INFLUENCE OF DIETARY INGREDIENTS ON PORK FAT QUALITY

by

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B.S., North Dakota State University, 2005

A THESIS

submitted in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

Department of Animal Sciences and Industry
College of Agriculture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2008

Approved by:

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Abstract

Five-hundred and four barrows and gilts were used in four experiments to determine the influence of dietary ingredients on fat quality. Experiment 1 evaluated feeding duration of choice white grease (CWG) and soybean oil. Increasing feeding duration of pigs fed CWG or soybean oil increased (quadratic, $P \leq 0.01$) iodine value (IV) in jowl fat and backfat. Pigs fed soybean oil had increased ($P \leq 0.01$) IV in jowl and backfat compared with pigs fed CWG. In Exp. 2 dried distillers grains with solubles (DDGS), extruded expelled soybean meal (EESM), and CWG were used to evaluate diets with common iodine value product (IVP) from ingredients varying in unsaturated fat level and concentration. Pigs fed either diet with DDGS had increased ($P = 0.02$) backfat and jowl fat IV, compared with all other treatments. Pigs fed EESM had increased ($P = 0.04$) backfat and jowl fat IV compared with the control, low CWG, and high CWG. Pigs fed low CWG and high CWG had increased (P = 0.04) jowl fat IV compared to the control. Increasing dietary fat increased carcass fat IV, with unsaturated fats from DDGS and EESM having a greater affect than more saturated fats, such as CWG, even when formulated to the same IVP. Experiment 3 evaluated the effects of increasing CWG in corn- and sorghum-based diets on fat quality. There was a grain source × fat level interaction ($P = 0.04$) for IV in both backfat and jowl fat. Adding CWG increased IV in backfat and jowl fat for pigs fed corn- and sorghum-based diets; however, the greatest increase was between 0 and 2.5% CWG in sorghum-based diets and between 2.5 and 5% CWG in corn-based diets. Despite this interaction, pigs fed corn-based diets had increased ($P < 0.01$) backfat and jowl fat IV compared with pigs fed sorghum-based diets. Increasing CWG increased (linear, $P < 0.01$) IV in backfat and jowl fat.

Experiment 4 examined the effects of DDGS on fat quality. Backfat, jowl fat, and belly fat IV increased (linear, $P = 0.02$) with increasing DDGS in both the pigs marketed on d 57 and 78.

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Effects of choice white grease or soybean oil on growth performance, carcass characteristics and carcass fat quality of grow-finish pigs

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ABSTRACT: A total of 144 barrows and gilts (average initial BW, 44 kg) were used in an 82 d experiment to evaluate the effects of dietary fat source and feeding duration on growth performance, carcass characteristics, and carcass fat quality. Dietary treatments were a corn-soybean meal control diet with no added fat or a 2 × 4 factorial with 5% choice white grease (CWG) or soybean oil fed from d 0 to 26, 54, 68, or 82. At the conclusion of the study (d-82), pigs were harvested, carcass characteristics were measured, and backfat and jowl fat samples were collected. Pigs fed soybean oil tended to have increased (P = 0.07) ADG compared with pigs fed CWG. Increasing feeding duration of pigs fed soybean oil increased (P < 0.01) ADG and G:F. Increasing feeding duration of pigs fed CWG improved (quadratic, P = 0.02) G:F. Increasing feeding duration of pigs fed soybean oil or CWG increased yield (quadratic, P = 0.05) and hot carcass weight (P = 0.02). Dietary fat source and feeding duration did not affect backfat depth, loin depth, or lean percentage (P > 0.12). As expected, barrows had greater ADG and ADFI (P < 0.01), and poorer G:F (P = 0.03) than gilts. Also, barrows had greater last rib (P = 0.04) and 10th rib backfat and reduced loin depth, and lean percentage (P < 0.01) compared with gilts. Increasing feeding duration of pigs fed CWG or soybean oil increased (quadratic, P < 0.01) iodine value (IV) and decreased (quadratic, P < 0.01) saturated fatty acids in jowl fat and backfat. Pigs fed soybean oil had increased (quadratic, P < 0.01) IV and decreased (quadratic, P < 0.01) saturated fatty acids in jowl fat and backfat compared with pigs fed CWG. Increasing feeding duration of soybean oil reduced (quadratic, P < 0.01) the amount of 18:1 fatty acid deposited in jowl fat and backfat by shifting fat deposition to linoleic acid (18:2) as compared with feeding CWG. Barrows had lower (P = 0.03) IV and a greater (P = 0.04) percentage of saturated fatty

acids in the jowl fat and backfat than gilts. Barrows had decreased ($P = 0.04$) percentage C18:2 in jowl fat and backfat and C18:3 in backfat. In summary, adding soybean oil or CWG increased pig growth and level of unsaturated fat deposited. Also, the increase in unsaturated fat deposited was directly related to the level of unsaturated fats in the dietary fat source and the length of feeding duration.

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

INTRODUCTION

Research has shown that added dietary fat improves ADG and G:F in growing and finishing pigs in both a research and commercial environment (Pettigrew and Moser, 1991; De la Llata et al., 2001). Fatty acids absorbed from the diet, especially polyunsaturated fatty acids, specifically inhibit endogenous synthesis of fatty acids, inflating the effect of dietary fat composition influencing body fat composition. Therefore, it is possible to manipulate the composition of body fat quite dramatically by selection of dietary fats (Pettigrew and Esnaola, 2001). A consequence of fatty acid absorption from the diet is that endogenous syntheses of fatty acids are inhibited (Allee et al., 1971). Because dietary fats are more unsaturated than the triglycerides the pig synthesizes endogenously, this can also lead to increased softness of carcass fat.

Fatty acid composition of pork fat affects both 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).

Iodine value (IV) is an estimate of the amount of unsaturated fatty acids present, and therefore an indicator of carcass fat 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 unsaturated fatty acids (AOCS, 1998). Acceptable IV range from 70 (Barton and Gade, 1987; Madsen et al., 1992) to 75 g/100 g (Boyd et al., 1997), and some U. S. packing plants have set their maximum IV at 73 g/100 g. There is little data available on the influence of feeding duration of dietary fat on IV.

The objective of this trial was to evaluate the influence of feeding duration of soybean oil or CWG and gender on growth performance, carcass characteristics, and carcass fat composition.

MATERIALS AND METHODS

The experimental protocols used in these studies were approved by the Kansas State University Institutional Animal Care and Use Committee. The trial was conducted at Kansas State University Swine Teaching and Research center in an environmentally controlled facility.

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. Pigs were blocked by gender and weight 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 m × 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 wks. The 9 treatments included a control diet plus 8 diets arranged in a 2 × 4 factorial based on fat source (choice white grease (CWG) or soybean oil) and feeding durations of 26, 54, 68, or 82-d. The control diet was corn-soybean meal-based without added fat. The CWG and soybean oil were added at 5% of the diet (as-fed).

Diets were formulated to be fed in three phases from d 0 to 26, 26 to 54, and 54 to 82 to correspond with approximate weight ranges of 41 to 68, 68 to 95, and 95 to 123 kg (Table 1). A constant true 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.

At the end of the 82-d trial, pigs were individually tattooed and sent to Triumph Foods, LLC (St. Joseph, MO) where standard carcass criteria of loin and backfat depth, hot carcass weight, lean percentage, and yield were measured. At 24-h postmortem, jowl and backfat samples were collected and frozen at 0° C until sample preparation and fatty acid analysis. Fat (50 µg) was combined with 2 mL of methanolic-HCl and 3 mL of internal standard (2 mg/mL of methyl Heptadecanoic acid (C17:0) in benzene) and subsequently was heated in a water bath for 120 min at 70°C for transmethylation. Upon cooling, the addition of 2 mL of benzene and 3 mL of K_2CO_3 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 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 the brackets indicate concentration (percentage) of the fatty acid (AOCS, 1998).

Saturated fatty acid percentage was determined by adding the percentage of each individual fatty acid.

Saturated, %= [C8:0] + [C10:0] + [C12:0] + [C14:0] + [C16:0] + [C17:0] + [C18:0] + [C20:0] + [C22:0] + [C24:0].

Statistical Analysis

Data were analyzed in a randomized complete-block design with pen as the experimental unit. Analysis of variance was performed by using the MIXED procedure of SAS (SAS Inst., Inc., Cary, NC). Orthogonal polynomials were used to determine linear and quadratic effects of increasing feeding duration of CWG and soybean oil. Pigs were blocked by weight within gender. The statistical model included random effect for block and fixed effect for gender, fat source, and feeding duration, with interactions for 2- and 3-way interactions for all fixed effects tested. Random effects included block. Hot carcass weight was used as a covariate for last rib backfat, 10^{th} rib backfat, loin eye area, and lean percentage.

RESULTS

There were no interactions ($P > 0.10$) observed, thus main effects are reported. Overall (d 0 to 82), pigs fed soybean oil tended ($P = 0.07$, Table 3) to have greater ADG compared with pigs fed CWG; however, there was no differences in ADFI and G:F. Increasing feeding duration of soybean oil increased (quadratic, $P < 0.01$) ADG and G:F. In addition, increasing feeding duration of CWG improved (quadratic, P = 0.02) G:F. As expected, barrows had increased ($P < 0.01$, Table 4) ADG, ADFI, and reduced ($P = 0.03$) G:F compared with gilts.

Pigs fed CWG tended ($P = 0.06$) to have improved yield compared with pigs fed soybean oil, but hot carcass weight, last rib and 10th rib backfat, loin depth, and lean percentage were similar for pigs fed the either fat source. Increasing feeding duration of diets containing CWG or soybean oil increased hot carcass weight (quadratic, $P = 0.02$) and yield (quadratic, $P = 0.05$). Barrows had increased ($P = 0.04$) hot carcass weight, last rib backfat, and 10th rib backfat, and decreased ($P < 0.01$) loin depth and percentage lean compared with gilts.

Increasing feeding duration of CWG or soybean oil increased (quadratic, $P < 0.01$, Table 4) IV in jowl fat and backfat. Pigs fed soybean oil had greater ($P < 0.01$) IV in jowl and backfat compared with those fed CWG. Barrows had lower IV in backfat ($P = 0.02$, Table 5) and jowl fat ($P = 0.03$) than gilts. Increasing feeding duration of CWG and soybean oil decreased (quadratic, $P < 0.01$) saturated fatty acids in the jowl and backfat. Pigs fed soybean oil had decreased ($P < 0.01$) saturated fatty acids in jowl and backfat compared with pigs fed CWG. Barrows also had a greater ($P = 0.04$, Table 5) percentage of saturated fatty acids in the jowl fat and backfat than gilts. Increasing feeding duration of soy oil increased (quadratic, $P < 0.01$) percentage C18:2, C18:3, and C20:1 fatty acids and decreased (quadratic, $P < 0.01$) percentage C16:1 and C18:1 in backfat and jowl fat. Increasing feeding duration of CWG; increased percentage C18:2 (quadratic, $P = 0.04$), C18:3 (quadratic, $P = 0.03$) and C20:1 in (quadratic, $P < 0.01$) backfat; increased (quadratic, $P < 0.01$) percentage C18:2, C18:3, and C20:1 in jowl fat. Increasing feeding duration of CWG also tended to increase (quadratic, $P = 0.08$)

percentage C16:1 in jowl fat and decreased (quadratic, $P < 0.01$) percentage C16:1 in jowl fat. Barrows had decreased ($P < 0.01$) percentage C18:2 and C18:3 in backfat and C20:1 in jowl fat compared with gilts. Barrows had decreased ($P = 0.04$) C18:2 in jowl fat and C20:1 in backfat compared with gilts.

Discussion

Feeding either fat source for increasing durations resulted in the expected improvements of G:F. However, ADG was only improved for those fed soybean oil. Pigs fed CWG had a numeric improvement, resulting in a 4% increase in ADG. Other research has shown feeding dietary fat 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). Improvement in hot carcass weight (De La Llata et al. 2001; and Weber et al., 2006), and yield (Smith et al. 1999) and no effects on 10th rib fat, last rib fat, loin depth, and lean percentage (Seerley et al., 1978; Tribble et al., 1979; Azain et al., 1991) agree with data from several authors when pigs were fed diets containing added fat. Also, the typical growth and carcass trait differences between barrows and gilts were observed, with barrows growing faster, having poorer G:F, and fatter carcasses than gilts.

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 soybean oil, CWG, or beef tallow. Similar to our data, Averette-Gatlin et al. (2003) observed that pigs consuming a diet supplemented with a more unsaturated fat source have higher IV compared with pigs fed a more saturated or hydrogenated fat source. Soybean oil has higher concentrations of polyunsaturated fats than most typical ingredients used in commercial diets. Dietary polyunsaturated fats are the most effective inhibitors of *de novo* synthesis (Clarke et al., 1990; Bee et al., 1999, 2002). Therefore, increasing the inclusion of these fats in diets causes pigs to deposit more dietary fats, which increases carcass IV and linoleic acid concentrations.

The increase in gilt IV over barrow IV agrees with data from Averette-Gatlin et al. (2002), who observed gilts having higher backfat IV than barrows. This may be because gilts tend to be leaner than barrows and have an increase in the percentage of lipid cell membrane in the fat tissue. Phospholipids are the primary lipid found in cell membranes and contain one saturated and one unsaturated fatty acid (Childs, 1995). Barton-Garde (1984) also found reducing backfat depth 10 mm led to an increase in IV of 4 g/100 g. Therefore, with split sex feeding, barrows may be able to consume diets with unsaturated fats for a longer period of time than gilts.

Boyd et al. (1997) showed that reducing dietary linoleic acid (C18:2) content from 3.7% to 1.9% for the final 28 kg of growth reduced backfat IV approximately 2 g/100 g compared with pigs fed 3.7% linoleic acid for the entire trial. Averette-Gatlin et al., (2002) found feeding 5% fully hydrogenated animal fat for 8 wk reduced backfat IV approximately 12 g/100 g compared with feeding 5% soybean oil for 8 wk when 5% soybean oil was fed three wk prior to the feeding of experimental diets. We saw a greater reduction in backfat IV and a similar reduction in jowl fat IV by removing soybean oil 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 *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 compared with all other fatty acids (Berschauer, 1984). This may be due to the level of unsaturation and concentration of linoleic acid in dietary ingredients. Feeding soybean oil increased levels of linoleic acid compared with feeding CWG. Averette-Gatlin et al. (2003) reported similar results, with pigs fed a diet supplemented with more unsaturated fat having increased linoleic acid. The increase in linoleic acid in backfat and jowl fat as feeding duration lengthened for CWG and soybean oil agrees with data from Boyd et al. (1997), who showed reducing dietary linoleic acid content from 3.7 to 1.9% for 34 d reduced linoleic acid in backfat by 9.7% compared with pigs fed 3.7% linoleic acid for the entire trial. Our data indicates 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% in backfat compared to feeding 1.7% 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 two fatty acids accounted for approximately 81.4% of the increase in backfat IV when soybean oil was added to the diet.

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

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Table 1. Fatty acid profile of fat sources

Item	Choice White Grease	Soybean Oil
Myristic acid (14:0), %	1.67	0.09
Palmitic acid (16:0), %	24.56	10.19
Palmitoleic acid (16:1), %	2.44	0.10
Margaric acid (17:0), %	0.82	0.13
Stearic acid (18:0), %	15.30	3.79
Oleic acid (18:1c9), %	35.81	21.04
Vaccenic acid (18:1n7), %	2.51	1.48
Linoleic acid (18:2n6), %	12.61	54.55
α-linolenic acid (18:3n3), %	0.90	7.56
Arachidic acid (20:0), %	0.22	0.31
Eicosadienoic acid (20:2), %	0.04	0.00
Arachidonic acid (20:4n6), %	0.51	0.10
Other fatty acids, %	0.24	0.05
Total SFA, %[1,]	42.94	14.75
Total MUFA, %[2]	40.80	22.63
Total PUFA, %[3]	13.76	62.16
Total *trans* fatty acids, %[4]	1.46	0.17
UFA:SFA ratio[5]	1.27	5.75
PUFA:SFA ratio[6]	0.32	4.21
Iodine value, g/100 g[7]	61.5	134.2

[1]Total saturated fatty acids = {[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.

[2]Total monounsaturated fatty acids = {[C14:1] + [C16:1] + [C18:1c9] + [C18:1n7] + [C20:1] + [C24:1]}, where the brackets indicate concentration.

[3]Total polyunsaturated fatty acids = {[C18:2n6] + [C18:3n3] + [C18:3n6] + [C20:2] + [C20:4n6]}, where the brackets indicate concentration.

[4]Total *trans* fatty acids = {[C18:1t] + [C18:2t] + [C18:3t]}, where the brackets indicate concentration.

[5]UFA:SFA ratio = [Total MUFA + Total PUFA] / Total SFA.

[6]PUFA:SFA ratio = Total PUFA / Total SFA.

[7]Calculated as 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 (AOCS, 1998).

Table 2. Diet composition (as-fed basis)[12]

Item	d 0 to 26 Control	d 0 to 26 5% CWG	d 0 to 26 5% soybean oil	d 26 to 54 Control	d 26 to 54 5% CWG	d 26 to 54 5% soybean oil	d 54 to 82 Control	d 54 to 82 5% CWG	d 54 to 82 5% soybean oil
Ingredient %,									
Corn	72.09	64.14	63.98	80.07	72.68	72.48	84.18	77.11	76.87
Soybean meal (46.5% CP)	25.16	28.11	28.27	17.28	19.67	19.87	13.37	15.44	15.68
Choice white grease	---	5.00	---	---	5.00	---	---	5.00	---
Soybean oil	---	---	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
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated composition									
True ileal digestible (TID) amino acids									
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
TID Lys:calorie ratio, g/Mcal ME	2.58	2.58	2.58	2.14	2.14	2.14	1.85	1.85	1.85
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
Dietary fat iodine value, g/100 g	106.9	53.3	92.1	107.1	64.4	89.9	106.6	60.9	85.2
Dietary iodine value[5]	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) composition values for ingredients.
[2]Dietary treatments 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 B12; 50 mg of niacin; 28 mg of panothenic acid; and 8 mg of riboflavin.
[4]Provided per kilogram of diet: 16.54 mg 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] IV of diet oil x % diet oil x 0.10.

Table 3. Effects of choice white grease, soybean oil, and feeding duration on growth performance and carcass characteristics[1]

Fat source:	Control	5% CWG				5% Soybean oil					Probability, P <				
												Feeding duration			
											Fat	CWG		Soybean oil	
Feeding duration, d:	82	26	54	68	82	26	54	68	82	SE	Source	Linear	Quad	Linear	Quad
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	0.42	0.14	0.32	0.01
ADFI, kg	3.15	3.18	3.05	3.02	2.96	3.31	2.95	3.08	3.11	0.09	0.54	0.81	0.23	0.93	0.79
G:F	0.35	0.37	0.38	0.38	0.38	0.38	0.37	0.39	0.39	0.01	0.30	0.47	0.02	0.37	0.01
Hot carcass weight, kg	90.6	91.5	94.1	94.9	94.3	92.5	94.7	96.1	95.9	1.88	0.22	0.63	0.02	0.56	0.01
Yield, %	72.5	72.1	73.3	73.5	73.3	71.8	73.2	72.4	73.1	0.34	0.06	0.32	0.01	0.18	0.05
Last rib backfat, mm[2]	24.4	23.1	23.1	26.9	22.4	22.9	22.1	23.6	26.4	1.52	0.80	0.64	0.99	0.12	0.58
10th rib backfat, mm[2]	17.8	17.5	17.8	18.3	17.8	17.5	18.5	17.3	20.1	0.92	0.43	0.72	0.72	0.24	0.97
Loin depth, mm[2]	56.4	60.2	58.2	59.9	60.2	57.4	58.2	61.7	59.9	1.89	0.51	0.30	0.84	0.95	0.17
Lean, %[2]	54.5	55.5	55.0	54.9	55.2	55.1	54.7	55.7	53.7	0.60	0.35	0.46	0.69	0.31	0.58

[1] Total of 144 pigs (initial BW 44 kg) with 2 pigs per pen and 8 pens per treatment. No treatment × gender interactions were observed (*P* > 0.10).
[2] Data analyzed using hot carcass weight as a covariate.

Table 4. Effect of gender on growth and carcass performance [1]

Item	Barrows	Gilts	SE	Probability
d 0 to 82				
ADG, kg	1.07	1.00	0.014	0.01
ADFI, kg	2.88	2.60	0.054	0.01
G:F	0.37	0.39	0.002	0.03
Hot carcass weight, kg	96.1	91.6	1.88	0.04
Yield, %	72.7	72.8	0.34	0.72
Last rib backfat, mm[2]	25.9	21.8	1.52	0.04
10th rib backfat, mm[2]	20.1	16.0	0.92	0.01
Loin depth, mm[2]	57.9	58.2	1.89	0.01
Lean, %[2]	53.6	56.4	0.60	0.01

[1] Total of 144 pigs (72 barrows and 72 gilts; initial BW 44 kg). No treatment × gender interactions were observed ($P > 0.10$).
[2] Data analyzed using hot carcass weight as a covariate.

