Effects of choice white grease and soybean oil on growth performance, carcass characteristics, and carcass fat quality of growing-finishing pigs

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Effects of choice white grease and soybean oil on growth performance, carcass characteristics, and carcass fat quality of growing-finishing pigs[1]

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ABSTRACT: A total of 144 barrows and gilts (initial BW = 44 kg) were used in an 82-d experiment to evaluate the effects of dietary fat source and duration of feeding fat on growth performance, carcass characteristics, and carcass fat quality. Dietary treatments were a corn-soybean meal control diet with no added fat and a 2 × 4 factorial arrangement of treatments with 5% choice white grease (CWG) or soybean oil (SBO) fed from d 0 to 26, 54, 68, or 82. At the conclusion of the study (d 82), pigs were slaughtered, carcass characteristics were measured, and backfat and jowl fat samples were collected. Fatty acid analysis was performed, and iodine value (IV) was calculated for all backfat and jowl fat samples. Pigs fed SBO tended to have increased ($P = 0.07$) ADG compared with pigs fed CWG. For pigs fed SBO, increasing feeding duration increased (quadratic, $P < 0.01$) ADG and G:F. For pigs fed CWG, increasing feeding duration improved (quadratic, $P < 0.01$) G:F. For pigs fed SBO or CWG, increasing feeding duration increased carcass yield (quadratic, $P < 0.04$) and HCW (quadratic, $P < 0.02$). Dietary fat source and feeding duration did not affect backfat depth, loin depth, or lean percentage. As expected, barrows had greater ADG and ADFI ($P < 0.01$) and poorer G:F ($P = 0.03$) than gilts. Barrows also had greater last-rib ($P = 0.04$) and 10th-rib backfat ($P < 0.01$) and reduced loin depth and lean percentage ($P < 0.01$) compared with gilts. Increasing feeding duration of CWG or SBO increased ($P < 0.10$) C18:2n-6, PUFA, PUFA:SFA ratio, and IV in jowl fat and backfat. Pigs fed SBO had greater ($P < 0.01$) C18:2n-6, PUFA, PUFA:SFA ratio, and IV but decreased ($P < 0.01$) C18:1 *cis*-9, C16:0, SFA, and MUFA concentrations compared with pigs fed CWG in jowl fat and backfat. Barrows had decreased ($P = 0.03$) IV in jowl fat and backfat compared with gilts. In summary, adding SBO or CWG increased the amount of unsaturated fat deposited. Increasing feeding duration of dietary fat increases the amount of unsaturated fatty acids, which leads to softer carcass fat.

Key words: carcass composition, dietary fat, growth, iodine value, swine

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INTRODUCTION

Added dietary fat improves ADG and G:F in growing-finishing pigs in research and commercial environments (Pettigrew and Moser, 1991; De la Llata et al., 2001). The composition of dietary fat also affects the fatty acid composition of the fat depots in pigs (Miller et al., 1990; Shackelford et al., 1990). Fatty acids absorbed from the diet, especially PUFA, specifically inhibit endogenous synthesis of fatty acids (Allee et al., 1971; Clarke et al., 1990). Therefore, it is possible to manipulate the composition of body fat quite dramatically through selection of dietary fats (Pettigrew and Esnaola, 2001).

Fatty acid composition of pork fat affects further processing characteristics and the ability of pork products to meet export specifications (Carr et al., 2005). Bacon from carcasses with soft fat has numerous problems, including slices sticking together, an oily appearance, separation of fat from lean during slicing, and an increased rate of oxidative rancidity (NPPC, 1999). Feeding dietary fats high in unsaturated fatty acids (**UFA**) may lead to reduced firmness of carcass fat (Rosenvold and Andersen, 2003).

Iodine value (**IV**) is an estimate of the amount of UFA present and, therefore, an indicator of carcass fat

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firmness (Eggert et al., 2001). Iodine will bind to unsaturated or double bonds in fatty acids; thus, a greater amount of iodine will bind to a sample that has a greater amount of UFA (AOCS, 1998). Acceptable IV ranges from 70 (Barton-Gade, 1987; Madsen et al., 1992) to 75 g/100 g (Boyd et al., 1997); and some US packing plants have set their maximum IV at 73 g/100 g of fat sample (D. Petry, Triumph Foods, St. Joseph, MO, personal communication). Currently, there are few data available on the influence of feeding duration of different dietary fats on IV. Therefore, the objective of this study was to evaluate the influence of feeding duration of soybean oil (**SBO**) and choice white grease (**CWG**) on growth performance, carcass characteristics, and carcass fat quality.

MATERIALS AND METHODS

All experimental procedures used in these studies were approved by the Kansas State University Institutional Animal Care and Use Committee.

Animals and Diets

One hundred forty-four crossbred barrows and gilts (327 × C22 PIC, Hendersonville, TN) with an average initial BW of 44 kg were used in an 82-d experiment conducted at the Kansas State University Swine Teaching and Research Center finishing facility. Pigs were blocked by sex and BW and allotted to 1 of 9 treatments with 8 replicate pens per treatment. Pigs were housed 2 per pen in an environmentally regulated finishing barn with 1.22 × 1.22 m totally slatted pens. Each pen was equipped with a 1-hole dry self-feeder and nipple waterer to provide ad libitum access to feed and water. Before the start of the experiment, pigs were fed a corn-soybean meal-based diet without added fat for approximately 7 wk. The 9 treatments were a control diet plus 8 diets arranged in a 2 × 4 factorial design based on fat source (CWG or SBO) and feeding duration (26, 54, 68, or 82 d). The control diet was corn-soybean meal-based without added fat. The CWG and SBO were added at 5% of the diet (as-fed). Pigs were switched to the control corn-soybean meal diet after the treatment diets were fed to their respective duration of feeding. A single lot of each fat source was purchased (CWG: Farmland Foods, Crete, NE, and SBO: North Central Kansas Processors, Washington, KS), and neither contained an antioxidant. The analyzed fatty acid profiles of CWG and SBO used in the study are shown in Table 1. Diets were formulated to be fed in 3 phases from d 0 to 26, 26 to 54, and 54 to 82 to correspond with approximate BW ranges of 44 to 68, 68 to 95, and 95 to 123 kg (Table 2). A constant standardized ileal digestible lysine:ME ratio was maintained by increasing soybean meal in the basal diet when adding the fat sources. Dietary treatments were formulated using ingredient values from NRC (1998). Pigs and feeders were weighed on d 12, 26, 40, 54, 68, and 82 to calculate ADG, ADFI, and G:F.

