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Carcass fat quality of pigs is not improved by adding corn germ, beef tallow, palm kernel oil, or glycerol to finishing diets containing distillers dried grains with solubles[1]

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ABSTRACT: The objective of this experiment was to test the hypothesis that the reduced carcass fat quality that is often observed in pigs fed diets containing distillers dried grains with solubles (DDGS) may be ameliorated if corn germ, beef tallow, palm kernel oil, or glycerol is added to diets fed during the finishing period. A total of 36 barrows and 36 gilts (initial BW 43.7 ± 2.0 kg) were individually housed and randomly allotted to 1 of 6 dietary treatments in a 2 × 6 factorial arrangement, with gender and diet as main factors. Each dietary treatment had 12 replicate pigs. A corn-soybean meal control diet and a diet containing corn, soybean meal, and 30% DDGS were formulated. Four additional diets were formulated by adding 15% corn germ, 3% beef tallow, 3% palm kernel oil, or 5% glycerol to the DDGS-containing diet. Growth performance, carcass characteristics, and LM quality were determined, and backfat and belly fat samples were collected for fatty acid analysis. There was no gender × diet interaction for any of the response variables measured. For the entire finisher period (d 0 to 88), diet had no effect on ADG, but pigs fed 3% palm kernel oil tended ($P < 0.10$) to have less ADFI and greater G:F than pigs fed the control diet. Barrows had greater ($P < 0.01$) ADG and ADFI, and less ($P < 0.001$) G:F than gilts. Pigs fed the DDGS diet had reduced ($P < 0.05$) loin eye area compared with pigs fed the control diet, but diet had no effect on other carcass characteristics. Barrows had greater ($P < 0.001$) final BW at the end of both phases, greater ($P < 0.001$) HCW and backfat thickness, and tended ($P = 0.10$) to have greater dressing percentage, but less ($P < 0.001$) fat-free lean percentage than gilts. Backfat of pigs fed the 5 DDGS-containing diets had less ($P < 0.05$) L* values than pigs fed the control diet and backfat of gilts had greater ($P < 0.001$) a* and b* values than barrows. Pigs fed the control diet had greater ($P < 0.05$) belly flop distance compared with pigs fed the 5 DDGS-containing diets, but no differences were observed among pigs fed the diets containing DDGS. Barrows had heavier ($P < 0.001$) bellies and greater ($P < 0.001$) belly flop distances than gilts. Diet had no effect on carcass fat iodine value (IV), but gilts tended ($P = 0.07$) to have greater backfat IV and greater ($P = 0.05$) belly fat IV than barrows. In conclusion, the hypothesis that carcass fat quality of pigs fed diets containing DDGS can be improved by inclusion of corn germ, beef tallow, palm kernel oil, or glycerol in finishing diets could not be confirmed.

Key words: corn germ, distillers dried grains with solubles, fat quality, glycerol, oil, pigs

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INTRODUCTION

Distillers dried grains with solubles (**DDGS**) contains high amounts of PUFA, especially linoleic acid (Stein and Shurson, 2009; Xu et al., 2010), which may suppress de novo lipid synthesis by promoting deposition of dietary fatty acids in adipose tissue (Clarke et al., 1990; Madsen et al., 1992). Therefore, feeding DDGS-based diets may increase deposition of PUFA in backfat and bellies, which results in increased fat iodine values (**IV**) and reduced belly fat firmness in

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finishing pigs (Whitney et al., 2006; Widmer et al., 2008; Benz et al., 2010). Pork produced from pigs fed diets containing unsaturated fatty acids may have reduced shelf life and increased susceptibility to oxidative damage (NPPC, 1999; Sheard et al., 2000; Averette Gatlin et al., 2002).

Addition of corn germ to a corn-soybean meal diet resulted in reduced belly fat IV (Widmer et al., 2008), but the mechanism behind this observation has not been elucidated. It is also possible that the increase in pork fat IV that is caused by PUFA in the diets may be prevented if saturated fats, such as beef tallow or palm kernel oil, are added to the diet (Averette Gatlin et al., 2002; Teye et al., 2006). Likewise, inclusion of glycerol in diets fed to growing pigs may reduce IV in muscle fat and backfat (Mourot et al., 1994), and carcass fat firmness is improved if glycerol is fed before slaughter (Schieck et al., 2010). To the best of our knowledge, this hypothesis has not been tested in diets containing 30% DDGS. Because inclusion of corn germ, tallow, palm kernel oil, and glycerol has been reported to improve carcass fat firmness in pigs fed diets containing no DDGS, we hypothesized that the increase in IV of backfat and belly fat that is often observed in pigs fed diets containing DDGS can be prevented by supplementing DDGS-based diets with corn germ, beef tallow, palm kernel oil, or glycerol.

MATERIALS AND METHODS

The protocol for the experiment was reviewed and approved by the Institutional Animal Care and Use Committee at the University of Illinois. Pigs used in the experiment were the offspring of G-performer boars mated to F-25 females (Genetiporc, Alexandria, MN).

Animals, Housing, Experimental Design, and Diets

A total of 36 barrows and 36 gilts with an initial BW of 43.7 ± 2.0 kg were used in the experiment. Pigs had been fed a corn-soybean meal-based diet without added fat before the start of the experiment. All pigs were housed individually in pens (0.9 × 1.8 m) with fully slatted concrete floors. A feeder and nipple drinker were installed in each pen. Pigs were allowed ad libitum access to feed and water throughout the experiment. The Experimental Animal Allotment Program (Kim and Lindemann, 2007) was used to randomly block pigs, based on BW to 1 of 6 dietary treatments in a 2 × 6 factorial arrangement with sex (barrows and gilts) and diet as main factors. There were 12 replicate pigs per diet (6 barrows and 6 gilts). The 6 dietary treatments were: 1) corn-soybean meal-based control diet with no DDGS and no added fat; 2) control diet with 30% DDGS; 3) DDGS diet with 15% corn germ; 4) DDGS diet with 3% beef tallow; 5) DDGS diet with 3% palm kernel oil; and 6) DDGS diet with 5% glycerol. The major ingredients used to formulate diets were corn, soybean meal, DDGS, corn germ, beef tallow, palm kernel oil, and glycerol (Tables 1 and 2). The inclusion rates for corn germ, beef tallow, and palm kernel oil were chosen to formulate diets that would contain a maximum of 7 to 8% fat to prevent poor flowability. Experimental diets were fed in 2 phases. Early finisher diets (Table 3) were fed during the initial 42 d and late finisher diets (Table 4) were fed during the final 46 d of the experiment. All diets were formulated to meet or exceed current estimates for nutrient requirements (NRC, 1998).