Table 5. Effects of choice white grease, soybean oil, and feeding duration on fatty acid composition of jowl fat[1]

											Probability, P <				
												Feeding duration			
Fat source:	Control	5% CWG[2]				5% Soybean oil					Fat	CWG		Soy oil	
Feeding duration, d:	82	26	54	68	82	26	54	68	82	SE	Source	Linear	Quad	Linear	Quad
Myristic acid (14:0), %	1.38	1.37	1.36	1.31	1.27	1.27	1.15	1.27	1.19	0.04	0.01	0.70	0.08	0.01	0.01
Palmitic acid (16:0), %	22.95	22.48	21.78	21.68	21.14	21.53	20.34	20.43	20.03	0.30	0.01	0.70	0.01	0.01	0.01
Palmitoleic acid (16:1), %	0.44	0.41	0.43	0.43	0.43	0.42	0.36	0.37	0.35	0.09	0.01	0.78	0.01	0.01	0.01
Margaric acid (17:0), %	9.46	9.32	8.79	8.99	8.88	9.14	8.74	8.40	8.59	0.02	0.01	0.40	0.61	0.48	0.01
Stearic acid (18:0), %	3.27	3.06	3.05	2.95	2.69	2.78	2.52	2.51	2.25	0.22	0.06	0.56	0.01	0.44	0.01
Oleic acid (18:1c9), %	44.96	44.93	45.20	45.22	45.32	42.48	40.74	38.82	38.75	0.36	0.01	0.84	0.41	0.01	0.01
Vaccenic acid (18:1n7), %	3.68	3.59	3.66	3.55	3.43	3.19	2.94	2.74	2.70	0.11	0.01	0.86	0.38	0.02	0.01
Linoleic acid (18:2n6), %	11.15	11.94	12.68	12.81	13.62	15.77	19.18	21.18	21.71	0.49	0.01	0.62	0.01	0.01	0.01
α-linolenic acid (18:3n3), %	1.61	1.61	1.57	1.59	1.71	1.69	1.26	1.82	1.68	0.04	0.01	0.63	0.01	0.01	0.01
Arachidic acid (20:0), %	0.59	0.65	0.71	0.70	0.76	1.11	1.57	1.82	1.90	0.01	0.03	0.77	0.42	0.38	0.92
Eicosadienoic acid (20:2), %	0.65	0.71	0.77	0.76	0.83	0.84	1.01	1.01	1.09	0.03	0.01	0.35	0.01	0.01	0.01
Arachidonic acid (20:4n6), %	0.19	0.23	0.23	0.25	0.28	0.23	0.24	0.25	0.25	0.01	0.23	0.22	0.01	0.05	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, %[3,]	34.71	34.06	32.84	32.90	32.19	32.83	31.06	30.93	30.61	0.47	0.01	0.60	0.01	0.01	0.01
Total MUFA, %[4]	52.27	51.95	52.30	52.07	51.81	48.77	46.49	44.35	43.99	0.45	0.01	0.88	0.87	0.01	0.01
Total PUFA, %[5]	13.02	13.99	14.86	15.03	16.00	18.39	22.45	24.71	25.39	0.56	0.01	0.59	0.01	0.01	0.01
Total *trans* fatty acids, %[6]	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[7]	1.89	1.94	2.05	2.04	2.11	2.05	2.23	2.24	2.27	0.04	0.01	0.67	0.01	0.02	0.01
PUFA:SFA ratio[8]	0.38	0.41	0.45	0.46	0.50	0.56	0.73	0.80	0.83	0.02	0.01	0.63	0.01	0.01	0.01
Iodine value, g/100 g[9]	67.1	68.8	70.3	70.2	71.5	73.3	79.1	80.9	82.0	0.81	0.01	0.56	0.01	0.01	0.01

[1]Total of 144 pigs (initial BW 44 kg) with 2 pigs per pen and 8 replications per treatment. No treatment × gender interactions were observed ($P > 0.10$).

[2]Choice white grease.

[3]Total saturated fatty acids = {[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.

[4]Total monounsaturated fatty acids = {[C14:1] + [C16:1] + [C18:1c9] + [C18:1n7] + [C20:1] + [C24:1]}, where the brackets indicate concentration.

[5]Total polyunsaturated fatty acids = {[C18:2n6] + [C18:3n3] + [C18:3n6] + [C20:2] + [C20:4n6]}, where the brackets indicate concentration.

[6]Total *trans* fatty acids = {[C18:1t] + [C18:2t] + [C18:3t]}, where the brackets indicate concentration.

[7]UFA:SFA ratio = [Total MUFA + Total PUFA] / Total SFA.

[8]PUFA:SFA ratio = Total PUFA / Total SFA.

[9]Calculated as 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 (AOCS, 1998).

Table 6. Effects of choice white grease, soybean oil, and feeding duration on fatty acid composition of backfat[a]

											Probability, $P <$				
												Feeding duration			
Fat source:	Control	5% CWG[2]				5% Soybean oil					Fat	CWG		Soy oil	
Feeding duration, d:	82	26	54	68	82	26	54	68	82	SE	Source	Linear	Quad	Linear	Quad
Myristic acid (14:0), %	1.36	1.33	1.31	1.24	1.22	1.29	1.11	1.19	1.06	0.04	0.01	0.81	0.01	0.27	0.01
Palmitic acid (16:0), %	24.66	24.16	23.19	22.94	22.47	23.95	21.61	21.11	20.35	0.39	0.01	0.75	0.01	0.69	0.01
Palmitoleic acid (16:1), %	2.58	2.36	2.46	2.38	2.27	2.36	1.96	1.80	1.57	0.09	0.01	0.33	0.29	0.70	0.01
Margaric acid (17:0), %	0.54	0.54	0.54	0.53	0.54	0.49	0.44	0.41	0.41	0.03	0.01	0.88	0.93	0.29	0.01
Stearic acid (18:0), %	12.61	12.70	11.39	11.53	11.27	12.32	11.09	10.51	10.37	0.32	0.01	0.67	0.01	0.89	0.01
Oleic acid (18:1c9), %	40.93	40.39	41.30	41.43	41.92	39.00	36.76	34.66	33.83	0.63	0.01	0.32	0.09	0.49	0.01
Vaccenic acid (18:1n7), %	2.77	2.70	2.89	2.90	2.93	2.53	2.26	2.19	2.02	0.72	0.01	0.37	0.01	0.21	0.01
Linoleic acid (18:2n6), %	11.97	13.07	14.05	14.14	14.42	15.07	20.95	23.83	25.79	0.86	0.01	0.43	0.03	0.39	0.01
α-linolenic acid (18:3n3), %	0.53	0.59	0.67	0.68	0.68	0.88	1.54	1.93	2.18	0.07	0.01	0.62	0.08	0.62	0.01
Arachidic acid (20:0), %	0.26	0.27	0.24	0.24	0.23	0.28	0.26	0.25	0.25	0.01	0.01	0.28	0.01	0.06	0.19
Eicosadienoic acid (20:2), %	0.59	0.65	0.70	0.72	0.74	0.68	0.90	0.94	1.01	0.03	0.01	0.23	0.01	0.19	0.01
Arachidonic acid (20:4n6), %	0.17	0.20	0.21	0.21	0.22	0.18	0.20	0.22	0.22	0.01	0.30	0.14	0.01	0.71	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, %[3,]	39.71	39.27	36.97	36.75	36.01	38.60	34.74	33.74	32.69	0.66	0.01	0.96	0.01	0.80	0.01
Total MUFA, %[4]	46.64	45.78	46.94	47.03	47.41	44.18	41.23	38.91	37.69	0.74	0.01	0.23	0.14	0.34	0.01
Total PUFA, %[5]	13.65	14.94	16.09	16.22	16.57	17.22	24.02	27.35	29.62	0.96	0.01	0.41	0.02	0.38	0.01
Total *trans* fatty acids, %[6]	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[7]	1.52	1.55	1.71	1.72	1.78	1.59	1.89	1.97	2.07	0.05	0.01	0.91	0.01	0.89	0.01
PUFA:SFA ratio[8]	0.35	0.38	0.44	0.44	0.46	0.45	0.70	0.82	0.92	0.04	0.01	0.62	0.02	0.84	0.01
Iodine value, g/100 g[9]	63.3	64.8	67.7	68.0	68.8	67.6	77.2	81.2	84.3	1.33	0.01	0.60	0.01	0.49	0.01

[1]Total of 144 pigs (initial BW 44 kg) with 2 pigs per pen and 8 replications per treatment. No treatment × gender interactions were observed ($P > 0.10$).

[2]Choice white grease.

[3]Total saturated fatty acids = {[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.

[4]Total monounsaturated fatty acids = {[C14:1] + [C16:1] + [C18:1c9] + [C18:1n7] + [C20:1] + [C24:1]}, where the brackets indicate concentration.

[5]Total polyunsaturated fatty acids = {[C18:2n6] + [C18:3n3] + [C18:3n6] + [C20:2] + [C20:4n6]}, where the brackets indicate concentration.

[6]Total *trans* fatty acids = {[C18:1t] + [C18:2t] + [C18:3t]}, where the brackets indicate concentration.

[7]UFA:SFA ratio = [Total MUFA + Total PUFA] / Total SFA.

[8]PUFA:SFA ratio = Total PUFA / Total SFA.

[9]Calculated as 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 (AOCS, 1998).

Table 7. Effect of gender on fatty acid composition of backfat [a]

Item	Barrows	Gilts	SE	Probability
Myristic acid (14:0), %	1.27	1.21	0.02	0.19
Palmitic acid (16:0), %	23.28	22.25	0.25	0.03
Palmitoleic acid (16:1), %	2.23	2.16	0.04	0.51
Margaric acid (17:0), %	0.50	0.49	0.01	0.64
Stearic acid (18:0), %	11.77	11.32	0.22	0.12
Oleic acid (18:1c9), %	39.19	38.76	0.27	0.49
Vaccenic acid (18:1n7), %	2.58	2.59	0.03	0.55
Linoleic acid (18:2n6), %	15.98	17.83	0.37	0.01
α-linolenic acid (18:3n3), %	1.00	1.12	0.03	0.14
Arachidic acid (20:0), %	0.26	0.24	0.01	0.18
Eicosadienoic acid (20:2), %	0.73	0.80	0.02	0.02
Arachidonic acid (20:4n6), %	0.19	0.21	0.005	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	0.006	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, g/100 g[8]	69.6	72.8	0.69	0.02

[1]Total of 144 pigs (72 barrows and 72 gilts; initial BW 44 kg). No treatment × gender interactions were observed ($P > 0.10$).
[2]Total saturated fatty acids = {[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 monounsaturated fatty acids = {[C14:1] + [C16:1] + [C18:1c9] + [C18:1n7] + [C20:1] + [C24:1]}, where the brackets indicate concentration.
[4]Total polyunsaturated fatty acids = {[C18:2n6] + [C18:3n3] + [C18:3n6] + [C20:2] + [C20:4n6]}, where the brackets indicate concentration.
[5]Total *trans* fatty acids = {[C18:1t] + [C18:2t] + [C18:3t]}, where the brackets indicate concentration.
[6]UFA:SFA ratio = [Total MUFA + Total PUFA] / Total SFA.
[7]PUFA:SFA ratio = Total PUFA / Total SFA.
[8]Calculated as 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 (AOCS, 1998).

Table 8. Effect of gender on fatty acid composition of jowl fat [a]

Item	Barrows	Gilts	SE	Probability, P <
Myristic acid (14:0), %	1.31	1.27	0.02	0.22
Palmitic acid (16:0), %	21.70	21.12	0.14	0.01
Palmitoleic acid (16:1), %	0.42	0.40	0.04	0.33
Margaric acid (17:0), %	8.97	8.88	0.01	0.19
Stearic acid (18:0), %	2.84	2.75	0.09	0.55
Oleic acid (18:1c9), %	43.06	42.89	0.16	0.89
Vaccenic acid (18:1n7), %	3.33	3.24	0.05	0.44
Linoleic acid (18:2n6), %	15.01	15.94	0.21	0.04
α-linolenic acid (18:3n3), %	6.76	7.76	0.02	0.23
Arachidic acid (20:0), %	1.05	1.11	0.004	0.31
Eicosadienoic acid (20:2), %	0.83	0.87	0.01	0.07
Arachidonic acid (20:4n6), %	0.23	0.25	0.005	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, g/100 g[8]	72.8	74.3	0.36	0.03

[1]Total of 144 pigs (72 barrows and 72 gilts; initial BW 44 kg). No treatment × gender interactions were observed ($P > 0.10$).

[2]Total saturated fatty acids = {[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 monounsaturated fatty acids = {[C14:1] + [C16:1] + [C18:1c9] + [C18:1n7] + [C20:1] + [C24:1]}, where the brackets indicate concentration.

[4]Total polyunsaturated fatty acids = {[C18:2n6] + [C18:3n3] + [C18:3n6] + [C20:2] + [C20:4n6]}, where the brackets indicate concentration.

[5]Total *trans* fatty acids = {[C18:1t] + [C18:2t] + [C18:3t]}, where the brackets indicate concentration.

[6]UFA:SFA ratio = [Total MUFA + Total PUFA] / Total SFA.

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

[8]Calculated as 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 (AOCS, 1998).

Effects of diets with common iodine value product from ingredients varying in unsaturated fat level and concentration on growth performance, carcass characteristics, and fat quality characteristics of finishing pigs

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ABTRACT: A total of 120 barrows with an initial BW of 47.9 kg were used in an 83-d trial to study the effects of diets with common iodine value products (IVP) from ingredients varying in unsaturated fat on growth performance, carcass characteristics, and fat quality. Pigs were blocked by BW and randomly allotted to 1 of 6 treatments with 2 pigs per pen with 10 replicate pens per treatment. Dietary treatments were fed in three phases and formulated to have three IVP levels (low, medium, and high) in each phase. The IVP levels in the three phases were 40, 42, and 44 for the low levels; 57, 54, and 53 for medium levels; and 65, 62, and 61 for high levels, respectively. Treatments were: 1) corn-soybean meal control diet with no added fat (low IVP); 2) corn-extruded expelled soybean meal (EESM) diet with no added fat (medium IVP); 3) corn-EESM diet with 15% dried distillers grains with solubles (DDGS; high IVP); 4) corn-soybean meal diet with 15% DDGS and choice white grease (CWG; medium IVP); 5) corn-soybean meal diet with low CWG (medium IVP); and 6) corn-soybean meal diet with high CWG (high IVP). On d 83, pigs were slaughtered and backfat and jowl samples were collected. From d 0 to 83, pigs fed the control diet, EESM, or high CWG had greater ($P = 0.05$) ADG compared with pigs fed EESM + 15% DDGS. Pigs fed the control diet had greater ($P = 0.05$) ADFI compared with pigs fed all other treatments. Pigs fed EESM + 15% DDGS and high CWG had improved ($P = 0.05$) G:F compared with pigs fed the control diet or those fed DDGS + CWG. Pigs fed high CWG had greater ($P = 0.05$) loin depth compared with pigs fed low CWG. Yield, fat depth, and percentage lean was unaffected by dietary treatment ($P > 0.10$). Pigs fed either diet with DDGS had increased ($P = 0.02$) backfat and jowl fat iodine value (IV), percentage linoleic acid, and total polyunsaturated fatty acids and reduced percentage saturated fatty acids compared with all other treatments. Pigs fed EESM had increased ($P = 0.04$) backfat and jowl fat IV, percentage linoleic acid and total polyunsaturated fatty acids compared with the control, low CWG, and high

CWG. Pigs fed low CWG and high CWG had increased ($P = 0.04$) jowl fat IV compared to the control. In conclusion, increasing dietary fat increased carcass fat IV, with unsaturated fats from DDGS and EESM having a greater affect than more saturated fats, such as CWG, even when formulated to the same IVP.

Keywords: carcass, dried distillers grains with solubles, dietary fat, iodine value, swine

INTRODUCTION

Pork producers are in a continuous search for feed ingredients that may lower diet costs while maintaining growth performance. Extruded expelled soybean meal (EESM) and dried distillers grains with solubles (DDGS) have both been successfully included in pig diets (Webster et al., 2003, Whitney et al., 2006). However, both feedstuffs increase the amount of unsaturated fat in the diet and therefore may influence carcass fat quality.

It is well documented that carcass fat composition is affected by the relative contribution of dietary fatty acids (Brooks 1971; Wood 1984; Gatlin et al, 2002). Increasing the amount of unsaturated fat in carcass fat creates softer fat, which affects both further processing characteristics and the ability of pork products to meet export specifications (Carr et al., 2005).

Iodine value (IV) is an estimate of the proportion of unsaturated fatty acids present, and, therefore, an indirect indicator of carcass fat 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 proportion of unsaturated fatty acids (AOCS, 1998).

Madsen (1992) and Boyd et al. (1997) developed equations to predict backfat iodine from calculating a dietary iodine value product (IVP). Iodine value product is calculated as: (IV of the dietary lipids) × (percentage dietary lipid) × 0.10. Boyd et al. (1997) estimated backfat IV as 52.4 × 0.315 (diet IVP). However, the relationship between multiple diets having similar IVP with differing IV of dietary lipids and percentage dietary lipid has not been evaluated. Therefore, the objective of this trial was to evaluate diets with common dietary IVP resulting from different ingredients varying in fat composition on finishing pig growth performance, carcass characteristics, and carcass fatty acid composition and IV.

MATERIALS AND METHODS

The experimental protocol used in this study was approved by the Kansas State University Institutional Animal Care and Use Committee. The trial was conducted at Kansas State University Swine Teaching and Research Center in an environmentally controlled finishing facility.

One hundred twenty crossbred barrows (PIC 1050, Hendersonville, TN) with an average initial BW of 47.9 kg were used in an 83-d experiment. Pigs were blocked by weight and allotted to 1 of 6 treatments with 10 replicate pens per treatment. Pigs were housed with 2 per 1.22 m × 1.22 m pen with totally slatted floors. Each pen was equipped with a 1-hole dry self-feeder and nipple waterer to allow *ad libitum* access to feed and water. Diets were formulated using NRC (1998) composition values for ingredients, except the ME value of DDGS in which 3,420 kcal/kg was used.

Dietary treatments were fed in three phases and formulated to have three levels of IVP (low, medium or high) for each phase (Tables 1 to 3). The three dietary phases were from d 0 to 26, d 26 to 55, and d 55 to 83. The IVP levels in the three phases were 40, 42, and 44 for the low levels; 57, 54, and 53 for medium levels; and 65, 62, and 61 for high levels, respectively. Treatments were: 1) corn-soybean meal control diet with no added fat (low IVP); 2) corn-EESM diet with no added fat (medium IVP); 3) corn-soybean meal diet with 15% DDGS and choice white grease (CWG; high IVP); 4) corn-EESM soybean meal diet with 15% DDGS (medium

IVP); 5) corn-soybean meal diet with low CWG (medium IVP); and 6) corn-soybean meal diet with high CWG (high IVP). Pigs were fed a similar corn-soybean meal-based diet for 7 wks before start of the experimental diets. A constant true ileal digestible lysine:ME ratio was maintained in each phase. The amount of dietary ingredients in each phase was altered to have a common diet IVP for treatments 2, 4, and 5 (medium IVP) and for diets 3 and 6 (high IVP). Pigs and feeders were weighed on d 12, 26, 41, 55, 69, and 83 to calculate ADG, ADFI, and G:F.

Pigs were slaughtered at Triumph Foods, LLC (St. Joseph, MO) at the end of the 83 d trial for collection of individual carcass data of hot carcass weight (HCW), loin and backfat depth, lean percentage, and yield. The pigs were marked with an individual tattoo before marketing. At 24 h postmortem, backfat and jowl samples were collected and frozen at 0° C fatty acid analysis. Fat (50 µg) was combined with 2 mL of methanolic-HCl and 3 mL of internal standard (2 mg/mL of methyl Heptadecanoic acid (C17:0) in benzene) and subsequently was heated in a water bath for 120 min at 70°C for transmethylation. Upon cooling, the addition of 2 mL of benzene and 3 mL of K_2CO_3 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 from the following equation:

$$IV= [C16:1] \times 0.95 + [C18:1] \times 0.86 + [C18:2] \times 1.732 +[C18:3] \times 2.616 + [C20:1] \times 0.785+[C22:1] \times 0.723$$, where the brackets indicate concentration (AOCS, 1998).

Saturated fatty acid percentage was determined by adding the percentage of each individual fatty acid.

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

Statistical Analysis

Data were analyzed in a randomized complete-block design with pen as the experimental unit. Pigs were blocked by weight. Analysis of variance was performed by using the MIXED procedure of SAS (SAS Inst., Cary, NC). Mean separation was achieved using the PDIFF option of SAS. Hot carcass weight was used as a covariate for last rib backfat, 10^{th} rib backfat, loin depth, and percentage lean.

RESULTS

Analyzed dietary IVP was generally lower than the calculated values. However, the treatment diets DDGS with CWG and high CWG had similar analyzed IVP (Tables 1, 2, and 3).

Overall (d 0 to 83), pigs fed the control diet, EESM or high CWG had greater ($P = 0.05$) ADG compared with pigs fed EESM + 15% DDGS (Table 5). Pigs fed the control diet had greater ($P = 0.05$) ADFI compared with pigs fed all other treatments. Pigs fed EESM + 15% DDGS and high CWG had improved ($P = 0.05$) G:F compared with pigs fed the control diet or those fed DDGS + CWG. Pigs fed high CWG had greater ($P = 0.05$) loin depth compared with pigs fed low CWG. Yield, fat depth and percentage lean were unaffected by dietary treatment ($P > 0.10$).