Table 1. Fatty acid profile of choice white grease (CWG) and soybean oil (SBO)[1]

	Fat source	
Item	CWG	SBO
Myristic acid (14:0), %	10.67	0.09
Palmitic acid (16:0), %	24.56	10.19
Palmitoleic acid (16:1), %	20.44	0.10
Margaric acid (17:0), %	0.82	0.13
Stearic acid (18:0), %	15.30	30.79
Oleic acid (18:1 *cis*-9), %	35.81	21.04
Vaccenic acid (18:1n-7), %	20.51	10.48
Linoleic acid (18:2n-6), %	12.61	54.55
α-Linolenic acid (18:3n-3), %	0.90	70.56
Arachidic acid (20:0), %	0.22	0.31
Eicosadienoic acid (20:2), %	0.04	0.00
Arachidonic acid (20:4n-6), %	0.51	0.10
Other fatty acids, %	0.24	0.05
Total SFA,[2] %	42.94	14.75
Total MUFA,[3] %	40.80	22.63
Total PUFA,[4] %	13.76	62.16
Total *trans* fatty acids,[5] %	10.46	0.17
UFA:SFA ratio[6]	10.27	50.75
PUFA:SFA ratio[7]	0.32	40.21
Iodine value,[8] g/100 g	61.5	134.2

[1]A single batch of each fat source was used in the study (CWG: Farmland Foods, Crete, NE, and SBO: North Central Kansas Processors, Washington, KS). Values represent the mean of 1 sample per fat source.

[2]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.

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

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

[5]Total *trans* fatty acids = {[C18:1 *trans*] + [C18:2 *trans*] + [C18:3 *trans*]}; brackets indicate concentration. Individual *trans* fatty acids were not included in the table.

[6]Unsaturated fatty acid (UFA):SFA ratio = [total MUFA + total PUFA]/total SFA.

[7]PUFA:SFA ratio = total PUFA/total SFA.

[8]Calculated as iodine value = [C16:1] × 0.95 + [C18:1] × 0.86 + [C18:2] × 1.732 + [C18:3] × 2.616 + [C20:1] × 0.785 + [C22:1] × 0.723; brackets indicate concentration (AOCS, 1998).

Carcass Characteristics

At the end of the 82-d trial, all pigs were individually tattooed and shipped approximately 250 km to the Triumph Foods processing plant (St. Joseph, MO). Pigs were slaughtered under commercial conditions. Carbon dioxide stunning was used. Standard carcass criteria of loin depth, backfat depth, HCW, lean percentage, fat-free lean index (**FFLI**), and yield were collected. Yield was calculated as HCW divided by BW. Fat depth and loin depth were measured with an optical probe (Fat-O-Meater, SFK Technology A/S, Herlev, Denmark) inserted between the third and fourth rib from the last rib (counting from the ham end of the carcass) and 7

Table 2. Diet composition (as-fed basis)[1,2]

Item	d 0 to 26			d 26 to 54			d 54 to 82		
	Control	5% CWG	5% SBO	Control	5% CWG	5% SBO	Control	5% CWG	5% SBO
Ingredient, %									
Corn	72.09	64.14	63.98	80.06	72.67	72.47	84.17	77.10	76.86
Soybean meal (46.5% CP)	25.16	28.11	28.27	17.28	19.67	19.87	13.37	15.44	15.68
CWG	—	5.00	—	—	5.00	—	—	5.00	—
SBO	—	—	5.00	—	—	5.00	—	—	5.00
Monocalcium phosphate (21% P)	1.05	1.05	1.05	1.00	1.00	1.00	0.80	0.80	0.80
Limestone	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Salt	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
L-Lys·HCl	0.15	0.15	0.15	0.13	0.13	0.13	0.13	0.13	0.13
Vitamin premix[3]	0.15	0.15	0.15	0.13	0.13	0.13	0.13	0.13	0.13
Trace mineral premix[4]	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Calculated composition									
Standardized ileal digestible (SID) AA									
Lys, %	0.95	1.01	1.02	0.75	0.80	0.81	0.65	0.69	0.70
Met:Lys ratio, %	28	27	27	30	29	29	32	31	30
Met+Cys:Lys ratio, %	57	55	55	63	60	59	67	63	63
Thr:Lys ratio, %	61	60	60	62	61	61	64	62	62
Trp:Lys ratio, %	19	19	19	19	19	19	19	19	19
Total Lys, %	1.07	1.13	1.14	1.07	1.13	1.14	1.07	1.13	1.14
SID Lys:calorie ratio, g/Mcal of ME	2.58	2.58	2.58	2.14	2.14	2.14	1.85	1.85	1.85
CP, %	17.97	18.67	18.73	14.97	15.45	15.52	13.50	13.86	13.92
Crude fat, %	3.2	7.9	7.9	3.4	8.1	8.1	3.5	8.2	8.2
ME, kcal/kg	3,319	3,544	3,566	3,326	3,551	3,573	3,338	3,663	3,585
Ca, %	0.64	0.65	0.65	0.61	0.62	0.62	0.56	0.57	0.57
P, %	0.60	0.59	0.59	0.55	0.55	0.55	0.50	0.49	0.49
Available P, %	0.29	0.29	0.29	0.27	0.27	0.27	0.22	0.22	0.22
Analyzed value									
CP (N × 6.25), %	17.61	19.01	18.36	14.77	15.23	15.47	13.45	14.62	14.14
Crude fat, %	2.04	5.71	4.37	2.24	5.80	4.49	2.23	5.75	4.45
Dietary fat IV,[5] g/100 g	106.9	53.3	92.1	107.1	64.4	89.9	106.6	60.9	85.2
Dietary IVP[6]	34.2	42.1	72.8	36.4	52.2	72.9	37.3	49.9	69.9