Feeding and Growth Performance

The 72 pigs that were used in the experiment were divided into 2 blocks of 36 pigs and within each block, 3 barrows and 3 gilts were allotted to each diet. The 2 blocks were allotted to treatment diets with a 1-wk interval and pigs in each block were harvested 1 wk apart to maintain the same number of days on feed for all pigs. Pigs were weighed at the beginning of the experiment, on d 42, and at the conclusion of the experiment (d 88). Daily allotments of feed were recorded and feed left in

Table 1. Analyzed composition in corn, soybean meal, distillers dried grains with solubles (DDGS), and corn germ (as-fed basis)

Item	Corn	Soybean meal	DDGS	Corn germ
DM, %	85.97	86.48	84.79	89.69
GE, kcal/kg	3,769	4,146	4,697	4,579
Ash, %	1.11	7.11	4.27	5.01
Ether extract, %	2.64	1.10	8.58	14.40
CP (N × 6.25), %	6.67	46.07	26.28	13.99
ADF	2.06	4.90	10.30	5.19
NDF	8.59	7.04	32.50	21.86
Indispensable AA, %				
Arg	0.29	3.24	1.12	0.88
His	0.19	1.13	0.75	0.39
Ile	0.21	2.06	1.00	0.43
Leu	0.66	3.42	2.76	1.02
Lys	0.22	2.81	0.94	0.70
Met	0.12	0.62	0.48	0.20
Phe	0.27	2.21	1.11	0.52
Thr	0.22	1.63	0.99	0.47
Trp	0.06	0.58	0.18	0.10
Val	0.29	2.22	1.34	0.64
Dispensable AA, %				
Ala	0.42	1.98	1.66	0.81
Asp	0.39	4.94	1.60	0.99
Cys	0.14	0.66	0.48	0.25
Glu	0.99	7.56	3.24	1.70
Gly	0.25	1.86	0.98	0.63
Pro	0.48	2.18	1.61	0.80
Ser	0.25	1.79	1.02	0.47
Tyr	0.18	1.58	0.82	0.36

the feeders was recorded on d 42 and at the conclusion of the experiment. Data for ADG, ADFI, and G:F were also calculated for each pig and summarized within each phase and overall for each sex and diet.

Slaughter and Carcass Evaluation

On the last day of the experiment, feed was removed from the feeders and the final BW of each pig was recorded. After an overnight fast, pigs were transported to the Meat Science Laboratory at the University of Illinois, Urbana. Pigs were kept in the holding pens at the Meat Science Laboratory for 0 to 3 h before being slaughtered and were allowed free access to water during this time. The live BW of each pig was recorded just before slaughter. Pigs were killed by electrical stunning, lifted off the floor, and exsanguinated. After reflex action had ended, pigs were scalded and washed. The HCW was then recorded and carcasses were chilled for 24 h. At 24 h postmortem, pH of the LM was measured at the 10th rib by a handheld pH star probe fitted with a glass electrode (SFK Technologies Inc., Cedar Rapids, IA; 2-point calibration; pH 4 and 7). Backfat was measured perpendicular to the skin at the 10th rib (NPPC, 1991). Loin eye area (**LEA**) was measured by tracing the outline of LM onto transparent paper and then measuring the area using a planimeter (Super Planix α Planimeter, Tamaya Technics Inc., Tokyo), and the average of the 2 measurements was reported as LEA for each carcass.

Table 2. Analyzed fatty acid composition (% total fatty acids) in corn, soybean meal, distillers dried grains with solubles (DDGS), corn germ, tallow, and palm kernel oil (as-fed basis)

Item	Corn	Soybean meal	DDGS	Corn germ	Beef tallow	Palm kernel oil
Caproic acid, C6:0	0.11	0.05	0.21	–	0.31	0.15
Capric acid, C10:0	0.02	0.09	–	–	0.09	0.06
Lauric acid, C12:0	0.01	–	0.06	–	0.21	0.18
Myristic acid, C14:0	0.08	0.14	0.24	–	3.67	1.32
Palmitic acid, C16:0	11.25	13.06	12.06	10.61	23.32	45.69
Palmitoleic acid, C16:1	0.14	0.13	0.11	–	3.08	0.17
Margaric acid, 17:0	0.04	0.13	0.03	–	1.32	0.10
Stearic acid, C18:0	2.07	4.08	2.14	1.38	17.92	4.04
Oleic acid, 18:1	23.74	16.19	23.32	25.25	42.52	36.34
Linoleic acid, C18:2	59.41	55.20	58.85	59.89	3.43	10.99
Linolenic acid, C18:3	1.62	10.09	1.66	1.36	0.58	0.43
Arachidic acid, C20:0	0.29	0.29	0.26	0.54	0.53	0.33
Gadoleic acid, C20:1	0.14	0.10	0.15	0.09	0.17	0.13
Eicosadienoic acid, C20:2	–	–	–	–	0.07	–
Eicosatrienoic acid, C20:3	0.10	0.28	–	–	–	–
Arachidonic acid, C20:4	–	–	0.02	–	–	–
Iodine value,[1] g/100 g	127.8	136.1	125.7	129.0	47.1	51.7

[1]Iodine value = ([16:1] × 0.95) + ([C18:1] × 0.86) + ([C18:2] × 1.732) + ([C18:3] × 2.616) + ([C20:1] × 0.785) + ([C22:1] × 0.723); brackets represent concentration (AOCS, 1998).

Subjective LM color scores on a scale from 1 to 6 (1 = pale pinkish gray to white, and 6 = dark purplish red) and LM marbling scores on a scale from 1 to 10 (1 = devoid and 10 = abundant) were determined (NPPC, 1999). Subjective LM firmness scores on a scale from 1 to 5 (1 = very soft and watery, and 5 = very firm and dry) was also determined (NPPC, 1991). Objective CIE L* (lightness), a* (redness), and b* (yellowness) values (CIE, 1978) of the loin muscle and fat obtained from the second layer were measured with a Minolta chromameter (CR-400; Minolta Camera Co., Osaka, Japan). A 2.5-cm chop was collected at the 10th rib from the loin muscle by removing the loin muscle from the left of the carcasses 24 h postmortem. The loin chop was placed in a plastic, Whirl-Pak bag and suspended from a fish hook for 24 h. Drip loss was calculated by comparing the final and initial weights of the chop.

At 24 h postmortem, the belly of each pig was removed from the left side of the carcass and laid flat on a stainless steel table at 2°C for 24 h. Belly length was then measured from the cranial to the caudal end of each belly, and belly width was measured from the dorsal to the ventral edge. A flop test was performed by draping a centered belly lengthwise over a suspended, stainless steel rod with the skin side down. The distance from skin surface to skin surface was measured at a standardized point, 10 cm down from the stainless steel rod, for each belly (Leick et al., 2010).