Pigs fed either diet with DDGS had increased ($P = 0.02$) backfat and jowl fat IV, percentage linoleic acid and total polyunsaturated fatty acids and reduced percentage saturated fatty acids compared with all other treatments (Table 6). Pigs fed EESM had increased ($P = 0.04$) backfat and jowl fat IV, percentage linoleic acid and total polyunsaturated fatty acids compared with the control, low CWG, and high CWG. Pigs fed low CWG and high CWG had increased jowl fat IV compared to the control. Pigs fed the control diet had increased ($P < 0.01$) backfat and jowl fat percentage saturated fatty acids compared with all other treatments.

DISCUSSION

Madsen (1992) and Boyd et al. (1997) developed equations to predict backfat iodine from calculating IVP. Our trial was designed to have three levels of IVP. Analyzed IVP was lower than the original calculated values because dietary fat IV and percentage fat were generally lower than predicted values. Although pigs fed the dietary treatments DDGS + CWG and high CWG had similar IVP of approximately 52, according to prediction equation from Boyd et al. (1997), backfat IV should be similar (67.1 g/100 g) between our treatments with similar IVP. However, pigs fed high CWG had lower backfat and jowl fat IV than pigs fed DDGS + CWG. Thus, IVP alone does not appear to be an accurate predictor of carcass fat IV when dietary fat differs in concentration, degree of saturation, a state in the diet.

Linoleic acid has been shown to have a greater impact on fat firmness compared with all other fatty acids (Berschauer, 1984). The diet containing DDGS and CWG had lower fat content, but a higher proportion of polyunsaturated fats than the high CWG diet. Because dietary polyunsaturated fats are the most effective inhibitors of *de novo* synthesis (Clarke et al., 1990; Bee et al., 1999, 2002), they may have a greater effect on carcass fat IV than the prediction equations formulated. This appeared to be the case in our trial because pigs fed the diet containing DDGS and CWG had considerably greater backfat and jowl IV than pigs fed the high CWG diet.

Jowl fat IV was approximately 5 g/100 g greater than backfat IV for all treatments except those containing DDGS, where jowl fat and backfat IV were similar. This can be explained by evaluating the effect each individual fatty acid had on IV. Pigs fed the control diet had an increase of 4 g/100 g from backfat to jowl fat due to C 18:1 fatty acids (effect of backfat C 18:1 = 36.05, effect of jowl fat C 18:1 = 40.05). This trend is similar for all treatments and explains why jowl fat IV is higher than backfat IV. The effect C 18:2 fatty acids had on IV is similar for jowl fat and backfat in most treatments. However, pigs fed either diet containing DDGS had less C 18:2 fatty acids in jowl fat than backfat. This difference was similar to the effect of C 18:1 fatty acids and, resulting in similar IV levels for the two fat depots.

Feeding pigs DDGS in diets increased backfat and jowl fat IV. This agrees with data from Whitney et al. (2006), who saw a linear increase in belly IV as DDGS levels increased in the diet. Pigs fed dietary unsaturated fat from EESM had increased backfat and jowl fat IV compared with pigs fed CWG. Averette-Gatlin et al. (2003) found similar results with pigs consuming a diet supplemented with an unsaturated fat source having higher IV compared with pigs fed a hydrogenated saturated fat source. The increase in linoleic acid (C18:2) from feeding soybean oil or corn oil from EESM and DDGS agrees with data from Averette-Gatlin (2003), who found that pigs fed a diet supplemented with more unsaturated fat had increased linoleic acid in belly fat.

Feeding 15% DDGS reduced ADG and ADFI. Linear reductions in ADG and ADFI have also been found when up to 30% DDGS was fed (Cromwell et al., 1993; Fu et al., 2004; Lineen, 2008). Conversely, other researchers have found no negative impact of increasing DDGS on pig performance (DeDecker et al., 2005). Similar to our results, Woodworth et al., (2001) and Webster et al. (2003) found that EESM had no effect on ADG when substituted for solvent extracted soybean meal.

These results confirm that adding fat to finishing pig diets improves growth performance, while feeding DDGS in this trial resulted in decreased ADG and ADFI. Adding DDGS, EESM, or CWG increased IV and percentage 18:2, and reduced percentage saturated fatty acids. Feeding ingredients with high levels of unsaturated fat, such as EESM and DDGS, had a greater impact on fat IV than CWG even when dietary iodine values were similar. Therefore, IVP was a poor predictor of carcass fat IV when an unsaturated and a saturated fat source were fed.

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Table 1. Analyzed chemical composition of dietary ingredients and values used in diet formulation (as-fed basis)

	EESM		DDGS	
Item	Assumed[4]	Analyzed[3]	Assumed[4]	Analyzed[3]
DM	89.0	90.3	93.0	91.6
CP	46.5	44.2	27.7	28.4
Crude Fiber	6.5	6.9	7.3	7.1
Ether Extract	3.9	7.1	8.4	5.0
Lys	3.02	2.87	0.62	0.97
Ilu	2.16	2.05	1.03	1.07
Leu	3.66	3.42	2.57	2.94
Met	0.67	0.62	0.50	0.48
Cys	0.74	0.71	0.52	0.51
Thr	1.85	1.69	0.94	0.96
Trp	0.65	0.63	0.25	0.20
Val	2.27	2.17	1.30	1.36

[1]Extruded expelled soybean meal.

[2]Dried distillers grains with solubles.

[3]Values represent the mean of 1 sample.

[4]Represents assumed values used in diet formulation.

Table 2. Phase 1 diet composition (as-fed basis)[12]

Ingredient, %	Control	EESM	EESM + DDGS	DDGS + CWG	Low CWG	High CWG
Corn	72.06	70.31	57.27	56.41	66.84	64.54
Soybean meal, (46.5% CP)	25.09	---	---	24.44	27.06	27.86
DDGS[3]	---	---	15.00	15.00	---	---
EESM[4]	---	26.85	25.15	---	---	---
CWG[5]	---	---	---	1.55	3.25	4.70
Monocalcium phosphate (21% P)	1.10	1.15	0.75	0.75	1.15	1.20
Limestone	0.95	0.90	1.05	1.05	0.90	0.90
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix[6]	0.15	0.15	0.15	0.15	0.15	0.15
Trace mineral premix[7]	0.15	0.15	0.15	0.15	0.15	0.15
L-Lys HCl	0.15	0.15	0.15	0.15	0.15	0.15
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated composition						
Total Lys, %	1.06	1.11	1.12	1.10	1.11	1.13
True ileal digestible (TID) amino acids						
Lys, %	0.95	0.98	0.98	0.97	0.99	1.01
Met:Lys ratio, %	28	28	31	31	27	27
Met & Cys:Lys ratio, %	57	56	64	64	56	55
Thr:Lys ratio, %	61	60	66	66	60	60
Trp:Lys ratio, %	19	19	21	21	19	19
ME, kcal/kg	3,315	3,441	3,441	3,394	3,463	3,526
TID Lys:calorie ratio, g/Mcal ME	2.58	2.58	2.58	2.58	2.58	2.58
Crude fat, %	3.2	4.5	5.1	5.4	6.3	7.6
CP, %	17.9	18.6	20.9	20.5	18.4	18.6
Ca, %	0.67	0.67	0.67	0.67	0.67	0.68
P, %	0.61	0.62	0.61	0.60	0.62	0.62
Available P, %	0.30	0.31	0.31	0.31	0.31	0.32
Calculated IVP, g/100 g[8]	40	57	65	57	57	65
Analyzed IVP[9]	33.3	50.0	53.8	57.4	46.3	54.7

[1] Diet fed in meal form from d 0 to 26.

[2] Diet composition was calculated using NRC (1998) composition values for ingredients, except the ME value of DDGS in which 3,420 kcal/kg was used.

[3] Dried distillers grains with solubles.

[4] Extruded expelled soybean meal.

[5] Choice white grease.

[6] Provided (per kilogram of diet): 11,025 IU of vitamin A, 1,654 IU of vitamin D_3, 44 IU of vitamin E, 4.4 mg of vitamin K (as menadione sodium bisulfate), 55.1 mg of niacin, 9.9 mg of riboflavin, and 0.044 mg of B_{12}.

[7] Provided (per kilogram of the diet): 39.7 mg of Mn (oxide), 165.4 mg of Fe (sulfate), 165 mg of Zn (oxide), 16.5 mg of Cu (sulfate), 0.30 mg of I (as Ca iodate), and 0.30 mg of Se (as Na selenite).

[8] IV of diet oil × % diet oil × 0.10.

[9] IV of diet oil from analyzed fatty acid composition × % analyzed diet oil × 0.10.

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

Ingredient, %	Control	EESM	EESM + DDGS	DDGS + CWG	Low CWG	High CWG
Corn	80.07	79.08	66.05	66.18	76.83	74.60
Soybean meal, (46.5% CP)	17.28	---	---	15.87	18.33	19.05
DDGS[3]	---	---	15.00	15.00	---	---
EESM[4]	---	18.20	16.50	---	---	---
CWG[5]	---	---	---	0.50	2.15	3.65
Monocalcium phosphate (21% P)	1.00	1.05	0.65	0.65	1.05	1.05
Limestone	0.90	0.90	1.05	1.05	0.90	0.90
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix[6]	0.13	0.13	0.13	0.13	0.13	0.13
Trace mineral premix[7]	0.13	0.13	0.13	0.13	0.13	0.13
L-Lys HCl	0.15	0.15	0.15	0.15	0.15	0.15
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated composition						
Total Lys, %	0.85	0.87	0.88	0.86	0.87	0.89
True ileal digestible (TID) amino acids						
Lys, %	0.75	0.77	0.77	0.76	0.77	0.79
Met:Lys ratio, %	30	30	35	35	30	29
Met & Cys:Lys ratio, %	63	62	71	72	61	60
Thr:Lys ratio, %	62	62	69	70	62	62
Trp:Lys ratio, %	19	19	21	21	19	19
ME, kcal/kg	3,326	3,407	3,410	3,357	3,421	3,489
TID Lys:calorie ratio, g/Mcal ME	2.14	2.14	2.14	2.14	2.14	2.14
Crude fat, %	3.4	4.3	4.9	4.6	5.4	6.8
CP, %	15.0	15.3	17.6	17.3	15.2	15.3
Ca, %	0.61	0.62	0.63	0.62	0.62	0.62
P, %	0.55	0.57	0.55	0.55	0.56	0.56
Available P, %	0.27	0.28	0.28	0.28	0.28	0.28
Calculated IVP, g/100 g[8]	42	54	62	54	54	62
Analyzed IVP[9]	37.7	46.7	58.9	49.8	44.0	54.5

[1] Diet fed in meal form from d 26 to 55.

[2] Diet composition was calculated using NRC (1998) composition values for ingredients, except the ME value of DDGS in which 3,420 kcal/kg was used.

[3] Dried distillers grains with solubles.

[4] Extruded expelled soybean meal.

[5] Choice white grease.

[6] Provided (per kilogram of diet): 11,025 IU of vitamin A, 1,654 IU of vitamin D_3, 44 IU of vitamin E, 4.4 mg of vitamin K (as menadione sodium bisulfate), 55.1 mg of niacin, 9.9 mg of riboflavin, and 0.044 mg of B_{12}.

[7] Provided (per kilogram of the diet): 39.7 mg of Mn (oxide), 165.4 mg of Fe (sulfate), 165 mg of Zn (oxide), 16.5 mg of Cu (sulfate), 0.30 mg of I (as Ca iodate), and 0.30 mg of Se (as Na selenite).

[8] IV of diet oil × % diet oil × 0.10.

[9] IV of diet oil from analyzed fatty acid composition × % analyzed diet oil × 0.10.

Table 4. Phase 3 diet composition (as-fed basis)[12]

Ingredient, %	Control	EESM	EESM + DDGS	DDGS + CWG	Low CWG	High CWG
Corn	84.18	83.54	70.50	71.13	81.79	79.66
Soybean meal, (46.5% CP)	13.37	---	---	11.67	14.06	14.74
DDGS[3]	---	---	15.00	15.00	---	---
EESM[4]	---	14.00	12.30	---	---	---
CWG[5]	---	---	---	---	1.70	3.15
Monocalcium phosphate (21% P)	0.80	0.80	0.45	0.45	0.85	0.85
Limestone	0.90	0.90	1.00	1.00	0.85	0.85
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix[6]	0.13	0.13	0.13	0.13	0.13	0.13
Trace mineral premix[7]	0.13	0.13	0.13	0.13	0.13	0.13
L-Lys HCl	0.15	0.15	0.15	0.15	0.15	0.15
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Composition						
Total Lys, %	0.74	0.76	0.77	0.75	0.76	0.77
True ileal digestible (TID) amino acids						
Lys, %	0.65	0.66	0.66	0.65	0.67	0.68
Met:Lys ratio, %	32	32	38	38	32	31
Met & Cys:Lys ratio, %	67	66	77	78	65	64
Thr:Lys ratio, %	64	63	72	72	63	63
Trp:Lys ratio, %	19	18	21	21	19	19
ME, kcal/kg	3,335	3,399	3,401	3,344	3,412	3,476
TID Lys:calorie ratio, g/Mcal ME	1.85	1.85	1.85	1.85	1.85	1.85
Crude fat, %	3.5	4.2	4.8	4.2	5.1	6.5
CP, %	13.5	13.8	16.0	15.8	13.6	13.8
Ca, %	0.56	0.56	0.56	0.55	0.55	0.55
P, %	0.50	0.50	0.49	0.49	0.50	0.50
Available P, %	0.22	0.22	0.23	0.23	0.23	0.23
Calculated IVP, g/100 g[8]	44	53	61	53	53	61
Analyzed IVP[9]	37.1	45.9	55.3	46.5	41.3	47.0

[1] Diet fed in meal form from d 55 to 83.
[2] Diet composition was calculated using NRC (1998) composition values for ingredients, except the ME value of DDGS in which 3,420 kcal/kg was used.
[3] Dried distillers grains with solubles.
[4] Extruded expelled soybean meal.
[5] Choice white grease.
[6] Provided (per kilogram of diet): 11,025 IU of vitamin A, 1,654 IU of vitamin D_3, 44 IU of vitamin E, 4.4 mg of vitamin K (as menadione sodium bisulfate), 55.1 mg of niacin, 9.9 mg of riboflavin, and 0.044 mg of B_{12}.
[7] Provided (per kilogram of the diet): 39.7 mg of Mn (oxide), 165.4 mg of Fe (sulfate), 165 mg of Zn (oxide), 16.5 mg of Cu (sulfate), 0.30 mg of I (as Ca iodate), and 0.30 mg of Se (as Na selenite).
[8] IV of diet oil × % diet oil × 0.10.
[9] IV of diet oil from analyzed fatty acid composition × % analyzed diet oil × 0.10.

Table 5. Analyzed fatty acid profile of dietary ingredients

_Item	EESM[2]	DDGS[3]	CWG[4]
Myristic acid (14:0), %	0.09	0.07	1.76
Palmitic acid (16:0), %	10.17	14.25	24.43
Palmitoleic acid (16:1), %	0.10	0.15	2.35
Margaric acid (17:0), %	0.12	0.10	0.89
Stearic acid (18:0), %	3.78	2.11	15.63
Oleic acid (18:1c9), %	21.01	26.46	34.80
Vaccenic acid (18:1n7), %	1.48	0.76	2.34
Linoleic acid (18:2n6), %	54.48	52.86	13.07
α-linolenic acid (18:3n3), %	7.55	1.52	1.05
Arachidic acid (20:0), %	0.31	0.45	0.23
Gadoleic acid (20:1)	n.d.[1]	0.29	0.04
Eicosadienoic acid (20:2), %	0.10	0.10	0.45
Arachidonic acid (20:4n6), %	0.05	0.05	0.21
Other fatty acids, %	0.75	0.83	2.76
Total SFA, %[2,]	14.87	17.45	43.31
Total MUFA, %[3]	22.69	27.75	41.33
Total PUFA, %[4]	62.43	54.80	15.33
Total *trans* fatty acids, %[5]	0.16	0.23	1.86
UFA:SFA ratio[6]	5.72	4.73	1.31
PUFA:SFA ratio[7]	4.20	3.14	0.35
Iodine value, g/100 g[8]	134	120	62

[1]n.d. = not detectable.
[2] Dried distillers grains with solubles.
[3]Extruded expelled soybean meal.
[4] Choice white grease.
[5]Total saturated fatty acids = {[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.
[6]Total monounsaturated fatty acids = {[C14:1] + [C16:1] + [C18:1c9] + [C18:1n7] + [C20:1] + [C24:1]}, where the brackets indicate concentration.
[7]Total polyunsaturated fatty acids = {[C18:2n6] + [C18:3n3] + [C18:3n6] + [C20:2] + [C20:4n6]}, where the brackets indicate concentration.
[8]Total *trans* fatty acids = {[C18:1t] + [C18:2t] + [C18:3t]}, where the brackets indicate concentration.
[9]UFA:SFA ratio = [Total MUFA + Total PUFA] / Total SFA.
[10]PUFA:SFA ratio = Total PUFA / Total SFA.
[11]Calculated as 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 (AOCS, 1998).

Table 6. Effects of diets with common iodine value product from ingredients varying in unsaturated fat level and concentration on growth performance and carcass characteristics [1]

_Item	Control	EESM[2]	EESM + DDGS[3]	DDGS + CWG[4]	Low CWG	High CWG	SE
D 0 to 83							
ADG, kg	0.94[a]	0.94[a]	0.83[b]	0.91[ab]	0.93[ab]	0.99[a]	0.04
ADFI, kg	2.89[a]	2.71[b]	2.52[c]	2.69[b]	2.61[bc]	2.66[bc]	0.07
G:F	0.32[b]	0.34[ab]	0.38[a]	0.33[b]	0.35[ab]	0.36[a]	0.03
Yield, %	73.0	71.7	72.0	73.0	73.1	73.0	0.5
Last rib fat, mm[5]	23.9	22.9	22.4	23.9	23.4	24.6	1.0
10th rib fat, mm[5]	20.8	19.8	20.8	20.1	19.8	21.1	1.0
Loin depth, mm[5]	51.8[ab]	50.8[ab]	54.1[ab]	52.8[ab]	49.0[a]	55.6[b]	2.3
Lean, %[5]	50.8	50.9	51.2	51.1	50.6	51.3	0.5

[abc] Treatments with different superscripts differ $P < 0.05$.

[1] Total of 120 pigs (initial BW 47.9 kg) with 2 pigs per pen and 10 pens per treatment.

[2] Dried distillers grains with solubles.

[3] Extruded expelled soybean meal.

[4] Choice white grease.

[5] Data analyzed using hot carcass weight as a covariate.

