The interactive effects of high-fat, high-fiber diets and ractopamine HCl on finishing pig growth performance, carcass characteristics, and carcass fat quality[1,2]

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ABSTRACT: A total of 576 mixed-sex pigs (PIC 327 × 1,050; initial BW = 55.8 ± 5.5 kg) were used to determine the effects of corn dried distillers grains with solubles (DDGS) and wheat middlings (midds) withdrawal 24 d before harvest in diets without or with ractopamine HCl (RAC) on growth performance, carcass characteristics, and carcass fat quality. From d 0 to 49, pigs were fed a corn-soybean meal–based diet (CS) or a diet high in unsaturated fat and crude fiber provided by 30% DDGS and 19% wheat midds (HFF) and not balanced for energy. On d 49, pens of pigs previously fed CS diets remained on the CS diet. Half of the HFF-fed pigs were switched to the CS–based diets, which served as the withdrawal regimen. Finally, half of the HFF-fed pigs remained on the same HFF diet. All 3 regimens were fed without or with 10 mg/kg RAC. There were 12 pens per treatment with 8 pigs per pen. No significant diet regimen × RAC interactions were observed. From d 0 to 49, pigs fed the CS diet had increased ($P < 0.001$) ADG and G:F compared with pigs fed the HFF diet. Overall (d 0 to 73), pigs fed the CS diets throughout had greater ($P < 0.001$) ADG and G:F than those fed the HFF diets throughout. Pigs fed the withdrawal diets had greater ($P = 0.014$) ADG, but similar G:F to those fed the HFF diets throughout. Pigs fed the CS diets throughout had greater ($P = 0.025$) carcass yield compared with pigs fed the HFF diets throughout, with those fed the withdrawal diets intermediate. Pigs fed RAC had greater ($P < 0.001$) ADG, G:F, and carcass yield ($P = 0.061$than pigs not fed RAC. Jowl, backfat, belly, and leaf fat iodine value (IV) were lowest ($P < 0.001$) for pigs fed the CS diets, highest ($P < 0.015$) for those fed HFF diets throughout, and intermediate for pigs fed the withdrawal diet. There were no differences in either full or rinsed intestine or organ weights between pigs that were fed CS diets throughout and pigs fed the withdrawal diet; however, pigs fed the HFF diets throughout the study had increased ($P = 0.002$) rinsed cecum and full large intestine weights ($P = 0.003$) compared with the pigs fed the withdrawal diets. Withdrawing the HFF diet and switching to a CS diet for the last 24 d before harvest partially mitigated negative effects on carcass yield and IV often associated with high-fat, high-fiber ingredients such as DDGS and wheat midds. Feeding RAC for the last 24 d before market, regardless of dietary regimen, improved growth performance and carcass yield.

Key words: dried distillers grains with solubles, fiber, growth, iodine value, pigs, withdrawal

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INTRODUCTION

By-product ingredients such as corn dried distillers grains with solubles (**DDGS**) and wheat middlings (**midds**) are commonly used in diet formulation. An abundance of research has been conducted to determine levels at which DDGS can be included in the diet without negatively affecting growth performance. Research has demonstrated that growth performance compared with a corn-based diet does not change when DDGS (> 9% oil) are added up to 20% (Drescher et al., 2008; Widmer et al., 2008) or 30% (Cook et al., 2005; DeDecker et al., 2005) of the diet. A review by Stein and Shurson (2009) also concluded that feeding up to 30% DDGS in the diet does not have detrimental effects on growth performance.

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A major concern with feeding a high amount of DDGS (> 9% oil) is increased iodine value (**IV**) and decreased carcass yield (Whitney et al., 2006; Linneen et al., 2008; Xu et al., 2010a), but complete dietary withdrawal of DDGS and wheat midds before marketing has been shown to be successful in lowering IV and improving carcass yield (Hill et al., 2008; Xu et al., 2010b; Asmus et al., 2014).

Ractopamine HCl (**RAC**; Paylean, Elanco Animal Health, Greenfield, IN) is sometimes added to finishing swine diets before marketing to increase weight gain, G:F, and carcass yield (Apple et al., 2007). Therefore, in addition to using a withdrawal diet before marketing, feeding RAC may help mitigate the negative effects of high-fiber diets on carcass yield. Thus, the objective of this study was to determine the possible interactive effects of RAC on growth performance, carcass characteristics, carcass fat quality, and intestinal weights of pigs fed a corn-soybean meal-based diet, versus those fed a diet high in unsaturated fat and fiber provided by corn DDGS and wheat midds and the effectiveness of using a withdrawal strategy just before market.

MATERIALS AND METHODS

General

The protocols for this experiment were approved by the Kansas State University (**K-State**) Institutional Animal Care and Use Committee.

This experiment 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 (2.4 × 3.1 m) that allowed for 0.93m^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 1.2-m pit underneath for manure storage. 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 food and water.

Animals and Diets

A total of 575 pigs (PIC 327 × 1050: PIC Hendersonville, TN; initial BW = 55.8 ± 5.5 kg) were used in 2 consecutive trials (73 and 72 d, respectively). Initially, pens of pigs (4 barrows and 4 gilts per pen) were randomly allotted to 1 of 2 dietary treatments with initial pen weight balanced across treatments. The dietary treatments included a corn-soybean meal–based control diet and a diet with 30% corn DDGS and 19% wheat midds. Diets were not balanced for energy. In each replicate trial, 12 pens of pigs were fed the corn-soybean meal control diet, and 24 pens were fed the high-fat, high-fiber diet. On d 49, pens of pigs previously fed corn-soybean meal-based diets remained on the corn-soybean meal-based diet. Half of the high-fat, high-fiber fed pigs were switched to the corn-soybean meal-based diets, which served as the withdrawal regimen, while half of the high-fat, high-fiber-fed pigs remained on the same high-fat, high-fiber diet. All 3 regimens were fed without or with 10 mg/kg RAC. Thus, there were 72 total pens with 12 replications of the 6 final dietary treatments. Dietary treatments were fed in 3 phases (Tables 1 and 2). Total AA and SID coefficients were derived from NRC (1998) and used diet formulation. All diets were prepared at the K-State Animal Sciences and Industry feed mill and fed in meal form.

Composite samples of the corn DDGS and wheat midds from each feed delivery were analyzed in a commercial laboratory (Ward Laboratories, Inc., Kearney, NE; Table 3) for DM (AOAC 934.01, 2006), CP (AOAC 990.03, 2006), ether extract (AOAC 920.39 A, 2006), crude fiber (AOAC 978.10, 2006), ash (AOAC 942.05, 2006), Ca (AOAC 965.14/985.01, 2006.), P (AOAC 965.17/985.01, 2006), ADF and NDF (ANKOM Technology, Macedon, NY). Composite samples of complete diets sampled at the feeder during each phase were used to measure bulk density (Seedburo Model 8800, Seedburo Equipment, Chicago, IL; Tables 1 and 2). Bulk density of a material represents the mass per unit of volume (g/L).

Pigs and feeders were weighed on d 0, 28, 49, and 73 to calculate ADG, ADFI, and G:F. In the first trial, all pigs were weighed individually before marketing to allow for calculation of carcass yield. The second-heaviest barrow in each pen (1 pig per pen, 6 pigs per treatment) was identified to be harvested for carcass data collection at the Kansas State University Meats Lab, and all other pigs were transported to a commercial packing facility, but no other carcass measurements were collected. For the pigs slaughtered at K-State, HCW was measured immediately after evisceration. Following evisceration, the entire pluck (heart, lungs, liver, kidneys, spleen, stomach, cecum, large intestine, and small intestine) was weighed, and then the individual organs were weighed (heart, liver, and kidneys as well as the stomach, small and large intestine, and cecum). After organ weights were recorded, the large intestine, stomach, and cecum were physically stripped, flushed with water, and weighed again. Belly, jowl, backfat, and leaf fat samples were taken from all 36 pigs and were analyzed for their fatty acid content according to the procedure by Metcalfe and Schmitz (1961). Belly fat samples were taken along the proximal end of the teat line. Jowl fat samples were collected from the distal end of the carcass. Backfat samples were taken midline at the 10th rib, with care taken to sample all 3 layers of adipose tissue. Leaf fat was collected in its