Chemical Analysis and Calculations

Corn, soybean meal, DDGS, corn germ, and all diets were analyzed for DM, by oven drying at 135°C for 2 h (Method 930.15; AOAC Int., 2007), and dry ash (Method 942.05; AOAC Int., 2007). Gross energy was determined using bomb calorimetry (Model 6300, Parr Instruments, Moline, IL). Benzoic acid was used as the standard for calibration. The CP in all samples was analyzed using a combustion procedure (Method 990.03; AOAC Int., 2007). Aspartic acid was used as a calibration standard and CP was calculated as N × 6.25. The concentration of ether extract in the ingredients and diets was also analyzed (Method 2003.06; AOAC Int., 2007) using an automated analyzer (Soxtec 2050; FOSS North America, Eden Prairie, MN). Analyses of AA in diets and ingredients were conducted on a Hitachi Amino Acid Analyzer (Model L8800; Hitachi High Technologies America, Inc., Pleasanton, CA), using ninhydrin for postcolumn derivatization and norleucine as the internal standard [Method 982.30 E(a, b c); AOAC Int., 2007]. Acid detergent fiber (Method 973.18; AOAC Int., 2007) and NDF (Holst, 1973) were analyzed in all diets.

Fatty acid analysis of ingredients, diets, belly fat, and backfat samples was conducted as described in detail (Averette-Gatlin et al., 2002; Meadus et al., 2010), using

Table 3. Composition of early finisher diets (as-fed basis)

	Diet					
Item	Control	DDGS[1]	Corn germ	Beef tallow	Palm kernel oil	Glycerol
Ingredient, %						
Ground corn	72.65	55.45	41.70	52.40	52.40	50.38
Soybean meal, 48% CP	25.00	12.25	11.00	12.25	12.25	12.25
DDGS	–	30.00	30.00	30.00	30.00	30.00
Corn germ	–	–	15.00	–	–	–
Beef tallow	–	–	–	3.00	–	–
Palm kernel oil	–	–	–	–	3.00	–
Glycerol	–	–	–	–	–	5.00
Ground limestone	0.85	1.20	1.30	1.20	1.20	1.20
Dicalcium phosphate	0.80	0.10	–	0.13	0.13	0.15
L-Lys HCL	–	0.30	0.30	0.32	0.32	0.32
NaCl	0.40	0.40	0.40	0.40	0.40	0.40
Vitamin mineral premix[2]	0.30	0.30	0.30	0.30	0.30	0.30
Analyzed composition, %						
DM	87.33	87.33	88.25	87.85	87.36	82.39
GE, kcal/kg	3,768	4,091	4,185	4,326	4,302	4,191
ME, kcal/kg[3]	3,330	3,335	3,359	3,483	3,483	3,323
CP (N × 6.25)	15.36	16.67	15.32	17.26	17.46	17.37
Ether extract	2.35	4.85	6.08	7.48	7.39	4.13
Ash	2.85	4.10	4.37	4.58	4.77	4.35
ADF	2.73	5.00	4.42	4.68	4.70	4.70
NDF	9.21	18.40	18.58	14.58	14.34	14.99
Dietary IV,[4] g/100 g	126.7	126.4	127.1	105.2	101.8	127.8
Indispensable AA, %						
Arg	1.00	0.91	0.83	0.87	0.92	0.90
His	0.44	0.50	0.45	0.47	0.49	0.44
Ile	0.66	0.69	0.60	0.65	0.68	0.66
Leu	1.36	1.73	1.54	1.63	1.65	1.64
Lys[5]	0.85	1.04	1.04	0.98	1.04	0.96
Met	0.23	0.31	0.28	0.28	0.30	0.29
Phe	0.76	0.80	0.71	0.75	0.79	0.77
Thr	0.58	0.66	0.60	0.63	0.65	0.61
Trp	0.18	0.17	0.16	0.16	0.18	0.18
Val	0.77	0.87	0.79	0.83	0.85	0.83

[1]DDGS = distillers dried grains with solubles.

[2]The vitamin-micromineral premix provided these quantities of vitamins and microminerals per kilogram of complete diet: Vitamin A as retinyl acetate, 11,128 IU; vitamin D3 as cholecalciferol, 2204 IU; vitamin E as DL-alpha tocopheryl acetate, 66 IU; vitamin K as menadione nicotinamide bisulfite, 1.42 mg; thiamin as thiamine mononitrate, 0.24 mg; riboflavin, 6.58 mg; pyridoxine as pyridoxine hydrochloride, 0.24 mg; vitamin B12, 0.03 mg; D-pantothenic acid as D-calcium pantothenate, 23.5 mg; niacin as nicotinamide and nicotinic acid, 44 mg; folic acid, 1.58 mg; biotin, 0.44 mg; Cu, 10 mg as copper sulfate; Fe, 125 mg as iron sulfate; I, 1.26 mg as potassium iodate; Mn, 60 mg as manganese sulfate; Se, 0.3 mg as sodium selenite; and Zn, 100 mg as zinc oxide.

[3]Values for ME were calculated rather than analyzed.

[4]Iodine value (IV) = ([16:1] × 0.95) + ([C18:1] × 0.86) + ([C18:2] × 1.732) + ([C18:3] × 2.616) + ([C20:1] × 0.785) + ([C22:1] × 0.723); brackets represent concentration (AOCS, 1998).

[5]All diets were formulated to contain 0.83% standardized ileal digestible Lys.

a Hewlett-Packard 5890 gas chromatograph (Hewlett-Packard, Avondale, PA). Briefly, samples were placed in a glass tube and after the reagent had been added, samples were heated in a boiling water bath. Samples were then cooled and methyl alcohol and HCl were added to each tube. Samples were then placed in the boiling water bath for 10 min and after mixing and vortexing, the aqueous phase was discarded. Sodium hydroxide was added before samples were mixed and centrifuged, and the organic layer was moved to a clean vial and dried. Methyl esters were then redissolved using hexane. Iodine value of ingredients, diets, belly fat, and backfat were calculated using this equation (AOCS, 1998): IV = ([16:1] × 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.