[1]Diet composition was calculated using NRC (1998) values for ingredients; CWG = choice white grease; SBO = soybean oil.

[2]Diets fed in meal form.

[3]Provided per kilogram of diet: 11,023 IU of vitamin A; 1,653 IU of vitamin D; 44 IU of vitamin E; 4 mg of vitamin K; 0.04 mg of vitamin B_{12}; 50 mg of niacin; 28 mg of pantothenic acid; and 8 mg of riboflavin.

[4]Provided per kilogram of diet: 16.54 mg of Cu from Cu sulfate; 0.149 mg of I from Ca iodate; 165 mg of Fe from Fe sulfate; 38.6 mg of Mn from Mn oxide; 0.149 mg of Se from Na selenite; and 165 mg of Zn from Zn oxide.

[5]Dietary fat iodine value (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; brackets indicate concentration (AOCS, 1998).

[6]Dietary IV product (IVP) = analyzed IV of dietary crude fat × % crude fat × 0.10 (Madsen et al., 1992).

cm from the dorsal midline of the hot carcass. Lean percentage was provided from the packing plant (calculated with a proprietary equation), and FFLI was calculated according to the NPPC (1999) procedures.

Fatty Acid Analysis

After exiting the kill floor, carcasses were sent through deep chill chambers (approximately −40°C) for approximately 90 min. After deep chill, carcasses were segregated on an outside rail in a holding cooler. Approximately 2 h after exiting deep chill, the right side jowl was removed with a perpendicular cut flush with the carcass shoulder. A small (approximately 100 g) sample of backfat was removed from the 10th-rib area off the carcass midline. An attempt was made to remove all layers of backfat. The jowl fat and backfat samples were placed in a vacuum bag that was vacuum sealed, stored at approximately 4°C, and then transported to Kansas State University under chilled conditions. Samples were frozen at −18°C until sample preparation and fatty acid analysis. Samples were thawed and dissected to separate adipose tissue from skin and lean tissue. Adipose tissue was subsampled and ground. Grinding was performed by cutting fat samples into about 1-cm^3 pieces, freezing the pieces in a bath of liquid N_2, and grinding them into very fine particles in a stainless-steel grinding tub powered by a blender (Waring Commercial Blender, Dynamics Corporation of America, New Hartford, CT). Ground fat (50 μg) was then weighed into screw-cap tubes with Teflon-lined caps. Fat was combined with 3 mL of methanolic-HCl and 2 mL of

internal standard [2 mg/mL of methyl tridecanoic acid (C13:0) in benzene] and subsequently heated in a water bath for 135 min at 70°C for transmethylation; then tubes were vortexed at 45 and 90 min. When the tubes cooled, 2 mL of benzene and 5 mL of K_2CO_3 were added, which allowed the methyl esters to be extracted and transferred to a vial for subsequent quantification of the methylated fatty acids by gas chromatography for fatty acid analysis. From the fatty acid analysis, an IV was calculated using 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 the brackets indicate concentration (percentage) of the fatty acid (AOCS, 1998).

Statistical Analyses

Data were analyzed in a randomized complete block design by using the MIXED procedure (SAS Inst. Inc., Cary, NC) with the pen as the experimental unit. Pigs were blocked by BW within sex. Orthogonal polynomials were used to determine linear and quadratic effects of increasing feeding duration of CWG and soybean oil. Contrast coefficients were derived using the integrative matrix language (PROC IML) procedures of SAS. The statistical model included block as the random effect and sex, fat source, feeding duration, and all their 2-way and 3-way interactions as fixed effects. Hot carcass weight was used as a covariate for last-rib backfat, 10th-rib backfat, loin eye area, and lean percentage. Statistical significance and tendencies were set at $P \leq 0.05$ and $P < 0.10$, respectively, for all statistical tests.

RESULTS

Growth Performance

No interaction between fat source and feeding duration was observed, so main effects are reported. Overall (d 0 to 82), pigs fed SBO tended ($P = 0.07$) to have greater ADG compared with pigs fed CWG; however, there were no differences in ADFI or G:F (Table 3). Increasing feeding duration of SBO increased (quadratic, $P < 0.01$) ADG and G:F. In addition, increasing feeding duration of CWG improved (quadratic, $P < 0.01$) G:F. As expected, barrows had increased ($P < 0.01$, Table 4) ADG and ADFI and reduced ($P = 0.03$) G:F compared with gilts.

Carcass Characteristics

Pigs fed CWG have improved ($P < 0.05$) yield compared with pigs fed SBO, but HCW, last-rib and 10th-rib backfat, loin depth, and lean percentage were similar for pigs fed either fat source. Increasing feeding duration of diets containing CWG or SBO increased HCW (quadratic, $P < 0.01$) and yield (quadratic, $P < 0.05$). Barrows had increased ($P < 0.05$) HCW and last-rib and 10th-rib backfat and decreased ($P < 0.01$) loin depth and percentage lean compared with gilts.

