Effects of choice white grease or poultry fat on growth performance, carcass leanness, and meat quality characteristics of growing-finishing pigs[1,2]

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ABSTRACT: Eighty-four crossbred gilts were used to evaluate the effects of dietary choice white grease (CWG) or poultry fat (PF) on growth performance, carcass characteristics, and quality characteristics of longissimus muscle (LM), belly, and bacon of growing-finishing pigs. Pigs (initially 60 kg) were fed a control diet with no added fat or diets containing 2, 4, or 6% CWG or PF. Diets were fed from 60 to 110 kg and contained 2.26 g lysine/Mcal ME. Data were analyzed as a 2 × 3 factorial plus a control with main effects of fat source (CWG and PF) and fat level (2, 4, and 6%). Pigs fed the control diet, 2% fat, and 4% fat had greater ($P < 0.05$) ADFI than pigs fed 6% fat. Pigs fed 6% fat had greater ($P < 0.05$) gain/feed (G/F) than pigs fed the control diet or other fat levels. Subcutaneous fat over the longissimus muscle from pigs fed CWG had more ($P < 0.05$) moisture than that from pigs fed PF. Feeding dietary fat (regardless of source or level) reduced ($P < 0.05$) the amount of saturated fats present in the LM. Similarly, 4 or 6% fat decreased ($P < 0.05$) the amount of saturated fats and increased unsaturated fats present in the bacon. No differences ($P > 0.05$) were observed for ADG, dressing percentage, leaf fat weight, LM pH, backfat depth, LM area, percentage lean, LM visual evaluation, LM water-holding capacity, Warner-Bratzler shear and sensory evaluation of the LM and bacon, fat color and firmness measurements, or bacon processing characteristics. Adding dietary fat improved G/F and altered the fatty acid profiles of the LM and bacon, but differences in growth rate, carcass characteristics, and quality and sensory characteristics of the LM and bacon were minimal. Dietary additions of up to 6% CWG or PF can be made with little effect on quality of pork LM, belly, or bacon.

Key Words: Animal Fat, Carcass Composition, Meat Quality, Pigs, Poultry Fat

 J. Anim. Sci. 2001. 79:1491–1501

Introduction

Improving the rate and efficiency of gain is a common goal of swine producers. Supplementing swine diets with fat is a practical method of achieving this goal. Adding 5 or 10% fat to diets for growing-finishing pigs has been shown to increase gain/feed (**G/F**) and decrease ADFI without affecting carcass characteristics (Williams et al., 1994). However, in a review, Pettigrew and Moser (1991) concluded that adding fat to diets for growing-finishing pigs generally decreased percentage of carcass lean. In a large commercial farm study including 1,200 barrows, De La Llata et al. (1999) demonstrated that 6% added fat increased G/F but decreased ADFI and percentage of carcass lean.

As prices for corn, soybean meal, and live hogs continue to fluctuate, producers are forced to investigate the use of alternative fat sources for swine diets. Poultry fat (**PF**) is inexpensive and abundant in certain regions of the United States. However, to date, only a few studies have investigated its use in swine diets. Seerley et al. (1978) determined that growth performance and carcass characteristics were not affected by PF. However, Woodworth et al. (1999) concluded that 6% PF increased G/F but decreased ADFI, carcass leanness, and belly firmness.

The Pork Chain Quality Audit (Cannon et al., 1996) linked PF to unacceptably soft bellies. Highly unsaturated fats such as PF have been reported to reduce pork quality (Miller et al., 1993). For these reasons, this experiment was undertaken to investigate the influence

[1]Contribution No. 00-418-J from the Kansas Agric. Exp. Sta., Manhattan.

[2]Appreciation is expressed to the U. S. Poultry & Egg Assoc., Tucker, GA for partial financial support of this experiment and to Tyson Foods, Inc., Springdale, AR, for providing the poultry fat.

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Received July 5, 2000.

Accepted January 4, 2001.

of two fat sources differing in degree of saturation (choice white grease [**CWG**] and PF) on growth performance, carcass characteristics, and quality measures of the longissimus muscle (**LM**) and belly of growing-finishing pigs.

Materials and Methods

General

Pigs used in this experiment were terminal offspring of PIC L326 boars × C15 sows (PIC, Franklin, KY). Experimental procedures were approved by the Kansas State University Institutional Animal Care and Use Committee (Protocol No. 1106). The fatty acid profiles and several quality indicators of the CWG and PF were determined prior to the initiation of the experiment using AOAC (1995) procedures (Table 1). Compared to PF, the CWG contained more palmitic (16:0), stearic (18:0), and oleic (18:1) acids but less palmitoleic (16:1) and linoleic (18:2) acids.

Growth Performance

Eighty-four crossbred gilts (initially 60 kg BW) were allotted randomly by weight and ancestry to one of seven dietary treatments with two pigs per pen and six replicate pens per treatment. The corn-soybean meal-based control diet had no added fat and was formulated to be nutritionally adequate (NRC, 1988); maintain accepted amino acid ratios relative to lysine (Baker, 1995); and contain 0.75% total lysine, 0.55% total calcium, 0.50% total phosphorus, and 2.26 g lysine/Mcal ME. Ethoxyquin was added as an antioxidant to all diets. Poultry fat and CWG were added at 2, 4, or 6% of the diet to provide the additional treatments (Table 2). The ratios of corn and soybean meal were changed to adjust total lysine levels from 0.75 to 0.81% and maintain the lysine:calorie ratio of the control diet. All diets were fed in meal form.

Gilts were housed in an environmentally regulated finishing barn in 1.2- × 1.2-m totally slatted-floored pens with one self-feeder and a nipple waterer to allow ad libitum access to feed and water, respectively. Pigs and feeders were weighed every 14 d to determine ADG, ADFI, and G/F. When the mean weight of a replicate block of pens reached 110 kg BW, all pigs within that replicate were slaughtered to collect carcass, LM, and belly data.