Table 4. Composition of late finisher diets (as-fed basis)

	Diet					
Item	Control	DDGS[1]	Corn germ	Beef tallow	Palm kernel oil	Glycerol
Ingredient, %						
Ground corn	79.65	62.40	43.43	59.37	59.37	57.37
Soybean meal, 48% CP	18.25	5.50	4.25	5.50	5.50	5.50
DDGS	–	30.00	30.00	30.00	30.00	30.00
Corn germ	–	–	15.00	–	–	–
Beef tallow	–	–	–	3.00	–	–
Palm kernel oil	–	–	–	–	3.00	–
Glycerol	–	–	–	–	–	5.00
Ground limestone	0.80	1.09	1.30	1.09	1.09	1.09
Dicalcium phosphate	0.60	–	–	–	–	–
L-Lys HCL	–	0.30	0.30	0.32	0.32	0.32
L-Trp	–	0.01	0.02	0.02	0.02	0.02
NaCl	0.40	0.40	0.40	0.40	0.40	0.40
Vitamin mineral premix[2]	0.30	0.30	0.30	0.30	0.30	0.30
Analyzed composition, %						
DM	86.70	86.46	86.61	88.15	88.30	85.68
GE, kcal/kg	3,891	4,119	4,200	4,361	4,346	4,206
ME, kcal/kg[3]	3,341	3,345	3,361	3,493	3,493	3,333
CP (N × 6.25)	14.46	15.73	15.92	13.55	13.58	13.64
Ether extract	3.02	4.60	5.68	8.38	8.21	4.92
Ash	3.52	3.84	4.11	3.49	3.39	3.39
ADF	2.32	4.48	3.99	4.57	4.64	4.97
NDF	7.54	14.55	16.47	14.99	14.71	16.52
Dietary IV,[4] g/100 g	129.1	126.3	126.3	95.3	97.1	122.4
Indispensable AA, %						
Arg	0.85	0.73	0.72	0.68	0.62	0.73
His	0.39	0.43	0.38	0.42	0.39	0.45
Ile	0.57	0.57	0.54	0.55	0.50	0.56
Leu	1.24	1.52	1.48	1.52	1.40	1.58
Lys[5]	0.72	0.81	0.80	0.83	0.79	0.89
Met	0.22	0.26	0.27	0.26	0.24	0.29
Phe	0.66	0.67	0.65	0.65	0.60	0.66
Thr	0.50	0.57	0.58	0.53	0.49	0.61
Trp	0.16	0.15	0.16	0.14	0.16	0.16
Val	0.67	0.73	0.71	0.72	0.66	0.75

[1]DDGS = distillers dried grains with solubles.

[2]The vitamin-micromineral premix provided these quantities of vitamins and microminerals per kilogram of complete diet: Vitamin A as retinyl acetate, 11,128 IU; vitamin D_3 as cholecalciferol, 2204 IU; vitamin E as DL-alpha tocopheryl acetate, 66 IU; vitamin K as menadione nicotinamide bisulfite, 1.42 mg; thiamin as thiamine mononitrate, 0.24 mg; riboflavin, 6.58 mg; pyridoxine as pyridoxine hydrochloride, 0.24 mg; vitamin B12, 0.03 mg; D-pantothenic acid as D-calcium pantothenate, 23.5 mg; niacin as nicotinamide and nicotinic acid, 44 mg; folic acid, 1.58 mg; biotin, 0.44 mg; Cu, 10 mg as copper sulfate; Fe, 125 mg as iron sulfate; I, 1.26 mg as potassium iodate; Mn, 60 mg as manganese sulfate; Se, 0.3 mg as sodium selenite; and Zn, 100 mg as zinc oxide.

[3]Values for ME were calculated rather than analyzed.

[4]Iodine value (IV) = ([16:1] × 0.95) + ([C18:1] × 0.86) + ([C18:2] × 1.732) + ([C18:3] × 2.616) + ([C20:1] × 0.785) + ([C22:1] × 0.723); brackets represent concentration (AOCS, 1998).

[5]All diets were formulated to contain 0.66% standardized ileal digestible Lys.

Statistical Analyses

Data were analyzed using the MIXED procedure (SAS Inst. Inc., Cary, NC) as a 2 × 6 factorial arrangement with sex and diet as main factors. Pig was the experimental unit for all analyses. The model included sex, diet, and sex × diet interaction as fixed effects, and block and replicate as random effects. However, interactions between sex and diet were not significant for any response variables analyzed. Therefore, the interaction was removed from the final model. Least squares means were calculated for each independent variable. When treatment effect was a significant source of variation, the PDIFF option of SAS was used to separate means. Significance and tendencies were considered at $P \leq 0.05$ and $P \leq 0.10$, respectively, for all analyses.

Table 5. Effect of adding corn germ, beef tallow, palm kernel oil, and crude glycerol to DDGS-containing diets on growth performance of finishing pigs[1,2,3]

	Diet								Sex			
Item	Control	DDGS	Corn germ	Beef tallow	Palm kernel oil	Glycerol	SEM	*P*-value	Barrows	Gilts	SEM	*P*-value
Early finisher (d 0 to 42)												
Initial BW, kg	43.5	43.3	43.8	43.8	43.5	44.1	1.0	0.90	44.3	43.1	1.0	0.01
ADG, kg	1.03	0.98	1.02	1.03	1.03	1.01	0.03	0.85	1.08	0.95	0.02	<0.001
ADFI, kg	2.73	2.64	2.68	2.61	2.55	2.77	0.07	0.28	2.89	2.44	0.04	<0.001
G:F	0.38	0.37	0.39	0.40	0.40	0.37	0.01	0.08	0.38	0.39	0.01	0.07
Final BW, kg	86.9	84.3	86.8	87.1	86.7	86.5	1.6	0.85	89.8	83.0	0.9	<0.001
Late finisher (d 42 to 88)												
ADG, kg	0.95	0.93	0.93	0.93	0.94	0.90	0.04	0.96	0.93	0.93	0.02	0.84
ADFI, kg	2.97[a]	2.70[ab]	2.79[ab]	2.77[ab]	2.54[b]	2.69[ab]	0.09	0.04	2.89	2.59	0.05	<0.001
G:F	0.33	0.35	0.33	0.34	0.37	0.34	0.01	0.20	0.32	0.36	0.01	<0.001
Final BW, kg	130.6	127.0	129.5	129.8	129.9	128.0	2.5	0.92	132.4	125.9	1.4	0.002
Entire period (d 0 to 88)												
ADG, kg	0.99	0.95	0.97	0.98	0.98	0.95	0.03	0.91	1.00	0.94	0.02	0.01
ADFI, kg	2.85	2.67	2.74	2.70	2.54	2.73	0.07	0.06	2.89	2.52	0.04	<0.001
G:F	0.35	0.36	0.36	0.37	0.39	0.35	0.01	0.10	0.35	0.38	0.01	0.001

[a,b]Within a row, means without a common superscript differ ($P < 0.05$).

[1]Data for diets are means of 12 observations per treatment (6 barrows and 6 gilts). Data for sex are means of 36 observations.