Table 3. Effects of choice white grease (CWG), soybean oil (SBO), and feeding duration on growth performance and carcass characteristics of finishing pigs[1]

												P-value				
	Control	5% CWG				5% SBO						Feeding duration				
													CWG		SBO	
Item	82 d	26 d	54 d	68 d	82 d	26 d	54 d	68 d	82 d	SE	Fat source	Linear	Quadratic	Linear	Quadratic
Growth performance (d 0 to 82)																
ADG, kg	0.99	1.02	1.03	1.04	1.04	1.03	1.03	1.08	1.07	0.03	0.07	0.31	0.16	0.15	0.01
ADFI, kg	3.15	3.18	3.05	3.02	2.96	3.31	2.95	3.08	3.11	0.09	0.53	0.95	0.18	0.94	0.67
G:F	0.35	0.37	0.38	0.38	0.38	0.38	0.37	0.39	0.39	0.01	0.29	0.27	0.01	0.18	0.01
Carcass characteristic																
HCW, kg	90.6	91.5	94.1	94.9	94.3	92.5	94.7	96.1	95.9	1.9	0.21	0.39	0.02	0.29	0.01
Yield, %	72.5	72.1	73.3	73.5	73.3	71.8	73.2	72.4	73.1	0.3	0.05	0.68	0.01	0.25	0.04
Last-rib backfat, mm^2	24.4	23.1	23.1	26.9	22.4	22.9	22.1	23.6	26.4	1.5	0.80	0.73	0.85	0.10	0.95
10th-rib backfat, mm^2	17.8	17.5	17.8	18.3	17.8	17.5	18.5	17.3	20.1	0.9	0.42	0.70	0.67	0.20	0.67
Loin depth, mm^2	56.4	60.2	58.2	59.9	60.2	57.4	58.2	61.7	59.9	1.9	0.51	0.29	0.72	0.85	0.15
Lean,[2] %	54.5	55.5	55	54.9	55.2	55.1	54.7	55.7	53.7	0.6	0.35	0.45	0.60	0.22	0.86

[1]Total of 144 pigs (initial BW = 44 ± 1.1 kg) with 2 pigs per pen and 8 pens per treatment. No treatment × sex interactions were observed.
[2]Data were analyzed using HCW as a covariate.

Table 4. Effects of sex on growth performance and carcass characteristics of finishing pigs[1]

	Sex			
Item	Barrows	Gilts	SE	*P*-value
Growth performance (d 0 to 82)				
ADG, kg	1.07	1.00	0.01	0.01
ADFI, kg	2.88	2.60	0.05	0.01
G:F	0.37	0.39	0.00	0.03
Carcass characteristic				
HCW, kg	96.1	91.6	1.9	0.04
Yield, %	72.7	72.8	0.3	0.72
Last-rib backfat, mm^2	25.9	21.8	1.5	0.04
10th-rib backfat, mm^2	20.1	16.0	0.9	0.01
Loin depth, mm^2	57.9	58.2	1.9	0.01
Lean,[2] %	53.6	56.4	0.6	0.01

[1]Total of 144 pigs (72 barrows and 72 gilts; initial BW = 44 ± 1.1 kg) with 2 pigs per pen and 36 observations per treatment. No treatment × sex interactions were observed.

[2]Data were analyzed using HCW as a covariate.

Fat Quality Characteristics

Pigs fed CWG had greater ($P < 0.01$) C18:1 *cis*-9, C16:0, SFA, and MUFA concentrations but reduced ($P < 0.01$) C18:2n-6, PUFA, UFA:SFA ratio, and PUFA:SFA ratio compared with pigs fed SBO in both jowl fat and backfat (Tables 5 and 6, respectively). Pigs fed SBO had greater ($P < 0.01$) IV in jowl fat and backfat compared with pigs fed CWG. Increasing feeding duration of SBO increased (quadratic, $P < 0.01$) C18:2n-6, PUFA, UFA:SFA ratio, and PUFA:SFA ratio and decreased (quadratic, $P < 0.01$) C18:1 *cis*-9, C16:0, SFA, and MUFA concentrations in jowl fat and backfat. Likewise, increasing feeding duration of CWG increased (quadratic, $P < 0.04$) C18:2n-6, PUFA, UFA:SFA ratio, and PUFA:SFA ratio and decreased (quadratic, $P < 0.02$) C16:0 and SFA concentrations in jowl fat and backfat. Feeding CWG in increasing duration did not affect C18:1 *cis*-9 or MUFA in jowl fat, but they increased (quadratic, $P < 0.04$) in backfat. Increasing feeding duration of CWG or SBO increased (quadratic, $P < 0.01$) IV in backfat and tended (linear, $P < 0.10$) to increase IV in jowl fat.

No differences were observed in C18:1 *cis*-9 and MUFA concentrations between barrows and gilts in jowl fat and backfat (Tables 7 and 8, respectively). However, barrows had reduced ($P < 0.05$) C18:2n-6, PUFA, UFA:SFA ratio, and PUFA:SFA ratio and greater ($P < 0.05$) C16:0 and SFA concentrations in jowl fat and backfat compared with gilts. Barrows had decreased IV in jowl fat ($P = 0.03$) and backfat ($P = 0.02$) compared with gilts.