Table 1. Characterization of poultry fat and choice white grease[a]

Item	Choice white grease	Poultry fat
Fatty acid, %		
Palmitic acid (16:0)	23.30	22.20
Palmitoleic acid (16:1)	3.50	8.40
Stearic acid (18:0)	11.00	5.10
Oleic acid (18:1)	47.10	42.30
Linoleic acid (18:2)	11.00	19.30
Other fatty acids	4.10	2.70
Quality indicators		
Total fatty acids, %	97.90	98.70
Free fatty acids, %	3.20	3.20
Moisture, impurities, and unsaponifiables, %	0.78	1.30
Peroxide value, meq/kg	7.30	0.20
Calculated iodine value[b]	68.4	83.9

[a]Values are means of duplicate analyses from each fat sample.
[b]Calculated using values of 0% myristoleic acid (14:1) and 1% linolenic (18:3) acid.

Table 2. Percentage composition of diets (as-fed basis)[a]

Item	Control diet
Corn	83.33
Soybean meal (46.5% CP)	14.07
Monocalcium phosphate	1.01
Limestone	0.83
Salt	0.35
L-Lysine·HCl	0.15
Vitamin premix[b]	0.15
Trace mineral premix[c]	0.10
Ethoxyquin	0.01
Choice white grease[d]	—
Poultry fat[d]	—

[a]Diets were formulated to contain 2.26 g lysine/Mcal ME, 0.55% total calcium, and 0.50% total phosphorus. Dietary total lysine levels ranged from 0.75 to 0.81%.
[b]Provided per kg of complete diet: vitamin A, 6,614 IU; vitamin D_3, 992 IU; vitamin E, 26.45 IU; menadione (menadione dimethylpyrimidinol bisulphite), 2.64 mg; vitamin B_{12}, 0.02 mg; riboflavin, 5.96 mg; pantothenic acid, 19.85 mg; and niacin, 33.08 mg.
[c]Provided per kg of complete diet: Zn, 110.2 mg; Fe, 110.2; Mn, 26.5 mg; Cu, 11.0; I, 0.2 mg; and Se, .2 mg.
[d]Choice white grease and poultry fat were added at 2, 4, or 6% at the expense of corn and soybean meal to make the experimental diets. The ratios of corn and soybean meal were adjusted accordingly to maintain identical lysine:calorie ratios.

Carcass Characteristics

Pigs were slaughtered at the Kansas State University Abattoir. Hot carcass and leaf fat weights were collected at slaughter. At 45 min postmortem, LM pH was measured at the 10th rib using a Metoxy stainless steel pH electrode and meter (Model HM-17 MX, TOA Electronics, Tokyo, Japan). Ultimate LM pH was measured at 24 h postmortem using a Fisher Accument pH Meter Model 620 and Orion Ross Electrode Combination pH electrode (Fisher Scientific, Pittsburgh, PA). The pH sample was prepared by combining 10 g of LM tissue (trimmed of fat and connective tissue) with 100 mL of distilled water for 20 s using a Seward Laboratory Blender 400 Stomacher (Tekmar Co., Cincinnati, OH). Also at 24 h postmortem, backfat thickness at the first rib, last rib, and last lumbar vertebra from both sides of the carcass were averaged to calculate backfat thickness at these locations. Carcass length also was measured at that time. Additionally, the left side of each carcass was ribbed between the 10th and 11th ribs to determine LM area and 10th rib fat thickness. Percentage of lean was calculated from NPPC (1991) equations for percentage of lean with 5% fat.

Longissimus Muscle and Fat Quality

Carcasses were ribbed and fabricated after 24 h postmortem. After allowing for a 30-min bloom, the LM at the 10th rib was evaluated by a three-person panel for marbling, color, and firmness (NPPC, 1991). Three replicate measurements of the 10th rib cut surface of the LM and surrounding subcutaneous fat were evaluated for instrumental color (CIE, 1976; L*, a*, and b*) using a Minolta Chroma Meter Model CR-200 with illuminant C and 1-cm aperture (Minolta Co., Osaka, Japan). The Hunter a* and b* values were used to calculate saturation index, $(a^{*2} + b^{*2})^{1/2}$; hue angle, arc tangent (b*/a*); and a*:b* ratio.

A 15.24-cm loin section from approximately the 10th rib to the 6th rib was stored in a cooler at 1°C for 24 h. At 48 h postmortem, three 2.54-cm chops were cut on a Hobart bandsaw (Hobart Mfg. Co., Troy, OH). The first, from posterior to anterior, was used to evaluate drip loss (modified from Kauffman et al., 1986) after 24 and 48 h of suspension in a sealed container. The weight loss of each sample was measured and reported as a percentage of the original weight. The second 2.54-cm chop was used to evaluate expressible fluid using a modification of the water-holding capacity procedure of Grau and Hamm (1953). Samples (500 to 600 mg) were pressed on Whatman No. 1 filter paper (15 cm diameter) between two 15-cm^2 Plexiglas plates using a Carver Laboratory Press (Model B, Fred S. Carver Inc., Summit NJ) for 5 min at 352 kg/cm^2. Water-binding capacity was reported as the ratio of meat film area to total fluid area. The third 2.54-cm chop was trimmed of all external fat and used for compositional analysis. The samples were frozen in liquid N, pulverized with a Waring Blender, stored at –23°C, and sent to an independent laboratory to determine fatty acid composition using AOAC (1995) procedures.