[2]Diet × sex interactions were not significant.

[3]DDGS = distillers dried grains with solubles.

RESULTS

Growth Performance

There were no differences in ADG among dietary treatments in either early or late finisher phases, or during the overall period (Table 5). As a result, there were no differences in BW at the end of either phase. There were also no differences in ADFI among the dietary treatments during the early finisher phase, but ADFI of pigs fed the diet with 3% palm kernel oil was less ($P <$ 0.05) than for pigs fed the control diet during the late finisher phase. Overall, there was a tendency ($P = 0.06$) for less ADFI for pigs fed the diet containing palm kernel oil compared with pigs fed the control diet. In the early finisher phase, there was also a tendency ($P = 0.08$) for pigs fed diets containing beef tallow or palm kernel oil to have greater G:F than pigs fed the diets containing DDGS or glycerol, but there were no differences in G:F in the late finisher phase. However, for the entire finisher period, there was a tendency ($P = 0.10$) for pigs fed the diet containing palm kernel oil to have greater G:F than pigs fed the control diet or the diet containing glycerol.

Barrows were heavier ($P < 0.05$) than gilts at the start of the experiment and at the end of both the early and late finisher phases. Barrows had greater ADG ($P <$ 0.05) than gilts during the early finisher phase and the overall period, and ADFI was greater ($P < 0.05$) for barrows than for gilts in both phases and for the overall period. Gilts tended ($P = 0.07$) to have greater G:F during the early finisher phase and had greater ($P < 0.05$) G:F than barrows during the late finisher phase and the overall period.

Carcass Characteristics

Except for LEA, there were no differences in carcass characteristics among dietary treatments (Table 6). Loin eye area of pigs fed the control diet or the diet containing corn germ was greater ($P < 0.05$) than for pigs fed the diets containing DDGS or DDGS and palm kernel oil. Pigs fed the diets containing beef tallow or glycerol also had greater ($P < 0.05$) loin eye area than pigs fed the diet containing DDGS. Barrows had greater (P < 0.05) live BW, HCW, and backfat thickness, but less ($P < 0.05$) fat-free lean percentage than gilts. There was also a tendency ($P = 0.10$) for barrows to have greater dressing percentage than gilts, but no differences were observed in LEA between barrows and gilts.

Muscle Quality

Diet had no effect on subjective color, marbling, firmness, 24-h pH, 48-h drip loss, and objective color (L*, a*, b*) of LM. There were no differences in a* and b* values of backfat among dietary treatments, but the L* value of backfat from pigs fed the control diet was greater ($P <$ 0.05) than for pigs fed the 5 DDGS-containing diets. Gilts had less ($P < 0.05$) marbling and reduced ($P < 0.01$) 24-h LM pH compared with barrows. Gilts had greater ($P <$ 0.05) a* and b* values of backfat than barrows, but the L* value was not different between barrows and gilts. There

Table 6. Effect of adding corn germ, beef tallow, palm kernel oil, and glycerol to DDGS-containing diets on carcass characteristics and loin muscle quality of finishing pigs[1,2,3]

	Diet								Sex			
Item	Control	DDGS	Corn germ	Beef tallow	Palm kernel oil	Glycerol	SEM	*P*-value	Barrows	Gilts	SEM	*P*-value
Carcass characteristics												
BW, kg	127.1	122.7	126.1	126.1	125.9	124.4	2.32	0.80	128.7	122.1	1.34	<0.001
HCW, kg	99.4	95.1	98.4	98.5	98.0	96.1	1.85	0.56	100.4	94.7	1.07	<0.001
Dressing,[4] %	78.1	77.5	78.0	78.1	77.8	77.2	0.30	0.18	78.00	77.6	0.17	0.10
Backfat, cm	1.93	1.73	1.93	1.85	1.96	1.84	0.11	0.66	2.27	1.47	0.06	<0.001
Loin eye area, cm^2	54.7[a]	47.5[c]	54.4[a]	52.5[ab]	50.1[bc]	51.5[ab]	1.74	0.003	51.0	52.6	1.34	0.16
FFL,[5] %	54.5	54.2	54.6	54.5	53.6	54.5	0.59	0.84	52.3	56.3	0.34	<0.001
Loin muscle quality												
24-h LM pH	5.59	5.55	5.62	5.62	5.58	5.61	0.03	0.36	5.62	5.56	0.02	< 0.001
48-h drip loss, %	8.41	7.47	6.74	12.72	8.61	6.90	3.05	0.75	6.76	10.19	1.76	0.17
Subjective evaluation[6]												
Color	2.67	2.67	2.58	2.75	2.33	2.58	0.25	0.73	2.64	2.56	0.20	0.60
Marbling	2.00	1.50	1.67	1.42	1.50	1.58	0.16	0.14	1.78	1.44	0.09	0.01
Firmness	2.50	2.58	2.33	2.42	1.83	2.42	0.37	0.13	2.42	2.28	0.33	0.39
LM color[7]												
L*	54.4	51.9	50.9	50.5	53.9	51.5	1.62	0.18	51.8	52.5	1.23	0.51
a*	7.79	8.55	7.69	8.28	8.29	8.05	0.71	0.86	8.13	8.09	0.57	0.93
b*	4.74	4.31	3.16	3.40	4.39	3.51	0.68	0.29	3.89	3.95	0.49	0.89
Backfat color												
L*	76.4[a]	73.7[b]	73.3[b]	73.8[b]	73.7[b]	74.0[b]	0.88	<0.001	74.3	74.1	0.81	0.48
a*	3.81	4.58	4.19	3.74	4.26	3.97	0.39	0.65	3.55	4.64	0.22	0.001
b*	4.87	5.10	4.71	4.77	4.85	4.57	0.26	0.61	4.39	5.23	0.19	<0.001

[a–c]Within a row, means without a common superscript differ ($P < 0.05$).

[1]Data for diets are means of 12 observations per treatment (6 barrows and 6 gilts). Data for sex are means of 36 observations.

[2]Diet × sex interactions were not significant.

[3]DDGS = distillers dried grains with solubles.

[4]Dressing, % = HCW/live wt × 100.

[5]Fat-free lean (FFL), % = as calculated from NPPC (1999).

[6]Subjective evaluations based on National Pork Producers Council (Des Moines, IA) standards (NPPC, 1991).

[7]L* = lightness; a* = redness; b* = yellowness.

were also no differences between barrows and gilts for the other LM quality characteristics.