DISCUSSION

Supplementing swine diets with fat is a practical method of achieving greater rate and efficiency of BW gain. As expected, feeding either fat source or feeding duration resulted in improvements in G:F. However, ADG was improved only in pigs fed SBO. Numerous studies have shown that feeding dietary fat (CWG) improves ADG (De la Llata et al., 2001) and G:F (Smith et al., 1999; De la Llata et al., 2001; Weber et al., 2006). In comparing dietary fat sources, Morgan et al. (1992) showed that pigs fed 5% SBO had greater ADG than pigs fed 5% beef tallow. Suomi et al. (1993) and Leskanich et al. (1997) also observed that ADG increased in response to feeding diets containing a greater amount of unsaturated fat compared with more saturated fat. These studies, including the current study, indicate that the difference in ADG between the SBO- and CWG-fed pigs may be partly related to dietary fatty acid composition. Stahly (1984) reported that the digestibility of dietary fats is increased when diets have a greater proportion of UFA, which may increase energy digestibility of the total diet. Improvement in HCW (De la Llata et al., 2001; Weber et al., 2006) and yield (Smith et al., 1999) and a lack of effect on 10th-rib backfat depth, last-rib backfat depth, loin depth, and lean percentage (Seerley et al., 1978; Tribble et al., 1979; Azain et al., 1991) also have been observed in pigs fed diets containing added fat. Typical growth and carcass trait differences between barrows and gilts were observed in this study as barrows demonstrated faster growth, poorer G:F, and fatter carcasses than gilts.

Farnworth and Kramer (1987) and Chilliard (1993) showed that dietary fat inhibits de novo fatty acid synthesis in favor of direct deposition of dietary fatty acids in adipose tissue. These observations indicate the possibility of manipulating carcass fat composition by careful selection of dietary fat sources and feed ingredients on the basis of fat quality criteria. One consequence of feeding added dietary fat is the alteration of carcass fat composition. Weber et al. (2006) observed an increase in IV in backfat and belly fat from feeding pigs SBO, CWG, or beef tallow. Similar to our data, Averette Gatlin et al. (2003) observed that pigs consuming a diet supplemented with a more unsaturated

Table 5. Effects of choice white grease (CWG), soybean oil (SBO), and feeding duration on fatty acid composition of jowl fat of finishing pigs[1]

											P-value				
												Feeding duration			
	Control	5% CWG				5% SBO						CWG		SBO	
Item	82 d	26 d	54 d	68 d	82 d	26 d	54 d	68 d	82 d	SE	Fat source	Linear	Quadratic	Linear	Quadratic
Myristic acid (C14:0), %	1.38	1.37	1.36	1.31	1.27	1.27	1.15	1.27	1.19	0.04	0.01	0.27	0.03	0.03	0.01
Palmitic acid (C16:0), %	22.95	22.48	21.78	21.68	21.14	21.53	20.34	20.43	20.03	0.30	0.01	0.40	0.01	0.07	0.01
Palmitoleic acid (C16:1), %	0.44	0.41	0.43	0.43	0.43	0.42	0.36	0.37	0.35	0.09	0.01	0.63	0.01	0.01	0.01
Margaric acid (C17:0), %	9.46	9.32	8.79	8.99	8.88	9.14	8.74	8.40	8.59	0.02	0.01	0.73	0.86	0.28	0.01
Stearic acid (C18:0), %	3.27	3.06	3.05	2.95	2.69	2.78	2.52	2.51	2.25	0.22	0.06	0.61	0.05	0.32	0.01
Oleic acid (C18:1 *cis*-9), %	44.96	44.93	45.20	45.22	45.32	42.48	40.74	38.82	38.75	0.36	0.01	0.18	0.83	0.11	0.01
Vaccenic acid (C18:1n-7), %	3.68	3.59	3.66	3.55	3.43	3.19	2.94	2.74	2.70	0.11	0.01	0.30	0.19	0.01	0.01
Linoleic acid (C18:2n-6), %	11.15	11.94	12.68	12.81	13.62	15.77	19.18	21.18	21.71	0.49	0.01	0.13	0.01	0.01	0.01
α-Linolenic acid (C18:3n-3), %	1.61	1.61	1.57	1.59	1.71	1.69	1.26	1.82	1.68	0.04	0.01	0.20	0.02	0.01	0.01
Arachidic acid (C20:0), %	0.59	0.65	0.71	0.70	0.76	1.11	1.57	1.82	1.90	0.01	0.03	0.31	0.33	0.55	0.64
Eicosadienoic acid (C20:2), %	0.65	0.71	0.77	0.76	0.83	0.84	1.01	1.01	1.09	0.03	0.01	0.06	0.01	0.01	0.01
Arachidonic acid (C20:4n-6), %	0.19	0.23	0.23	0.25	0.28	0.23	0.24	0.25	0.25	0.01	0.23	0.01	0.01	0.01	0.01
Other fatty acids, %	1.01	1.04	1.09	1.09	1.10	0.97	0.93	0.95	0.93	0.03	0.01	0.67	0.01	0.36	0.03
Total SFA,[2] %	34.71	34.06	32.84	32.90	32.19	32.83	31.06	30.93	30.61	0.47	0.01	0.42	0.02	0.10	0.01
Total MUFA,[3] %	52.27	51.95	52.30	52.07	51.81	48.77	46.49	44.35	43.99	0.45	0.01	0.18	0.57	0.06	0.01
Total PUFA,[4] %	13.02	13.99	14.86	15.03	16.00	18.39	22.45	24.71	25.39	0.56	0.01	0.11	0.01	0.01	0.01
Total *trans* fatty acids,[5] %	0.27	0.26	0.27	0.26	0.28	0.22	0.18	0.21	0.21	0.02	0.01	0.60	0.97	0.03	0.02
UFA:SFA ratio[6]	1.89	1.94	2.05	2.04	2.11	2.05	2.23	2.24	2.27	0.04	0.01	0.34	0.01	0.01	0.01
PUFA:SFA ratio[7]	0.38	0.41	0.45	0.46	0.50	0.56	0.73	0.80	0.83	0.02	0.01	0.43	0.01	0.01	0.01
Iodine value,[8] g/100 g	67.1	68.8	70.3	70.2	71.5	73.3	79.1	80.9	82.0	0.8	0.01	0.10	0.15	0.03	0.01