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

	Phase 1		Phase 2	
Item	Corn-soy	High-fat, high fiber	Corn-soy	High-fat, high fiber
Ingredient, %				
Corn	78.93	40.00	82.64	43.56
Soybean meal (46.5% CP)	18.84	8.71	15.32	5.20
DDGS[2]	–	30.00	–	30.00
Wheat middlings	–	19.00	–	19.00
Monocalcium P (21% P)	0.35	–	0.25	
Limestone	1.00	1.28	0.98	1.29
Salt	0.35	0.35	0.35	0.35
Vitamin premix[3]	0.13	0.13	0.10	0.10
Trace mineral premix[4]	0.13	0.13	0.10	0.10
L-Lys HCl	0.15	0.29	0.14	0.28
L-Thr	0.01	–	–	–
Phytase[5]	0.125	0.125	0.125	0.125
Total	100.0	100.0	100.0	100.0
Calculated analysis				
Standardized ileal digestible (SID) amino acids, %				
Lys	0.79	0.79	0.69	0.69
Ile:Lys	70	74	72	76
Met:Lys	30	37	32	41
Met &Cys:Lys	62	77	66	83
Thr:Lys	63	69	64	72
Trp:Lys	19	19	19	19
Val:Lys	81	94	85	99
Total Lys, %	0.89	0.94	0.78	0.83
ME, kcal/kg	3,343	3,277	3,352	3,279
NE, kcal/kg	2,276	2,158	2,293	2,172
SID Lys: ME, g/Mkcal	2.36	2.41	2.06	2.10
CP, %	15.6	18.9	14.3	17.6
Crude fat, %	3.4	5.7	3.5	5.8
Crude fiber, %	2.5	4.9	2.4	4.8
NDF, %	9.3	19.0	9.3	19.0
ADF, %	3.2	6.6	3.1	6.5
Ca, %	0.53	0.56	0.49	0.55
P, %	0.42	0.56	0.39	0.55
Available P, %	0.16	0.27	0.13	0.27
Bulk density[6], g/L	723	554	687	526

[1]Diets were fed in meal form from d 0 to 49 of the experiment. Total AA and SID coefficients were derived from NRC (1998) and used diet formulation.

[2]Dried distillers 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]Phytase was added to all diets at a rate of 0.125% to provide 778.4 phytase units (FTU)/kg of complete diet and a 0.12% P release.

[6]Diet samples were taken from the feeders during each phase. Values represent composite samples from both samples.

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

	Phase 3			
	Corn-soy		High-fat, high fiber	
Item RAC:	-	+	-	+
Ingredient, %				
Corn	84.97	75.30	45.79	36.03
Soybean meal (46.5% CP)	13.15	22.72	3.04	12.69
DDGS[2]	–	–	30.0	30.0
Wheat middlings	–	–	19.0	19.0
Monocalcium P (21% P)	0.20	0.15	–	–
Limestone	0.93	0.90	1.40	1.40
Salt	0.35	0.35	0.35	0.35
Vitamin premix[3]	0.08	0.08	0.08	0.08
Trace mineral premix[4]	0.08	0.08	0.08	0.08
L-Lys HCl	0.13	0.17	0.27	0.31
DL-Met	–	0.02	–	–
L-Thr	0.01	0.06	–	–
RactopamineHCl, 10 mg/kg[5]	–	0.05	–	0.05
Phytase[6]	0.125	0.125	0.125	0.125
Total	100	100	100	100
Calculated analysis				
Standardized ileal digestible (SID) amino acids, %				
Lys	0.63	0.90	0.63	0.90
Ile:Lys	73	69	78	72
Met:Lys	33	30	43	35
Met &Cys:Lys	69	60	88	72
Thr:Lys	67	67	74	67
Trp:Lys	19	19	19	19
Val:Lys	87	79	91	89
Total Lys, %	0.72	1.01	0.77	1.06
ME, kcal/kg	3,356	3,354	3,277	3,272
NE, kcal/kg	2,306	2,271	2,183	2,145
SID Lys: ME, g/Mkcal	1.88	2.68	1.92	2.75
CP, %	13.5	17.2	16.7	20.4
Crude fat, %	3.5	3.3	5.8	5.6
Crude fiber, %	2.4	2.5	4.8	4.9
NDF, %	9.3	9.3	19.0	18.9
ADF, %	3.1	3.3	6.4	6.7
Ca, %	0.46	0.47	0.59	0.62
P, %	0.37	0.40	0.54	0.58
Available P, %	0.10	0.10	0.26	0.27
Bulk density[7], g/L	744	–	552	–

[1]Diets were fed in meal form from d 49 to 73 of the experiment. Total AA and SID coefficients were derived from NRC (1998) and used diet formulation.

[2]Dried distillers 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]Paylean; Elanco Animal Health, Greenfield, IN.

[6]Phytase was added to all diets at a rate of 0.125% to provide 778.4 phytase units (FTU)/kg of complete diet and a 0.12% P release.

[7]Diet samples were taken from the feeders during each phase. Values represent composite samples from both samples.

Table 3. Chemical analysis of dried distillers grains with solubles (DDGS) and wheat middlings (as-fed basis)[1]

	Trial 1		Trial 2	
Item	DDGS	Wheat middlings	DDGS	Wheat middlings
Nutrient, %				
DM, %	92.0	90.7	90.2	89.7
CP, %	29.0	17.0	29.2	14.3
Crude fat, %	9.7	4.1	8.4	3.3
Crude fiber, %	7.7	7.8	8.5	7.9
ADF, %	12.1	12.9	13.5	10.2
NDF, %	27.4	33.5	27.6	31.4
Ash, %	5.9	5.6	4.3	5.3

[1]Values represent the mean of composite samples of ingredients taken from every feed delivery within each trial.

entirety and subsampled before fatty acid analysis. After carcasses had chilled for 24 h at 0°C, 10th-rib backfat and LM area measurements were taken.

In the second trial, all pigs were transported approximately 2 h to a commercial packing plant (Farmland Foods, Crete, NE). Before transport, pigs were individually weighed and tattooed to allow for carcass data collection at the packing plant and data retrieval by pen. Hot carcass weights were measured immediately after evisceration to allow for calculation of carcass yield. Belly and jowl fat samples (collected from the same anatomical locations as in trial 1) were collected from each carcass and analyzed for their fatty acid content.

Fat samples were handled and prepared for analysis based on procedures outlined by Benz et al. (2010). All fatty acid analysis on fat samples for this experiment was conducted in the University of Nebraska Department of Nutrition and Health Sciences Analytical Lab (Lincoln, NE; Supelco SP-2330; Metcalfe and Schmitz, 1961). Iodine value was calculated from the following equation (AOCS, 1998): IV = [C16:1] × 0.95 + [C18:1] × 0.86 + [C18:2] × 1.732 + [C18:3] × 2.616 + [C20:1] × 0.785 + [C22:1] × 0.723, where brackets indicate concentration (%).

Percentage carcass yield was calculated by dividing HCW at the plant by live weight at the farm before transport to the K-State Meat Lab or commercial packing plant (trials 1 and 2, respectively).

Statistical Analysis

Data were analyzed as a completely randomized design using the PROC MIXED procedure of SAS (SAS Inst. Inc., Cary, NC) with pen as the experimental unit. Contrasts were used to evaluate differences in performance of pigs that were maintained on corn-soybean meal diets or high-fat, high-fiber diets or that were removed from high-fat, high-fiber diets to corn-soybean meal diets at d 49. Contrasts also were used to determine the effects of using RAC. Differences between treatments were determined using least squares means. Results were considered significant at $P \leq 0.050$ and a trend at $P > 0.050$ and $P \leq 0.100$.

RESULTS

Chemical Analysis

The corn DDGS used in both trials were similar, yet slightly greater in CP than the published value for DDGS (> 10% oil) in the NRC (2012), at 29.1 vs. 27.3% CP, respectively (Table 3). The same was not true for the wheat midds; those used in trial 1 were analyzed to contain 17.0% CP, whereas those in trial 2 analyzed 14.3% CP. The published value for CP in wheat midds according to NRC (2012) is 15.8%. The oil (ether extract) content of corn DDGS and wheat midds used in trials 1 and 2 were 9.7, 8.4% and 4.1 and 3.3%, respectively. The NDF and ADF components of DDGS and wheat midds varied only slightly from published NRC (2012) values. Bulk density decreased as high-fiber ingredients such as wheat midds and DDGS were included in the diets (Tables 1 and 2). Although DDGS contains more oil, fatty acid analysis of the ingredients showed that the wheat midds containd slightly more linoleic acid (C18:2n-6), resulting in a greater IV for wheat midds than DDGS (Table 4). Similarly, PUFA concentrations were greater in the wheat midds than DDGS.