Belly Quality

There were no differences in belly length, belly width, or belly weight among the dietary treatments (Table 7). However, belly flop distance was greater ($P < 0.05$) for pigs fed the control diet than for pigs fed the 5 DDGS-containing diets, but there were no differences in belly flop distance among pigs fed the diets containing DDGS. Barrows had heavier ($P < 0.001$) bellies and greater ($P < 0.001$) belly flop distance than gilts.

Carcass Fat Composition and Quality

Except for a tendency ($P = 0.06$) for greater concentration of gadoleic acid in backfat of pigs fed the corn germ diet than in pigs fed the control diet or the diet containing beef tallow, no differences were observed in the fatty acid composition of backfat among pigs on the different dietary treatments (Table 8). As a result, there was no effect of dietary treatment on backfat IV.

Backfat of barrows contained more ($P < 0.05$) palmitic acid and palmitoleic acid than backfat of gilts, and there was a tendency ($P = 0.07$) for barrows to have a greater concentration of total SFA in backfat compared with gilts. In contrast, there was a tendency ($P = 0.09$) for gilts to have greater concentrations of linoleic acid and total PUFA in backfat than barrows.

There were no differences in the fatty acid composition of belly fat among pigs fed the 6 dietary treatments, except that the concentration of oleic acid was greater ($P < 0.05$) in belly fat from pigs fed the control diet than from pigs on other dietary treatments, except for pigs fed the diet containing beef tallow (Table 9). Pigs fed the diet containing beef tallow also had greater ($P < 0.05$) oleic acid concentration in belly fat than pigs fed the diets containing DDGS, corn germ, or glycerol. The concentration of total MUFA was greater ($P < 0.05$) in belly fat from pigs fed the control diet compared with pigs fed the diets containing DDGS or corn germ. Pigs fed the

Table 7. Effect of adding corn germ, beef tallow, palm kernel oil, and glycerol to DDGS-containing diets on belly quality of finishing pigs[1,2,3]

	Diet								Sex			
Item	Control	DDGS	Corn germ	Beef tallow	Palm kernel oil	Glycerol	SEM	*P*-value	Barrows	Gilts	SEM	*P*-value
Belly length, cm	63.6	61.9	61.7	62.1	60.4	62.0	1.6	0.52	62.2	61.6	1.4	0.45
Belly width, cm	23.7	24.3	24.6	24.6	24.6	24.5	0.5	0.81	24.7	24.1	0.3	0.16
Belly weight, kg	8.1	8.2	8.5	8.3	8.2	8.2	2.8	0.83	8.6	7.9	2.8	<0.001
Flop distance, cm	18.1[a]	9.7[b]	9.6[b]	10.0[b]	8.8[b]	10.3[b]	0.8	<0.001	13.2	9.0	0.5	<0.001

[a,b]Within a row, means without a common superscript differ ($P < 0.05$).

[1]Data for diets are means of 12 observations per treatment (6 barrows and 6 gilts). Data for sex are means of 36 observations.

[2]Diet × sex interactions were not significant.

[3]DDGS = distillers dried grains with solubles.

diet containing beef tallow also had greater ($P < 0.05$) total MUFA in belly fat than pigs fed the diet containing DDGS. However, there was no effect of dietary treatment on the IV of belly fat. Belly fat from barrows contained more ($P < 0.05$) palmitic acid but less ($P < 0.05$) α-linolenic acid than gilts; barrows tended ($P = 0.07$) to have a reduced PUFA:SFA ratio compared with gilts. Gilts tended ($P = 0.07$) to have greater backfat IV and greater ($P = 0.05$) belly fat IV than barrows.

DISCUSSION

Growth Performance

The concentration of Lys in DDGS used in this experiment was greater than the average for DDGS (Stein and Shurson, 2009). This resulted in a Lys:CP ratio of 3.58%, which is also greater than average DDGS, indicating that the DDGS used in this experiment had not been heat damaged (Kim et al., 2012). The fact that pigs fed the DDGS-containing diets had ADG and G:F that was not different from that of pigs fed the control diet indicates that if a good quality DDGS is included in diets fed to pigs, growth performance is not compromised. This observation is in agreement with data from several previous experiments (Stein and Shurson, 2009).

Inclusion of 10% corn germ in a corn-soybean meal diet fed to growing-finishing pigs does not affect growth performance (Widmer et al., 2008) and recently it was reported that up to 30% corn germ may be included in diets containing DDGS without changing pig growth performance (Lee et al., 2012). Thus, results of this experiment indicating that the addition of 15% corn germ to a diet based on corn, soybean meal, and 30% DDGS does not change pig performance is in agreement with previous research.

Growth performance of pigs fed corn-soybean meal diets with 5% or 10% tallow is not different from that of pigs fed diets with no tallow (Apple et al., 2009; Realini et al., 2010) and results of the current experiment agree with these observations. Likewise, ADG of

Table 8. Effect of adding corn germ, beef tallow, palm kernel oil, and glycerol to DDGS-containing diets on backfat quality of finishing pigs[1,2,3]

	Diet								Sex			
Item	Control	DDGS	Corn germ	Beef tallow	Palm kernel oil	Glycerol	SEM	*P*-value	Barrows	Gilts	SEM	*P*-value
Myristic acid (14:0), %	1.61	1.77	1.93	1.76	1.79	1.82	0.21	0.56	1.83	1.73	0.19	0.33
Palmitic acid (16:0), %	22.60	21.36	21.10	21.52	22.73	22.48	0.70	0.40	22.70	21.23	0.41	0.01
Palmitoleic acid (16:1), %	2.04	2.07	1.96	1.96	2.02	2.03	0.15	0.99	2.13	1.89	0.10	0.02
Margaric acid (17:0), %	0.30	0.40	0.40	0.35	0.28	0.30	0.05	0.16	0.32	0.36	0.04	0.17
Stearic acid (18:0), %	11.12	9.75	9.62	10.16	9.39	10.40	0.64	0.44	10.40	9.87	0.37	0.43
Oleic acid (18:1 *cis*-9), %	38.24	35.37	35.34	37.10	36.49	36.21	0.93	0.24	36.75	36.17	0.54	0.45
Linoleic acid (18:2n-6), %	20.40	24.96	24.89	23.08	23.38	22.76	1.84	0.54	21.92	24.56	1.06	0.09
α-Linolenic acid (18:3n-3), %	0.71	0.79	0.83	0.77	0.76	0.69	0.06	0.61	0.74	0.78	0.04	0.48
Arachidic acid (20:0), %	0.26	0.36	0.34	0.29	0.25	0.26	0.05	0.57	0.28	0.31	0.03	0.52
Gadoleic acid (20:1), %	0.57	0.62	0.81	0.57	0.63	0.61	0.08	0.06	0.62	0.64	0.06	0.70
Arachidonic acid (20:4n-6), %	0.34	0.40	0.45	0.35	0.38	0.37	0.06	0.60	0.37	0.39	0.05	0.46
Iodine value,[4] g/100 g	72.7	78.6	78.6	76.6	76.6	75.2	2.6	0.61	74.4	78.4	1.5	0.07

[1]Data for diets are means of 12 observations per treatment (6 barrows and 6 gilts). Data for sex are means of 36 observations.