[1]Total of 144 pigs (initial BW = 44 ± 1.1 kg) with 2 pigs per pen and 8 replications per treatment. No treatment × sex interactions were observed.
[2]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.
[3]Total MUFA = {[C14:1] + [C16:1] + [C18:1 *cis*-9] + [C18:1n-7] + [C20:1] + [C24:1]}; brackets indicate concentration.
[4]Total PUFA = {[C18:2n-6] + [C18:3n-3] + [C18:3n-6] + [C20:2] + [C20:4n-6]}; brackets indicate concentration.
[5]Total *trans* fatty acids = {[C18:1 *trans*] + [C18:2 *trans*] + [C18:3 *trans*]}; brackets indicate concentration. Individual *trans* fatty acids were not included in the table.
[6]Unsaturated fatty acid (UFA):SFA ratio = [total MUFA + total PUFA]/total SFA.
[7]PUFA:SFA ratio = total PUFA/total SFA.
[8]Calculated as iodine value = [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 the brackets indicate concentration (AOCS, 1998).

Table 6. Effects of choice white grease (CWG), soybean oil (SBO), and feeding duration on fatty acid composition of backfat of finishing pigs[1]

											P-value				
												Feeding duration			
	Control	5% CWG				5% SBO					Fat	CWG		SBO	
Item	82 d	26 d	54 d	68 d	82 d	26 d	54 d	68 d	82 d	SE	source	Linear	Quadratic	Linear	Quadratic
Myristic acid (C14:0), %	1.36	1.33	1.31	1.24	1.22	1.29	1.11	1.19	1.06	0.04	0.01	0.85	0.01	0.07	0.01
Palmitic acid (C16:0), %	24.66	24.16	23.19	22.94	22.47	23.95	21.61	21.11	20.35	0.39	0.01	0.34	0.01	0.11	0.01
Palmitoleic acid (C16:1), %	2.58	2.36	2.46	2.38	2.27	2.36	1.96	1.80	1.57	0.09	0.01	0.27	0.13	0.14	0.01
Margaric acid (C17:0), %	0.54	0.54	0.54	0.53	0.54	0.49	0.44	0.41	0.41	0.03	0.01	0.86	0.92	0.10	0.01
Stearic acid (C18:0), %	12.61	12.70	11.39	11.53	11.27	12.32	11.09	10.51	10.37	0.32	0.01	0.69	0.01	0.42	0.01
Oleic acid (C18:1 *cis*-9), %	40.93	40.39	41.30	41.43	41.92	39.00	36.76	34.66	33.83	0.63	0.01	0.37	0.03	0.03	0.01
Vaccenic acid (C18:1n-7), %	2.77	2.70	2.89	2.90	2.93	2.53	2.26	2.19	2.02	0.72	0.01	0.56	0.01	0.01	0.01
Linoleic acid (C18:2n-6), %	11.97	13.07	14.05	14.14	14.42	15.07	20.95	23.83	25.79	0.86	0.01	0.24	0.02	0.01	0.01
α-Linolenic acid (C18:3n-3), %	0.53	0.59	0.67	0.68	0.68	0.88	1.54	1.93	2.18	0.07	0.01	0.38	0.05	0.01	0.01
Arachidic acid (C20:0), %	0.26	0.27	0.24	0.24	0.23	0.28	0.26	0.25	0.25	0.01	0.01	0.50	0.01	0.06	0.07
Eicosadienoic acid (C20:2), %	0.59	0.65	0.70	0.72	0.74	0.68	0.90	0.94	1.01	0.03	0.01	0.07	0.01	0.01	0.01
Arachidonic acid (C20:4n-6), %	0.17	0.20	0.21	0.21	0.22	0.18	0.20	0.22	0.22	0.01	0.30	0.04	0.01	0.72	0.01
Other fatty acids, %	1.01	1.04	1.03	1.04	1.06	0.95	0.90	0.92	0.91	0.03	0.01	0.66	0.37	0.12	0.01
Total SFA,[2] %	39.71	39.27	36.97	36.75	36.01	38.60	34.74	33.74	32.69	0.66	0.01	0.44	0.01	0.13	0.01
Total MUFA,[3] %	46.64	45.78	46.94	47.03	47.41	44.18	41.23	38.91	37.69	0.74	0.01	0.30	0.04	0.02	0.01
Total PUFA,[4] %	13.65	14.94	16.09	16.22	16.57	17.22	24.02	27.35	29.62	0.96	0.01	0.22	0.01	0.01	0.01
Total *trans* fatty acids,[5] %	0.28	0.27	0.23	0.25	0.25	0.22	0.19	0.19	0.21	0.01	0.01	0.27	0.02	0.01	0.01
UFA:SFA ratio[6]	1.52	1.55	1.71	1.72	1.78	1.59	1.89	1.97	2.07	0.05	0.01	0.62	0.01	0.34	0.01
PUFA:SFA ratio[7]	0.35	0.38	0.44	0.44	0.46	0.45	0.70	0.82	0.92	0.04	0.01	0.42	0.01	0.11	0.01
Iodine value,[8] g/100 g	63.3	64.8	67.7	68.0	68.8	67.6	77.2	81.2	84.3	1.3	0.01	0.31	0.01	0.02	0.01