Growth Performance

From d 0 to 49, pigs fed the corn-soybean meal–based diet had increased ($P < 0.001$) ADG and G:F compared with pigs fed the high-fat, high-fiber diet (Table 5). From d 49 to 73, no significant interactions were observed between high-fat, high-fiber withdrawal regimen and RAC for any response criteria. Pigs maintained on the corn-soybean meal diet or those switched to the corn-soybean meal diet on d 49 (high-fat, high-fiber withdrawal) had similar ADG and G:F, and both were greater ($P < 0.050$) than pigs maintained on the high-fat, high-fiber diet throughout. Regardless of dietary treatment, pigs fed RAC had improved ($P < 0.001$) ADG and G:F. Overall (d 0 to 73), pigs fed the corn-soybean meal diet throughout had greater ($P < 0.003$) ADG and G:F than those fed the high-fat, high-fiber withdrawal regimen or those fed the high-fat, high-fiber diets for the duration of the study. Pigs fed the withdrawal diet had greater ($P < 0.003$) ADG and ADFI but similar G:F to that of pigs fed high-fat, high-fiber diets throughout. Pigs fed RAC had increased ($P < 0.001$) ADG and G:F compared with those not fed RAC.

Table 4. Fatty acid analysis of dried distillers grains with solubles (DDGS) and wheat middlings (as-fed basis)

	Exp. 1		Exp. 2	
Item	DDGS	Wheat middlings	DDGS	Wheat middlings
Myristic acid (C14:0), %	0.05	0.11	0.06	0.10
Palmitic acid (C16:0), %	13.71	15.62	13.64	15.42
Palmitoleic acid (C16:1), %	0.17	0.21	0.16	0.19
Margaric acid (C17:0), %	0.15	0.28	0.14	0.29
Stearic acid (C18:0), %	2.16	1.02	2.08	1.14
Oleic acid (C18:1 *cis*-9), %	25.22	16.62	24.75	16.33
Vaccenic acid (C18:1n-7), %	1.23	1.53	1.22	1.40
Linoleic acid (C18:2n-6), %	54.06	56.74	54.59	56.87
α-Linolenic acid (C18:3n-3), %	1.53	4.20	1.58	4.26
Arachidic acid (C20:0), %	0.43	0.26	0.42	0.24
Gadoleic acid (C20:1), %	0.25	0.70	0.24	0.71
Eicosadienoic acid (C20:2), %	0.08	0.14	0.09	0.174
Arachidonic acid (C20:4n-6), %	0.04	0.06	0.04	0.06
Other fatty acids, %	0.87	2.58	1.00	2.79
Total SFA,[1]%	16.50	17.29	16.33	17.19
Total MUFA[2], %	27.11	19.25	26.55	18.83
Total PUFA[3], %	55.71	61.13	56.30	61.33
Total *trans* fatty acids,[4]%	0.08	ND	0.10	0.06
UFA:SFA ratio[5]	5.02	4.65	5.07	4.66
PUFA:SFA ratio[6]	3.38	3.54	3.45	3.57
Iodine value,[7] g/100g	120	124	120	124

[1]Total SFA = ([C8:0] + [C10:0] + [C12:0] + [C14:0] + [C16:0] + [C17:0] + [C18:0] + [C20:0] + [C22:0] + [C24:0]), brackets indicate concentration.

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

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

[4]Total *trans* fatty acids = ([C18:1 *trans*] + [C18:2 *trans*] + [C18:3 *trans*]), brackets indicate concentration.

[5]UFA: SFA = (total MUFA + total PUFA)/total SFA.

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

[7]Calculated as IV value (IV) = [C16:1] × 0.9502 + [C18:1] × 0.8598 + [C18:2] × 1.7315 + [C18:3] × 2.6152 + [C20:1] × 0.7852 + [C20:4] × 3.2008; brackets indicate concentration.

Carcass Characteristics

Pigs that remained on high-fat, high-fiber diets throughout had decreased ($P < 0.003$) final BW compared with those maintained on the corn-soybean meal diets throughout or switched from high-fat, high-fiber to the corn-soybean meal diet (Table 5). Of the pigs slaughtered at K-State, those fed corn-soybean meal-based diets for the duration of the study or withdrawal diets had greater ($P <$ 0.009 and 0.059, respectively) HCW than pigs fed high-fat, high-fiber diets throughout. Pigs fed either the corn-soybean meal-based diet throughout or those withdrawn from the high-fat, high-fiber diets also had increased ($P <$ 0.030) carcass yield compared with those that remained on high-fat, high-fiber diets for the entire study.

Of the pigs slaughtered at the commercial packing plant, those fed high-fat, high-fiber diets throughout had decreased ($P < 0.001$) carcass yield and HCW compared with pigs fed corn-soybean meal diets for the entire study, whereas pigs that were switched from high-fat, high-fiber to corn-soybean meal diets on d 49 were intermediate ($P < 0.001$) for carcass yield. However, HCW was not different among pigs either maintained on the corn-soybean meal diets throughout the study or switched at d 49 from the high-fat, high-fiber diet to the corn-soybean meal diet.

For pigs slaughtered at the K-State Meats Lab, those fed RAC had increased ($P < 0.002$) carcass yield and tended ($P < 0.061$) to have increased HCW compared with pigs that were not fed RAC. No differences were observed in 10th-rib fat depth or LM area among the different dietary regimens; however, RAC tended to decrease ($P < 0.104$) backfat. In pigs slaughtered at the commercial packing plant, those fed RAC had increased ($P < 0.001$) HCW and carcass yield.

Intestine and Organ Weights

No differences were observed in intestine and organ weights between pigs that were fed corn-soybean meal diets for the duration of the study and pigs switched to the corn-soybean meal from the high-fat, high-fiber diet at d 49 (Table 6); however, pigs that remained on the high-fat, high-fiber diets throughout the study had increased ($P <$ 0.050) full cecum weights compared with the pigs the corn-soybean meal diets throughout. Pigs that remained on the high-fat, high-fiber diets throughout the study had decreased ($P < 0.003$) full or rinsed large intestine weights compared with the pigs the corn-soybean meal diets throughout and those fed withdrawal diet. Pigs fed RAC had decreased ($P < 0.005$) rinsed stomach weight and tended to have decreased ($P = 0.07$) full stomach weight compared with pigs that were not fed RAC. Leaf fat was decreased ($P < 0.050$) in pigs fed the high-fat, high-fiber diets throughout compared with those fed either the corn-soybean meal diet with those switched from the high-fat, high-fiber to the corn-soybean meal diet intermediate.

Carcass Fatty Acid Composition

In jowl fat samples, regardless of the harvesting facility, palmitic (C16:0), stearic (C18:0), and oleic (C18:1 *cis*-9) acid concentrations were increased ($P < 0.050$) in pigs fed corn-soybean meal-based diets compared with those fed high-fat, high-fiber diets until marketing, with those fed withdrawal diets being intermediate in concentration (Tables 7 and 8). Pigs fed high-fat, high-fiber-based diets had increased ($P < 0.05$) linoleic (C18:2n-6), acid concentrations compared with those fed the corn-soybean meal diets with those fed the withdrawal diets intermediate. Therefore, IV was lowest ($P < 0.001$) for pigs fed the corn-soybean meal diet throughout and highest for those fed high-fat, high-fiber throughout, with those on the withdrawal regimen intermediate.