[2]Diet × sex interactions were not significant.

[3]DDGS = distillers dried grains with solubles.

[4]Iodine value = ([16:1] × 0.95) + ([C18:1] × 0.86) + ([C18:2] × 1.732) + ([C18:3] × 2.616) + ([C20:1] × 0.785) + ([C22:1] × 0.723); brackets represent concentration (AOCS, 1998).

Table 9. Effect of adding corn germ, beef tallow, palm kernel oil, and glycerol to DDGS-containing diets on belly fat quality of finishing pigs[1,2,3]

Item	Diet						SEM	P-value	Sex		SEM	P-value
	Control	DDGS	Corn germ	Beef tallow	Palm kernel oil	Glycerol			Barrows	Gilts		
Myristic acid (14:0), %	1.76	2.07	1.99	1.83	1.94	2.23	0.18	0.43	2.07	1.88	0.11	0.17
Palmitic acid (16:0), %	21.27	20.99	20.59	21.07	21.76	22.24	0.55	0.34	21.90	20.73	0.32	0.01
Palmitoleic acid (16:1), %	2.87	3.02	2.67	2.81	2.63	2.86	0.21	0.71	2.84	2.78	0.14	0.67
Margaric acid (17:0), %	0.24	0.27	0.28	0.32	0.23	0.25	0.03	0.29	0.27	0.26	0.02	0.68
Stearic acid (18:0), %	8.45	7.29	7.63	8.28	8.30	7.56	0.46	0.33	8.12	7.72	0.29	0.27
Oleic acid (18:1 *cis*-9), %	42.95[a]	39.56[c]	39.89[c]	42.23[ab]	40.50[bc]	39.58[c]	0.82	0.01	40.78	40.79	0.48	0.98
Linoleic acid (18:2n-6), %	18.69	22.83	22.53	19.22	20.31	21.53	1.39	0.19	20.07	21.63	0.80	0.17
α-Linolenic acid (18:3n-3), %	0.74	0.91	0.89	0.82	0.85	0.86	0.04	0.06	0.81	0.88	0.02	0.03
Arachidic acid (20:0), %	0.17	0.22	0.21	0.20	0.14	0.18	0.04	0.74	0.18	0.19	0.02	0.64
Gadoleic acid (20:1), %	0.63	0.56	0.66	0.72	0.75	0.60	0.08	0.30	0.66	0.65	0.05	0.79
Arachidonic acid (20:4n-6), %	0.36	0.36	0.40	0.36	0.32	0.32	0.03	0.50	0.34	0.37	0.02	0.35
Iodine value,[4] g/100 g	74.9	79.4	79.1	75.4	75.7	77.0	1.9	0.38	75.4	78.4	1.07	0.05

[a–c]Within a row, means without a common superscript differ ($P < 0.05$).

[1]Data for diets are means of 12 observations per treatment (6 barrows and 6 gilts). Data for sex are means of 36 observations.

[2]Diet × sex interactions were not significant.

[3]DDGS = distillers dried grains with solubles.

[4]Iodine value = ([16:1] × 0.95) + ([C18:1] × 0.86) + ([C18:2] × 1.732) + ([C18:3] × 2.616) + ([C20:1] × 0.785) + ([C22:1] × 0.723); brackets represent concentration (AOCS, 1998).

pigs fed corn-soybean meal diets containing 40% sorghum DDGS is not affected by the addition of tallow to the diet, but G:F is improved (Feoli et al., 2008a). Data from this experiment also indicate that inclusion of 3% palm kernel oil in a corn-soybean meal-DDGS diet has no effect on growth performance of growing-finishing pigs. This observation is in agreement with data indicating that addition of 2.8% palm kernel oil to diets based on wheat, barley, and soybean meal does not affect pig growth performance (Teye et al., 2006). Based on these data, it is evident that ADG and G:F of finishing pigs are not improved if 3% tallow or palm kernel oil is added to diets containing corn, soybean meal, and DDGS.

Inclusion of 8% glycerol in corn-soybean meal diets may improve ADG, ADFI, and G:F (Schieck et al., 2010), but we failed to confirm this observation by adding 5% glycerol to the diet. It is possible that the reason for this difference is that in the present experiment, glycerol was included in a diet that also contained DDGS. Growth performance of pigs fed diets containing 5% glycerol and 20% DDGS is not different from that of pigs fed a control diet without glycerol (Duttlinger et al., 2012), and the present results indicate that inclusion of 5% glycerol in a diet that contains 30% DDGS also has no impact on pig growth performance.

Carcass Characteristics

The observation that dressing percentage of pigs fed the DDGS-containing diets was not different from that of pigs fed the control diet is in agreement with results of some previous experiments (Drescher et al., 2008; Hill et al., 2008; Widmer et al., 2008). However, in a review of 18 experiments, it was observed that in 8 of these experiments, dressing percentage was reduced as DDGS was included in the diet (Stein and Shurson, 2009). It is not clear why dressing percentage is sometimes reduced when DDGS is included in the diet but not in other cases.

The reduced LEA of pigs fed the diet containing DDGS compared with pigs fed the control diet is largely a result of the numerically reduced HCW for these pigs, because lean percentage was not affected by DDGS. This observation is also in agreement with results of most previous experiments (Stein and Shurson, 2009). The lack of an effect of feeding glycerol on carcass characteristics of finishing pigs is consistent with published data (Kijora et al., 1997; Lammers et al., 2008; Schieck et al., 2010).

Muscle Quality

The lack of an effect of DDGS on LM marbling, firmness, drip loss, and color indicates that addition of DDGS to corn-soybean meal diets does not affect LM quality. This observation is in agreement with previous data (Whitney et al., 2006; Widmer et al., 2008). A reduction in a* and b* values of LM was reported when DDGS-containing diets were fed to pigs (Xu et al., 2010), and LM b* values were reduced by including DDGS in the diet (Widmer et al., 2008). There were, however, no changes in LM objective color scores in this experiment when DDGS was added to the diet. The fact that yellowness and redness of LM of pigs is not changed if diets are supplemented with DDGS, alone or in combination with tallow, palm kernel oil, corn germ, or glycerol, indicates that consumers would not be able to distinguish between loin chops from pigs fed DDGS-containing diets and chops from pigs fed corn-soybean meal diets.