[1]Total of 144 pigs (initial BW = 44 ± 1.1 kg) with 2 pigs per pen and 8 replications per treatment. No treatment × sex interactions were observed.
[2]Total SFA = {[C8:0] + [C10:0] + [C12:0] + [C14:0] + [C16:0] + [C17:0] + [C18:0] + [C20:0] + [C22:0] + [C24:0]}, where the brackets indicate concentration.
[3]Total MUFA = {[C14:1] + [C16:1] + [C18:1 *cis*-9] + [C18:1n-7] + [C20:1] + [C24:1]}, where the brackets indicate concentration.
[4]Total PUFA = {[C18:2n-6] + [C18:3n-3] + [C18:3n-6] + [C20:2] + [C20:4n-6]}, where the brackets indicate concentration.
[5]Total *trans* fatty acids = {[C18:1 *trans*] + [C18:2 *trans*] + [C18:3 *trans*]}, where the brackets indicate concentration. Individual *trans* fatty acids were not included in the table.
[6]Unsaturated fatty acid (UFA):SFA ratio = [total MUFA + total PUFA]/total SFA.
[7]PUFA:SFA ratio = total PUFA/total SFA.
[8]Calculated as iodine value = [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 the brackets indicate concentration (AOCS, 1998).

Table 7. Effect of sex on fatty acid composition of jowl fat of finishing pigs[1]

Item	Sex		SE	*P*-value
	Barrows	Gilts		
Myristic acid (C14:0), %	1.31	1.27	0.02	0.22
Palmitic acid (C16:0), %	21.70	21.12	0.14	0.01
Palmitoleic acid (C16:1), %	0.42	0.40	0.04	0.33
Margaric acid (C17:0), %	8.97	8.88	0.01	0.19
Stearic acid (C18:0), %	2.84	2.75	0.09	0.55
Oleic acid (C18:1 *cis*-9), %	43.06	42.89	0.16	0.89
Vaccenic acid (C18:1n-7), %	3.33	3.24	0.05	0.44
Linoleic acid (C18:2n-6), %	15.01	15.94	0.21	0.04
α-Linolenic acid (C18:3n-3), %	6.76	7.76	0.02	0.23
Arachidic acid (C20:0), %	1.05	1.11	0.00	0.31
Eicosadienoic acid (C20:2), %	0.83	0.87	0.01	0.07
Arachidonic acid (C20:4n-6), %	0.23	0.25	0.01	0.01
Other fatty acids, %	1.00	1.03	0.01	0.09
Total SFA,[2] %	32.88	32.13	0.22	0.04
Total MUFA,[3] %	49.57	49.21	0.19	0.77
Total PUFA,[4] %	17.55	18.65	0.24	0.03
Total *trans* fatty acids,[5] %	0.24	0.24	0.01	0.91
UFA:SFA ratio[6]	2.05	2.12	0.02	0.04
PUFA:SFA ratio[7]	0.54	0.59	0.01	0.02
Iodine value,[8] g/100 g	72.8	74.3	0.4	0.03

[1]Total of 144 pigs (72 barrows and 72 gilts; initial BW = 44 ± 1.1 kg) with 2 pigs per pen and 36 observations per treatment. No treatment × sex interactions were observed.

[2]Total SFA = {[C8:0] + [C10:0] + [C12:0] + [C14:0] + [C16:0] + [C17:0] + [C18:0] + [C20:0] + [C22:0] + [C24:0]}, where the brackets indicate concentration.

[3]Total MUFA = {[C14:1] + [C16:1] + [C18:1 *cis*-9] + [C18:1n-7] + [C20:1] + [C24:1]}, where the brackets indicate concentration.

[4]Total PUFA = {[C18:2n-6] + [C18:3n-3] + [C18:3n-6] + [C20:2] + [C20:4n-6]}, where the brackets indicate concentration.

[5]Total *trans* fatty acids = {[C18:1 *trans*] + [C18:2 *trans*] + [C18:3 *trans*]}, where the brackets indicate concentration. Individual *trans* fatty acids were not included in the table.

[6]Unsaturated fatty acid (UFA):SFA ratio = [total MUFA + total PUFA]/total SFA.

[7]PUFA:SFA ratio = total PUFA/total SFA.

[8]Calculated as iodine value = [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 the brackets indicate concentration (AOCS, 1998).

fat source had greater IV than pigs fed a more saturated or hydrogenated fat source. Soybean oil has greater concentrations of PUFA than most animal fats used in commercial swine diets. Dietary PUFA are the most effective inhibitors of de novo fat synthesis (Clarke et al., 1990; Bee et al., 1999, 2002). Therefore, increasing the amount of these fats in diets or increasing feeding duration causes pigs to deposit more dietary fats, which increases carcass IV and linoleic acid concentrations.

Gilt IV was greater than barrow IV in this study, which agrees with Averette-Gatlin et al. (2002) who also observed greater backfat IV in gilts than in barrows. Correa et al. (2008) also observed greater belly fat IV in gilts than in barrows; however, Lo Fiego et al. (1992) observed the opposite. That was likely because in that study gilts were fatter than barrows. Fat composition reflects the degree of fat deposition: the greater the fat deposition, the more saturated the fat (Wood and Enser, 1982; Lo Fiego, 1996; De Smet et al., 2004). Generally, barrows have greater backfat than gilts (Cromwell et al., 1993; Hansen and Lewis, 1993), which may indicate that gilts have greater fat IV than barrows. Barton-Gade (1984) observed that pigs with a backfat depth of 10 mm or less had an IV increase of 4 g/100 g, which supports this assumption. Therefore, with split-sex feeding, barrows may be able to consume diets with unsaturated fats for a longer period of time than gilts without negatively affecting fat firmness.