After 24 h postmortem, a 12.7-cm portion of the LM, from the 11th rib and posterior, was removed, boned, vacuum-packaged, and held at 1°C for 5 d before freezing at –23°C. The frozen portion was faced and cut into 2.54-cm chops using the Hobart bandsaw. The second chop (anterior to posterior) from each loin was thawed for 24 h at 5°C in a McCall refrigerator (Kolpak Industries, Parsons, TN) and used to evaluate Warner-Bratzler shear force (AMSA, 1995). Chops were cooked to an internal temperature of 35°C, turned, and cooked to an internal temperature of 71°C in a Blodgett DFG-100-3 Series dual-flow gas convection oven (The G. S. Blodgett Ovens Co., Burlington, VT). The internal temperature was monitored by 30-gauge, Type T thermocouples, which were placed in the geometric centers of the chops and attached to a DORIC Minitrend 205 temperature monitor (Emerson Electric S. A., Doric Div., San Diego, CA). Chops were weighed before and after cooking to determine percentage of cooking loss. After the chops had cooled to room temperature (21°C), six 1.27-cm-diameter cores from each chop were removed with a mechanical coring device parallel to the muscle fiber orientation. Cores were sheared perpendicular to the muscle fiber orientation using a Warner-Bratzler shear V-blade attached to an Instron Universal Testing Machine (Model 5401, Instron Corp., Canton, MA) fitted with a 50-kg compression load cell with a crosshead speed of 250 mm/min. Peak force values of cores sheared through the center were used to determine the mechanical tenderness of the sample.

Chops from pigs fed the control diet (no added fat), 6% CWG, and 6% PF were used for sensory analysis. The 2.54-cm chop used for sensory analysis was cut immediately anterior to the chop used for Warner-Bratzler shear force analysis. The chop was thawed and cooked following the same procedures as described for Warner-Bratzler shear force analysis. The chops then were removed and cut into uniform (1.27 × 1.27 × approximately 2.54 cm) sections, which were placed into warmers until they were served to panelists. A trained 12-member sensory panel (AMSA, 1995) evaluated the chops in an environmentally controlled (21 ± 1°C; 55 ± 5% relative humidity) room partitioned into booths with a mixture of adjustable red and green light that provided 107.64 lm of light. Chops were served warm to panelists, who evaluated myofibrilar tenderness, connective tissue amount, overall tenderness, juiciness, flavor intensity, and off-flavors.

At 24 h postmortem, a 12.7-cm portion of the fat covering the LM at the 11th rib and posterior was removed at the seam between the backfat and connective tissue surrounding the LM. The anterior half of the fat was vacuum-packaged and frozen at –23°C for later moisture analysis using a CEM Fat Extraction System (Model FES, CEM Corp., Matthews, NC). The posterior half of the fat was vacuum-packaged and held in a 1°C cooler for 2 d and then used for firmness determination with a compression device attached to the Instron. Six cores (1.27 × 2.54 cm in diameter) were taken from the fat sample, and a texture profile analysis using the Instron was evaluated. The fat sample was compressed to 75% of total compression, and peak force was measured.

Belly and Bacon Quality

At 24 h postmortem, the bellies were separated from the carcasses, and the spareribs were removed. Each belly with the skin side down was centered and laid longitudinally over a metal bar that ran perpendicular to the length of the belly. Measurements of the distance between the anterior and posterior ends of the belly were recorded initially and after 10 min to evaluate firmness.

The bellies then were split into anterior and posterior halves at the 10th rib and allowed to bloom for 30 min before color measurements of lean (obliquus externus abdominis) and fat were obtained from the cut surface using the Minolta color spectrophotometer to obtain L*, a*, and b* values as previously described. The posterior portions of the bellies were vacuum-packaged using an Ultravac vacuum packager (Model 2000-B, Koch Supplies, Kansas City, MO) and held for 5 d at 1°C. Twelve cores 2.54 cm in diameter × 1.9 cm high (six cores each from the dorsal and ventral surfaces) were taken from the posterior portion of each belly and compressed to 75% of the sample height using the Instron with a 500-kg load cell and 200 mm/min crosshead speed. Peak force values were used to identify differences in belly firmness. A cross-sectional sample from the anterior cut surface of each posterior belly half was frozen using liquid N and analyzed to determine fatty acid composition as described for the longissimus muscle.

The anterior halves of the bellies were frozen and held at–23°C until further processing. After thawing (5°C for 36 h), bellies were cured, smoked, and sliced for shear-force determination, sensory evaluation, and fatty acid composition. The curing brine consisted of water (83.92%), salt (13.43%), sugar (2.33%), sodium nitrite (0.16%), and anti-cake agent (0.16%). Each belly was weighed and pumped to 5% of its green weight using a Formaco Reisaer (Model FGM 20/40, Food Machinery Co., A/S, Copenhagen, Denmark) multineedle injection pump. Additional curing brine (5% of the total belly green weight) was added to a tumbler (Food Processing Equipment Corp., Sante Fe Springs, CA) before all bellies were tumbled. The bellies were placed on bacon hangers and held at 2°C for 8 h. The cured bellies then were heat-processed for 8 h and smoked with natural hickory smoke in a Mauer smokehouse (H. Mauer Sohne K. G., Reichenau, West Germany). Skins were removed from the bellies after 2 h in the smokehouse. The cooking process ended when the product's internal temperature reached 51°C. The products were chilled at 6.6°C for 24 h and held at 1°C until sliced. Bellies were cut into 4-mm-thick bacon slices (Berkel 919/1, Berkel Inc., LaPorte, IN). Slice firmness and fat separation (hole) scores then were evaluated subjectively on a scale of 1 to 8, where 1 = very soft and oily or high degree of fat separation (extremely abundant number of holes) and 8 = very brittle and flaky or no fat separation (no holes present) for slicing firmness and fat separation score, respectively.