The L* value of backfat is reduced when DDGS is added to a corn-soybean meal diet (Xu et al., 2010) and results of this experiment are in agreement with those of Xu et al. (2010). Feeding DDGS to laying hens resulted in increased egg yolk color compared with eggs from hens fed a corn-soybean meal diet, which was explained by the greater concentration of xanthophylls in DDGS compared with corn and soybean meal (Masa'deh et al., 2011). It was also concluded that xanthophylls in DDGS are highly available. It is, therefore, possible that backfat color in pigs fed DDGS-containing diets was affected by the increased level of xanthophylls in the DDGS diets, compared with the control diet. The lack of an effect of including corn germ, tallow, palm kernel oil, or glycerol to the DDGS-containing diet on L* values of backfat indicate that the darker color caused by DDGS is not changed by including other lipid sources or glycerol in the diet. It is, therefore, likely that it is the xanthophylls in DDGS that results in the darker backfat color in pigs.

Belly Quality

Belly firmness of pigs fed DDGS-containing diets is reduced compared with pigs fed corn-soybean meal diets with no DDGS (Whitney et al., 2006; Cromwell et al., 2011). The increased belly flop distance observed in this experiment is in agreement with this observation. As expected, the analyzed fatty acid composition of corn germ was similar to that in corn and DDGS, which may explain the lack of an effect of corn germ on belly flop distance when added to a diet containing DDGS. It is, however, surprising that the dietary inclusion of beef tallow and palm kernel oil did not ameliorate the negative effect of DDGS on belly flop distance. It was expected that addition of these fat sources to the diet would have resulted in deposition of more SFA in belly fat (Lizardo et al., 2002), which theoretically should have improved belly flop distance. However, inclusion of either 5% tallow or 5% palm oil to a corn-soybean meal diet containing 40% sorghum DDGS also failed to improve belly firmness of finishing pigs (Feoli et al., 2008a), whereas pigs fed 5% coconut oil had belly firmness that was not different from that of pigs fed diets without DDGS (Feoli et al., 2008b). Coconut oil contains ~90% SFA compared with 50% in both tallow and palm kernel oil. Therefore, the inclusion rate or fat source may influence the effects of dietary saturated fats in negating the effects of DDGS on belly firmness. Pigs fed 8% glycerol tended to have firmer bellies compared with pigs that were not fed glycerol (Schieck et al., 2010), but results of this experiment indicate that 5% glycerol is not effective in improving belly firmness of pigs fed diets containing 30% DDGS.

Carcass Fat Quality

In most experiments, fat IV is increased as DDGS is included in the diet (Stein and Shurson, 2009). Recent data indicate that carcass fat IV of pigs fed diets containing DDGS is increased, regardless of the fat depot that is analyzed (Benz et al., 2010; Xu et al., 2010). However, due to large standard errors of the calculated values for IV, we were not able to detect significant changes in IV values among treatments, although there were large numerical differences. The fact that pigs in this experiment were individually housed may have contributed to the relatively large SE that were observed. In addition, in the present experiment, IV values were calculated from the fatty acid composition of the fat depots, whereas IV values were directly measured in fat depots in some of the previous experiments. It is possible that this difference in the procedures used to determine IV values is the reason for the lack of an effect of DDGS on IV values in this experiment.

Belly fat IV was reduced in pigs fed a corn-soybean meal diet containing 10% corn germ compared with pigs fed corn-soybean meal diets or DDGS-containing diets (Widmer et al., 2008). We hypothesized that this may be an effect of increased de novo synthesis of fatty acids in pigs fed diets containing corn germ due to increased energy intake. The fat depots in pigs reflect a combination of de novo synthesized fatty acids and fatty acids originating from the diet (Lizardo et al., 2002). Fatty acids synthesized de novo are usually more saturated than fatty acids originating from plant oils included in the diet and de novo fatty acid synthesis is increased if energy intake increases, as is reflected in the more saturated fat depots in barrows, compared with gilts, even if the same diet is consumed. Therefore, there is not always a direct relationship between dietary fatty acid composition and fatty acid composition of fat depots in pigs, as was demonstrated in the experiment by Widmer et al. (2008). However, results of the present experiment are not in agreement with the earlier observation. We were unable to verify an increased energy intake, and therefore deposition of more saturated fatty acids, in pigs fed the diet containing corn germ. The reason for this discrepancy is not clear, but IV of corn germ is similar to IV in DDGS and when corn germ is added to a diet that also contains DDGS, the concentration of total fat and PUFA increases to a level that is much greater than if corn germ is added to a corn-soybean meal diet without DDGS. As a consequence, if energy intake does not increase, more unsaturated fatty acids are deposited in the fat depots of pigs.

Jowl fat IV was unaffected when 5% tallow or 5% palm oil was added to a corn-soybean meal diet containing 40% sorghum DDGS (Feoli et al., 2008a). Results of the present experiment are in agreement with data reported by Feoli et al. (2008a). The reason for this observation may be that inclusion of 30% DDGS results in addition of ~3% corn oil to the diets. This may have negated the potential positive effects of tallow or palm kernel oil on the fatty acid composition of carcass fat.

Inclusion of glycerol in diets may reduce the degree of unsaturation in backfat (Mourot et al., 1994). However, this effect does not appear to impact fat deposition in pigs fed diets containing DDGS. The negative effects of DDGS on pork fat quality were also not ameliorated by the inclusion of 5% glycerol in a diet containing 20% DDGS (Duttlinger et al., 2012).

Gender Effects

Typical growth and carcass trait differences between barrows and gilts were observed in this experiment. The softer bellies and greater carcass fat IV in gilts compared with barrows is also consistent with previous research (Averette-Gatlin et al., 2002; Correa et al., 2008; Benz et al., 2010). Greater fat deposition increases the degree of saturation of carcass fat (Wood and Enser, 1982; Lo Fiego, 1996; De Smet et al., 2004). As a result, IV increases as fat depth decreases (Barton-Gade, 1984), which is likely the reason for the observed differences in carcass fat IV between gilts and barrows.

Conclusions

Inclusion of corn germ, beef tallow, palm kernel oil, or glycerol in DDGS-containing diets fed to finishing pigs did not improve carcass fat quality. It is possible that greater quantities of these ingredients are needed to improve fat quality, but this may result in formulation of diets that will be difficult to handle in commercial production units. Further research is, therefore, needed to identify alternative strategies to negate the negative effects of DDGS on carcass fat quality. Reduction in the inclusion rate of DDGS during the finishing phase or use of a source of DDGS with a reduced concentration of fat may also be strategies that potentially result in reduction of the negative effects of DDGS on carcass fat quality.

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