 or 19% (IV = 74.8 and 76.6, respectively) when pigs were moved to the low- or medium-fiber diet. The 47-d reduction period improved IV by 78 and 27% (IV = 70.6 and 75.8, respectively) when pigs were moved to the low- and medium-fiber diets, respectively. These results indicate that IV is improved by approximately 0.35 g per week for every 10% DDGS removed from the diet, which is supported by recent research conducted by Hill et al. (2008) and Jacela et al. (2009). However, these studies looked at the incorporation of unsaturated fatty acids into the carcass, not the removal (clearance) of unsaturated fatty acids after they have been deposited. The current trial was not able to show the same magnitude of response. It is possible that the rapid improvement in fat quality was not obvious in this trial because fat quality was measured in jowl fat samples, which are deposited early and have a slow turnover rate, which could cause them to be slow to show improvements due to a dietary change (Bergstrom et al., 2010).

Table 11. Effect of dietary fiber levels before marketing on finishing pig intestinal and organ weights,[1,2] %

	Treatment						SEM
	1	2	3	4	5	6	
d 0 to 43	Low[3]	High[4]	High	High	High	High	
d 43 to 67	Low	Low	Medium[5]	High	High	High	
d 67 to 90	Low	Low	Medium	Low	Medium	High	
Item							
Full pluck	9.83	10.75	10.77	10.29	10.57	10.70	0.30
Whole intestine	6.09	6.64	6.92	6.33	6.69	6.92	0.25
Stomach							
Full	0.70	0.82	0.81	0.84	0.79	0.78	0.05
Stripped	0.51	0.55	0.55	0.55	0.55	0.56	0.02
Rinsed	0.51	0.52	0.52	0.53	0.53	0.54	0.02
Cecum							
Full	0.58	0.49	0.72	0.57	0.62	0.63	0.07
Stripped	0.21	0.20	0.23	0.19	0.21	0.21	0.01
Rinsed	0.20	0.19	0.21	0.19	0.21	0.20	0.01
Large intestine							
Full	2.42	2.67	3.07	2.52	2.84	3.23	0.17
Stripped	1.25	1.27	1.37	1.22	1.29	1.47	0.06
Rinsed	1.17	1.21	1.28	1.15	1.21	1.33	0.05
Small intestine							
Full	2.22	2.56	2.28	2.12	2.29	2.18	0.10
Heart	0.37	0.35	0.35	0.35	0.36	0.34	0.01
Lungs	0.49	0.53	0.46	0.46	0.51	0.49	0.02
Liver	1.44	1.48	1.43	1.50	1.47	1.57	0.05
Kidneys	0.29	0.30	0.35	0.31	0.32	0.32	0.01
Spleen	0.14	0.17	0.18	0.17	0.16	0.16	0.01
Reproductive tract	0.44	0.50	0.44	0.47	0.43	0.44	0.06

[1]A total of 264 pigs [327 × 1050, PIC (Hendersonville, TN); initial BW = 41.0 ± 1.1 kg] were used in this 90-d study; 6 pens per treatment and 7 or 8 pigs per pen.

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

[3]Refers to low-fiber corn-soybean meal–based diet without distillers dried grains with solubles (DDGS) or wheat middlings (midds).

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

[5]Refers to medium-fiber diet with 15% DDGS and 9.5% midds.

The greatest impact of fiber reduction strategy was on large intestine weights, with the response similar to the yield response. These results agree with research by Agyekum et al. (2012) who reported pigs fed DDGS diets for 28 d had heavier colon plus rectum and portal-drained viscera than pigs fed the control diet. Increasing the duration of fiber reduction decreased (linear, $P < 0.05$) full and stripped large intestine weights. As fiber level increased in the diet from d 43 to 67 or 67 to 90, full and stripped large intestine weights also increased ($P < 0.05$), with pigs fed the low-fiber diet during the reduction period also having lighter ($P < 0.05$) full large intestine weight than those fed the medium-fiber diet. High dietary fiber may indirectly increase the animals' maintenance requirement by repartitioning nutrients from the carcass to the visceral organs (Ferrell, 1988). Anugwa et al. (1989) saw substantially greater weights of the total gastrointestinal tract and greater relative stomach weight when pigs were fed high-fiber diets (40% alfalfa meal). This result agrees with the increased large intestine weights in our current study, but no differences were detected in stomach weights in our study. The high-fiber diet fed in the last feeding period in the present study was greater in CP than the low-fiber diet (16.8 vs. 13.5%), which could be a confounding factor because excess CP could be causing part of the increases in liver and kidney weights (Anugwa et al., 1989). Agyekum et al. (2012) found no differences in liver weights with diets similar in CP (18.2 vs. 18.1%); however, the pigs used in their study were much lighter in final BW than in our study (36.5 vs. 103 kg).