Boyd et al. (1997) showed that reducing dietary linoleic acid (C18:2n-6) content from 3.7 to 1.9% for the final 28 kg of growth reduced backfat IV approximately 2 g/100 g compared with feeding pigs 3.7% linoleic acid for the entire trial. Averette Gatlin et al. (2002) found that feeding 5% fully hydrogenated animal fat for 8 wk reduced backfat IV approximately 12 g/100 g compared with feeding 5% SBO for 8 wk when 5% SBO was fed 3 wk before feeding experimental diets. We saw a greater reduction in backfat IV and a similar reduction in jowl fat IV by removing SBO from d 26 to 82. Thus, removing added dietary fat has a similar or greater effect on reducing carcass fat IV as feeding a fully hydrogenated fat source. This may indicate that de novo synthesis has a greater effect on reducing carcass fat IV than feeding predominantly hydrogenated and saturated dietary fats.

Linoleic acid has been shown to have a greater impact on fat firmness than all other fatty acids (Berschauer, 1984). This may be due to the level of unsaturation

Table 8. Effect of sex on fatty acid composition of backfat of finishing pigs[1]

Item	Sex		SE	*P*-value
	Barrows	Gilts		
Myristic acid (C14:0), %	1.27	1.21	0.02	0.19
Palmitic acid (C16:0), %	23.28	22.25	0.25	0.03
Palmitoleic acid (C16:1), %	2.23	2.16	0.04	0.51
Margaric acid (C17:0), %	0.50	0.49	0.01	0.64
Stearic acid (C18:0), %	11.77	11.32	0.22	0.12
Oleic acid (C18:1 *cis*-9), %	39.19	38.76	0.27	0.49
Vaccenic acid (C18:1n-7), %	2.58	2.59	0.03	0.55
Linoleic acid (C18:2n-6), %	15.98	17.83	0.37	0.01
α-Linolenic acid (C18:3n-3), %	1.00	1.12	0.03	0.14
Arachidic acid (C20:0), %	0.26	0.24	0.01	0.18
Eicosadienoic acid (C20:2), %	0.73	0.80	0.02	0.02
Arachidonic acid (C20:4n-6), %	0.19	0.21	0.01	0.02
Other fatty acids, %	0.98	0.99	0.01	0.83
Total SFA,[2] %	37.35	35.78	0.46	0.05
Total MUFA,[3] %	44.30	43.81	0.31	0.49
Total PUFA,[4] %	18.34	20.41	0.41	0.01
Total *trans* fatty acids,[5] %	0.24	0.23	0.01	0.46
UFA:SFA ratio[6]	1.69	1.81	0.04	0.04
PUFA:SFA ratio[7]	0.50	0.59	0.02	0.01
Iodine value,[8] g/100 g	69.6	72.8	0.7	0.02

[1]Total of 144 pigs (72 barrows and 72 gilts; initial BW = 44 ± 1.1 kg) with 2 pigs per pen and 36 observations per treatment. No treatment × sex interactions were observed.

[2]Total SFA = {[C8:0] + [C10:0] + [C12:0] + [C14:0] + [C16:0] + [C17:0] + [C18:0] + [C20:0] + [C22:0] + [C24:0]}, where the brackets indicate concentration.

[3]Total MUFA = {[C14:1] + [C16:1] + [C18:1 *cis*-9] + [C18:1n-7] + [C20:1] + [C24:1]}, where the brackets indicate concentration.

[4]Total PUFA = {[C18:2n-6] + [C18:3n-3] + [C18:3n-6] + [C20:2] + [C20:4n-6]}, where the brackets indicate concentration.

[5]Total *trans* fatty acids = {[C18:1 *trans*] + [C18:2 *trans*] + [C18:3 *trans*]}, where the brackets indicate concentration. Individual *trans* fatty acids were not included in the table.

[6]Unsaturated fatty acid (UFA):SFA ratio = [total MUFA + total PUFA]/total SFA.

[7]PUFA:SFA ratio = total PUFA/total SFA.

[8]Calculated as iodine value = [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 the brackets indicate concentration (AOCS, 1998).

and concentration of linoleic acid in dietary ingredients. Feeding SBO increased linoleic acid compared with feeding CWG. Averette Gatlin et al. (2003) also reported pigs fed a diet supplemented with more unsaturated fat had increased linoleic acid. The increase in linoleic acid in backfat and jowl fat as feeding duration of CWG and soybean oil lengthened agrees with data from Boyd et al. (1997), who showed that reducing dietary linoleic acid content from 3.7 to 1.9% for 34 d reduced linoleic acid in backfat by 9.7% compared with feeding 3.7% linoleic acid for the entire trial. In the present study, reducing dietary linoleic acid from 1.7 to 1.2% by removing soybean oil from the diet for 14, 28, or 56 d reduced linoleic acid by 7.6, 18.8, and 41.6%, respectively, in backfat compared with feeding 1.7% linoleic acid until market; however, not including soybean oil in the diet reduced linoleic acid by 53.5% in backfat. The increase in linoleic acid content of the fat was at the expense of oleic acid. These 2 fatty acids accounted for approximately 81.4% of the increase in backfat IV when soybean oil was added to the diet.

In conclusion, barrows had a reduced IV and amount of linoleic acid compared with gilts, as expected. Feeding fat increased the softness of fat deposits, as measured by IV and the amount of linoleic acid, with SBO having a more dramatic effect than CWG. Feeding 5% CWG for the entire 82-d trial resulted in jowl fat IV below the 73 g/100 g maximum jowl fat IV established by some packing plants; however, feeding 5% SBO for as short of a period as 26 d resulted in jowl fat IV over the maximum threshold, even when it was removed from the diet 56 d before market. Further research on feeding regimens that could overcome the large increase in carcass IV when unsaturated fat sources are included in the diet is warranted.

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