Table 5. Effects of fat and fiber withdrawal without or with ractopamine HCl (RAC[1]) on growth performance and carcass characteristics[2]

	Treatment							Probability, $P <$				
	A	B	C	D	E	F		d 0 to 49	d 49 to 73 and d 0 to 73			
d 0 to 49 diet:	Corn-soy	Corn-soy	High-fat, high fiber	High-fat, high fiber	High-fat, high fiber	High-fat, high fiber		Corn-soy vs. High-fat, high fiber[3]	Corn-soy vs. high-fat, high fiber withdrawal[4]	Corn-soy vs. high-fat, high fiber[5]	High-fat, high-fiber withdrawal vs. high-fat, high fiber[6]	RAC vs. no RAC[7]
d 49 to 73 diet:	Corn-soy	Corn-soy	Corn-soy	Corn-soy	High-fat, high fiber	High-fat, high fiber						
Item RAC:	-	+	-	+	-	+	SEM					
d 0 to 49												
ADG, kg	1.02	1.01	0.96	0.96	0.95	0.96	0.04	0.001	–	–	–	–
ADFI, kg	2.79	2.75	2.72	2.77	2.69	2.68	0.05	0.129	–	–	–	–
G:F	0.365	0.366	0.352	0.347	0.354	0.358	0.009	0.001	–	–	–	–
d 49 to 73												
ADG, kg	0.91	1.09	0.92	1.12	0.86	0.99	0.09	–	0.460	0.016	0.002	0.001
ADFI, kg	3.15	3.04	3.31	3.25	3.17	3.11	0.14	–	0.002	0.435	0.018	0.109
G:F	0.286	0.358	0.278	0.343	0.271	0.317	0.016	–	0.218	0.001	0.014	0.001
d 0 to 73												
ADG, kg	0.98	1.03	0.95	1.01	0.92	0.97	0.05	–	0.033	0.001	0.014	0.001
ADFI, kg	2.91	2.84	2.91	2.92	2.84	2.82	0.07	–	0.235	0.279	0.025	0.420
G:F	0.337	0.364	0.325	0.346	0.324	0.343	0.011	–	0.001	0.001	0.635	0.001
BW, kg												
d 0	55.7	55.7	55.8	55.8	56.0	56.0	2.8	0.734	0.841	0.698	0.851	0.993
d 49	105.4	105.1	103.0	102.9	102.7	102.9	1.5	0.009	0.027	0.020	0.892	0.910
d 73	126.8	130.5	125.2	129.3	122.9	126.3	1.8	–	0.235	0.001	0.026	0.001
Carcass traits												
HCW,[8] kg	100.9	102.6	99.0	100.3	91.0	99.2	2.4	–	0.402	0.009	0.059	0.061
Carcass yield,[8] %	73.26	75.13	73.31	74.98	71.91	73.96	0.54	–	0.920	0.025	0.031	0.002
Average backfat,[8] mm	25.5	19.7	19.9	17.9	20.0	17.7	1.9	–	0.189	0.227	0.978	0.104
Loin eye area,[8] cm	49.53	51.94	51.55	55.55	51.35	50.97	0.75	–	0.148	0.841	0.239	0.231
HCW,[9] kg	92.2	97.8	91.4	95.6	88.5	91.4	1.3	–	0.222	0.001	0.005	0.001
Carcass yield,[9] %	74.22	75.13	73.73	74.58	72.77	73.61	0.19	–	0.006	0.001	0.001	0.001

[1] Paylean; Elanco Animal Health, Greenfield, IN.

[2] A total of 575 pigs (PIC 327 × 1050: PIC Hendersonville, TN; initial BW = 55.8 ± 5.5 kg) were used in 2 consecutive studies (73 and 72 d, respectively). There were 8 pigs per pen and 12 replications per treatment. There were no fiber withdrawal × RAC interactions.

[3] Treatments A, B vs. C, D, E, F.

[4] Treatments A, B vs. C, D.

[5] Treatments A, B vs. E, F.

[6] Treatments C, D vs. E, F.

[7] Treatments A, C, E vs. B, D, F.

[8] Values represent 36 barrows (6 observations per treatment) selected for harvest at the Kansas State University Meat Lab, Manhattan, KS (Exp. 1).

[9] Values represent 283 pigs that were shipped approximately 2 h to Farmland Foods, Crete, NE (Exp. 2).

There were no differences in fatty acid profile or IV among pigs fed without or with RAC slaughtered at the K-State Meats Lab (Table 7). In pigs slaughtered at the commercial packing plant, those fed RAC had decreased ($P < 0.050$) palmitic (C16:0), and stearic (C18:0), acid concentrations but increased linoleic (C18:2n-6) acid than those not fed RAC (Table 8). This resulted in pigs fed RAC having greater ($P < 0.011$) IV than those not fed RAC.

In backfat, concentrations of palmitic (C16:0) acid were greater ($P < 0.050$) in pigs fed the corn-soybean meal diets throughout compared with those fed high-fat, high-fiber diets throughout, or withdrawal pigs who were not different from the high-fat, high-fiber throughout (Table 9). Stearic acid concentrations were not affected by dietary regimen. In pigs fed corn-soybean meal throughout, oleic acid was increased ($P < 0.003$) and linoleic acid was decreased ($P < 0.01$) compared with those fed high-fat, high-fiber throughout, with those fed the withdrawal regimen intermediate in concentration. Iodine value was decreased ($P < 0.015$) in pigs fed corn-soybean meal throughout, greatest in pigs fed high-fat, high-fiber throughout, and the withdrawal regimen intermediate. Pigs fed RAC tended ($P < 0.100$) to have decreased stearic acid and increased linoleic acid that resulted in increased ($P < 0.004$) IV compared to pigs not fed RAC.

In belly fat samples from pigs that were harvested at K-State, palmitic and stearic acid concentrations

Table 6. Effects of fat and fiber withdrawal without or with ractopamine HC1 (RAC[1]) on intestine and organ weights (Exp. 1)[2]

	Treatment							Probability, P <			
	A	B	C	D	E	F					
d 0 to 49 diet: d 49 to 73 diet:	Corn-soy Corn-soy	Corn-soy Corn-soy	High-fat, high fiber Corn-soy	High-fat, high fiber Corn-soy	High-fat, high fiber High-fat, high fiber	High-fat, high fiber High-fat, high fiber		Corn-soy vs. high-fat, high fiber withdrawal[3]	Corn-soy vs. high-fat, high fiber[4]	High-fat, high fiber withdrawal vs. high-fat, high fiber[5]	RAC vs. no RAC[6]
Item RAC:	-	+	-	+	-	+	SEM				
Whole intestine	8.17	8.69	8.26	8.68	9.26	8.92	0.45	0.924	0.155	0.184	0.592
Stomach											
Full	1.04	1.14	1.29	0.90	1.21	1.00	0.11	0.973	0.891	0.918	0.066
Rinsed	0.72	0.70	0.75	0.67	0.78	0.70	0.02	0.803	0.164	0.249	0.005
Cecum											
Full	0.63	0.69	0.79	0.73	0.78	0.92	0.09	0.299	0.049	0.328	0.558
Rinsed	0.33	0.34	0.36	0.34	0.30	0.31	0.02	0.452	0.092	0.018	0.725
Large intestine											
Full	4.38	4.30	4.24	4.64	5.41	5.36	0.29	0.739	0.001	0.003	0.699
Rinsed	2.01	1.90	1.96	2.00	1.89	1.99	0.09	0.757	0.869	0.636	0.893
Small intestine											
Full	3.37	3.59	3.47	3.37	3.64	3.09	0.22	0.768	0.585	0.801	0.425
Heart	0.46	0.43	0.45	0.42	0.42	0.45	0.02	0.703	0.703	1.000	0.586
Liver	2.05	1.96	2.08	2.13	2.12	2.11	0.07	0.151	0.137	0.957	0.774
Kidneys	0.47	0.47	0.47	0.45	0.46	0.51	0.02	0.740	0.408	0.250	0.381
Leaf fat	1.80	1.74	1.61	1.46	1.40	1.29	0.17	0.171	0.015	0.254	0.433

[1]Paylean; Elanco Animal Health, Greenfield, IN.
[2]Values represent 36 barrows (6 pigs per treatment) selected for harvest at the Kansas State University Meat Lab, Manhattan, KS. There were no fiber withdrawal × RAC interactions.
[3]Treatments A, B vs. C, D.
[4]Treatments A, B vs. E, F.
[5]Treatments C, D vs. E, F.
[6]Treatments A, C, E vs. B, D, F.