Bacon slices were cooked for 10 min (5 min on each side) in the Blodgett oven. The slices then were removed, sectioned into 2.54- × 2.54-cm pieces, and placed into warmers until they were served to panelists. The 12-member trained sensory panel evaluated bacon samples for brittleness, flavor intensity, saltiness, and aftertastes in the same sensory testing room previously described for the longissimus muscle evaluation.

Additional bacon strips were cooked following the same procedure outlined for the sensory evaluation. The slices were removed from the oven, blotted, cut into 2.54- × 2.54-cm pieces, allowed to equilibrate to room temperature (21°C), and then sheared using a Warner-Bratzler shear flat blade attachment. Peak force values were recorded to evaluate differences in bacon toughness.

Statistical Analyses

Data were analyzed in a randomized complete block design using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC). The two fat sources (CWG and PF) and three fat levels (2, 4, and 6% added fat) were analyzed as a 2 × 3 factorial plus a control (no added fat). When interactions occurred ($P < 0.05$), interaction means were separated using orthogonal contrasts to compare control (no added fat) pigs with pigs fed different fat sources and levels. Linear and quadratic effects (Peterson, 1985) of fat level (0, 2, 4, and 6%) within a source (CWG or PF) also were evaluated. Pen was the experimental unit for the growth performance data; however, individual pig was used as the experimental unit for all carcass and quality measurements. Hot carcass weight was used as a covariate for the analysis of carcass characteristics.

Results

Growth Performance

Neither energy source nor level affected ADG ($P > 0.05$; Table 3). Feeding 6% of either CWG or PF reduced ($P < 0.05$) ADFI. Adding 6% of either CWG or PF increased ($P < 0.05$) G/F, and increasing levels of CWG linearly ($P < 0.01$) improved G/F. Final BW did not differ ($P < 0.05$) among dietary treatments and ranged from 109.8 to 111.7 kg.

Carcass Characteristics

Increasing CWG or PF did not affect ($P > 0.05$) any of the measured carcass characteristics (Table 4), including dressing percentage, LM pH, carcass length, backfat thickness, LM area, or calculated percentages of lean.

Longissimus Muscle and Fat Quality

Choice white grease and PF did not affect ($P > 0.05$) visual or instrumental evaluations of the LM (Table 5). In addition, LM drip loss percentages at 24 and 48 h, water-binding capacity, shear-force values, and percentage cooking loss were not affected ($P > 0.05$) by dietary treatment.

Feeding CWG or PF (regardless of level) decreased ($P < 0.05$) the amount of saturated fat in the longissimus muscle, and increasing dietary fat linearly decreased ($P < 0.05$) the amount of saturated fat (Table 6). Specifically, increasing dietary fat reduced ($P < 0.05$) myristic (14:0) and palmitic (16:0) acids, and the decrease of 16:0 was linear ($P < 0.05$). Longissimus muscles from pigs fed CWG had greater ($P < 0.05$) levels of heptadecanoic

Table 3. Growth performance of gilts fed choice white grease or poultry fat[a]

Item	Control	Choice white grease, %			Poultry fat, %			SEM
		2	4	6	2	4	6	
Initial BW, kg	60.9	60.4	59.2	59.7	60.1	60.8	61.0	0.60
ADG, kg	0.92	0.96	0.98	0.94	0.93	0.93	0.94	0.01
ADFI, kg[b]	3.13	3.22	3.14	2.91	3.04	3.14	2.92	0.05
G/F[cd]	0.31	0.30	0.32	0.33	0.31	0.30	0.33	0.01
Final BW, kg	110.1	111.7	111.2	109.9	109.8	110.2	111.1	1.30

[a]Values are means of 84 pigs with six replicate pens per treatment and two pigs per pen.
[b]Effect of fat level ($P < 0.05$); control, 2% fat, and 4% fat > 6% fat.
[c]Effect of fat level ($P < 0.05$); 6% fat > control, 2% fat, and 4% fat.
[d]Linear effect of choice white grease ($P < 0.01$).

(17:1) and oleic (18:1) acids than those from pigs fed PF. Longissimus muscles from pigs fed the control diet had less ($P < 0.05$) linoleic acid (18:2) than those from pigs fed 4 or 6% fat. Additionally, increasing fat level linearly increased ($P < 0.05$) the amount of 18:2. A fat type × fat level interaction ($P < 0.05$) was observed for eicosanoic acid (20:1). Longissimus muscles from pigs fed the control diet and 4% CWG had greater 20:1 than those from pigs fed 2% CWG, 4% PF, or 6% PF. As PF increased, levels of 20:1 linearly decreased ($P < 0.05$). Other fatty acids, including palmitoleic (16:1), stearic (18:0), linolenic (18:3), arachic (20:0), eicosadienoic (20:2), and eicosatrienoic (20:3) acids, were not affected ($P > 0.05$) by dietary treatment.

Sensory evaluations of myofibrillar tenderness, connective tissue amount, overall tenderness, juiciness, flavor intensity, and off-flavor intensity were similar ($P > 0.05$) for LM from pigs fed the control diet or 6% of either CWG or PF (Table 7).

Adding CWG or PF had no effect ($P > 0.05$) on instrumental color or texture profile values of S.C. fat over the LM (Table 8). However, the fat from pigs fed CWG had more ($P < 0.05$) moisture than that from pigs fed PF.

Belly and Bacon Quality

Neither source nor level of added dietary fat affected ($P > 0.05$) instrumental color evaluations of the belly lean or fat (Table 9). Belly firmness, whether measured by flexure test or Instron, also was not affected ($P > 0.05$) by dietary treatment.