Table 7. Effects of diets with common iodine value product from ingredients varying in unsaturated fat level and concentration on carcass fat quality [1]

_Item	Control	EESM	EESM + DDGS	DDGS + CWG	Low CWG	High CWG	SE
Backfat							
Myristic acid (14:0), %	1.42[bc]	1.36[ab]	1.32[a]	1.31[a]	1.46[c]	1.41[bc]	0.03
Palmitic acid (16:0), %	26.05[c]	25.14[b]	23.86[a]	23.93[a]	25.47[bc]	24.90[b]	0.27
Palmitoleic acid (16:1), %	2.35[bc]	2.18[b]	1.95[a]	2.09[ab]	2.53[c]	2.25[b]	0.08
Margaric acid (17:0), %	0.51[ab]	0.52[b]	0.46[a]	0.51[ab]	0.54[b]	0.50[ab]	0.02
Stearic acid (18:0), %	14.20[c]	13.37[bc]	12.20[a]	12.09[a]	12.97[ab]	13.36[bc]	0.32
Oleic acid (18:1c9), %	39.12[c]	37.50[b]	36.34[a]	37.36[ab]	39.79[cd]	40.71[d]	0.42
Vaccenic acid (18:1n7), %	2.59[c]	2.41[b]	2.20[a]	2.36[b]	2.81[d]	2.81[d]	0.06
Linoleic acid (18:2n6), %	11.16[a]	14.44[b]	18.39[c]	17.27[c]	11.75[a]	11.32[a]	0.55
α-linolenic acid (18:3n3), %	0.52[a]	0.92[c]	0.98[c]	0.73[b]	0.59[a]	0.57[a]	0.04
Arachidic acid (20:0), %	0.30[b]	0.30[bc]	0.27[ab]	0.27[ab]	0.26[a]	0.25[a]	0.01
Eicosadienoic acid (20:2), %	0.57[a]	0.68[b]	0.83[c]	0.80[c]	0.60[a]	0.66[b]	0.02
Arachidonic acid (20:4n6), %	0.19[ab]	0.18[a]	0.21[b]	0.22[bc]	0.20[abc]	0.19[ab]	0.01
Other fatty acids, %	1.01	1.00	1.03	1.11	1.02	1.06	0.03
Total SFA, %[2,]	42.83[c]	41.06[b]	38.43[a]	38.48[a]	41.03[b]	40.78[b]	0.52
Total MUFA, %[3]	44.44[c]	42.43[b]	40.83[a]	42.15[b]	45.50[cd]	46.16[d]	0.47
Total PUFA, %[4]	12.74[a]	16.51[b]	20.74[c]	19.37[c]	13.47[a]	13.05[a]	0.65
Total *trans* fatty acids, %[5]	0.33[b]	0.28[a]	0.30[a]	0.30[b]	0.33[b]	0.37[c]	0.01
UFA:SFA ratio[6]	1.34[a]	1.44[b]	1.61[c]	1.60[c]	1.44[b]	1.45[b]	0.03
PUFA:SFA ratio[7]	0.30[a]	0.40[b]	0.54[c]	0.51[c]	0.33[a]	0.32[a]	0.02
Iodine value, g/100 g[8]	59.92[a]	64.99[b]	70.78[c]	69.34[c]	62.11[a]	61.82[a]	0.94
Jowl fat							
Myristic acid (14:0), %	1.48[bc]	1.41[ab]	1.39[a]	1.42[ab]	1.51[c]	1.46[bc]	0.03
Palmitic acid (16:0), %	24.34[d]	23.48[bc]	22.59[a]	23.05[ab]	23.82[cd]	23.18[b]	0.20
Palmitoleic acid (16:1), %	3.07[b]	2.96[ab]	2.75[a]	2.90[ab]	3.19[b]	3.01[ab]	0.11
Margaric acid (17:0), %	0.46	0.49	0.46	0.49	0.51	0.53	0.02
Stearic acid (18:0), %	10.57[b]	10.05[ab]	9.42[a]	9.61[a]	9.85[a]	9.74[a]	0.24
Oleic acid (18:1c9), %	42.89[b]	41.32[a]	40.82[a]	41.33[a]	43.15[b]	43.71[b]	0.40
Vaccenic acid (18:1n7), %	3.47[bc]	3.30[ab]	3.11[a]	3.21[a]	3.57[c]	3.57[c]	0.09
Linoleic acid (18:2n6), %	10.98[a]	13.78[b]	16.13[c]	14.85[b]	11.57[a]	11.82[a]	0.43
α-linolenic acid (18:3n3), %	0.61[a]	0.95[d]	0.97[d]	0.76[c]	0.69[bc]	0.69[b]	0.28
Arachidic acid (20:0), %	0.23[a]	0.24[a]	0.21[ab]	0.22[ab]	0.21[ab]	0.20[b]	0.01
Eicosadienoic acid (20:2), %	0.61[a]	0.73[b]	0.84[c]	0.79[c]	0.66[a]	0.72[b]	0.02
Arachidonic acid (20:4n6), %	0.21[a]	0.22[ab]	0.23[b]	0.23[ab]	0.22[ab]	0.23[ab]	0.01
Other fatty acids, %	1.08	1.12	1.12	1.18	1.11	1.17	0.37
Total SFA, %[2,]	37.43[c]	36.07[b]	34.41[a]	35.18[ab]	36.26[b]	35.48[b]	0.37
Total MUFA, %[3]	49.83[b]	47.93[a]	47.07[a]	47.83[a]	50.28[b]	50.72[b]	0.50
Total PUFA, %[4]	12.73[a]	15.99[b]	18.52[c]	16.99[b]	13.46[a]	13.80[a]	0.48
Total *trans* fatty acids, %[5]	0.34[bc]	0.27[a]	0.32[bc]	0.32[b]	0.31[b]	0.36[c]	0.01
UFA:SFA ratio[6]	1.67[a]	1.77[bc]	1.91[d]	1.85[cd]	1.76[b]	1.82[bc]	0.03
PUFA:SFA ratio[7]	0.34[a]	0.44[c]	0.54[d]	0.48[c]	0.37[ab]	0.39[b]	0.02
Iodine value, g/100 g[8]	64.60[a]	68.80[c]	72.30[e]	70.16[d]	66.25[b]	67.09[bc]	0.61

[abcd] Treatments with different superscripts differ $P < 0.05$.

[1]Total of 120 pigs with 2 pigs per pen and ten pens per treatment.

[2]Total saturated fatty acids = {[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 monounsaturated fatty acids = {[C14:1] + [C16:1] + [C18:1c9] + [C18:1n7] + [C20:1] + [C24:1]}, where the brackets indicate concentration.

[4]Total polyunsaturated fatty acids = {[C18:2n6] + [C18:3n3] + [C18:3n6] + [C20:2] + [C20:4n6]}, where the brackets indicate concentration.

[5]Total *trans* fatty acids = {[C18:1t] + [C18:2t] + [C18:3t]}, where the brackets indicate concentration.

[6]UFA:SFA ratio = [Total MUFA + Total PUFA] / Total SFA.

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

[8]Calculated as 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 (AOCS, 1998).

Effects of increasing choice white grease in corn- and sorghum-based diets on growth performance, carcass characteristics, and fat quality characteristics of finishing pigs

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ABSTRACT: One hundred twenty barrows and gilts (TR4 × 1050; initial BW 54.4 kg) were used in an 83-d experiment to evaluate the effects of increasing added fat to corn- or sorghum-based diets on growth performance, carcass characteristics, and carcass fat quality characteristics. Treatments were arranged in a 2 × 2 × 3 factorial based on grain source (corn or sorghum), gender, and added fat (0, 2.5, or 5% choice white grease; CWG). At the end of the trial, pigs were slaughtered and jowl fat and backfat samples were collected. Overall, there were no 2- or 3-way interactions ($P > 0.10$) observed for growth performance. Pigs fed sorghum-based diets had increased ($P < 0.01$) ADG compared with those fed corn-based diets. The increase in ADG was due to a numerical ($P = 0.15$) increase in ADFI for pigs fed sorghum-based diets with no difference in G:F. Increasing CWG improved (quadratic , $P < 0.01$) ADG; however, there were no differences in ADFI or G:F. There were no gender differences for growth performance parameters. There was a tendency ($P = 0.06$) for a grain source × fat level interaction for 10th rib fat depth. This was due to an increase in 10th rib fat depth between pigs fed 0% and 2.5% CWG in corn-based diets; however, the increase occurred between 2.5% and 5% CWG in pigs fed sorghum-based diets. Pigs fed corn-based diets tended to have greater ($P = 0.09$) yield, 10th rib backfat, and percentage lean when compared to pigs fed sorghum-based diets. Increasing CWG increased (linear, $P = 0.02$) 10th rib backfat, tended to increase (linear, $P = 0.08$) hot carcass weight, and decreased (linear, $P = 0.07$) percentage lean. Barrows tended to have greater ($P = 0.06$) yield and decreased ($P = 0.07$) percentage lean when compared with gilts. There were no gender differences in 10th rib fat depth, loin depth, and last rib fat depth. For carcass fat quality, there was a grain source by fat level interaction ($P = 0.04$) for iodine value (IV) in both backfat and jowl fat. Adding CWG increased IV in backfat and jowl fat for pigs fed sorghum- and corn-based diets; however, the greatest increase was between 0 and 2.5% CWG in sorghum-based

diets and between 2.5 and 5% CWG in corn-based diets. Despite this interaction, pigs fed corn-based diets had increased ($P < 0.01$) backfat and jowl fat IV and percentage C 18:2 fatty acids compared with pigs fed sorghum-based diets. Pigs fed corn-based diets had increased ($P < 0.01$) monounsaturated fats and polyunsaturated fats in backfat and jowl fat. Increasing CWG increased (linear, $P < 0.01$) IV in backfat and jowl fat, percentage C 18:2 fatty acids in backfat (quadratic, $P < 0.01$) and jowl fat (linear, $P < 0.01$), and decreased (linear, $P < 0.01$) percentage saturated fatty acids in jowl fat and backfat. In summary, feeding sorghum-based diets reduced carcass fat IV and levels of unsaturated fats compared with corn-based diets. As expected, adding CWG increased carcass fat IV regardless of cereal grain in the diet.

Keywords: added fat, corn, iodine value, sorghum, swine

INTRODUCTION

Research has well established that added dietary fat improves ADG and G:F in growing and finishing pigs (Pettigrew and Moser, 1991 and De la Llata et al., 2001). Fatty acids absorbed from the diet, especially polyunsaturated fatty acids, specifically inhibit endogenous synthesis of fatty acids, inflating the effect of dietary fat composition influencing body fat composition. Therefore, it is possible to manipulate the composition of body fat quite dramatically by selection of dietary fats (Pettigrew and Esnaola, 2001). Because most common dietary fats are more unsaturated than the triglycerides the pig synthesizes endogenously, this can also lead to increased softness of carcass fat.

Iodine value (IV) is an estimate of the proportion of unsaturated fatty acids present, and therefore an indicator of carcass fat 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 proportion of unsaturated fatty acids (AOCS, 1998). Acceptable IV range from 70

(Barton and Gade, 1987; Madsen et al., 1992) to 75 g/100 g (Boyd et al., 1997). Some U. S. packing plants have set their maximum IV at 73 g/100 g.

Carr et al. (2005) showed pigs fed barley-based diets had lower IV than pigs fed high energy corn-based diets. Sorghum is a cereal grain that is frequently used in swine diets where it is regionally grown. Additionally, sorghum has lower oil content than corn, which may lead to pigs having a lower carcass fat IV. With this in mind, the objectives of this trial were to evaluate the effects of adding fat to corn- and sorghum-diets on growth performance, carcass characteristics, and fat quality characteristics of finishing barrows and gilts.

MATERIALS AND METHODS

One hundred twenty crossbred barrows and gilts, (TR4 × 1050, PIC Hendersonville, TN) with an initial BW of 54.4 kg were used in an 83-d experiment. Pigs were blocked by BW and allotted to 1 of 6 treatments. There were 2 pigs per pen with 10 replicate pens per treatment. Pigs were housed in an environmentally-regulated finishing barn with 1.52 × 1.52 m pens with totally slatted flooring. Each pen was equipped with a 1-hole dry self-feeder and nipple waterer to allow *ad libitum* access to feed and water. Pigs and feeders were weighed on d 14, 22, 39, 53, 67, and 83 to calculate ADG, ADFI, and G:F.

Treatments were arranged in a 2 × 2 × 3 factorial based on gender, grain source (corn or sorghum), and added fat (0, 2.5, or 5% choice white grease). Before to being placed on test, all pigs were fed a similar corn-soybean meal-based diet for 7 wk. Diets were fed in 3 phases from d 0 to 22, 22 to 53, and 53 to 83 to correspond with approximate weight ranges of 41 to 68, 68 to 95, and 95 to 123 kg. A constant true ileal digestible lysine:ME ratio was maintained by altering the corn, sorghum, and soybean meal level in the basal diet when adding dietary fat.

Pigs were slaughtered at Triumph Foods, LLC (St. Joseph, MO) at the end of the 83-d trial for collection of individual carcass data including hot carcass weight (HCW), loin and backfat depth, lean percentage, and yield. The pigs were marked with an individual tattoo before marketing. At 24 h postmortem, backfat and jowl samples were collected and frozen at 0° C until fatty acid analysis. Fat (50 μg) was combined with 2 mL of methanolic-HCl and 3 mL of internal standard (2 mg/mL of methyl Heptadecanoic acid (C17:0) in benzene) and subsequently was heated in a water bath for 120 min at 70°C for transmethylation. Upon cooling, the addition of 2 mL of benzene and 3 mL of K_2CO_3 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 from the following equation:

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 (AOCS, 1998).

Saturated fatty acid percentage was determined by adding the percentage of each individual fatty acid.

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.

Statistical Analysis

Data were analyzed as a randomized complete-block design with pen as the experimental unit. Analysis of variance was performed by using the MIXED procedure of SAS (SAS Inst., Cary, NC). Pigs were block by weight within gender. The statistical model included random effect for block. Fixed effects were gender, grain source, fat level, with 2- and 3-way interactions for all fixed effects tested. Hot carcass weight was used as a covariate for 10th rib backfat, last rib backfat, loin depth, and percentage lean.

RESULTS

Overall, there were no 2- and 3-way interactions ($P > 0.10$) observed for growth performance. Pigs fed sorghum-based diets had increased ($P < 0.01$) ADG compared with pigs fed corn-based diets (Table 4). The increase in ADG was due to a numerical ($P = 0.15$) increase in ADFI for pigs fed sorghum-based diets, as there was no difference in G:F. Also, pigs fed increasing CWG had improved (quadratic, $P < 0.01$) ADG; however, there were no differences in ADFI or G:F. There were no gender differences for growth performance criteria ($P > 0.49$) although barrows had numerically higher ADFI and lower G:F compared with gilts.

For carcass characteristics, there was a tendency ($P = 0.06$) for a grain source × fat level interaction for 10^{th} rib fat depth. The interaction occurred because the greatest increase in 10^{th} rib fat depth was between 0 and 2.5% CWG for pigs fed corn-based diets, while the greatest increase was between 2.5 and 5% CWG for pigs fed sorghum-based diets. Pigs fed corn-based diets tended to have greater ($P = 0.09$) yield, 10^{th} rib backfat, and percentage lean when compared with pigs fed sorghum-based diets. Increasing CWG increased (linear, $P = 0.02$) 10^{th} rib backfat, tended to increase (linear, $P = 0.08$) hot carcass weight, and tended to decrease (linear, $P = 0.07$) percentage lean. Barrows tended to have greater ($P = 0.06$) yield and decreased ($P = 0.07$) percentage lean when compared to gilts (Table 6). There were no gender differences in 10^{th} rib fat depth, loin depth, and last rib fat depth.

For carcass fat quality, there was a grain source × fat level interaction ($P = 0.04$) for IV in both backfat and jowl fat (Tables 7 and 8). Adding CWG increased IV in backfat and jowl fat for pigs fed corn- and sorghum-based diets; however, the greatest increase was between 0 and 2.5% CWG in sorghum-based diets and between 2.5 and 5% CWG in corn-based diets. Despite this interaction, pigs fed corn-based diets had increased ($P < 0.01$) backfat and jowl fat IV and percentage C 18:2 fatty acids compared with pigs fed sorghum-based diets. Pigs fed corn-based diets had increased ($P < 0.01$) monounsaturated fats and polyunsaturated fats in backfat and jowl fat. Increasing the level of CWG in the diet increased (linear, $P < 0.01$) IV in backfat and jowl fat, percentage C 18:2 fatty acids in backfat (quadratic, $P < 0.01$) and jowl fat (linear, $P < 0.01$), and decreased (linear, $P < 0.01$) percentage saturated fatty acids in jowl fat and backfat.

When evaluating fat depots, backfat had increased percentage saturated fatty acids (SFA) and decreased percentage monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA), UFA:SFA ratio, PUFA:SFA ratio and IV compared with jowl fat in pigs fed corn- or sorghum-based diets.

DISCUSSION

Pigs fed sorghum-based diets had backfat and jowl fat IV approximately 2 g/100 g lower than pigs fed corn-based diets. Similarly, Carr et al. (2005) showed a numeric decrease of approximately 2 to 3 g/100g in backfat IV from feeding barley-based diets compared with corn-based diets. The reduction in carcass fat IV is similar because the amount of dietary fat is similar in sorghum and barley, with both having lower overall fat content than corn.

The increase in jowl fat and backfat IV from increasing dietary CWG agrees with data from Weber et al. (2006) who saw an increase in IV in backfat and belly fat from feeding pigs soybean oil, CWG, or beef tallow. This is due to an increase in the percentage of polyunsaturated fatty acids in the diet. Dietary polyunsaturated fats are the most effective inhibitors of *de novo synthesis* (Clarke et al., 1990; Bee et al., 1999, 2002). Therefore, increasing the inclusion of these fats in diets causes pigs to deposit more unsaturated dietary fats, which increases carcass IV.

Linoleic acid (C 18:2) has been shown to have a greater impact on fat firmness compared with all other fatty acids (Berschauer, 1984). Averette-Gatlin et al. (2003) and Boyd et al. (1997)

showed increasing the amount of dietary unsaturated fats increased linoleic acid levels in backfat. Similarly, our data show that pigs fed corn-based diets have higher linoleic acid levels than pigs fed sorghum-based diets. The interaction between fat level and grain source for backfat and jowl fat IV and linoleic acid occurred because the greatest increase was between 0 and 2.5% CWG for sorghum-based diets and between 2.5 and 5% CWG for corn-based diets. The reason for this interaction is unknown.

Backfat IV were lower than jowl fat IV; however, increasing CWG in both corn- and sorghum-based diets narrowed the difference. Benz et al. (2008a) saw similar results, as the feeding duration of CWG increased, backfat IV became more similar to jowl fat IV. Also in that same study, as feeding duration of soybean oil increased up to 68-d, backfat and jowl fat IV became more similar. However, when soybean oil was fed for 82-d, backfat IV was actually higher than jowl fat IV. Benz et al. (2008b) showed backfat IV approximately 6 g/100 g lower than jowl fat IV, except for diets fed a higher level of unsaturated fat from feeding 15% dried distillers grain with solubles and replacing traditional soybean meal with extruded expelled soybean meal.

Madsen (1992) and Boyd et al. (1997) developed equations to predict backfat iodine from calculating a dietary Iodine value product (IVP). Iodine value product is calculated as: (IV of the dietary lipids) × (percentage dietary lipid) × 0.10. Boyd et al., (1997) estimated backfat IV as 52.4 × 0.315 (diet IVP). Pigs fed corn- or sorghum-based diets with no added fat had similar backfat IV to what is predicted for the equation; however, adding CWG caused the predicted backfat IV to be higher than analyzed values. Benz et al., (2008b) saw similar results, with predicted IV of pigs fed higher levels of CWG being higher than analyzed values.

Adding CWG increases dietary energy level, and consistent with our data, has resulted in increased ADG (Campbell and Taverner 1988; Southern et al., 1989; De La Llata et al., 2001). Pigs fed sorghum-based diets had increased ADG compared with pigs fed corn-based diets; which was due to a numeric increase in ADFI. Similarly, Shelton et al. (2004) observed pigs fed waxy and non-waxy sorghum having higher ADFI during all phases of growth, and higher ADG during the early grower phase than pigs fed corn. Also, Hancock et al. (1992) showed pigs fed extruded corn-based diets had similar G:F to pigs fed extruded sorghum-based diets. Pigs fed corn-based diets tended to have increased yields. When combined with the reduction in ADG for pigs fed corn-based diets, there was no difference in HCW. In agreement with our data, De La Llata et al. (2001) found an increase in backfat depth when 6% CWG was added for the length of the entire experiment.

We did not find the expected gender differences in growth performance and fat quality; however, the typical numerical differences in growth performance occurred with barrows having 6% higher ADFI and 4% poorer G:F than gilts.

Feeding fat increased the softness of fat deposits as measured by IV and the amount of linoleic acid. Substituting sorghum for corn lowered IV and the percentage of linoleic acid to the point that pigs fed sorghum-based diets with 5% CWG had similar IV and percentage linoleic acid to pigs fed corn-based diets with no added fat. Therefore, higher energy sorghum-based diets could be fed while having fewer concerns about fat quality. Additionally, if pigs fed corn-based diets are at or just above maximum IV threshold, sorghum could be substituted to prevent exceeding the maximum IV.

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Table 1. Analyzed chemical composition of dietary ingredients and values used in diet formulation (as-fed basis)

	Corn		Sorghum	
Item	Assumed[2]	Analyzed[1]	Assumed[2]	Analyzed[1]
DM	89.0	89.2	89.0	89.1
CP	8.5	8.1	9.2	9.0
Crude Fiber	2.2	2.2	2.4	2.2
Ether Extract	3.5	3.7	2.9	3.2
Lys	0.26	0.24	0.22	0.23
Ilu	0.28	0.25	0.37	0.33
Leu	0.99	0.84	1.21	1.19
Met	0.17	0.15	0.17	0.16
Cys	0.19	0.17	0.17	0.15
Thr	0.29	0.28	0.31	0.30
Trp	0.06	0.05	0.10	0.08
Val	0.39	0.34	0.46	0.42

[1]Values represent the mean of 1 sample.

[2]Represents assumed values used in diet formulation.

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

Ingredients	Grain source: Added fat:	Corn 0%	Corn 2.5%	Corn 5%	Sorghum 0%	Sorghum 2.5%	Sorghum 5%
Corn		72.18	68.18	64.19	- - -	- - -	- - -
Sorghum		- - -	- - -	- - -	72.25	68.25	64.20
Soybean meal (46.5% CP)		25.23	26.70	28.14	25.25	26.73	28.25
Choice white grease		- - -	2.50	5.00	- - -	2.50	5.00
Monocalcium phosphate (21% P)		1.03	1.05	1.10	0.93	0.98	1.00
Limestone		0.85	0.85	0.85	0.85	0.85	0.85
Salt		0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix[2]		0.10	0.10	0.10	0.10	0.10	0.10
Trace mineral premix[3]		0.10	0.10	0.10	0.10	0.10	0.10
L-Lys HCl		0.15	0.15	0.15	0.15	0.15	0.15
DL-Met		0.02	0.02	0.02	0.02	0.02	0.02
Total		100.00	100.00	100.00	100.00	100.00	100.00
Calculated values							
Total Lys, %		1.07	1.10	1.13	1.04	1.08	1.11
True ileal digestible (TID) amino acids							
Lys, %		0.95	0.98	1.01	0.93	0.97	1.00
Met:Lys ratio, %		29	29	28	30	29	28
Met & Cys:Lys ratio, %		59	58	56	58	57	56
Thr:Lys ratio, %		61	60	60	64	63	62
Trp:Lys ratio, %		19	19	19	22	22	22
ME, kcal/kg		3,326	3,438	3,548	3,271	3,385	3,500
CP, %		18.0	18.4	18.7	18.5	18.9	19.2
Crude fat, %		3.2	5.6	7.9	2.5	4.9	7.3
Ca, %		0.62	0.63	0.64	0.60	0.61	0.62
P, %		0.59	0.60	0.60	0.58	0.59	0.59
Available P, %		0.28	0.29	0.30	0.28	0.29	0.29
TID Lys:Cal ratio, g/Mcal ME		2.58	2.58	2.58	2.58	2.58	2.58
Analyzed values							
Crude fat, %		2.2	5.1	8.4	2.2	4.1	6.7
Dietary fat IV, g/100 g		111.14	92.39	85.71	108.65	87.88	71.32
Dietary IVP[4]		35.56	51.37	72.62	26.88	42.88	51.96

[1]Diet fed in meal form from d 0 to 22.
[2]Provided (per kilogram of diet): 11,025 IU of vitamin A, 1,654 IU of vitamin D_3, 44 IU of vitamin E, 4.4 mg of vitamin K (as menadione sodium bisulfate), 55.1 mg of niacin, 9.9 mg of riboflavin, and 0.044 mg of B_{12}.
[3]Provided (per kilogram of the diet): 39.7 mg of Mn (oxide), 165.4 mg of Fe (sulfate), 165 mg of Zn (oxide), 16.5 mg of Cu (sulfate), 0.30 mg of I (as Ca iodate), and 0.30 mg of Se (as Na selenite).
[4] Dietary Iodine Value Product = IV (in Diet oil) × % Diet Oil × 0.10.