Table 7. Effects of fat and fiber withdrawal without or with ractopamine HCl (RAC[1]) on fatty acid analysis of jowl fat samples (Exp. 1)[2]

	Treatment							Probability, P <			
	A	B	C	D	E	F					
d 0 to 49 diet: d 49 to 73 diet:	Corn-soy Corn-soy	Corn-soy Corn-soy	High-fat, high- fiber Corn-soy	High-fat, high- fiber Corn-soy	High-fat, high-fiber High-fat, high- fiber	High-fat, high-fiber High-fat, high- fiber		Corn-soy vs. high-fat, high fiber withdrawal[3]	Corn-soy vs. high-fat, high-fiber[4]	High-fat, high-fiber withdrawal vs. high-fat, high fiber[5]	RAC vs. no RAC[6]
Item RAC:	-	+	-	+	-	+	SEM				
Myristic acid (C14:0), %	1.37	1.34	1.40	1.31	1.30	1.33	0.04	0.979	0.292	0.315	0.321
Palmitic acid (C16:0), %	23.10	23.24	22.21	21.81	21.31	21.23	0.32	0.001	0.001	0.020	0.643
Palmitoleic acid (C16:1), %	3.55	3.70	3.48	3.17	3.26	3.10	0.13	0.020	0.001	0.230	0.281
Stearic acid (C18:0), %	9.20	9.28	8.87	8.97	8.49	8.63	0.25	0.185	0.006	0.141	0.592
Oleic acid (C18:1 *cis*-9), %	48.50	48.59	45.24	45.67	44.02	42.74	0.79	0.001	0.001	0.009	0.675
Vaccenic acid (C18:1n-7), %	0.23	0.18	0.20	0.24	0.20	0.20	0.04	0.649	0.841	0.515	0.929
Linoleic acid (C18:2n-6), %	10.31	9.64	14.24	14.54	16.56	17.63	0.67	0.001	0.001	0.001	0.649
α-Linolenic acid (C18:3n-3), %	0.46	0.52	0.61	0.60	0.70	0.76	0.03	0.001	0.001	0.001	0.108
Arachidic acid (C20:0), %	0.21	0.21	0.17	0.20	.021	0.24	0.02	0.317	0.392	0.072	0.157
Gadoleic acid (C20:1), %	1.03	0.97	0.87	1.02	0.91	0.97	0.06	0.340	0.289	0.934	0.300
Eicosadienoic acid (C20:2), %	0.53	0.49	0.66	0.77	0.77	0.84	0.04	0.001	0.001	0.018	0.125
Arachidonic acid (C20:4n-6), %	0.20	0.22	0.25	0.26	0.26	0.29	0.02	0.143	0.001	0.032	0.587
Other fatty acids, %	1.33	1.64	1.81	2.01	2.01	2.05	0.23	0.469	0.016	0.089	0.968
Iodine value,[7] g/100g	65.76	64.97	70.09	70.74	73.18	74.06	0.82	0.001	0.001	0.001	0.736

[1]Paylean; Elanco Animal Health, Greenfield, IN.
[2]Values represent 36 barrows (6 per treatment) selected for harvest at the Kansas State University Meat Lab, Manhattan, KS. There were no fiber withdrawal × RAC interactions.
[3]Treatments A, B vs. C, D.
[4]Treatments A, B vs. E, F.
[5]Treatments C, D vs. E, F.
[6]Treatments A, C, E vs. B, D, F.
[7]Calculated as IV value (IV) = [C16:1] × 0.9502 + [C18:1] × 0.8598 + [C18:2] × 1.7315 + [C18:3] × 2.6152 + [C20:1] × 0.7852 + [C20:4] × 3.2008; brackets indicate concentration.

Table 8. Effects of fat and fiber withdrawal without or with ractopamine HCl (RAC[1]) on fatty acid analysis of jowl fat samples (Exp. 2)[2]

	Treatment							Probability, $P <$			
	A	B	C	D	E	F					
d 0 to 49 diet:	Corn-soy	Corn-soy	High-fat, high- fiber	High-fat, high- fiber	High-fat, high- fiber	High-fat, high- fiber		Corn-soy vs. high-fat, high- fiber withdrawal[3]	Corn-soy vs. high-fat, high-fiber[4]	High-fat, high-fiber withdrawal vs. high-fat, high- fiber[5]	RAC vs. no RAC[6]
d 49 to 73 diet:	Corn-soy	Corn-soy	Corn-soy	Corn-soy	High-fat, high- fiber	High-fat, high- fiber					
Item RAC:	-	+	-	+	-	+	SEM				
Myristic acid (C14:0), %	1.35	1.31	1.30	1.29	1.28	1.28	0.02	0.067	0.001	0.427	0.372
Palmitic acid (C16:0), %	23.35	22.83	22.09	21.90	21.48	21.57	0.15	0.001	0.001	0.001	0.001
Palmitoleic acid (C16:1), %	3.67	3.58	3.51	3.44	3.30	3.40	0.08	0.051	0.001	0.098	0.747
Stearic acid (C18:0), %	9.72	9.57	9.05	8.79	8.82	8.56	0.13	0.001	0.001	0.071	0.034
Oleic acid (C18:1 *cis*-9), %	48.27	48.20	46.30	45.79	45.85	45.56	0.25	0.001	0.001	0.144	0.126
Vaccenic acid (C18:1n-7), %	0.59	0.56	0.52	0.56	0.51	0.47	0.02	0.141	0.001	0.030	0.681
Linoleic acid (C18:2n-6), %	9.25	9.78	12.84	13.58	14.25	14.38	0.26	0.001	0.001	0.001	0.018
α-Linolenic acid (C18:3n-3), %	0.49	0.53	0.59	0.65	0.63	0.66	0.02	0.001	0.001	0.074	0.001
Arachidic acid (C20:0), %	0.22	0.22	0.21	0.22	0.20	0.21	0.01	0.658	0.308	0.580	0.268
Gadoleic acid (C20:1), %	0.93	0.97	0.93	0.95	0.95	0.99	0.02	0.455	0.118	0.023	0.007
Eicosadienoic acid (C20:2), %	0.47	0.52	0.64	0.70	0.73	0.76	0.02	0.001	0.001	0.001	0.001
Arachidonic acid (C20:4n-6), %	0.30	0.32	0.35	0.38	0.36	0.36	0.01	0.001	0.001	0.887	0.082
Other fatty acids, %	1.41	1.59	1.68	1.76	1.64	1.80	0.06	0.001	0.001	0.992	0.002
Iodine value,[7] g/100g	63.52	64.44	68.10	69.08	70.08	70.23	0.35	0.001	0.001	0.001	0.011

[1]Paylean; Elanco Animal Health, Greenfield, IN.

[2]Values represent 283 pigs that were shipped approximately 2 h to Farmland Foods, Crete, NE. There were no fiber withdrawal × RAC interactions.

[3]Treatments A, B vs. C, D.

[4]Treatments A, B vs. E, F.

[5]Treatments C, D vs. E, F.

[6]Treatments A, C, E vs. B, D, F.

[7]Calculated as IV value (IV) = [C16:1] × 0.9502 + [C18:1] × 0.8598 + [C18:2] × 1.7315 + [C18:3] × 2.6152 + [C20:1] × 0.7852 + [C20:4] × 3.2008; brackets indicate concentration.

decreased ($P < 0.053$) in pigs fed high-fat, high-fiber diets compared with those fed either the corn-soybean meal or withdrawal diets, although pigs fed corn-soybean meal–based diets were not different than those fed withdrawal diets (Table 10). Oleic acid concentrations, however, were greater ($P < 0.023$) in pigs fed corn-soybean meal–based diets compared with those fed withdrawal- and high-fat, high-fiber diets, although pigs fed withdrawal diets were not different than those fed high-fat, high-fiber diets.

In belly fat samples from pigs that were harvested at the commercial packing plant, palmitic, stearic, and oleic acid concentrations were increased ($P < 0.003$) in pigs fed corn-soybean meal diets for the duration of the study compared to those that were fed high-fat, high-fiber diets for the duration of the study, with withdrawal pigs having intermediate fatty acid concentrations (Table 11). Linoleic acid concentrations and IV were greater in pigs fed high-fat, high-fiber diets throughout compared with those fed corn-soybean meal throughout, with those fed the withdrawal regimen intermediate. In pigs fed RAC, linoleic acid concentrations and IV were increased ($P < 0.05$) compared with those not fed RAC.