A fat type × fat level interaction ($P < 0.05$) was observed for bacon fat separation (hole) scores (Table 10). Bacon from pigs fed 2% CWG had lower (more fat separation and greater number of holes) scores than bacon from pigs fed 2% PF. Dietary treatment did not affect ($P > 0.05$) bacon slicing indices or peak force values. In addition, sensory evaluations of the bacon for brittleness, flavor intensity, saltiness, off-flavor, and aftertaste were similar ($P > 0.05$) among dietary treatments.

Bacon from pigs fed the control diet or diets containing 2% fat had more saturated and less unsaturated fat ($P < 0.05$) than that from pigs fed diets containing

Table 4. Carcass characteristics of gilts fed choice white grease or poultry fat[a,b]

Item	Control	Choice white grease, %			Poultry fat, %			SEM
		2	4	6	2	4	6	
Hot carcass weight, kg	84.3	83.8	84.0	83.6	83.3	83.8	83.0	0.50
Dressing percentage	76.6	75.0	75.5	76.1	75.9	76.0	74.7	0.80
Leaf fat, kg	1.31	1.43	1.46	1.30	1.38	1.55	1.49	0.11
pH at 45 min[c]	6.3	6.4	6.5	6.3	6.4	6.3	6.3	0.09
pH at 24 h[c]	5.8	5.8	5.9	5.9	5.8	5.8	5.8	0.04
Backfat, cm								
First rib	3.91	3.73	3.84	3.73	3.89	3.84	3.84	0.04
10th rib	1.98	1.93	2.06	1.96	2.03	1.96	1.96	0.04
Last rib	2.39	2.29	2.34	2.34	2.29	2.26	2.41	0.04
Last lumbar	1.96	1.78	2.03	1.91	1.98	1.93	2.06	0.04
Average[d]	2.75	2.60	2.73	2.66	2.72	2.68	2.77	0.03
Carcass length, cm	81.0	81.3	81.0	80.7	80.3	82.5	80.4	0.22
LMA, cm^2	33.6	35.2	33.0	34.0	33.4	31.2	34.2	0.55
Percentage lean[e]	54.7	54.5	53.6	54.7	53.7	54.1	54.1	0.86

[a]Values are means of 84 pigs with 12 pigs per treatment.
[b]No differences, $P > 0.05$.
[c]Longissimus muscle pH taken near the 10th rib.
[d]Average backfat calculated as the average of first rib, last rib, and last lumbar fat.
[e]Percentage lean was calculated from NPPC (1991) equations for percentage lean with 5% fat.

Table 5. Quality characteristics of longissimus muscles from gilts fed choice white grease or poultry fat[a,b]

		Choice white grease, %			Poultry fat, %			
Item	Control	2	4	6	2	4	6	SEM
Visual evaluation								
Color[c]	2.51	2.53	2.69	2.36	2.47	2.49	2.42	0.12
Firmness/wetness[c]	2.88	2.79	3.04	2.82	2.67	2.83	2.63	0.14
Marbling[c]	2.64	2.38	2.60	2.36	2.39	2.60	2.14	0.20
Lean color								
L*	51.4	50.9	49.4	52.1	54.0	50.5	52.3	1.20
a*	11.4	12.2	11.0	11.2	11.0	11.8	13.1	0.66
b*	7.9	8.2	7.2	7.9	7.9	7.9	9.1	0.55
Hue angle	48.5	46.8	44.8	50.2	51.3	44.8	48.6	2.50
Saturation index	13.9	14.7	13.2	13.7	14.4	14.2	15.9	0.80
a*/b*	1.47	1.51	1.60	1.43	1.47	1.54	1.45	0.06
Drip loss, %[d]								
24 h	2.21	3.36	2.24	2.73	2.94	2.29	3.73	0.55
48 h	3.85	5.19	3.81	4.39	4.58	3.51	4.98	0.72
Water-binding capacity, %[e]	37.23	36.3	39.19	36.91	35.79	38.97	36.92	1.50
Cooking loss, %	13.49	13.12	12.15	14.31	13.03	19.10	12.32	4.20
Warner-Bratzler shear, kg	4.11	4.18	4.05	4.18	4.00	4.97	4.18	0.42

[a]Values are means of 84 pigs with 12 pigs per treatment.
[b]No differences, $P > 0.05$.
[c]Scored on a scale of 1 to 5 (NPPC, 1991), where 1 = pale pinkish gray, very soft and watery, and practically devoid and 5 = dark purplish red, very firm and dry, and moderately abundant for color, firmness/wetness, and marbling, respectively.
[d]Expressed as a percentage loss of the original sample weight.
[e]Filter paper press percentage is derived by dividing the area of the meat by the area of the fluid after compression with a Carver Press.

4 or 6% fat (Table 11). Specifically, bacon from pigs fed the control diet had more ($P < 0.05$) 16:0 than that from pigs fed diets containing added fat, and bacon from pigs fed 2% fat had more ($P < 0.05$) 16:0 than that from pigs fed 4 or 6% added fat. In addition, increasing dietary fat linearly decreased ($P < 0.05$) 16:0 levels in the bacon. Bacon from pigs fed CWG contained more ($P < 0.05$) 17:1 and 20:1 than that from pigs fed PF. Bacon from

Table 6. Fatty acid composition of longissimus muscle from gilts fed choice white grease or poultry fat[a]