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

	Grain source:	Corn			Sorghum		
Ingredients	Added fat:	0%	2.5%	5%	0%	2.5%	5%
Corn		80.26	76.53	72.81	- - -	- - -	- - -
Sorghum		- - -	- - -	- - -	80.10	76.35	72.60
Soybean meal (46.5% CP)		17.27	18.47	19.66	17.53	18.73	19.97
Choice white grease		- - -	2.50	5.00	- - -	2.50	5.00
Monocalcium phosphate (21% P)		0.93	0.95	0.98	0.83	0.85	0.90
Limestone		0.85	0.85	0.85	0.85	0.85	0.85
Salt		0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix[2]		0.10	0.10	0.10	0.10	0.10	0.10
Trace mineral premix[3]		0.10	0.10	0.10	0.10	0.10	0.10
L-Lys HCl		0.15	0.15	0.15	0.15	0.15	0.15
Total		100.00	100.00	100.00	100.00	100.00	100.00
Calculated values							
Total Lys, %		0.85	0.87	0.90	0.82	0.85	0.88
True ileal digestible (TID) amino acids							
Lys, %		0.75	0.78	0.80	0.74	0.76	0.79
Met:Lys ratio, %		30	30	29	31	30	29
Met & Cys:Lys ratio, %		63	61	60	62	60	59
Thr:Lys ratio, %		63	62	61	67	66	65
Trp:Lys ratio, %		19	19	19	23	23	22
ME, kcal/kg		3,333	3,445	3,555	3,271	3,385	3,500
CP, %		15.0	15.2	15.5	15.7	15.9	16.1
Crude fat, %		3.4	5.8	8.1	2.6	5.0	7.4
Ca, %		0.58	0.58	0.59	0.56	0.57	0.58
P, %		0.54	0.54	0.54	0.53	0.53	0.54
Available P, %		0.25	0.26	0.26	0.25	0.25	0.26
TID Lys:Cal ratio, g/Mcal ME		2.14	2.14	2.14	2.14	2.14	2.14
Analyzed values							
Crude fat, %		3.3	5.9	8.6	2.2	4.8	6.1
Dietary fat IV, g/100 g		113.97	94.99	84.76	106.83	90.83	83.71
Dietary IVP[4]		38.75	54.73	68.95	21.76	45.38	61.98

[1]Diet fed in meal form from d 22 to 53.
[2]Provided (per kilogram of diet): 11,025 IU of vitamin A, 1,654 IU of vitamin D_3, 44 IU of vitamin E, 4.4 mg of vitamin K (as menadione sodium bisulfate), 55.1 mg of niacin, 9.9 mg of riboflavin, and 0.044 mg of B_{12}.
[3]Provided (per kilogram of the diet): 39.7 mg of Mn (oxide), 165.4 mg of Fe (sulfate), 165 mg of Zn (oxide), 16.5 mg of Cu (sulfate), 0.30 mg of I (as Ca iodate), and 0.30 mg of Se (as Na selenite).
[4] Dietary Iodine Value Product = IV (in Diet oil) × % Diet Oil × 0.10.

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

	Grain Source:	Corn			Sorghum		
Ingredients	Added fat:	0%	2.5%	5%	0%	2.5%	5%
Corn		84.18	80.54	76.98	- - -	- - -	- - -
Sorghum		- - -	- - -	- - -	83.90	80.35	76.75
Soybean meal (46.5% CP)		13.44	14.56	15.60	13.82	14.82	15.91
Choice white grease		- - -	2.50	5.00	- - -	2.50	5.00
Monocalcium phosphate (21% P)		0.88	0.90	0.93	0.78	0.83	0.85
Limestone		0.80	0.80	0.80	0.80	0.80	0.80
Salt		0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix[2]		0.10	0.10	0.10	0.10	0.10	0.10
Trace mineral premix[3]		0.10	0.10	0.10	0.10	0.10	0.10
L-Lys HCl		0.15	0.15	0.15	0.15	0.15	0.15
Total		100.00	100.00	100.00	100.00	100.00	100.00
Calculated values							
Total Lys, %		0.74	0.77	0.79	0.72	0.74	0.77
True ileal digestible (TID) amino acids							
Lys, %		0.65	0.68	0.70	0.64	0.66	0.69
Met:Lys ratio, %		32	31	30	33	32	31
Met & Cys:Lys ratio, %		66	65	63	65	63	62
Thr:Lys ratio, %		64	63	62	69	67	66
Trp:Lys ratio, %		19	19	19	23	23	23
ME, kcal/kg		3,337	3,449	3,562	3,273	3,388	3,502
CP, %		13.5	13.8	13.9	14.3	14.4	14.6
Crude fat, %		3.5	5.9	8.2	2.6	5.1	7.5
Ca, %		0.54	0.54	0.55	0.52	0.53	0.54
P, %		0.51	0.51	0.52	0.50	0.51	0.51
Available P, %		0.24	0.24	0.25	0.23	0.24	0.25
TID Lys:Cal ratio, g/Mcal ME		1.85	1.85	1.85	1.85	1.85	1.85
Analyzed values							
Crude fat, %		3.1	5.6	8.6	2.2	3.5	6.7
Dietary fat IV, g/100 g		120.3	99.03	84.03	94.62	85.38	83.21
Dietary IVP[4]		42.11	58.03	69.21	24.99	43.14	62.11

[1]Diet fed in meal form from d 53 to 83.
[2]Provided (per kilogram of diet): 11,025 IU of vitamin A, 1,654 IU of vitamin D_3, 44 IU of vitamin E, 4.4 mg of vitamin K (as menadione sodium bisulfate), 55.1 mg of niacin, 9.9 mg of riboflavin, and 0.044 mg of B_{12}.
[3]Provided (per kilogram of the diet): 39.7 mg of Mn (oxide), 165.4 mg of Fe (sulfate), 165 mg of Zn (oxide), 16.5 mg of Cu (sulfate), 0.30 mg of I (as Ca iodate), and 0.30 mg of Se (as Na selenite).
[4] Dietary Iodine Value Product = IV (in Diet oil) × % Diet Oil × 0.10.

Table 5. Effects of adding fat to corn- and sorghum-based diets on growth performance and carcass characteristics[1]

Item	Grain source: Corn 0%	Corn 2.5%	Corn 5%	Sorghum 0%	Sorghum 2.5%	Sorghum 5%	Fat level SE	Source SE	Probability, P< Source	Fat Level Linear	Fat Level Quad	Source × Fat level
D 0 to 83												
ADG, kg	0.89	0.93	0.97	0.95	0.99	1.01	0.02	0.01	0.01	0.01	0.98	0.89
ADFI, kg	2.55	2.61	2.53	2.67	2.64	2.73	0.01	0.01	0.15	0.51	0.23	0.61
G:F	0.35	0.35	0.38	0.36	0.37	0.37	0.01	0.01	0.90	0.18	0.16	0.68
Hot carcass wt, kg	93.9	97.1	98.7	96.5	100.2	100.4	1.2	1.0	0.46	0.08	0.92	0.34
Yield, %	73.0	73.6	73.3	72.2	72.8	72.4	0.37	0.30	0.06	0.28	0.36	0.91
10th rib fat, mm[2]	16.5	18.3	18.0	18.3	18.3	20.6	1.5	1.3	0.06	0.02	0.77	0.06
Loin depth, mm[2]	61.0	63.5	63.0	61.2	64.8	62.2	23.6	18.8	0.98	0.52	0.03	0.80
Last rib fat, mm[2]	22.4	25.1	24.9	24.1	24.4	25.4	1.5	0.8	0.83	0.18	0.61	0.44
Lean, %[2]	53.9	53.6	53.4	53.2	53.5	52.3	0.28	0.26	0.09	0.07	0.13	0.13

[1] Total of 120 pigs (initial BW 54.4 kg) with 2 pigs per pen and 10 replicates per treatment.
[2] Hot carcass weight used as a covariate for statistical analysis.

Table 6. Effects of adding fat to corn- and sorghum-based diets on growth performance and carcass characteristics[1]

Item	Added fat:	Fat level 0%	Fat level 2.5%	Fat level 5%	Source Corn	Source Sorghum	Fat level SE	Source SE	Probability, P< Source	Probability, P< Fat Level Linear	Probability, P< Fat Level Quad	Probability, P< Source × Fat level
D 0 to 83												
ADG, kg		0.92	0.96	0.99	0.93	0.99	0.02	0.01	0.01	0.89	0.01	0.98
ADFI, kg		2.60	2.63	2.65	2.57	2.68	0.01	0.01	0.15	0.49	0.51	0.23
G:F		0.36	0.36	0.37	0.36	0.37	0.02	0.01	0.90	0.49	0.18	0.16
Hot carcass wt, kg		95.7	97.3	98.6	96.6	97.7	1.2	1.0	0.46	0.08	0.92	0.34
Yield, %		72.5	73.2	73.1	73.3	72.5	0.37	0.30	0.06	0.28	0.36	0.91
10^{th} rib fat, mm[2]		17.3	18.3	19.8	17.8	19.3	1.5	1.3	0.06	0.02	0.77	0.06
Loin depth, mm[2]		61.2	64.5	62.2	62.7	62.7	23.6	18.8	0.98	0.52	0.03	0.80
Last rib fat, mm[2]		23.1	24.9	25.4	24.4	24.6	1.5	0.8	0.83	0.18	0.61	0.44
Lean, %[2]		53.6	53.6	52.6	53.6	52.9	0.28	0.26	0.09	0.07	0.13	0.13

[1] Total of 120 pigs (initial BW 54.4 kg) with 2 pigs per pen and 10 replicates per treatment.
[2] Hot carcass weight used as a covariate for statistical analysis.

Table 7. Effects of gender on growth performance and carcass characteristics[1]

Item	Barrows	Gilts	SE	Probability, P<
D 0 to 83				
ADG, kg	0.96	0.95	0.01	0.89
ADFI, kg	2.70	2.55	0.01	0.49
G:F	2.81	2.69	0.01	0.49
Hot carcass wt, kg	97.5	96.8	1.0	0.64
Yield, %	73.4	72.4	0.32	0.06
10th rib fat, mm[2]	19.1	17.8	1.5	0.15
Loin depth, mm[2]	62.2	63.0	18.8	0.53
Last rib fat, mm[2]	24.6	24.1	0.8	0.69
Lean, %[2]	52.9	53.6	0.22	0.07

[1] Total of 120 pigs (60 barrows and 60 gilts; initial weight 54.4 kg).
[2] Hot carcass weight used as a covariate for statistical analysis.

Table 8. Effects of adding fat to corn- and sorghum-based diets on backfat quality[1]

Item	Grain source: Added fat:	Corn 0%	Corn 2.5%	Corn 5%	Sorghum 0%	Sorghum 2.5%	Sorghum 5%	Fat level SE	Source SE	Probability, P < Source	Fat Level Linear	Fat Level Quad	Source × Fat level
Myristic acid (14:0), %		1.45	1.41	1.36	1.50	1.40	1.40	0.02	0.02	0.27	0.01	0.41	0.55
Palmitic acid (16:0), %		25.15	24.04	23.43	25.52	23.70	24.08	0.22	0.18	0.26	0.01	0.02	0.23
Palmitoleic acid (16:1), %		2.43	2.29	2.25	2.55	2.38	2.41	0.07	0.06	0.10	0.14	0.41	0.95
Margaric acid (17:0), %		0.59	0.61	0.59	0.56	0.63	0.59	0.01	0.01	0.69	0.52	0.05	0.34
Stearic acid (18:0), %		13.32	12.34	11.89	13.42	11.89	12.12	0.25	0.20	0.97	0.01	0.08	0.54
Oleic acid (18:1c9), %		37.67	38.66	39.93	39.70	40.58	40.94	0.04	0.04	0.01	0.01	0.45	0.19
Vaccenic acid (18:1n7), %		2.67	2.76	2.91	2.91	3.10	3.03	0.33	0.27	0.01	0.01	0.96	0.53
Linoleic acid (18:2n6), %		13.76	14.78	14.47	11.03	13.24	12.45	0.31	0.25	0.01	0.02	0.01	0.37
α-linolenic acid (18:3n3), %		0.65	0.72	0.71	0.66	0.76	0.70	0.02	0.01	0.53	0.03	0.01	0.65
Arachidic acid (20:0), %		0.26	0.25	0.23	0.25	0.22	0.24	0.01	0.01	0.09	0.01	0.09	0.14
Eicosadienoic acid (20:2), %		0.66	0.74	0.77	0.56	0.70	0.65	0.02	0.01	0.01	0.01	0.01	0.22
Arachidonic acid (20:4n6), %		0.21	0.22	0.23	0.19	0.22	0.22	0.01	0.01	0.07	0.01	0.26	0.43
Other fatty acids, %		1.16	1.18	1.21	1.16	1.19	1.18	0.03	0.02	0.77	0.36	0.77	0.79
Total SFA, %[2,]		41.27	39.15	38.00	41.77	38.34	38.92	0.41	0.34	0.54	0.01	0.03	0.26
Total MUFA, %[3]		43.11	44.02	45.46	45.50	46.40	46.72	0.39	0.32	0.01	0.01	0.01	0.50
Total PUFA, %[4]		15.62	16.82	16.54	12.73	15.26	14.36	0.34	0.28	0.01	0.02	0.01	0.37
Total *trans* fatty acids, %[5]		0.28	0.26	0.30	0.28	0.29	0.31	0.01	0.01	0.58	0.16	0.36	0.68
UFA:SFA ratio[6]		1.43	1.56	1.63	1.40	1.62	1.58	0.03	0.02	0.62	0.01	0.03	0.24
PUFA:SFA ratio[7]		0.38	0.43	0.44	0.31	0.40	0.37	0.01	0.01	0.01	0.01	0.01	0.33
Iodine value, g/100 g[8]		63.77	66.55	67.21	60.96	65.95	64.68	0.55	0.45	0.01	0.01	0.01	0.27

[1]Total of 120 pigs with 2 pigs per pen and 10 replicates per treatment.
[2]Total saturated fatty acids = {[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 monounsaturated fatty acids = {[C14:1] + [C16:1] + [C18:1c9] + [C18:1n7] + [C20:1] + [C24:1]}, where the brackets indicate concentration.
[4]Total polyunsaturated fatty acids = {[C18:2n6] + [C18:3n3] + [C18:3n6] + [C20:2] + [C20:4n6]}, where the brackets indicate concentration.
[5]Total *trans* fatty acids = {[C18:1t] + [C18:2t] + [C18:3t]}, where the brackets indicate concentration.
[6]UFA:SFA ratio = [Total MUFA + Total PUFA] / Total SFA.
[7]PUFA:SFA ratio = Total PUFA / Total SFA.
[8]Calculated as 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 (AOCS, 1998).

Table 9. Effects of adding fat to corn- and sorghum-based diets on jowl fat quality[1]

Item	Grain source: / Added fat:	Corn 0%	Corn 2.5%	Corn 5%	Sorghum 0%	Sorghum 2.5%	Sorghum 5%	Fat level SE	Source SE	Probability: Source	Probability: Fat Level Linear	Probability: Fat Level Quad	Probability: Source × Fat level
Myristic acid (14:0), %		1.45	1.52	1.42	1.56	1.45	1.44	0.03	0.02	0.41	0.09	0.52	0.05
Palmitic acid (16:0), %		23.29	23.10	22.04	24.00	22.71	22.57	0.21	0.17	0.16	0.01	0.84	0.08
Palmitoleic acid (16:1), %		3.08	3.00	3.03	3.29	2.98	2.83	0.07	0.06	0.93	0.03	0.42	0.09
Margaric acid (17:0), %		0.55	0.52	0.56	0.50	0.55	0.52	0.01	0.01	0.32	0.64	0.68	0.14
Stearic acid (18:0), %		10.18	9.72	8.82	10.22	9.62	9.63	0.18	0.14	0.19	0.01	0.90	0.22
Oleic acid (18:1c9), %		40.26	41.39	41.86	42.07	42.34	43.25	0.26	0.21	0.01	0.09	0.49	0.02
Vaccenic acid (18:1n7), %		3.33	3.45	3.49	3.42	3.22	3.50	0.13	0.11	0.81	0.61	0.47	0.62
Linoleic acid (18:2n6), %		14.53	14.09	15.30	11.93	13.81	12.99	0.32	0.26	0.01	0.01	0.94	0.68
α-linolenic acid (18:3n3), %		0.87	0.83	0.90	0.81	0.91	0.83	0.02	0.02	0.37	0.58	0.63	0.04
Arachidic acid (20:0), %		0.20	0.20	0.18	0.20	0.18	0.20	0.01	0.003	0.94	0.24	0.87	0.06
Eicosadienoic acid (20:2), %		0.73	0.74	0.82	0.62	0.74	0.75	0.02	0.01	0.01	0.01	0.68	0.04
Arachidonic acid (20:4n6), %		0.28	0.26	0.29	0.23	0.27	0.25	0.01	0.01	0.03	0.38	0.91	0.07
Other fatty acids, %		1.24	1.17	1.29	1.14	1.23	1.23	0.03	0.03	0.48	0.28	0.51	0.17
Total SFA, %[2,]		36.21	35.56	33.49	36.98	35.02	34.87	0.37	0.29	0.14	0.01	0.89	0.14
Total MUFA, %[3]		47.04	48.18	48.81	49.11	48.90	49.97	0.32	0.26	0.01	0.02	0.54	0.44
Total PUFA, %[4]		16.76	16.27	17.70	13.91	16.09	15.16	0.37	0.30	0.01	0.08	0.51	0.02
Total *trans* fatty acids, %[5]		0.28	0.27	0.38	0.30	0.31	0.32	0.02	0.02	0.77	0.07	0.12	0.22
UFA:SFA ratio[6]		1.77	1.81	1.99	1.71	1.86	1.87	0.03	0.02	0.13	0.01	0.98	0.12
PUFA:SFA ratio[7]		0.47	0.46	0.53	0.38	0.46	0.44	0.01	0.01	0.01	0.02	0.72	0.03
Iodine value, g/100 g[8]		69.24	69.30	72.24	66.22	69.64	68.87	0.57	0.46	0.01	0.01	0.66	0.03

[1]Total of 120 pigs with 2 pigs per pen and 10 replicates.
[2]Total saturated fatty acids = {[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 monounsaturated fatty acids = {[C14:1] + [C16:1] + [C18:1c9] + [C18:1n7] + [C20:1] + [C24:1]}, where the brackets indicate concentration.
[4]Total polyunsaturated fatty acids = {[C18:2n6] + [C18:3n3] + [C18:3n6] + [C20:2] + [C20:4n6]}, where the brackets indicate concentration.
[5]Total *trans* fatty acids = {[C18:1t] + [C18:2t] + [C18:3t]}, where the brackets indicate concentration.
[6]UFA:SFA ratio = [Total MUFA + Total PUFA] / Total SFA.
[7]PUFA:SFA ratio = Total PUFA / Total SFA.
[8]Calculated as 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 (AOCS, 1998).