In leaf fat, concentrations of palmitic and stearic acid were greater ($P < 0.002$) in pigs fed corn-soybean meal diets throughout and those fed withdrawal diets compared with those fed high-fat, high-fiber diets throughout (Table 12). Oleic acid was greatest in in pigs fed corn-soybean meal throughout than those fed high-fat, high-fiber throughout, with those fed the withdrawal regimen intermediate. Also in leaf fat samples, linoleic acid concentrations and IV were decreased ($P < 0.003$) in pigs fed corn-soybean meal-based diets throughout compared with those fed high-fat, high-fiber diets, with withdrawal pigs intermediate. There were no differences in leaf fat IV among pigs fed without or with RAC.

DISCUSSION

In general, the proximate analysis and fatty acid values of DDGS and wheat midds used in this trial were similar to values reported in the NRC (2012). Bulk densities of high-fat, high-fiber test diets were similar to values reported by Asmus et al. (2014), who fed DDGS and wheat midds at the same inclusion levels as the current study. The high-fat, high-fiber regimen used by Asmus et al. (2014) has been used as a model to test the effects of unsaturated fat and fiber (30% DDGS and 19% wheat midds) withdrawal before harvest on HCW and carcass yield. Similar to the results of Asmus et al. (2014), the feeding strategy employed herein was successful in creating these differences in HCW and yield.

Table 9. Effects of fat and fiber withdrawal without or with ractopamine HCl (RAC[1]) on fatty acid analysis of backfat samples (Exp. 1)[2]

	Treatment										
	A	B	C	D	E	F		Probability, $P <$			
d 0 to 49 diet:	Corn-soy	Corn-soy	High-fat, high- fiber	High-fat, high- fiber	High-fat, high-fiber	High-fat, high-fiber		Corn-soy vs. high-fat, high- fiber withdrawal[3]	Corn-soy vs. high-fat, high-fiber[4]	High fiber withdrawal vs. high-fat, high- fiber[5]	RAC vs. no RAC[6]
d 49 to 73 diet:	Corn-soy	Corn-soy	Corn-soy	Corn-soy	High-fat, high- fiber	High-fat, high- fiber					
Item RAC:	-	+	-	+	-	+	SEM				
Myristic acid (C14:0), %	1.37	1.35	1.39	1.27	1.34	1.22	0.06	0.573	0.180	0.434	0.095
Palmitic acid (C16:0), %	23.87	23.28	22.62	21.99	22.07	20.93	0.59	0.040	0.001	0.179	0.111
Palmitoleic acid (C16:1), %	2.87	3.03	2.68	2.49	2.45	2.34	0.12	0.005	0.001	0.128	0.648
Stearic acid (C18:0), %	10.86	9.92	10.15	9.64	10.10	9.04	0.60	0.410	0.171	0.586	0.093
Oleic acid (C18:1 *cis*-9), %	45.84	45.64	41.10	42.36	39.02	39.31	0.79	0.001	0.001	0.003	0.486
Vaccenic acid (C18:1n-7), %	0.21	0.21	0.28	0.04	0.13	0.14	0.06	0.350	0.193	0.719	0.091
Linoleic acid (C18:2n-6), %	11.23	12.56	17.11	17.92	20.25	22.07	0.82	0.001	0.001	0.001	0.053
α-Linolenic acid (C18:3n-3), %	0.53	0.63	0.72	0.76	0.77	0.85	0.04	0.001	0.001	0.095	0.025
Arachidic acid (C20:0), %	0.25	0.23	0.27	0.15	0.25	0.24	0.05	0.550	0.816	0.402	0.205
Gadoleic acid (C20:1), %	0.92	0.87	0.79	0.91	0.79	0.80	0.05	0.288	0.036	0.281	0.463
Eicosadienoic acid (C20:2), %	0.50	0.56	0.69	0.75	0.79	0.86	0.04	0.001	0.001	0.022	0.086
Arachidonic acid (C20:4n-6), %	0.21	0.34	0.36	0.28	0.34	0.37	0.05	0.353	0.097	0.458	0.476
Other fatty acids, %	1.34	1.38	1.86	1.45	1.70	1.84	0.18	0.123	0.033	0.538	0.609
Iodine value,[7] g/100g	64.54	67.47	71.39	73.45	74.77	78.37	1.65	0.001	0.001	0.015	0.039

[1]Paylean; Elanco Animal Health, Greenfield, IN.

[2]Values represent 36 barrows (6 per treatment) selected for harvest at the Kansas State University Meat Lab, Manhattan, KS. There were no fiber withdrawal × RAC interactions.

[3]Treatments A, B vs. C, D.

[4]Treatments A, B vs. E, F.

[5]Treatments C, D vs. E, F.

[6]Treatments A, C, E vs. B, D, F.

[7]Calculated as IV value (IV) = [C16:1] × 0.9502 + [C18:1] × 0.8598 + [C18:2] × 1.7315 + [C18:3] × 2.6152 + [C20:1] × 0.7852 + [C20:4] × 3.2008; brackets indicate concentration.

Stein and Shurson (2009) reviewed several studies and determined that feeding of corn DDGS (>9% oil) in swine finisher diets at levels of up to 30% will not result in decreased growth performance. In support of this finding, Jacela et al. (2010) fed 30% DDGS and observed no decreases in growth performance, but saw a substantial increase in IV of pigs fed DDGS compared with those fed a control corn-soybean meal diet. Xu et al. (2010a) also determined that although feeding DDGS at levels of up to 30% will not have detrimental effects on growth performance, feeding DDGS at levels of greater than 20% will likely result in poorer carcass and fat quality. Slayer et al. (2012) conducted a study to determine if the fat provided in the diet from DDGS or wheat midds was additive in increasing IV; it was observed, again, that feeding 30% DDGS had no effect on growth criteria, but as 10 or 20% midds were included in diets containing 30% DDGS, growth performance and carcass characteristics reduced linearly. This response was probably as a result of the added fiber and low bulk density provided by the wheat midds. Based on the conclusions from that study, however, the negative effects on fat IV of adding wheat midds to diets containing DDGS were not additive. In another trial reported by Slayer et al. (2012), it was determined that pigs fed DDGS at a constant rate of 15% had increased IV compared with pigs fed 20% wheat midds. Furthermore, Asmus et al. (2014) and Nemechek et al. (2013) fed diets containing 30% DDGS and approximately 19 to 20% wheat midds. In all cases, IV increased substantially and carcass yield decreased with the use of high-fat, high-fiber ingredients. Therefore, these diets were used as a model in the current study to investigate ways to mitigate the decreased yield and IV level that is unacceptable for some pork processors.

Similar to findings by Asmus et al. (2014), carcass yield in the present study was either fully (for pigs slaughtered at K-State Meats Lab) or partially (for pigs slaughtered at the commercial packing plant) recovered by feeding a withdrawal diet for the last 3 wk before marketing. On the other hand, Gaines et al. (2007), did not observed fully recovered carcass yield from pigs withdrawn from high-fiber diets for the last 3 wk but did see fully recovered carcass yield when pigs were withdrawn from high-fiber diets for 6 wk. Xu et al. (2010b) reported that regardless of fiber level or when pigs were withdrawn to corn-soybean meal control diets, carcass yields did not differ. Similarly, Jacela et al. (2010), observed that feeding duration and withdrawal strategies had no effects on HCW or carcass yield; however, the

Table 10. Effects of fat and fiber withdrawal without or with ractopamine HCl (RAC[1]) on fatty acid analysis of belly fat samples (Exp. 1)[2]