		Choice white grease, %			Poultry fat, %			
Fatty acid (% of total)	Control	2	4	6	2	4	6	SEM
14:0[b]	1.51	1.36	1.47	1.38	1.43	1.48	1.38	0.03
16:0[bc]	24.86	23.78	24.26	23.97	24.43	24.45	23.64	0.24
16:1	4.38	4.40	4.26	4.24	4.17	4.37	4.23	0.12
17:0	0.13	0.10	0.13	0.11	0.10	0.11	0.10	0.01
17:1[d]	0.16	0.16	0.18	0.20	0.15	0.14	0.14	0.01
18:0	11.24	10.69	10.96	10.53	11.34	11.28	10.48	0.30
18:1[d]	48.57	49.61	48.49	49.38	48.48	47.53	47.78	0.45
18:2[ce]	7.03	7.86	8.06	8.06	7.82	8.58	9.92	0.44
18:3	0.18	0.19	0.19	0.20	0.21	0.21	0.23	0.02
20:0	0.10	0.12	0.10	0.10	0.11	0.12	0.12	0.01
20:1[fg]	0.77[h]	0.68[i]	0.77[h]	0.72[hi]	0.71[hi]	0.65[i]	0.63[i]	0.03
20:2	0.38	0.36	0.48	0.38	0.33	0.41	0.38	0.03
20:3	0.41	0.39	0.38	0.44	0.44	0.37	0.45	0.04
Saturated fat, %[bc]	38.3	37.4	37.2	36.4	37.7	36.7	35.6	0.50
Unsaturated fat, %	61.7	62.6	62.8	63.6	62.3	63.3	64.4	0.50

[a]Values are means of 84 pigs with 12 pigs per treatment.
[b]Effect of fat level ($P < 0.05$); control > 2, 4, and 6% fat.
[c]Linear effect ($P < 0.05$) of fat.
[d]Effect of fat type ($P < 0.05$); choice white grease > poultry fat.
[e]Effect of fat level ($P < 0.05$); control < 4 and 6% fat.
[f]Treatment × fat level interaction ($P < 0.05$).
[g]Linear effect ($P < 0.05$) of PF.
[h,i]Within a row, means lacking a common superscript differ ($P < 0.05$).

Table 7. Sensory characteristics of longissimus muscles from gilts fed choice white grease or poultry fat[a,b]

		Fat source, 6%		
Item	Control	Choice white grease	Poultry fat	SEM
Myofibrilar tenderness[c]	6.0	6.1	6.1	0.25
Connective tissue amount[d]	6.9	6.9	7.0	0.14
Overall tenderness[c]	6.1	6.3	6.3	0.23
Juiciness[e]	5.4	5.5	5.4	0.11
Flavor intensity[f]	5.7	5.7	5.7	0.05
Off flavor intensity[g]	7.5	7.4	7.4	0.06

[a]Values are means of 36 pigs with 12 pigs per treatment.
[b]No differences, $P > 0.05$.
[c]Scored on a scale of 1 to 8, where 1 = extremely tough and 8 = extremely tender.
[d]Scored on a scale of 1 to 8, where 1 = abundant and 8 = none.
[e]Scored on a scale of 1 to 8, where 1 = extremely dry and 8 = extremely juicy.
[f]Scored on a scale of 1 to 8, where 1 = extremely bland and 8 = extremely intense.
[g]Scored on a scale of 1 to 8, where 1 = extremely intense and 8 = none.

pigs fed the control diet or diets containing 2% added fat contained less ($P < 0.05$) 20:3 than that from pigs fed diets containing 4 or 6% added fat. Dietary treatment did not affect ($P > 0.05$) the bacon profiles for other fatty acids, including 14:0, 16:1, 18:0, 18:2, and 18.3

Discussion

The reduction in ADFI and improvement in G/F from adding dietary fat is in general agreement with other studies (Southern et al., 1989; Azain et al., 1991; Williams et al., 1994; Smith et al., 1999). However, these responses contrast with results of Seerley et al. (1978), who observed no growth responses to PF fed at 2.5 and 5.0% of diet. Similar to our results, Woodworth et al. (1999) reported that 6% PF reduced ADFI and increased G/F. Soumi et al. (1993) and Leskanich et al. (1997) concluded that ADG increased in response to feeding diets containing a greater amount of unsaturated fat compared to more saturated fat. However, in the present studies, pigs fed CWG (minimum 61.6% unsaturated fatty acids) or PF (minimum 70.0% unsaturated fatty acids) had similar ADG.

In agreement with Seerley et al. (1978), feeding PF had no effect on carcass leanness. However, most research has indicated that carcass leanness decreases with the addition of dietary fat (Pettigrew and Moser, 1991). Woodworth et al. (1999) reported that pigs fed 6% PF had increased backfat compared to pigs fed a control diet, and De La Llata et al. (1999) also reported that pigs fed 6% CWG had decreased carcass leanness when CWG was fed throughout the growing-finishing period.

Few studies have evaluated further meat quality issues related to feeding high levels of dietary fat to growing-finishing pigs. No differences were observed in the present study for quality characteristics or sensory attributes of LM. However, Miller et al. (1990) concluded that increasing dietary canola oil lowered marbling scores, increased softness and coarseness, and negatively influenced flavor ratings of the LM. Seerley et al. (1978) fed PF and found that the fat was softer and more oily, but sensory attributes were not affected. Similarly, Woodworth et al. (1999) reported softer loins for pigs fed 6% PF. In agreement with the present study, Leskanich et al. (1997) found that changes in dietary

Table 8. Characteristics of subcutaneous fat from gilts fed choice white grease or poultry fat[a]

		Choice white grease, %			Poultry fat, %			
Item	Control	2	4	6	2	4	6	SEM
Loin fat color[b]								
L*	77.8	77.7	77.3	77.2	75.1	77.5	76.5	0.98
a*	5.2	5.0	5.0	4.9	5.5	4.7	4.8	0.37
b*	5.9	5.9	5.9	5.8	5.5	5.9	5.9	0.23
Saturation index	7.9	7.7	7.7	7.6	7.3	7.6	7.6	0.29
Backfat compression, kg[c]	107	110	100	92	107	94	101	7.49
Moisture, %[d]	12.42	13.24	12.72	13.04	9.82	10.76	11.29	0.97

[a]Values are means of 84 pigs with 12 pigs per treatment.
[b]Means derived from two readings of fat surrounding the longissimus muscle at the 10th rib.
[c]Six cores (1.27 × 2.54 cm in diameter) were compressed to 75%.
[d]Effect of fat type ($P < 0.05$); choice white grease > poultry fat.