Table 10. Effects of adding fat to corn- and sorghum-based diets on backfat quality[1]

	Fat level			Source		Fat level	Source	Probability, P<			
Grain source:									Fat Level		Source ×
Item Added fat:	0%	2.5%	5%	Corn	Sorghum	SE	SE	Source	Linear	Quad	Fat level
Myristic acid (14:0), %	1.47	1.40	1.38	1.41	1.43	0.02	0.02	0.27	0.01	0.41	0.55
Palmitic acid (16:0), %	25.26	23.86	23.75	24.21	24.43	0.22	0.18	0.26	0.01	0.02	0.23
Palmitoleic acid (16:1), %	2.48	2.34	2.33	2.32	2.45	0.07	0.06	0.10	0.14	0.41	0.95
Margaric acid (17:0), %	0.58	0.62	0.59	0.60	0.59	0.01	0.01	0.69	0.52	0.05	0.34
Stearic acid (18:0), %	13.30	12.10	12.01	12.52	12.48	0.25	0.20	0.97	0.01	0.08	0.54
Oleic acid (18:1c9), %	38.76	39.67	40.45	38.76	40.41	0.04	0.04	0.01	0.01	0.45	0.19
Vaccenic acid (18:1n7), %	2.80	2.94	2.97	2.78	3.01	0.33	0.27	0.01	0.01	0.96	0.53
Linoleic acid (18:2n6), %	12.46	13.97	13.44	14.32	12.24	0.31	0.25	0.01	0.02	0.01	0.37
α-linolenic acid (18:3n3), %	0.65	0.74	0.71	0.69	0.71	0.02	0.01	0.53	0.03	0.01	0.65
Arachidic acid (20:0), %	0.26	0.23	0.23	0.25	0.24	0.01	0.01	0.09	0.01	0.09	0.14
Eicosadienoic acid (20:2), %	0.62	0.72	0.71	0.73	0.63	0.02	0.01	0.01	0.01	0.01	0.22
Arachidonic acid (20:4n6), %	0.20	0.22	0.23	0.22	0.21	0.01	0.01	0.07	0.01	0.26	0.43
Other fatty acids, %	1.16	1.19	1.20	1.18	1.18	0.03	0.02	0.77	0.36	0.77	0.79
Total SFA, %[2,]	41.38	38.72	38.46	39.49	39.67	0.41	0.34	0.54	0.01	0.03	0.26
Total MUFA, %[3]	44.37	45.27	46.11	44.20	46.21	0.39	0.32	0.01	0.01	0.01	0.50
Total PUFA, %[4]	14.25	16.00	15.43	16.31	14.12	0.34	0.28	0.01	0.02	0.01	0.37
Total *trans* fatty acids, %[5]	0.28	0.28	0.31	0.28	0.29	0.01	0.01	0.58	0.16	0.36	0.68
UFA:SFA ratio[6]	1.42	1.59	1.61	1.54	1.53	0.03	0.02	0.62	0.01	0.03	0.24
PUFA:SFA ratio[7]	0.35	0.41	0.40	0.42	0.36	0.01	0.01	0.01	0.01	0.01	0.33
Iodine value, g/100 g[8]	62.54	66.24	65.94	65.82	63.86	0.03	0.02	0.01	0.01	0.46	0.04

[1]Total of 120 pigs with 2 pigs per pen and 10 replicates.
[2]Total saturated fatty acids = {[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 monounsaturated fatty acids = {[C14:1] + [C16:1] + [C18:1c9] + [C18:1n7] + [C20:1] + [C24:1]}, where the brackets indicate concentration.
[4]Total polyunsaturated fatty acids = {[C18:2n6] + [C18:3n3] + [C18:3n6] + [C20:2] + [C20:4n6]}, where the brackets indicate concentration.
[5]Total *trans* fatty acids = {[C18:1t] + [C18:2t] + [C18:3t]}, where the brackets indicate concentration.
[6]UFA:SFA ratio = [Total MUFA + Total PUFA] / Total SFA.
[7]PUFA:SFA ratio = Total PUFA / Total SFA.
[8]Calculated as 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 (AOCS, 1998).

Table 11. Effects of adding fat to corn- and sorghum-based diets on jowl fat quality[1]

Item	Grain source: Added fat:	Fat level 0%	Fat level 2.5%	Fat level 5%	Source Corn	Source Sorghum	Fat level SE	Source SE	Probability, P< Source	Fat Level Linear	Fat Level Quad	Source × Fat level
Myristic acid (14:0), %		1.50	1.49	1.43	1.46	1.48	0.03	0.02	0.41	0.09	0.52	0.05
Palmitic acid (16:0), %		23.51	22.91	22.36	22.79	23.08	0.21	0.17	0.16	0.01	0.84	0.08
Palmitoleic acid (16:1), %		3.17	2.99	2.94	3.03	3.03	0.07	0.06	0.93	0.03	0.42	0.09
Margaric acid (17:0), %		0.53	0.54	0.54	0.54	0.52	0.01	0.01	0.32	0.64	0.68	0.14
Stearic acid (18:0), %		10.11	9.67	9.25	9.55	9.82	0.18	0.14	0.19	0.01	0.90	0.22
Oleic acid (18:1c9), %		41.27	41.87	42.49	41.20	42.55	0.26	0.21	0.01	0.09	0.49	0.02
Vaccenic acid (18:1n7), %		3.39	3.33	3.49	3.43	3.37	0.13	0.11	0.81	0.61	0.47	0.62
Linoleic acid (18:2n6), %		13.34	13.95	14.14	14.64	12.94	0.32	0.26	0.01	0.01	0.94	0.68
α-linolenic acid (18:3n3), %		0.84	0.87	0.87	0.87	0.85	0.02	0.02	0.37	0.58	0.63	0.04
Arachidic acid (20:0), %		0.20	0.19	0.19	0.19	0.19	0.01	0.003	0.94	0.24	0.87	0.06
Eicosadienoic acid (20:2), %		0.69	0.74	0.78	0.77	0.70	0.02	0.01	0.01	0.01	0.68	0.04
Arachidonic acid (20:4n6), %		0.26	0.26	0.27	0.27	0.25	0.01	0.01	0.03	0.38	0.91	0.07
Other fatty acids, %		1.20	1.20	1.25	1.23	1.20	0.03	0.03	0.48	0.28	0.51	0.17
Total SFA, %[2,]		36.36	35.29	34.26	35.05	35.60	0.37	0.29	0.14	0.01	0.89	0.14
Total MUFA, %[3]		48.17	48.54	49.33	48.04	49.31	0.32	0.26	0.01	0.02	0.54	0.44
Total PUFA, %[4]		15.47	16.18	16.42	16.91	15.09	0.37	0.30	0.01	0.08	0.51	0.02
Total *trans* fatty acids, %[5]		0.30	0.29	0.35	0.31	0.31	0.02	0.02	0.77	0.07	0.12	0.22
UFA:SFA ratio[6]		1.76	1.84	1.93	1.86	1.81	0.03	0.02	0.13	0.01	0.98	0.12
PUFA:SFA ratio[7]		0.43	0.46	0.48	0.49	0.43	0.01	0.01	0.01	0.02	0.72	0.03
Iodine value, g/100 g[8]		68.03	69.47	70.48	70.29	68.29	0.57	0.46	0.01	0.01	0.66	0.03

[1]Total of 120 pigs with 2 pigs per pen and 10 replicates.
[2]Total saturated fatty acids = {[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 monounsaturated fatty acids = {[C14:1] + [C16:1] + [C18:1c9] + [C18:1n7] + [C20:1] + [C24:1]}, where the brackets indicate concentration.
[4]Total polyunsaturated fatty acids = {[C18:2n6] + [C18:3n3] + [C18:3n6] + [C20:2] + [C20:4n6]}, where the brackets indicate concentration.
[5]Total *trans* fatty acids = {[C18:1t] + [C18:2t] + [C18:3t]}, where the brackets indicate concentration.
[6]UFA:SFA ratio = [Total MUFA + Total PUFA] / Total SFA.
[7]PUFA:SFA ratio = Total PUFA / Total SFA.
[8]Calculated as 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 (AOCS, 1998).

Table 12. Effects of gender on backfat quality[1]

Item	Barrows	Gilts	SE	Probability, P<
Myristic acid (14:0), %	1.43	1.41	0.02	0.33
Palmitic acid (16:0), %	24.38	24.26	0.18	0.46
Palmitoleic acid (16:1), %	2.35	2.43	0.06	0.44
Margaric acid (17:0), %	0.60	0.58	0.01	0.18
Stearic acid (18:0), %	12.57	12.42	0.20	0.53
Oleic acid (18:1c9), %	39.47	39.73	0.04	0.55
Vaccenic acid (18:1n7), %	2.88	2.91	0.27	0.46
Linoleic acid (18:2n6), %	13.27	13.25	0.25	0.87
α-linolenic acid (18:3n3), %	0.70	0.70	0.01	0.93
Arachidic acid (20:0), %	0.24	0.24	0.01	0.92
Eicosadienoic acid (20:2), %	0.68	0.68	0.01	0.65
Arachidonic acid (20:4n6), %	0.22	0.22	0.01	0.48
Other fatty acids, %	1.20	1.16	0.03	0.27
Total SFA, %[2,]	39.74	39.41	0.34	0.36
Total MUFA, %[3]	45.05	45.40	0.32	0.43
Total PUFA, %[4]	15.20	15.19	0.28	0.84
Total *trans* fatty acids, %[5]	0.31	0.27	0.01	0.05
UFA:SFA ratio[6]	1.52	1.55	0.02	0.30
PUFA:SFA ratio[7]	0.38	0.39	0.01	0.56
Iodine value, g/100 g[8]	64.70	64.96	0.45	0.50

[1]Total of 120 pigs (60 barrows and 60 gilts).

[2]Total saturated fatty acids = {[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 monounsaturated fatty acids = {[C14:1] + [C16:1] + [C18:1c9] + [C18:1n7] + [C20:1] + [C24:1]}, where the brackets indicate concentration.

[4]Total polyunsaturated fatty acids = {[C18:2n6] + [C18:3n3] + [C18:3n6] + [C20:2] + [C20:4n6]}, where the brackets indicate concentration.

[5]Total *trans* fatty acids = {[C18:1t] + [C18:2t] + [C18:3t]}, where the brackets indicate concentration.

[6]UFA:SFA ratio = [Total MUFA + Total PUFA] / Total SFA.

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

[8]Calculated as 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 (AOCS, 1998).

Table 13. Effects of gender on jowl fat quality[1]

Item	Barrows	Gilts	SE	Probability, P<
Myristic acid (14:0), %	1.49	1.46	0.02	0.38
Palmitic acid (16:0), %	22.98	22.89	0.17	0.49
Palmitoleic acid (16:1), %	3.10	2.97	0.06	0.14
Margaric acid (17:0), %	0.56	0.51	0.01	0.01
Stearic acid (18:0), %	9.52	9.83	0.15	0.26
Oleic acid (18:1c9), %	41.61	42.09	0.21	0.08
Vaccenic acid (18:1n7), %	3.53	3.29	0.11	0.12
Linoleic acid (18:2n6), %	13.91	13.72	0.26	0.78
α-linolenic acid (18:3n3), %	0.87	0.85	0.02	0.39
Arachidic acid (20:0), %	0.19	0.20	0.004	0.26
Eicosadienoic acid (20:2), %	0.74	0.73	0.01	0.86
Arachidonic acid (20:4n6), %	0.27	0.26	0.01	0.52
Other fatty acids, %	1.24	1.20	0.03	0.30
Total SFA, %[2,]	35.24	35.38	0.30	0.97
Total MUFA, %[3]	48.62	48.71	0.26	0.68
Total PUFA, %[4]	16.14	15.91	0.30	0.75
Total *trans* fatty acids, %[5]	0.33	0.29	0.02	0.20
UFA:SFA ratio[6]	1.84	1.83	0.02	0.97
PUFA:SFA ratio[7]	0.46	0.45	0.01	0.78
Iodine value, g/100 g[8]	69.51	69.13	0.46	0.83

[1]Total of 120 pigs (60 barrows and 60 gilts).
[2]Total saturated fatty acids = {[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 monounsaturated fatty acids = {[C14:1] + [C16:1] + [C18:1c9] + [C18:1n7] + [C20:1] + [C24:1]}, where the brackets indicate concentration.
[4]Total polyunsaturated fatty acids = {[C18:2n6] + [C18:3n3] + [C18:3n6] + [C20:2] + [C20:4n6]}, where the brackets indicate concentration.
[5]Total *trans* fatty acids = {[C18:1t] + [C18:2t] + [C18:3t]}, where the brackets indicate concentration.

Effects of dried distiller grains with solubles on fat quality of finishing pigs

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ABSTRACT: A total of 1,112 pigs were used in a 78-d study evaluating the effects of increasing dried distiller grains with solubles (DDGS, 0, 5, 10, 15, or 20%) and gender on carcass fat quality. Growth performance for this trial was previously published and can be found in Linneen et al. (2008). All diets contained 6% choice white grease. The experiment was conducted in a commercial research finishing barn in southwestern Minnesota. There were 9 replicates per treatment with 25 to 28 pigs per pen. Barrows and gilts were distributed equally in each pen. On d 57, the three heaviest barrows from all pens were visually selected, removed, and marketed. From the pigs marketed on d 57, 6 pigs per treatment were randomly selected to analyze fat for fatty acid analysis. On d 78, the remaining pigs from each pen were individually tattooed and shipped to Swift processing plant (Worthington, MN). Jowl, backfat, and belly samples were collected on one barrow and one gilt that were randomly chosen from each pen. Samples were collected and frozen until further processing and analysis. Fat quality data was analyzed as a split plot with DDGS treatments as a whole plot and gender as the subplot. There was no gender by treatment interactions observed. Percentage C 16:0, C 18:1, and monounsaturated fatty acids (MUFA) decreased (linear, P = 0.05) in backfat, jowl fat, and belly fat in pigs marketed on d 57 and 78. Backfat, jowl fat, and belly fat percentage C 18:2 and polyunsaturated fatty acids (PUFA), and iodine value (IV) increased (linear, P = 0.02) with increasing DDGS in both pigs marketed on d 57 and 78. Percentage saturated fatty acids in belly fat decreased (linear, P = 0.05) with increasing DDGS in the pigs marketed on d 57 and 78. Gilts had increased (P = 0.05) percentage C 18:2 fatty acids, PUFA, and PUFA:SFA ratio in backfat compared to barrows. Gilts had reduced (P = 0.02) percentage C 16:0 fatty acids and increased C 18:1 fatty acids, MUFA, and UFA:SFA ratio in jowl fat compared to barrows. Gilts had reduced (P = 0.04) C 16:0 fatty acids and increased C 18:2 fatty acids, PUFA, UFA:SFA ratio,

PUFA:SFA ratio, and IV in belly fat compared with barrows. In summary, feeding DDGS linearly increased IV of backfat, jowl fat and belly fat with a similar response in all three fat depots.

Keywords: dried distillers grain with solubles, fat quality, iodine value, swine

INTRODUCTION

The inclusion of dried distiller grains with solubles (DDGS) in swine diets has increased rapidly in recent years because of increased availability and price competitiveness. Optimal inclusion levels have been determined by using growth performance and economics (Hastad et al., 2003; Fu et al., 2004; and Whitney et al., 2006); however, the additional unsaturated fat found in DDGS has led to decreased carcass fat quality (Whitney et al., 2006, Widmer et al., 2007). Carcass fat quality factors, such as color and fatty acid profile, affect both 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).

Iodine value (IV) is an estimate of the proportion of unsaturated fatty acids present and, therefore, an indicator of carcass fat 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 proportion of unsaturated fatty acids (AOCS, 1998). Acceptable IV range from 70 (Barton & Gade, 1987; Madsen et al., 1992) to 75 g/100 g (Boyd et al., 1997). Some U.S. packing plants have set their maximum IV at 73 g/100 g; however, little data is available on the influence of feeding duration of dietary fat on IV.

Whitney et al. (2006) found that belly fat IV increased 1.7 g/100 g for every 10% DDGS in growing/finishing diets. However, commercial packing plants are using other fat depots, such as jowl fat and backfat, to predict belly IV and ultimately carcass fat softness. Therefore, the objective of this study was to test the effect of DDGS and gender on carcass fat quality of jowl fat, belly fat, and backfat.

MATERIALS AND METHODS

A total of 1,112 pigs (PIC) initially 49.8 kg were used in a 78-d growth assay evaluating the effects of increasing DDGS (0, 5, 10, 15, or 20%) in the diet on pig growth performance and carcass characteristics. Pigs were randomly blocked and allotted to 1 of 5 treatments with 9 replications (pens) per treatment. Each pen contained 25 to 28 pigs.

Dietary treatments were fed in meal form and contained 0, 5, 10, 15, or 20% DDGS with 6% added fat. Treatments were fed in four phases with phase 1 fed from 49.8 to 59 kg, phase 2 from 59 to 82 kg, phase 3 from 82 to 105 kg, and phase 4 from 105 to 123 kg (Table 1, 2, 3, and 4, respectively). Diets were formulated to 0.98, 0.83, 0.73, and 0.66% true ileal digestible lysine and to maintain minimum available phosphorus of 0.28, 0.25, 0.23, and 0.22% for phases 1 to 4, respectively. The diet containing 20% DDGS in phase 4 did not include supplemental phosphorus and exceeded the minimum requirement (NRC, 1998). Pigs and feeders were weighed on d 0, 15, 29, 43, 57, and 78 to determine the response criteria of ADG, ADFI, and G:F.

On d 57, the three heaviest barrows from all pens were visually selected, removed, and marketed. From the pigs marketed on d 57, 6 pigs per treatment were randomly selected to analyze fat for fatty acid analysis. On d 78, the remaining pigs from each pen were individually tattooed and shipped to Swift processing plant (Worthington, MN). Jowl, backfat, and belly samples were collected on one barrow and one gilt that were randomly chosen from each pen to analyze fat for fatty acid analysis. Fat (50 µg) was combined with 2 mL of methanolic-HCl and w mL of internal standard (2 mg/mL of methyl Heptadecanoic acid (C17:0) in benzene) and subsequently was heated in a water bath for 120 min at 70°C for transmethylation. Upon cooling, the addition of 2 mL of benzene and 3 mL of K_2CO_3 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.

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).

Statistical Analysis:

Data were analyzed by Analysis of Variance using the MIXED procedure of SAS (SAS Inst., Inc., Cary, NC). Pigs from were blocked based on initial weight. Linear and polynomial contrasts were used to determine the effects of increasing DDGS. Pen was the experimental unit, except for data analyzing pigs marketed on d 57, where pig was the experimental unit since treatment but pen identification was not maintained for the pigs marketed on d 57. The fat analysis data for pigs marketed on d 57 was evaluated as a completely random design while the fat analysis data from the closeout pigs were analyzed as a split plot with DDGS treatments as a whole plot and gender as the subplot.

RESULTS

Growth performance for this trial was previously published and can be found at Linneen et al., (2008).

There was no gender by treatment interactions observed for fat quality parameters. The percentage C 16:0, C 18:1, and monounsaturated fatty acids (MUFA) decreased (linear, $P = 0.05$)

in backfat, jowl fat, and belly fat in both pigs marketed on d 57 (Tables 6, 7, and 8) and 78 that were fed increasing DDGS (Tables 9, 19, and 11). Also, backfat, jowl fat, and belly fat percentage C 18:2 fatty acids, polyunsaturated fatty acids (PUFA), and IV increased (linear, P = 0.02) with increasing DDGS in the diet for both the pigs marketed on d 57 and 78. Percentage saturated fatty acids in belly fat decreased (linear, P = 0.05) with increasing DDGS in pigs marketed on d 57 and 78.

Gilts had increased ($P = 0.05$) percentage C 18:2 fatty acids, PUFA, and PUFA:SFA ratio in backfat compared to barrows (Table 11). Gilts had reduced ($P = 0.02$) percentage C 16:0 fatty acids and increased C 18:1 fatty acids, MUFA, and UFA:SFA ratio in jowl fat compared to barrows (Table 12). Gilts had reduced ($P = 0.04$) C 16:0 fatty acids and increased C 18:2 fatty acids, PUFA, UFA:SFA ratio, PUFA:SFA ratio, and IV in belly fat compared with barrows (Table 13).

Pigs marketed on d 57 and 78 deposited similar amounts of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), and polyunsaturated fatty acids (PUFA) and had similar IV in backfat, jowl fat, and belly fat compared with pigs marketed at the end of the experiment.

DISCUSSION

Similar to our results, Whitney et al. (2006) fed diets containing 0, 10, 20, and 30% DDGS and saw a linear increase of approximately 1.7 g/100 g in belly fat IV for every 10% addition of DDGS. The increase in IV is due to the increased unsaturated fat provided by DDGS. Boyd et al. (1997), Averette-Gatlin et al. (2002), and Weber et al. (2006) have also demonstrated that increasing dietary unsaturated fat increases carcass IV.

Our data showed an increase of approximately 2.3, 1.6, and 2.2 g/100 g backfat, jowl fat, and belly fat respectively for every 10% DDGS included in the diet, possibly indicating jowl fat may be less responsive than other fat depots to increases in dietary level of unsaturated fats from DDGS. Benz et al. (2008b) saw similar results in which 15% DDGS with a small amount of choice white grease increased IV approximately 10 g/100 g in backfat, and 6 g/100 g in jowl fat.

Backfat IV were slightly higher than jowl and belly fat IV when pigs were fed 0% DDGS. As DDGS increased in the diet, backfat, jowl fat, and belly fat IV became more similar. Benz et al. (2008a, 2008b) reported similar results, with pigs fed increased levels of unsaturated fat having similar backfat and jowl fat IV. The 2 g/100 g difference observed in this trial from pigs fed 0% DDGS with 6% CWG is similar to the differences reported by feeding diets with 5% CWG (Benz et al., 2008a, 2008c).

Linoleic acid has been shown to have a greater impact on fat firmness compared to all other fatty acids (Berschauer, 1984). The linear increase in linoleic acid from feeding increasing DDGS agrees with data from Averette-Gatlin (2003), who showed that pigs fed a diet supplemented with more unsaturated fat have increased linoleic acid in belly fat. Boyd et al. (1997) also showed increasing dietary linoleic acid content increased linoleic acid content in backfat and belly fat.