	Treatment							Probability, $P <$			
	A	B	C	D	E	F					
d 0 to 49 diet:	Corn-soy	Corn-soy	High-fat, high-fiber	High-fat, high- fiber	High-fat, high-fiber	High-fat, high-fiber					
d 49 to 73 diet:	Corn-soy	Corn-soy	Corn-soy	Corn-soy	High-fat, high-fiber	High-fat, high-fiber		Corn-soy vs. high-fat, high- fiber withdrawal[3]	Corn-soy vs. high-fat, high-fiber[4]	High-fat, high-fiber withdrawal vs. high-fat, high- fiber[5]	RAC vs. no RAC[6]
Item RAC:	-	+	-	+	-	+	SEM				
Myristic acid (C14:0), %	1.52	1.46	1.51	1.41	1.41	1.39	0.06	0.642	0.122	0.271	0.184
Palmitic acid (C16:0), %	25.60	25.21	24.71	24.25	22.63	22.09	0.62	0.150	0.001	0.002	0.368
Palmitoleic acid (C16:1), %	3.34	3.34	3.03	2.67	3.12	2.91	0.22	0.035	0.149	0.471	0.303
Stearic acid (C18:0), %	12.36	11.80	11.75	12.59	9.67	9.75	1.17	0.937	0.053	0.045	0.903
Oleic acid (C18:1 *cis*-9), %	45.08	44.11	41.55	40.08	41.54	39.75	1.58	0.023	0.018	0.915	0.281
Vaccenic acid (C18:1n-7), %	0.26	0.24	0.20	0.19	0.20	0.19	0.03	0.057	0.064	0.954	0.572
Linoleic acid (C18:2n-6), %	8.41	10.27	13.54	14.42	16.96	19.30	0.64	0.001	0.001	0.001	0.003
α-Linolenic acid (C18:3n-3), %	0.43	0.53	0.58	0.67	0.71	0.77	0.03	0.001	0.001	0.001	0.001
Arachidic acid (C20:0), %	0.25	0.23	0.23	0.32	0.25	0.22	0.02	0.116	0.892	0.090	0.391
Gadoleic acid (C20:1), %	0.81	0.79	0.73	0.84	0.78	0.76	0.06	0.758	0.538	0.758	0.658
Eicosadienoic acid (C20:2), %	0.38	0.44	0.51	0.62	0.68	0.75	0.04	0.001	0.001	0.001	0.008
Arachidonic acid (C20:4n-6), %	0.18	0.22	0.23	0.24	0.27	0.31	0.01	0.025	0.001	0.001	0.012
Other fatty acids, %	1.40	1.37	1.43	1.71	1.78	1.84	0.12	0.127	0.001	0.055	0.317
Iodine value,[7] g/100g	59.06	61.80	65.02	65.31	71.56	74.12	1.68	0.009	0.001	0.001	0.201

[1]Paylean; Elanco Animal Health, Greenfield, IN.

[2]Values represent 36 barrows (6 per treatment) selected for harvest at the Kansas State University Meat Lab, Manhattan, KS. There were no fiber withdrawal × RAC interactions.

[3]Treatments A, B vs. C, D.

[4]Treatments A, B vs. E, F.

[5]Treatments C, D vs. E, F.

[6]Treatments A, C, E vs. B, D, F.

[7]Calculated as IV value (IV) = [C16:1] × 0.9502 + [C18:1] × 0.8598 + [C18:2] × 1.7315 + [C18:3] × 2.6152 + [C20:1] × 0.7852 + [C20:4] × 3.2008; brackets indicate concentration.

large amount of variation in quality, digestibility, and degree of hind-gut fermentation of fiber content in DDGS sources may account for the differences reported among researchers (Urriola et al., 2010).

No differences in organ weights (heart, liver, kidneys) among treatments were observed in the current study, which agrees with research by Agyekum et al. (2012) but contradicts results by Asmus et al. (2014), who reported minor differences in kidney weights. Anugwa et al. (1989) reported increased liver and kidney weights in pigs fed high-fiber diets with excess CP, which was identified as a possible confounding factor. Of the intestinal weights measured (whole intestine, full and rinsed stomach, full and rinsed cecum, full and rinsed large intestine, and full small intestine), the increased full cecum and large intestine weights in the present study agree with the findings of Anugwa et al. (1989) and Asmus et al. (2014). In agreement with our results, Asmus et al. (2014) observed that as fiber reduction strategies are implemented, full cecum and large intestine weights will regress back to that of control-fed pigs.

Studies have determined that the rate of change in the fatty acid profile of adipose tissue in pigs changes as the dietary intake of particular fatty acids increases (Wood, 1984; Teye et al., 2006; Wood et al., 2008). Research by Jacela et al. (2010) and Asmus et al. (2014) evaluated various unsaturated fat and fiber (provided by DDGS and wheat midds) withdrawal durations and the rate of change in fatty acid profile. Jacela et al. (2010) used diets containing 15 and 30% DDGS that were withdrawn at varying intervals to determine if improvements in backfat, belly, or jowl fat IV could be achieved before marketing relative to pigs fed either no DDGS or 30% DDGS for the entirety of the study. Asmus et al. (2014) again maintained control groups of pigs on control corn-soybean meal diets or with 30% DDGS and 19% wheat midds for the duration of the study. Other pigs were initially fed the high unsaturated fat, high-fiber diets and then reduced to a medium-fiber (15% DDGS, 9.5% midds) or low-fiber control diet (corn-soybean meal). Jacela et al. (2010) were able to determine that as DDGS withdrawal duration increases, IV for all fat depots will decrease. Asmus et al. (2014) reported that jowl IV decreased as low fat and fiber diets were fed for longer periods of time (23 to 47 d). Jacela et al. (2010) also observed that as DDGS withdrawal duration increases, IV for all fat depots decreases and indicated that jowl IV can be improved approximately 0.35 g/100 g per wk for every 10% DDGS withdrawn from the diet before marketing. In the current study, a similar decrease in IV

Table 11. Effects of fat and fiber withdrawal without or with ractopamine HCl (RAC[1]) on fatty acid analysis of belly fat samples (Exp. 2)[2]

	Treatment							Probability, $P <$			
	A	B	C	D	E	F					
d 0 to 49 diet:	Corn-soy	Corn-soy	High-fat, high-fiber	High-fat, high-fiber	High-fat, high-fiber	High-fat, high-fiber		Corn-soy vs. high-fat, high- fiber withdrawal[3]	Corn-soy vs. high-fat, high-fiber[4]	High-fat, high-fiber withdrawal vs. high-fat, high- fiber[5]	RAC vs. no RAC[6]
d 49 to 73 diet:	Corn-soy	Corn-soy	Corn-soy	Corn-soy	High-fat, high-fiber	High-fat, high-fiber					
Item RAC:	-	+	-	+	-	+	SEM				
Myristic acid (C14:0), %	1.43	1.39	1.38	1.38	1.35	1.37	0.02	0.123	0.003	0.174	0.862
Palmitic acid (C16:0), %	24.35	23.93	23.32	22.95	22.34	22.40	0.16	0.001	0.001	0.001	0.046
Palmitoleic acid (C16:1), %	3.60	3.57	3.46	3.45	3.15	3.24	0.07	0.038	0.001	0.001	0.766
Stearic acid (C18:0), %	10.74	10.64	10.16	9.75	9.76	9.55	0.14	0.001	0.001	0.022	0.027
Oleic acid (C18:1 *cis*-9), %	47.42	47.34	45.48	44.66	44.14	43.80	0.26	0.001	0.001	0.001	0.037
Vaccenic acid (C18:1n-7), %	0.60	0.59	0.55	0.55	0.52	0.53	0.02	0.003	0.001	0.072	0.989
Linoleic acid (C18:2n-6), %	8.61	9.07	12.01	13.21	14.74	14.98	0.27	0.001	0.001	0.001	0.002
α-Linolenic acid (C18:3n-3), %	0.43	0.49	0.53	0.62	0.62	0.64	0.01	0.001	0.001	0.001	0.001
Arachidic acid (C20:0), %	0.22	0.22	0.21	0.22	0.22	0.22	0.01	0.571	0.715	0.832	0.579
Gadoleic acid (C20:1), %	0.82	0.85	0.82	0.84	0.85	0.87	0.01	0.808	0.019	0.039	0.025
Eicosadienoic acid (C20:2), %	0.38	0.41	0.52	0.58	0.64	0.66	0.01	0.001	0.001	0.001	0.001
Arachidonic acid (C20:4n-6), %	0.29	0.30	0.32	0.36	0.36	0.38	0.01	0.001	0.001	0.001	0.008
Other fatty acids, %	1.12	1.20	1.22	1.42	1.31	1.38	0.05	0.002	0.001	0.658	0.004
Iodine value,[7] g/100g	61.39	62.27	65.72	67.32	69.22	69.48	0.38	0.001	0.001	0.001	0.002

[1]Paylean; Elanco Animal Health, Greenfield, IN.