Table 9. Quality characteristics of bellies from gilts fed choice white grease or poultry fat[a]

Item	Control	Choice white grease, % 2	4	6	Poultry fat, % 2	4	6	SEM
Belly lean color[b]								
L*	48.2	47.8	47.6	47.0	46.5	46.9	47.8	7.90
a*	22.3	19.6	20.7	20.1	19.8	19.9	21.3	0.68
b*	9.6	8.2	8.1	8.7	8.4	7.8	8.7	0.44
Hue angle	26.2	25.6	23.9	26.4	25.6	23.8	24.8	1.00
Saturation index	24.3	21.3	22.2	21.9	21.6	21.4	23.0	0.76
a*/b*	2.4	2.5	2.6	2.4	2.5	2.7	2.5	0.11
Belly fat color								
L*	79.5	79.9	79.6	80.2	79.5	79.5	79.9	0.59
a*	5.5	5.4	4.8	5.1	4.7	5.4	4.9	0.35
b*	6.2	6.2	5.8	6.1	5.9	6.5	6.1	0.22
Saturation index	8.4	8.3	7.6	8.0	7.6	8.5	7.9	0.34
a*/b*	0.88	0.87	0.83	0.84	0.78	0.83	0.80	0.05
Belly firmness, cm[c]								
Initial	23.4	22.1	25.9	19.3	23.4	22.9	18.0	3.05
10 min	18.3	17.5	20.8	15.2	17.3	17.8	13.2	2.49
Belly core compression, kg[d]								
Ventral belly	109	96	109	104	119	110	105	6.20
Dorsal belly	73.1	79.1	81.8	81.3	80.1	69.8	67.3	5.90

[a]Values are means of 84 pigs with 12 pigs per treatment (no differences, $P > 0.05$).
[b]Obliquus externus abdominis muscle.
[c]Bellies were placed longitudinally over a metal bar, and the distance between the rib end and ham end was measured initially and after 10 min of suspension.
[d]Six 2.54-cm-diameter cores were removed 2.54 cm from the dorsal or ventral belly edges. The skin was removed, and the cores were standardized to 2.54 cm depths from the outer surface. Cores then were compressed to 75%.

fat affect the fatty acid composition of pork carcasses without adversely affecting flavor. Additionally, Irie and Sakimoto (1992) found that dietary fat source did not affect fat or meat color. Miller et al. (1990) reported that shear force values of LM were not affected by added dietary fat, but Rhee et al. (1990) observed improved tenderness when pigs were fed unsaturated fats.

Shipp et al. (1993) determined that feeding 10% dietary PF had no influence on total monounsaturated fatty acids in intramuscular fat. Results of the present

Table 10. Characteristics of bacon from gilts fed choice white grease or poultry fat[a]

Item	Control	Choice white grease, % 2	4	6	Poultry fat, % 2	4	6	SEM
Bacon slice firmness score[b]	3.92	3.33	3.21	3.29	3.64	3.46	3.13	0.27
Bacon fat separation score[cd]	3.25[ef]	2.83[e]	3.42[ef]	3.08[ef]	3.44[f]	2.92[ef]	3.29[ef]	0.22
Bacon slice peak force, kg	5.86	5.49	5.47	5.76	5.83	5.90	5.99	0.47
Sensory evaluation[g]								
Brittleness[h]	5.3	5.5	5.3	5.3	5.4	5.4	5.2	0.16
Flavor intensity[i]	5.6	5.4	5.3	5.3	5.3	5.4	5.4	0.08
Saltiness[j]	5.1	5.0	4.8	4.9	4.8	5.0	4.8	0.09
Off-flavor[k]	1.3	1.3	1.2	1.3	1.4	1.3	1.4	0.06
Aftertaste[k]	4.0	3.8	3.9	3.7	3.8	4.2	3.9	0.15

[a]Values are means of 84 pigs with 12 pigs per treatment.
[b]Scored on a scale of 1 to 8, where 1 = very soft and oily and 8 = very brittle and flaky.
[c]Scored on a scale of 1 to 8, where 1 = high degree of fat separation (extremely abundant number of holes and 8 = no separation (no holes present).
[d]Fat type × fat level interaction ($P < 0.05$).
[e,f]Within a row, means lacking a common superscript differ ($P < 0.05$).
[g]Means of two 2.54-cm-long samples from each of 12 trained panelists.
[h]Scored on a scale of 1 to 8, where 1 = extremely soft and 8 = extremely crisp.
[i]Scored on a scale of 1 to 8, where 1 = extremely bland and 8 = extremely intense.
[j]Scored on a scale of 1 to 8, where 1 = extremely unsalty and 8 = extremely salty.
[k]Scored on a scale of 1 to 8, where 1 = extremely intense and 8 = none.