In our trial, barrows had reduced belly fat IV and percentage linoleic acid compared to gilts. Benz et al. (2008a) saw similar results when evaluating feeding duration of added fat, with barrows having decreased backfat and jowl fat IV compared with gilts; however, when the level of added fat in corn and sorghum-based diets was compared, there was no difference in backfat and jowl fat IV (Benz et al., 2008c). Averette-Gatlin et al. (2002) also reported barrows having lower IV compared with gilts. Barrows are generally regarded to have greater backfat than gilts (Cromwell et al., 1993; and Hansen and Lewis, 1993). This increase in backfat in barrows may be associated with increased *de novo* synthesis, and more adipocyte filling, resulting in a lower percentage of cell membrane in adipose tissue. Phospholipids are the primary lipid found in cell membranes and contain one saturated and one unsaturated fatty acid (Childs, 1995). Barton-Garde (1984) also reported pigs with backfat depth 10 mm lower had IV increased 4 g/100g.

Madsen (1992) and Boyd et al. (1997) developed equations to predict backfat iodine from dietary Iodine value product (IVP). Iodine value product is calculated as: (IV of the dietary lipids) × (percentage dietary lipid) × 0.10. Boyd et al. (1997) estimated backfat IV as 52.4 × 0.315 (diet IVP). This equation predicts backfat IV should range from 77 to 83 g/100g based on the IVP of our diets. Our actual backfat IV ranged from 68 to 73 g/100 g. Benz et al. (2008b) saw similar results in previous trials, with pigs fed diets higher in unsaturated fats having predicted backfat IV higher than analyzed backfat IV.

Increasing DDGS increased backfat, jowl fat, and belly fat IV 2.3, 1.6, and 2.2 g/100 g respectively, for every 10% DDGS included in the diets. Even with jowl fat being less responsive to increased levels of DDGS than backfat and belly fat, pigs fed diets with 20% DDGS and 6% CWG exceeded the maximum jowl IV of 73 g/100 g set by some packing plants.

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Table 1. Analyzed chemical composition of dietary ingredients and values used in diet formulation (as-fed basis)

Item	DDGS[1]	
	Assumed[3]	Analyzed[2]
DM	93	88.4
CP	27.7	25.8
Crude Fiber	7.3	10.3
Ether Extract	8.4	9.9
Lys	0.62	0.93
Ilu	1.03	1.07
Leu	2.57	3.07
Met	0.5	0.51
Cys	0.52	0.52
Thr	0.94	0.97
Trp	0.25	0.17
Val	1.3	1.37

[1]Dried distillers grains with solubles.
[2]Values represent the mean of 1 sample.
[3]Represents assumed values used in diet formulation.

Table 2. Phase 1 diet composition (fed from 49 to 59 kg; as-fed basis)[1]

	DDGS[2], %				
Item	0	5	10	15	20
Ingredient, %					
Corn	65.00	60.65	56.30	51.95	47.60
Soybean meal (46.5 % CP)	26.85	26.30	25.75	25.15	24.60
DDGS[23]	---	5.00	10.00	15.00	20.00
Choice white grease	6.00	6.00	6.00	6.00	6.00
Monocalcium phosphate (21% P)	0.63	0.50	0.38	0.25	0.13
Limestone	0.85	0.90	0.94	0.99	1.03
Salt	0.35	0.35	0.35	0.35	0.35
L-Lys HCl	0.150	0.150	0.150	0.150	0.150
Vitamin premix with phytase[4]	0.075	0.075	0.075	0.075	0.075
Trace mineral premix[5]	0.075	0.075	0.075	0.075	0.075
Total	100.00	100.00	100.00	100.00	100.00
Calculated composition					
True ileal digestible (TID) amino acids					
Lys, %	0.98	0.98	0.98	0.98	0.98
Met:Lys ratio, %	27	28	29	31	32
Met & Cys:Lys ratio, %	55	58	60	63	65
Thr:Lys ratio, %	60	62	64	66	68
Trp:lys ratio, %	19	20	20	21	21
Total Lys, %	1.10	1.10	1.10	1.11	1.11
CP, %	18.2	18.9	19.7	20.4	21.2
TID Lys:calorie ratio, g/Mcal of ME	2.71	2.71	2.71	2.70	2.70
ME, kcal/kg	3,616	3,618	3,622	3,624	3,627
Ca, %	0.55	0.55	0.55	0.55	0.55
P, %	0.50	0.49	0.49	0.49	0.48
Available P, %	0.28	0.28	0.28	0.28	0.28
Analyzed values					
Dietary fat IV g/100 g	80.9	83.9	88.0	87.5	89.1
Dietary IVP[6]	78.5	82.2	91.5	95.4	99.8

[1]Diet composition was calculated using NRC (1998) composition values for ingredients, except the ME value for DDGS in which 3,420 kcal/kg was used.
[2]Dried distiller grains with solubles.
[3]Dietary fat iodine value = 118.9.
[4]Provided per kilogram of diet: 11,023 IU of vitamin A; 1653 IU of vitamin D_3; 44 IU of vitamin E; 4 mg of vitamin K; 0.04 mg of Vitamin B_{12}; 50 mg of niacin; 28 mg of panothenic acid; 8 mg of riboflavin; and 300 FTU of phytase.
[5]Provided per kilogram of diet: 16.54 mg 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.
[6] Dietary iodine value product = analyzed IV of diet oil × analyzed % diet oil × 0.10.

Table 3. Phase 2 diet composition (fed from 59 to 82 kg; as-fed basis)[1]

Item	DDGS[2], %				
	0	5	10	15	20
Ingredient, %					
Corn	71.05	66.70	62.35	58.00	53.65
Soybean meal (46.5 % CP)	20.90	20.35	19.75	19.20	18.65
DDGS[23]	---	5.00	10.00	15.00	20.00
Choice white grease	6.00	6.00	6.00	6.00	6.00
Monocalcium phosphate (21% P)	0.58	0.45	0.33	0.20	0.08
Limestone	0.85	0.89	0.92	0.98	1.03
Salt	0.35	0.35	0.35	0.35	0.35
L-Lys HCl	0.150	0.150	0.150	0.150	0.150
Vitamin premix with phytase[4]	0.063	0.063	0.063	0.063	0.063
Trace mineral premix[5]	0.063	0.063	0.063	0.063	0.063
Total	100.00	100.00	100.00	100.00	100.00
Calculated composition					
True ileal digestible (TID) amino acids					
Lys, %	0.83	0.83	0.83	0.83	0.83
Met:Lys ratio, %	28	30	31	33	34
Met & Cys:Lys ratio, %	59	62	64	67	70
Thr:Lys ratio, %	61	63	65	68	70
Trp:lys ratio, %	19	20	20	21	22
Total Lys, %	0.93	0.94	0.94	0.94	0.94
CP, %	15.9	16.7	17.4	18.2	18.9
TID Lys:calorie ratio, g/Mcal of ME	2.29	2.29	2.29	2.29	2.29
ME, kcal/kg	3,620	3,622	3,627	3,629	3,633
Ca, %	0.52	0.52	0.52	0.52	0.52
P, %	0.46	0.46	0.46	0.45	0.45
Available P, %	0.25	0.25	0.25	0.25	0.25
Analyzed values					
Dietary fat IV g/100 g	84.2	86.4	86.2	87.3	88.6
Dietary IVP[6]	78.3	86.4	87.9	96.9	97.4

[1]Diet composition was calculated using NRC (1998) composition values for ingredients, except the ME value for DDGS in which 3,420 kcal/kg was used.
[2]Dried distiller grains with solubles.
[3]Iodine value = 118.9.
[4]Provided per kilogram of diet: 11,023 IU of vitamin A; 1653 IU of vitamin D_3; 44 IU of vitamin E; 4 mg of vitamin K; 0.04 mg of Vitamin B_{12}; 50 mg of niacin; 28 mg of panothenic acid; 8 mg of riboflavin; and 300 FTU of phytase.
[5]Provided per kilogram of diet: 16.54 mg 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.
[6] Dietary iodine value product = analyzed IV of diet oil × analyzed % diet oil × 0.10.

Table 4. Phase 3 diet composition (fed from 82 to 105 kg; as-fed basis)[1]

	DDGS[2], %				
Item	0	5	10	15	20
Ingredient, %					
Corn	75.15	70.80	66.45	62.10	57.75
Soybean meal(46.5 % CP)	16.90	16.35	15.80	15.20	14.65
DDGS[23]	---	5.00	10.00	15.00	20.00
Choice white grease	6.00	6.00	6.00	6.00	6.00
Monocalcium phosphate (21% P)	0.53	0.40	0.27	0.14	0.01
Limestone	0.80	0.84	0.89	0.93	0.97
Salt	0.35	0.35	0.35	0.35	0.35
L-Lys HCl	0.150	0.150	0.150	0.150	0.150
Vitamin premix with phytase[4]	0.063	0.063	0.063	0.063	0.063
Trace mineral premix[5]	0.063	0.063	0.063	0.063	0.063
Total	100.00	100.00	100.00	100.00	100.00
Calculated composition					
True ileal digestible (TID) amino acids					
Lys, %	0.73	0.73	0.73	0.73	0.73
Met:Lys ratio, %	30	32	33	35	37
Met & Cys:Lys ratio, %	62	65	68	71	75
Thr:Lys ratio, %	62	64	67	70	72
Trp:lys ratio, %	19	19	20	21	22
Total Lys, %	0.82	0.83	0.83	0.83	0.83
CP, %	14.4	15.1	15.9	16.7	17.4
TID Lys:calorie ratio, g/Mcal of ME	2.01	2.01	2.01	2.01	2.01
ME, kcal/kg	3,628	3,629	3,631	3,635	3,638
Ca, %	0.48	0.48	0.48	0.48	0.48
P, %	0.44	0.43	0.43	0.42	0.42
Available P, %	0.23	0.23	0.23	0.23	0.23
Analyzed values					
Dietary fat IV g/100 g	84.9	86.7	87.0	90.6	89.7
Dietary IVP[6]	74.7	83.3	84.4	91.5	97.8

[1]Diet composition was calculated using NRC (1998) composition values for ingredients, except the ME value for DDGS in which 3,420 kcal/kg was used.
[2]Dried distiller grains with solubles.
[3]Iodine value = 118.9.
[4]Provided per kilogram of diet: 11,023 IU of vitamin A; 1653 IU of vitamin D_3; 44 IU of vitamin E; 4 mg of vitamin K; 0.04 mg of Vitamin B_{12}; 50 mg of niacin; 28 mg of panothenic acid; 8 mg of riboflavin; and 300 FTU of phytase.
[5]Provided per kilogram of diet: 16.54 mg 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.
[6] Dietary iodine value product = analyzed IV of diet oil × analyzed % diet oil × 0.10.

Table 5. Phase 4 diet composition (fed from 105 to 123 kg; as-fed basis) [1]

	DDGS[2], %				
Item	0	5	10	15	20
Ingredient, %					
Corn	77.90	73.55	69.20	64.90	60.55
Soybean meal (46.5 % CP)	14.15	13.55	13.00	12.45	11.85
DDGS[23]	---	5.00	10.00	15.00	20.00
Choice white grease	6.00	6.00	6.00	6.00	6.00
Monocalcium phosphate (21% P)	0.53	0.39	0.26	0.13	-
Limestone	0.83	0.87	0.91	0.96	1.00
Salt	0.35	0.35	0.35	0.35	0.35
L-Lys HCl	0.150	0.150	0.150	0.150	0.150
Vitamin premix with phytase[4]	0.050	0.050	0.050	0.050	0.050
Trace mineral premix[5]	0.050	0.050	0.050	0.050	0.050
Total	100.00	100.00	100.00	100.00	100.00
Calculated composition					
True ileal digestible (TID) amino acids					
Lys, %	0.66	0.66	0.66	0.66	0.66
Met:Lys ratio, %	31	33	35	37	39
Met & Cys:Lys ratio, %	64	68	71	75	79
Thr:Lys ratio, %	63	65	68	71	74
Trp:lys ratio, %	18	19	20	21	22
Total Lys, %	0.75	0.75	0.75	0.76	0.76
CP, %	13.3	14.1	14.8	15.6	16.4
TID Lys:calorie ratio, g/Mcal of ME	1.82	1.82	1.82	1.82	1.81
ME, kcal/kg	3,626	3,629	3,633	3,636	3,639
Ca, %	0.48	0.48	0.48	0.48	0.48
P, %	0.43	0.42	0.42	0.41	0.41
Available P, %	0.22	0.22	0.22	0.22	0.22
Analyzed values					
Dietary fat IV g/100 g	86.9	90.0	86.9	86.6	87.1
Dietary IVP[6]	86.0	91.8	89.5	94.4	95.0

[1]Diet composition was calculated using NRC (1998) composition values for ingredients, except the ME value for DDGS in which 3,420 kcal/kg was used.
[2]Dried distiller grains with solubles.
[3]Iodine value = 118.9.
[4]Provided per kilogram of diet: 11,023 IU of vitamin A; 1653 IU of vitamin D_3; 44 IU of vitamin E; 4 mg of vitamin K; 0.04 mg of Vitamin B_{12}; 50 mg of niacin; 28 mg of panothenic acid; 8 mg of riboflavin; and 300 FTU of phytase.
[5]Provided per kilogram of diet: 16.54 mg 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.
[6] Dietary iodine value product = analyzed IV of diet oil × analyzed % diet oil × 0.10.

Table 6. Effects of increasing DDGS on backfat quality of pigs marketed on d 57[1]

	DDGS[2], %					Probability, P <			
Item	0	5	10	15	20	Treatment	Linear	Quadratic	SE
Myristic acid (14:0), %	1.29	1.29	1.32	1.29	1.28	0.85	0.61	0.40	0.04
Palmitic acid (16:0), %	22.45	21.87	22.05	21.71	21.21	0.20	0.03	0.73	0.40
Palmitoleic acid (16:1), %	2.70	2.52	2.64	2.42	2.40	0.20	0.05	0.72	0.13
Margaric acid (17:0), %	0.45	0.51	0.49	0.54	0.47	0.12	0.33	0.02	0.03
Stearic acid (18:0), %	10.30	10.09	9.87	10.28	9.53	0.88	0.53	0.95	0.51
Oleic acid (18:1c9), %	43.05	42.67	42.11	40.98	41.61	0.03	0.01	0.15	0.47
Vaccenic acid (18:1n7), %	3.33	3.25	3.29	3.15	3.13	0.20	0.03	0.79	0.08
Linoleic acid (18:2n6), %	13.08	14.28	14.65	16.07	16.71	0.01	0.01	0.60	0.56
α-linolenic acid (18:3n3), %	0.60	0.62	0.63	0.67	0.68	0.19	0.02	0.59	0.02
Arachidic acid (20:0), %	0.18	0.18	0.19	0.21	0.19	0.06	0.06	0.56	0.009
Gadoleic acid (20:1), %	0.06	0.06	0.06	0.06	0.06	0.42	0.94	0.16	0.002
Eicosadienoic acid (20:2), %	0.79	0.84	0.84	0.91	0.91	0.02	0.01	0.99	0.03
Arachidonic acid (20:4n6), %	0.30	0.34	0.33	0.32	0.34	0.33	0.31	0.50	0.02
Other fatty acids, %	1.42	1.48	1.52	1.41	1.46	0.89	0.96	0.62	0.07
Total SFA, %[3]	35.15	34.49	34.44	34.56	33.24	0.51	0.14	0.70	0.78
Total MUFA, %[4]	49.52	48.87	48.54	46.90	47.54	0.04	0.01	0.32	0.61
Total PUFA, %[5]	15.33	16.63	17.01	18.53	19.22	0.01	0.01	0.63	0.62
Total *trans* fatty acids, %[6]	0.35	0.35	0.38	0.28	0.30	0.61	0.22	0.79	0.05
UFA:SFA ratio[7]	1.86	1.91	1.91	1.90	2.01	0.52	0.15	0.64	0.07
PUFA:SFA ratio[8]	0.44	0.48	0.50	0.54	0.58	0.02	0.01	0.98	0.03
Iodine value, g/100 g[9]	67.7	70.8	70.5	71.8	72.1	0.02	0.01	0.20	0.87

[1]Total of 30 barrows (6 per treatment).
[2]Dried distiller grains with solubles.
[3]Total saturated fatty acids = {[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.
[4]Total monounsaturated fatty acids = {[C14:1] + [C16:1] + [C18:1c9] + [C18:1n7] + [C20:1] + [C24:1]}, where the brackets indicate concentration.
[5]Total polyunsaturated fatty acids = {[C18:2n6] + [C18:3n3] + [C18:3n6] + [C20:2] + [C20:4n6]}, where the brackets indicate concentration.
[6]Total *trans* fatty acids = {[C18:1t] + [C18:2t] + [C18:3t]}, where the brackets indicate concentration.
[7]UFA:SFA ratio = [Total MUFA + Total PUFA] / Total SFA.
[8]PUFA:SFA ratio = Total PUFA / Total SFA.
[9]Calculated as 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 (AOCS, 1998).

Table 7. Effects of increasing DDGS on jowl fat quality of pigs marketed on d 57[1]

	DDGS, %					Probability, P <			
Item	0	5	10	15	20	Treatment	Linear	Quadratic	SE
Myristic acid (14:0), %	1.31	1.32	1.35	1.31	1.31	0.90	0.91	0.48	0.04
Palmitic acid (16:0), %	22.05	21.66	21.98	21.49	20.96	0.16	0.04	0.39	0.35
Palmitoleic acid (16:1), %	2.93	2.72	2.87	2.61	2.62	0.20	0.09	0.93	0.13
Margaric acid (17:0), %	0.43	0.49	0.48	0.50	0.44	0.22	0.68	0.04	0.03
Stearic acid (18:0), %	9.34	9.42	9.39	9.80	9.02	0.75	0.84	0.42	0.44
Oleic acid (18:1c9), %	43.99	43.61	42.77	42.05	42.88	0.05	0.02	0.14	0.47
Vaccenic acid (18:1n7), %	3.54	3.43	3.45	3.31	3.33	0.26	0.05	0.72	0.08
Linoleic acid (18:2n6), %	12.93	13.86	14.08	15.30	15.71	0.01	0.01	0.99	0.56
α-linolenic acid (18:3n3), %	0.60	0.61	0.62	0.65	0.65	0.49	0.09	0.95	0.03
Arachidic acid (20:0), %	0.17	0.17	0.18	0.20	0.17	0.52	0.38	0.52	0.01
Gadoleic acid (20:1), %	0.07	0.06	0.07	0.07	0.06	0.92	0.82	0.68	0.004
Eicosadienoic acid (20:2), %	0.80	0.85	0.83	0.92	0.91	0.03	0.01	0.97	0.03
Arachidonic acid (20:4n6), %	0.32	0.35	0.34	0.33	0.35	0.44	0.34	0.86	0.02
Other fatty acids, %	1.52	1.46	1.62	1.49	1.58	0.65	0.56	0.93	0.09
Total SFA, %[3]	33.83	33.59	33.93	33.89	32.50	0.47	0.27	0.28	0.68
Total MUFA, %[4]	50.92	50.19	49.63	48.33	49.28	0.06	0.02	0.24	0.62
Total PUFA, %[5]	15.24	16.21	16.44	17.78	18.20	0.02	0.01	0.99	0.63
Total *trans* fatty acids, %[6]	0.36	0.32	0.41	0.29	0.32	0.38	0.43	0.73	0.05
UFA:SFA ratio[7]	1.96	1.98	1.95	1.95	2.08	0.46	0.27	0.27	0.06
PUFA:SFA ratio[8]	0.45	0.48	0.49	0.53	0.56	0.05	0.01	0.61	0.03
Iodine value, g/100 g[9]	69.3	70.3	70.3	71.3	72.9	0.11	0.02	0.53	1.00

[1] Total of 30 barrows (6 per treatment).
[2]Dried distiller grains with solubles.
[3]Total saturated fatty acids = {[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.
[4]Total monounsaturated fatty acids = {[C14:1] + [C16:1] + [C18:1c9] + [C18:1n7] + [C20:1] + [C24:1]}, where the brackets indicate concentration.
[5]Total polyunsaturated fatty acids = {[C18:2n6] + [C18:3n3] + [C18:3n6] + [C20:2] + [C20:4n6]}, where the brackets indicate concentration.
[6]Total *trans* fatty acids = {[C18:1t] + [C18:2t] + [C18:3t]}, where the brackets indicate concentration.
[7]UFA:SFA ratio = [Total MUFA + Total PUFA] / Total SFA.
[8]PUFA:SFA ratio = Total PUFA / Total SFA.
[9]Calculated as 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 (AOCS, 1998).