[2]Values represent 283 pigs that were shipped approximately 2 h to Farmland Foods, Crete, NE. There were no fiber withdrawal × RAC interactions.

[3]Treatments A, B vs. C, D.

[4]Treatments A, B vs. E, F.

[5]Treatments C, D vs. E, F.

[6]Treatments A, C, E vs. B, D, F.

[7]Calculated as IV value (IV) = [C16:1] × 0.9502 + [C18:1] × 0.8598 + [C18:2] × 1.7315 + [C18:3] × 2.6152 + [C20:1] × 0.7852 + [C20:4] × 3.2008; brackets indicate concentration.

of jowl fat was observed for pigs fed RAC (0.32 g/100 g per wk), or in pigs not fed RAC (0.30 g/100 g per wk), which agrees with the findings of Asmus et al. (2014) and Bergstrom et al. (2011). In the present study, it was observed that with a 24-d withdrawal, IV for all fat depots decreased, but complete mitigation of negative effects on fat quality was not achieved. These results agree with the findings of Jacela et al. (2010) and Asmus et al. (2014), who both reported IV that was still greater than that of pigs fed a control corn-soybean meal–based diet when a high unsaturated fat source such as DDGS were removed from the diet for up to 6 wk before marketing.

The current study also agrees with research by Benz et al. (2010), who also saw linearly increased IV in backfat, jowl, and belly fat depots with increasing DDGS. Similar to the study herein, they found that concentrations of C18:2n-6 and PUFA were linearly increased in all 3 fat depots, and C18:1 *cis*-9 and MUFA concentrations decreased linearly as DDGS increased (Benz et al., 2010). The rate of change in IV of different fat depots also has been determined to vary due to differences in turnover rates (Benz et al., 2010; Xu et al., 2010a). Research by Jacela et al. (2010), Benz et al. (2010), and Bergstrom et al. (2011) support the variable rate of change among fat depots, with backfat IV changing most rapidly and jowl IV changing at the slowest rate. The same trend was evident in the current study, with backfat and belly fat IV changing more than jowl fat IV as DDGS were fed in the diet; however, the change in IV in the leaf fat depot appeared to be even greater than that of the backfat depot.

These differences in fatty acid profile and IV among the different fat depots evaluated may be related to the relative time the adipocytes fill. For example, jowl fat is deposited relatively early and thus was more affected by the high-fat, high-fiber diet fed from d 0 to 49. On the other hand, leaf, belly, and backfat depots are deposited relatively late and therefore the withdrawal period would likely influence their fatty acid composition to a greater extent than jowl fat (Wiegand et al., 2011).

Ractopamine HCl is a phenethanolamine β-adrenergic agonist that is used in swine finishing diets before marketing because it is known to repartition nutrients from fat deposition to increased protein synthesis and muscle gain (Apple et al., 2007). Although the response to RAC is well established, it was the initial hypothesis of the current study that RAC might have an interactive effect when used with high-fiber diets in the finisher phase, because RAC is known to increase carcass yield and high-fat, high-fiber diets have been shown to decrease carcass yield. However, an interactive response was not observed. Feeding RAC increased carcass yield regardless of withdrawal regimen.

Table 12. Effects of fat and fiber withdrawal without or with ractopamine HCl (RAC[1]) on fatty acid analysis of leaf fat samples (Exp. 1)[2]

	Treatment							Probability, $P <$			
	A	B	C	D	E	F					
d 0 to 49 diet: / d 49 to 73 diet:	Corn-soy Corn-soy	Corn-soy Corn-soy	High-fat, high-fiber Corn-soy	High-fat, high-fiber Corn-soy	High-fat, high-fiber High-fat, high-fiber	High-fat, high-fiber High-fat, high-fiber		Corn-soy vs. high-fat, high- fiber withdrawal[3]	Corn-soy vs. high-fat, high-fiber [4]	High-fat, high-fiber withdrawal vs. high-fat, high fiber[5]	RAC vs. no RAC[6]
Item RAC:	-	+	-	+	-	+	SEM				
Myristic acid (C14:0), %	1.45	1.41	1.60	1.45	1.39	1.45	0.07	0.137	0.853	0.106	0.426
Palmitic acid (C16:0), %	27.96	27.83	27.96	26.70	25.25	24.62	0.51	0.226	0.001	0.001	0.087
Palmitoleic acid (C16:1), %	2.32	2.25	2.12	2.07	2.00	1.90	0.13	0.126	0.012	0.242	0.481
Stearic acid (C18:0), %	18.01	18.18	17.37	16.90	15.72	14.29	0.69	0.130	0.001	0.003	0.269
Oleic acid (C18:1 *cis*-9), %	38.77	38.66	34.95	36.41	33.51	33.59	1.00	0.003	0.001	0.030	0.524
Vaccenic acid (C18:1n-7), %	0.18	0.17	0.16	0.18	0.16	1.15	0.01	0.744	0.168	0.281	0.857
Linoleic acid (C18:2n-6), %	8.46	8.53	12.57	12.83	18.02	19.80	0.79	0.001	0.001	0.001	0.243
α-Linolenic acid (C18:3n-3), %	0.35	0.40	0.49	0.48	0.64	0.73	0.03	0.002	0.001	0.001	0.108
Arachidic acid (C20:0), %	0.26	0.29	0.27	0.28	0.35	0.26	0.04	0.931	0.436	0.389	0.505
Gadoleic acid (C20:1), %	0.67	0.69	0.63	0.72	0.60	0.64	0.05	0.886	0.223	0.278	0.237
Eicosadienoic acid (C20:2), %	0.37	0.36	0.42	0.50	0.54	0.65	0.02	0.001	0.001	0.001	0.002
Arachidonic acid (C20:4n-6), %	0.11	0.15	0.16	0.14	0.24	0.27	0.02	0.304	0.001	0.001	0.415
Other fatty acids, %	1.09	1.07	1.30	1.34	1.59	1.66	0.13	0.055	0.001	0.021	0.751
Iodine value,[7] g/100g	52.14	52.35	56.23	57.90	64.96	68.35	1.48	0.001	0.001	0.001	0.122

[1]Paylean; Elanco Animal Health, Greenfield, IN.

[2]Values represent 36 barrows (6 per treatment) selected for harvest at the Kansas State University Meat Lab, Manhattan, KS. There were no fiber withdrawal × RAC interactions

[3]Treatments A, B vs. C, D.

[4]Treatments A, B vs. E, F.

[5]Treatments C, D vs. E, F.

[6]Treatments A, C, E vs. B, D, F.

[7]Calculated as IV value (IV) = [C16:1] × 0.9502 + [C18:1] × 0.8598 + [C18:2] × 1.7315 + [C18:3] × 2.6152 + [C20:1] × 0.7852 + [C20:4] × 3.2008; brackets indicate concentration.

Overall conclusions drawn in a review by Apple et al. (2007) were that RAC usage alters the fatty acid composition of subcutaneous fat, but no indication was reported that RAC usage would have an interactive effect when fed in conjunction with high-fat, high-fiber diets. Because of the increased rate of change in IV in the backfat depot (Bergstrom et al., 2011), it was suspected that RAC may have interactive effects with the fatty acid profile of the backfat depot because of its effects on reducing backfat depth. In the current study, however, IV was increased in the backfat depot of pigs harvested at K-State and in the belly and jowl fat depots of pigs harvested at the commercial packing facility with the use of RAC, but there were no interactive effects observed between RAC and high-fat, high-fiber diets.

In summary, pigs fed RAC had increased ADG and G:F as well as carcass yield, regardless of withdrawal regimen. Feeding high-unsaturated fat, high-fiber ingredients such as DDGS and wheat midds until marketing generally decreases growth performance, increases full intestine weight, decreases carcass yield, and increases carcass fat IV compared with pigs fed a corn-soybean meal diet. Withdrawal of high-unsaturated fat, high-fiber diets containing DDGS and wheat midds to corn-soybean meal diets in the weeks immediately before harvest will restore carcass yield to values similar to pigs fed corn-soybean meal-based diets but will only partially mitigate negative effects on carcass fat IV.

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