Table 11. Fatty acid composition of bellies from gilts fed choice white grease or poultry fat[a]

		Choice white grease, %			Poultry fat, %			
Fatty acid (% of total)	Control	2	4	6	2	4	6	SEM
14:0	1.42	1.32	1.35	1.29	1.37	1.38	1.30	0.03
16:0[bc]	24.63	23.76	23.23	22.78	23.96	23.42	23.32	0.31
16:1	3.55	3.65	3.52	3.65	3.66	3.97	3.87	0.10
17:0	0.21	0.16	0.19	0.17	0.17	0.15	0.15	0.01
17:1[d]	0.20	0.18	0.24	0.23	0.18	0.18	0.18	0.02
18:0	11.49	11.02	10.48	10.08	11.02	13.28	10.58	1.18
18:1	44.71	45.88	45.83	46.68	45.66	42.82	45.65	1.10
18:2	11.57	11.79	12.80	12.79	11.83	11.77	12.74	0.50
18:3	0.42	0.39	0.44	0.42	0.38	0.43	0.41	0.02
20:0	0.17	0.13	0.12	0.12	0.13	0.20	0.13	0.02
20:1[d]	0.65	0.67	0.71	0.70	0.65	0.60	0.63	0.03
20:2	0.45	0.52	0.48	0.48	0.46	0.43	0.48	0.03
20:3[e]	0.24	0.25	0.34	0.32	0.24	0.27	0.28	0.02
Saturated fat, %[f]	37.88	36.69	35.66	34.73	39.43	35.70	36.00	1.11
Unsaturated fat, %[e]	61.79	63.29	64.34	65.27	60.57	64.28	63.98	1.10

[a]Values are means of 84 pigs with 12 pigs per treatment.
[b]Effect of fat level ($P < 0.05$); control > 2, 4, and 6% fat; 2% > 6% fat.
[c]Linear effect ($P < 0.05$) of fat.
[d]Effect of fat type ($P < 0.05$); choice white grease > poultry fat.
[e]Effect of fat level ($P < 0.05$); control and 2% fat < 4 and 6% fat.
[f]Effect of fat level ($P < 0.05$); control and 2% fat > 4 and 6% fat.

study generally supported this concept, but PF seemed to cause a negative correlation between 16:0 and 18:2. Brooks (1971) also reported this negative correlation when soybean oil was added to swine diets. Shipp et al. (1993) observed a decrease in 18:0 when PF was fed; however, this was not observed in the present study.

St. John et al. (1987) and Miller et al. (1993) observed softer and oilier fat on carcasses when increased levels of unsaturated fats were added to swine diets. These responses were attributed to the lower melting points of the unsaturated fats relative to those of saturated fats. Additionally, Myer et al. (1985) reported darker carcass fat when pigs were fed diets containing peanuts. These alterations in fat color, softness, and oiliness were not observed from feeding 6% CWG or PF in the present study. The explanation for increased moisture content of fat from feeding CWG compared to PF is not known at this time.

Feeding unsaturated fats such as CWG and PF can cause decreases in fat firmness, resulting in bellies that are unacceptable for bacon production (Miller et al., 1993). Unsaturated fats are generally softer and more susceptible to rancidity than saturated fats (Moerck and Ball, 1973). Softer fat and increased rancidity are detrimental in bacon, because the slices have a larger surface area of fat exposed to oxygen. Recently, Rogers and Etzler (2000) found that bellies from swine fed diets containing catfish oil were inferior and more susceptible to rancidity compared to bellies from pigs fed other fat sources. St. John et al. (1987) reported that feeding high levels of canola oil rendered pork bellies unacceptable for bacon production; however, Ziprin et al. (1990) found that adding unsaturated fats to swine diets did not adversely affect belly quality. A previous report noted that color was negatively affected (less white fat) by fat sources (Shackelford et al., 1990). Belly color and firmness were not affected by CWG or PF in the present study. Similarly, Skelley et al. (1975) reported no differences in belly firmness as a result of adding dietary fat.

Miller et al. (1990) reported that canola oil decreased slicing yields, because the bacon tended to fall apart upon pressing and slicing. This problem was not observed in the present study, as indicated by bacon slice firmness and fat separation scores. However, our laboratory environment was less severe than the tempering, pressing, and high-speed slicing found in commercial operations.

Shackelford et al. (1990) reported no differences in bacon tenderness from pigs fed added dietary fat. They concluded that variations in meatiness and width of slice after cooking had a greater effect on tenderness than dietary treatment. Mazhar et al. (1990) concluded that panelists could detect off-flavors and lower quality in bacon from pigs fed added fat. Shackelford et al. (1990) suggested that off-flavors were attributable to high dietary 18:3 content. No differences were observed in the present study for bacon tenderness or sensory evaluations, and dietary and bacon 18:3 values were similar.

Reports of fatty acid profiles for bacon are limited. Mazhar et al. (1990) concluded that canola oil increased linolenic acid levels in bacon samples, and these have been linked to bacon off-flavors (Shackelford et al., 1990). The alterations in the bacon fatty acid profiles in the present study are consistent with those observed for the longissimus muscle; CWG and PF increased the degree of unsaturation and decreased the degree of saturation.

Choice white grease and PF can be incorporated effectively into swine diets without detriment to quality of the LM, belly, or bacon. One explanation for the different responses observed with dietary inclusion of PF may be related to the dietary level and variability in starting materials. For example, the PF diets evaluated herein and by Shipp et al. (1993) and Seerley et al. (1978) all seemed to vary considerably in concentrations of select fatty acids. Unless a uniform poultry fat product can be supplied continually, variable responses in growth performance, carcass characteristics, and meat and belly quality from its supplementation to swine diets may occur.

Implications

These data indicate that dietary fat (choice white grease or poultry fat) added as 6% of the diet improves feed efficiency throughout the growing-finishing phases of growth. Although fatty acid profiles of the longissimus muscle and belly (bacon) were altered by additions of these fats, quality characteristics of both did not seem to be affected. Additionally, bacon characteristics were not influenced by 6% additions of either fat. Therefore, if it is economical, up to 6% of choice white grease or poultry fat can be added to swine diets as an energy source with minimal influence on carcass composition or quality components of the longissimus muscle, belly, or bacon.

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