Table 8. Effects of increasing DDGS on belly fat quality of pigs marketed on d 57[1]

	DDGS, %					Probability, P <			
Item	0	5	10	15	20	Treatment	Linear	Quadratic	SE
Myristic acid (14:0), %	1.27	1.26	1.29	1.25	1.20	0.67	0.34	0.33	0.05
Palmitic acid (16:0), %	22.76	22.08	22.13	21.75	21.10	0.10	0.01	0.81	0.43
Palmitoleic acid (16:1), %	2.47	2.31	2.40	2.18	2.11	0.11	0.02	0.73	0.11
Margaric acid (17:0), %	0.46	0.53	0.54	0.58	0.50	0.07	0.15	0.02	0.03
Stearic acid (18:0), %	11.05	10.77	10.46	10.76	10.23	0.81	0.32	0.96	0.54
Oleic acid (18:1c9), %	42.35	41.74	40.88	39.70	40.51	0.02	0.01	0.19	0.53
Vaccenic acid (18:1n7), %	3.15	3.07	3.09	2.96	2.92	0.10	0.01	0.72	0.07
Linoleic acid (18:2n6), %	13.27	14.69	15.75	17.20	17.82	0.01	0.01	0.59	0.64
α-linolenic acid (18:3n3), %	0.60	0.64	0.66	0.70	0.70	0.05	0.01	0.53	0.03
Arachidic acid (20:0), %	0.20	0.19	0.19	0.21	0.21	0.66	0.38	0.43	0.01
Gadoleic acid (20:1), %	0.06	0.06	0.06	0.06	0.06	0.75	0.74	0.30	0.003
Eicosadienoic acid (20:2), %	0.78	0.83	0.86	0.91	0.95	0.01	0.01	0.96	0.03
Arachidonic acid (20:4n6), %	0.29	0.34	0.33	0.31	0.34	0.19	0.14	0.29	0.02
Other fatty acids, %	1.30	1.50	1.37	1.41	1.36	0.43	0.85	0.24	0.08
Total SFA, %[3]	36.18	35.39	35.08	35.11	33.71	0.30	0.05	0.76	0.83
Total MUFA, %[4]	48.37	47.55	46.79	45.21	45.91	0.01	0.01	0.32	0.62
Total PUFA, %[5]	15.45	17.05	18.13	19.67	20.37	0.01	0.01	0.60	0.70
Total *trans* fatty acids, %[6]	0.33	0.37	0.32	0.29	0.30	0.84	0.41	0.84	0.06
UFA:SFA ratio[7]	1.77	1.83	1.85	1.85	1.97	0.29	0.05	0.67	0.07
PUFA:SFA ratio[8]	0.43	0.48	0.52	0.56	0.61	0.01	0.01	0.96	0.03
Iodine value, g/100 g[9]	67.5	69.6	70.8	72.0	73.8	0.02	0.01	0.92	1.20

[1] Total of 120 pigs with 2 pigs per pen (one barrow and one gilt) and 10 replicates.
[2]Dried distiller grains with solubles.
[3]Total saturated fatty acids = {[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.
[4]Total monounsaturated fatty acids = {[C14:1] + [C16:1] + [C18:1c9] + [C18:1n7] + [C20:1] + [C24:1]}, where the brackets indicate concentration.
[5]Total polyunsaturated fatty acids = {[C18:2n6] + [C18:3n3] + [C18:3n6] + [C20:2] + [C20:4n6]}, where the brackets indicate concentration.
[6]Total *trans* fatty acids = {[C18:1t] + [C18:2t] + [C18:3t]}, where the brackets indicate concentration.
[7]UFA:SFA ratio = [Total MUFA + Total PUFA] / Total SFA.
[8]PUFA:SFA ratio = Total PUFA / Total SFA.
[9]Calculated as 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 (AOCS, 1998).

Table 9. Effects of increasing DDGS on backfat quality on pigs marketed on d 78[1]

Item	DDGS, %					Probability, P<			SE
	0	5	10	15	20	Treatment	Linear	Quadratic	
Myristic acid (14:0), %	1.28	1.31	1.27	1.20	1.21	0.02	0.01	0.53	0.29
Palmitic acid (16:0), %	22.63	22.50	22.20	21.76	21.71	0.04	0.01	0.90	0.28
Palmitoleic acid (16:1), %	2.31	2.31	2.28	2.04	2.08	0.02	0.01	0.69	0.07
Margaric acid (17:0), %	0.53	0.49	0.50	0.53	0.55	0.33	0.22	0.17	0.02
Stearic acid (18:0), %	10.90	10.42	10.20	10.80	10.74	0.47	0.94	0.16	0.30
Oleic acid (18:1c9), %	41.91	42.08	41.75	40.26	40.33	0.01	0.01	0.51	0.45
Vaccenic acid (18:1n7), %	3.17	3.17	3.13	2.95	2.94	0.01	0.01	0.47	0.06
Linoleic acid (18:2n6), %	13.75	14.31	15.24	16.79	16.97	0.01	0.01	0.63	0.50
α-linolenic acid (18:3n3), %	0.62	0.61	0.64	0.66	0.64	0.09	0.05	0.43	0.02
Arachidic acid (20:0), %	0.20	0.19	0.18	0.17	0.18	0.34	0.07	0.29	0.01
Gadoleic acid (20:1), %	0.07	0.07	0.06	0.07	0.06	0.51	0.93	0.88	0.005
Eicosadienoic acid (20:2), %	0.79	0.81	0.81	0.86	0.83	0.18	0.06	0.70	0.02
Arachidonic acid (20:4n6), %	0.24	0.23	0.25	0.25	0.24	0.55	0.46	0.66	0.02
Other fatty acids, %	1.61	1.51	1.50	1.66	1.54	0.26	0.90	0.65	0.06
Total SFA, %[3]	36.00	35.31	34.74	34.92	34.80	0.35	0.07	0.30	0.49
Total MUFA, %[4]	47.97	48.14	47.73	45.91	45.93	0.01	0.01	0.48	0.54
Total PUFA, %[5]	16.02	16.54	17.52	19.16	19.27	0.01	0.01	0.64	0.54
Total *trans* fatty acids, %[6]	0.53	0.49	0.50	0.54	0.50	0.78	0.69	0.90	0.04
UFA:SFA ratio[7]	1.78	1.84	1.89	1.87	1.88	0.28	0.06	0.27	0.04
PUFA:SFA ratio[8]	0.45	0.47	0.51	0.55	0.56	0.01	0.01	0.45	0.02
Iodine value, g/100 g[9]	68.3	70.0	71.2	72.4	72.8	0.01	0.01	0.33	0.76

[1] Total of 120 pigs with 2 pigs per pen (one barrow and one gilt) and 10 replicates.
[2]Dried distiller grains with solubles.
[3]Total saturated fatty acids = {[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.
[4]Total monounsaturated fatty acids = {[C14:1] + [C16:1] + [C18:1c9] + [C18:1n7] + [C20:1] + [C24:1]}, where the brackets indicate concentration.
[5]Total polyunsaturated fatty acids = {[C18:2n6] + [C18:3n3] + [C18:3n6] + [C20:2] + [C20:4n6]}, where the brackets indicate concentration.
[6]Total *trans* fatty acids = {[C18:1t] + [C18:2t] + [C18:3t]}, where the brackets indicate concentration.
[7]UFA:SFA ratio = [Total MUFA + Total PUFA] / Total SFA.
[8]PUFA:SFA ratio = Total PUFA / Total SFA.
[9]Calculated as 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 (AOCS, 1998).

Table 10. Effects of increasing DDGS on jowl fat quality on pigs marketed on d 78[1]

	DDGS, %					Probability, P <			
Item	0	5	10	15	20	Treatment	Linear	Quadratic	SE
Myristic acid (14:0), %	1.29	1.34	1.29	1.28	1.24	0.22	0.16	0.18	0.04
Palmitic acid (16:0), %	21.89	21.99	21.71	21.75	20.95	0.15	0.04	0.32	0.34
Palmitoleic acid (16:1), %	2.52	2.64	2.51	2.44	2.48	0.36	0.39	0.43	0.10
Margaric acid (17:0), %	0.47	0.44	0.47	0.48	0.51	0.06	0.12	0.07	0.02
Stearic acid (18:0), %	10.05	9.56	9.58	9.80	9.44	0.43	0.22	0.43	0.35
Oleic acid (18:1c9), %	43.40	43.23	43.02	42.50	42.23	0.21	0.05	0.34	0.44
Vaccenic acid (18:1n7), %	3.40	3.47	3.35	3.29	3.30	0.17	0.12	0.36	0.07
Linoleic acid (18:2n6), %	13.57	13.83	14.52	14.86	16.15	0.01	0.01	0.31	0.56
α-linolenic acid (18:3n3), %	0.62	0.62	0.65	0.63	0.68	0.18	0.06	0.51	0.02
Arachidic acid (20:0), %	0.17	0.17	0.18	0.17	0.16	0.72	0.38	0.35	0.01
Gadoleic acid (20:1), %	0.06	0.07	0.07	0.07	0.07	0.38	0.14	0.51	0.005
Eicosadienoic acid (20:2), %	0.80	0.82	0.85	0.87	0.89	0.04	0.01	0.94	0.02
Arachidonic acid (20:4n6), %	0.26	0.26	0.27	0.27	0.30	0.28	0.08	0.34	0.02
Other fatty acids, %	1.51	1.57	1.53	1.59	1.60	0.81	0.39	0.82	0.06
Total SFA, %[3]	34.29	33.92	33.65	33.93	32.73	0.27	0.06	0.94	0.62
Total MUFA, %[4]	49.89	49.93	49.45	48.83	48.62	0.16	0.05	0.30	0.56
Total PUFA, %[5]	15.82	16.14	16.90	17.24	18.64	0.02	0.01	0.34	0.61
Total *trans* fatty acids, %[6]	0.49	0.51	0.48	0.49	0.48	0.39	0.76	0.95	0.04
UFA:SFA ratio[7]	1.92	1.95	1.99	1.96	2.07	0.21	0.05	0.96	0.05
PUFA:SFA ratio[8]	0.46	0.48	0.51	0.51	0.57	0.02	0.01	0.47	0.03
Iodine value, g/100 g[9]	70.7	70.8	71.9	72.6	73.8	0.01	0.01	0.49	0.74

[1] Total of 120 pigs with 2 pigs per pen (one barrow and one gilt) and 10 replicates.
[2]Dried distiller grains with solubles.
[3]Total saturated fatty acids = {[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.
[4]Total monounsaturated fatty acids = {[C14:1] + [C16:1] + [C18:1c9] + [C18:1n7] + [C20:1] + [C24:1]}, where the brackets indicate concentration.
[5]Total polyunsaturated fatty acids = {[C18:2n6] + [C18:3n3] + [C18:3n6] + [C20:2] + [C20:4n6]}, where the brackets indicate concentration.
[6]Total *trans* fatty acids = {[C18:1t] + [C18:2t] + [C18:3t]}, where the brackets indicate concentration.
[7]UFA:SFA ratio = [Total MUFA + Total PUFA] / Total SFA.
[8]PUFA:SFA ratio = Total PUFA / Total SFA.
[9]Calculated as 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 (AOCS, 1998).

Table 11. Effects of increasing DDGS on belly fat quality of pigs marketed on d 78[1]

	DDGS, %					Probability, P <			
Item	0	5	10	15	20	Treatment	Linear	Quadratic	SE
Myristic acid (14:0), %	1.30	1.30	1.24	1.20	1.20	0.01	0.01	0.85	0.03
Palmitic acid (16:0), %	22.42	22.03	21.59	21.38	21.13	0.01	0.01	0.56	0.23
Palmitoleic acid (16:1), %	2.44	2.48	2.36	2.23	2.22	0.13	0.02	0.68	0.09
Margaric acid (17:0), %	0.48	0.46	0.49	0.49	0.50	0.67	0.24	0.79	0.02
Stearic acid (18:0), %	10.29	9.80	9.97	10.03	9.98	0.75	0.57	0.41	0.29
Oleic acid (18:1c9), %	42.71	42.48	42.08	41.52	41.27	0.08	0.01	0.83	0.48
Vaccenic acid (18:1n7), %	3.27	3.28	3.24	3.08	3.08	0.04	0.01	0.47	0.07
Linoleic acid (18:2n6), %	13.54	14.58	15.37	16.40	16.96	0.01	0.01	0.73	0.56
α-linolenic acid (18:3n3), %	0.61	0.65	0.68	0.69	0.69	0.01	0.01	0.15	0.02
Arachidic acid (20:0), %	0.20	0.20	0.18	0.18	0.18	0.17	0.04	0.36	0.007
Gadoleic acid (20:1), %	0.07	0.07	0.07	0.07	0.06	0.91	0.40	0.91	0.005
Eicosadienoic acid (20:2), %	0.81	0.82	0.86	0.89	0.90	0.01	0.01	0.85	0.02
Arachidonic acid (20:4n6), %	0.24	0.26	0.29	0.28	0.28	0.02	0.01	0.04	0.01
Other fatty acids, %	1.61	1.59	1.59	1.58	1.55	0.95	0.44	0.91	0.05
Total SFA, %[3]	35.13	34.19	33.89	33.67	33.40	0.03	0.01	0.36	0.41
Total MUFA, %[4]	49.06	48.87	48.29	47.48	47.16	0.03	0.01	0.70	0.59
Total PUFA, %[5]	15.80	16.93	17.81	18.84	19.43	0.01	0.01	0.66	0.59
Total *trans* fatty acids, %[6]	0.55	0.56	0.54	0.56	0.53	0.94	0.84	0.88	0.04
UFA:SFA ratio[7]	1.85	1.93	1.96	1.97	2.00	0.03	0.01	0.38	0.03
PUFA:SFA ratio[8]	0.45	0.50	0.53	0.56	0.59	0.01	0.01	0.60	0.02
Iodine value, g/100 g[9]	70.2	71.5	72.4	73.3	74.5	0.01	0.01	0.95	0.61

[1] Total of 120 pigs with 2 pigs per pen (one barrow and one gilt) and 10 replicates.
[2]Dried distiller grains with solubles.
[3]Total saturated fatty acids = {[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.
[4]Total monounsaturated fatty acids = {[C14:1] + [C16:1] + [C18:1c9] + [C18:1n7] + [C20:1] + [C24:1]}, where the brackets indicate concentration.
[5]Total polyunsaturated fatty acids = {[C18:2n6] + [C18:3n3] + [C18:3n6] + [C20:2] + [C20:4n6]}, where the brackets indicate concentration.
[6]Total *trans* fatty acids = {[C18:1t] + [C18:2t] + [C18:3t]}, where the brackets indicate concentration.
[7]UFA:SFA ratio = [Total MUFA + Total PUFA] / Total SFA.
[8]PUFA:SFA ratio = Total PUFA / Total SFA.
[9]Calculated as 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 (AOCS, 1998).

Table 12. Effects of gender on backfat quality[1]

	Barrows	Gilts	SE	Probability, P <
Myristic acid (14:0), %	1.28	1.22	0.02	0.03
Palmitic acid (16:0), %	22.37	21.94	0.19	0.11
Palmitoleic acid (16:1), %	2.26	2.14	0.04	0.07
Margaric acid (17:0), %	0.53	0.51	0.02	0.32
Stearic acid (18:0), %	10.49	10.73	0.19	0.40
Oleic acid (18:1c9), %	41.58	40.94	0.32	0.21
Vaccenic acid (18:1n7), %	3.12	3.02	0.04	0.05
Linoleic acid (18:2n6), %	14.87	16.01	0.36	0.03
α-linolenic acid (18:3n3), %	0.62	0.65	0.02	0.37
Arachidic acid (20:0), %	0.19	0.17	0.006	0.06
Gadoleic acid (20:1), %	0.07	0.06	0.003	0.25
Eicosadienoic acid (20:2), %	0.83	0.81	0.01	0.36
Arachidonic acid (20:4n6), %	0.23	0.25	0.01	0.13
Other fatty acids, %	1.57	1.55	0.04	0.67
Total SFA, %[2,]	35.28	35.01	0.31	0.58
Total MUFA, %[3]	47.58	46.68	0.39	0.13
Total PUFA, %[4]	17.14	18.31	0.39	0.03
Total *trans* fatty acids, %[5]	0.53	0.48	0.03	0.19
UFA:SFA ratio[6]	1.84	1.86	0.02	0.62
PUFA:SFA ratio[7]	0.49	0.53	0.01	0.05
Iodine value, g/100 g[8]	70.7	71.1	0.46	0.52

[1] Total of 120 pigs with 2 pigs per pen (one barrow and one gilt).

[2]Total saturated fatty acids = {[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 monounsaturated fatty acids = {[C14:1] + [C16:1] + [C18:1c9] + [C18:1n7] + [C20:1] + [C24:1]}, where the brackets indicate concentration.

[4]Total polyunsaturated fatty acids = {[C18:2n6] + [C18:3n3] + [C18:3n6] + [C20:2] + [C20:4n6]}, where the brackets indicate concentration.

[5]Total *trans* fatty acids = {[C18:1t] + [C18:2t] + [C18:3t]}, where the brackets indicate concentration.

[6]UFA:SFA ratio = [Total MUFA + Total PUFA] / Total SFA.

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

[8]Calculated as 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 (AOCS, 1998).

Table 13. Effects of gender on jowl fat quality[1]

	Barrows	Gilts	SE	Probability, P, <
Myristic acid (14:0), %	1.30	1.28	0.02	0.40
Palmitic acid (16:0), %	21.96	21.31	0.34	0.02
Palmitoleic acid (16:1), %	2.44	2.61	0.07	0.09
Margaric acid (17:0), %	0.50	0.44	0.02	0.01
Stearic acid (18:0), %	10.04	9.25	0.20	0.01
Oleic acid (18:1c9), %	42.37	43.41	0.29	0.02
Vaccenic acid (18:1n7), %	3.29	3.44	0.05	0.03
Linoleic acid (18:2n6), %	14.54	14.68	0.34	0.63
α-linolenic acid (18:3n3), %	0.64	0.64	0.01	0.99
Arachidic acid (20:0), %	0.18	0.16	0.006	0.02
Gadoleic acid (20:1), %	0.07	0.07	0.003	0.65
Eicosadienoic acid (20:2), %	0.84	0.85	0.01	0.57
Arachidonic acid (20:4n6), %	0.27	0.28	0.01	0.34
Other fatty acids, %	1.55	1.57	0.04	0.63
Total SFA, %[2,]	34.40	32.87	0.36	0.01
Total MUFA, %[3]	48.70	50.05	0.39	0.02
Total PUFA, %[4]	16.89	17.07	0.37	0.60
Total *trans* fatty acids, %[5]	0.50	0.47	0.03	0.39
UFA:SFA ratio[6]	1.92	2.05	0.03	0.01
PUFA:SFA ratio[7]	0.50	0.52	0.01	0.16
Iodine value, g/100 g[8]	71.6	72.3	0.47	0.25

[1] Total of 120 pigs with 2 pigs per pen (one barrow and one gilt).

[2]Total saturated fatty acids = {[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 monounsaturated fatty acids = {[C14:1] + [C16:1] + [C18:1c9] + [C18:1n7] + [C20:1] + [C24:1]}, where the brackets indicate concentration.

[4]Total polyunsaturated fatty acids = {[C18:2n6] + [C18:3n3] + [C18:3n6] + [C20:2] + [C20:4n6]}, where the brackets indicate concentration.

[5]Total *trans* fatty acids = {[C18:1t] + [C18:2t] + [C18:3t]}, where the brackets indicate concentration.

[6]UFA:SFA ratio = [Total MUFA + Total PUFA] / Total SFA.

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

[8]Calculated as 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 (AOCS, 1998).

Table 14. Effects of gender on belly fat quality[1]

	Barrows	Gilts	SE	Probability, P <
Myristic acid (14:0), %	1.27	1.22	0.02	0.01
Palmitic acid (16:0), %	22.00	21.36	0.15	0.01
Palmitoleic acid (16:1), %	2.40	2.28	0.06	0.11
Margaric acid (17:0), %	0.49	0.49	0.01	0.97
Stearic acid (18:0), %	9.98	10.04	0.19	0.95
Oleic acid (18:1c9), %	42.10	41.87	0.34	0.54
Vaccenic acid (18:1n7), %	3.22	3.15	0.05	0.28
Linoleic acid (18:2n6), %	14.97	15.92	0.39	0.02
α-linolenic acid (18:3n3), %	0.65	0.68	0.02	0.02
Arachidic acid (20:0), %	0.19	0.18	0.007	0.06
Gadoleic acid (20:1), %	0.06	0.07	0.003	0.11
Eicosadienoic acid (20:2), %	0.84	0.87	0.01	0.04
Arachidonic acid (20:4n6), %	0.25	0.29	0.01	0.01
Other fatty acids, %	1.58	1.58	0.03	0.93
Total SFA, %[2,]	34.36	33.68	0.25	0.04
Total MUFA, %[3]	48.32	47.95	0.44	0.45
Total PUFA, %[4]	17.32	18.36	0.42	0.02
Total *trans* fatty acids, %[5]	0.54	0.56	0.03	0.60
UFA:SFA ratio[6]	1.92	1.98	0.02	0.04
PUFA:SFA ratio[7]	0.51	0.55	0.01	0.01
Iodine value, g/100 g[8]	71.8	72.9	0.44	0.03

[1] Total of 120 pigs with 2 pigs per pen (one barrow and one gilt).

[2]Total saturated fatty acids = {[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 monounsaturated fatty acids = {[C14:1] + [C16:1] + [C18:1c9] + [C18:1n7] + [C20:1] + [C24:1]}, where the brackets indicate concentration.

[4]Total polyunsaturated fatty acids = {[C18:2n6] + [C18:3n3] + [C18:3n6] + [C20:2] + [C20:4n6]}, where the brackets indicate concentration.

[5]Total *trans* fatty acids = {[C18:1t] + [C18:2t] + [C18:3t]}, where the brackets indicate concentration.

[6]UFA:SFA ratio = [Total MUFA + Total PUFA] / Total SFA.

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

[8]Calculated as 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 (AOCS, 1998).