The fiber level fed and length of fiber reduction had minor effects on most organ weights except for the digestive tract, which, as expected, was most influenced by dietary fiber levels. But, unexpectedly, lowering the fiber level in the diet for the last 47 d actually increased ($P = 0.03$) small intestine weight, whether calculated on a weight basis (Tables 9 and 10) or percentage of live weight basis (Tables 11 and 12). Stomach weights were not influenced by feeding duration, other than a tendency ($P = 0.08$) for stripped stomach weight to be decreased as the length of fiber reduction increased. Similarly, the influence of fiber reduction strategy on cecum weights was minor, with only small reductions ($P = 0.08$) in full, stripped, and rinsed cecum weights when the low-fiber diet was fed during the reduction period instead of the medium-fiber diet.

For the other organs, spleen weight decreased (quadratic, $P = 0.02$) as the duration of fiber reduction increased, but no other differences were observed in spleen weight. As fiber levels were lowered 47 d before market, kidney weight decreased (quadratic, $P < 0.01$), with greater reductions when pigs were fed the low-fiber diet compared with the medium-fiber diet during the reduction period. Pond et al. (1988) also found reduced kidney weight but no difference in heart weight when high fiber (80% alfalfa meal) was fed. Conversely, lungs, liver, and reproductive tract weights were not influenced by fiber level or fiber reduction strategy in the current study. It should be noted that Pond et al. (1988) found differences in empty colon, small intestine, and cecum weights, showing increases in actual organ weights. In our study, the most notable differences were in full intestinal weights, implying gut fill was a large contributor to the yield reduction compared with increased intestine weights.

In summary, reducing the dietary fiber level from DDGS and midds before market can improve G:F, carcass yield, carcass IV, and reduce large intestine

Table 12. Main effect of dietary fiber levels before marketing on finishing pig intestinal and organ weights,[1] %

	Probability, $P <$						
	Duration[2]		Fiber level, d 43 to 90[3]		Fiber level, d 67 to 90[4]		Low vs. medium fiber[5]
Item	Linear	Quadratic	Linear	Quadratic	Linear	Quadratic	
Full pluck	0.09	0.22	0.92	0.91	0.34	0.85	0.63
Whole intestine	0.05	0.52	0.45	0.65	0.11	0.83	0.21
Stomach							
Full	0.33	0.12	0.63	0.81	0.43	0.78	0.63
Stripped	0.08	0.28	0.79	0.89	0.90	0.77	0.91
Rinsed	0.19	0.85	0.42	0.78	0.79	0.92	0.88
Cecum							
Full	0.65	0.86	0.16	0.11	0.51	0.82	0.07
Stripped	0.53	0.87	0.77	0.10	0.39	0.45	0.07
Rinsed	0.86	0.99	0.46	0.28	0.37	0.18	0.04
Large intestine							
Full	0.005	0.74	0.03	0.57	0.006	0.88	0.04
Stripped	0.04	0.23	0.04	0.97	0.009	0.50	0.18
Rinsed	0.06	0.49	0.12	0.83	0.02	0.65	0.20
Small intestine							
Full	0.44	0.21	0.01	0.47	0.68	0.27	0.58
Heart	0.17	0.71	0.66	0.86	0.68	0.51	0.85
Lungs	0.80	0.93	0.19	0.08	0.45	0.18	0.63
Liver	0.04	0.37	0.18	0.10	0.26	0.22	0.37
Kidneys	0.34	0.16	0.45	0.01	0.62	0.44	0.02
Spleen	0.29	0.02	0.49	0.11	0.47	0.99	0.62
Reproductive tract	0.94	0.75	0.53	0.69	0.76	0.71	0.43

[1]A total of 264 pigs [327 × 1050, PIC (Hendersonville, TN); initial BW = 41.0 ± 1.1 kg] were used in a 90-d study; 6 pens per treatment and 7 or 8 pigs per pen.

[2]Effect of duration (0, 43, 67 or 90 d) of fiber reduction regardless of fiber level fed during reduction period.

[3]Effect of fiber level (low, medium, high) fed from d 43 to 90 (last 47 d before market; treatments 2, 3, and 6).

[4]Effect of fiber level (low, medium, high) fed from d 67 to 90 (last 23 d before market; treatments 4, 5, and 6).

[5]Effect of low vs. medium fiber after pigs were fed high fiber from d 0 to 43 (treatments 2 and 4 vs. 3 and 5).

weight; however, the optimal length of fiber reduction time depends on the targeted response criteria. Shorter reductions are effective at recovering yield, but longer reductions are necessary to improve carcass fat quality.

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