Interactive effects of dietary fat source and slaughter weight in growing-finishing swine: II. Fatty acid composition of subcutaneous fat


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ABSTRACT: Crossbred pigs (n = 288) were used to test the interactive effects of dietary fat source and slaughter weight on the fatty acid composition of subcutaneous fat. Pigs were blocked by initial BW (28.1 kg), and, within blocks, pens (8 pigs/pen) were randomly assigned to either grower and finisher diets devoid of added fat (Ctrl) or diets formulated with 5% beef tallow (BT), poultry fat (PF), or soybean oil (SBO). Immediately after treatment allotment, as well as at mean block BW of 45.5, 68.1, 90.9, and 113.6 kg, 1 pig was randomly selected from each pen, slaughtered, and, within 1 h postmortem, samples of backfat were removed from each carcass between the 4th and 8th thoracic vertebra and separated into the inner, middle, and outer layers for fatty acid composition analysis. During the first 17.4 kg of BW gain, percentages of all SFA increased by more than 4% in subcutaneous fat of pigs fed the Ctrl and BT diets, but decreased by 4.4 and 7.7% in pigs fed the PF and SBO diets, respectively (fat source × slaughter weight, \( P < 0.001 \)). Proportions of all MUFA in subcutaneous fat from BT-fed pigs increased by 6.1% during the first 17.4 kg of BW gain, but MUFA percentages in SBO-fed pigs decreased by 9.1% between 28.1 and 45.5 kg (fat source × slaughter weight, \( P < 0.001 \)). Conversely, percentages of all PUFA from SBO-fed pigs increased by 39.9%, whereas PUFA concentrations in BT-fed pigs decreased by 12.6% as slaughter weight increased from 28.1 to 45.5 kg (fat source × slaughter weight, \( P < 0.001 \)). Resultant iodine values (IV) of subcutaneous fat from SBO-fed pigs increased (\( P < 0.05 \)) from 73.5 to 85.2 within the first 17.4 kg of BW gain, and remained elevated above those of their contemporaries fed the Ctrl, BT, or PF diets at each subsequent slaughter weight (fat source × slaughter weight, \( P < 0.001 \)). The inner backfat layer had the greatest (\( P < 0.05 \)) proportions of all SFA and the least (\( P < 0.05 \)) proportions of all PUFA, whereas the outer layer had the least (\( P < 0.05 \)) percentages of all SFA but the greatest (\( P < 0.05 \)) percentages of all MUFA. Even though the middle and outer subcutaneous fat layers had similar (\( P > 0.05 \)) PUFA percentages, the greatest (\( P < 0.05 \)) and least (\( P < 0.05 \)) IV were in the outer and middle layers, respectively. As expected, the fat source included in swine diets was responsible for the fatty acid compositional changes in subcutaneous fat, yet the results of this study indicate that feeding 5% SBO dramatically increased the polyunsaturation of subcutaneous fat within the first 17.4 kg of BW gain, with backfat IV exceeding 80 thereafter.

Key words: dietary fat source, fatty acid composition, pig, slaughter weight, subcutaneous fat

INTRODUCTION

It is generally accepted that the fatty acid composition of pork subcutaneous fat is largely a reflection of the fatty acid composition of swine diets; however, only a small number of studies have used biopsy or serial slaughter to measure changes in fatty acid composition during the grower and finisher phases (Irie and Sakimoto, 1992; Fontanillas et al., 1998; Pascual et al., 2006). Evidence suggests that 50 to 60% of the change in fatty acid composition of porcine adipose tissue associated with manipulating dietary fat concentration, fat source, or both occurs during the first 14 to 35 d on the par-
ticular diet, and diminishes with a longer time on feed (Koch et al., 1968; Wood et al., 1994; Wiseman and Agunbiade, 1998). Irie and Sakimoto (1992) observed dramatic increases in PUFA concentrations in porcine subcutaneous fat biopsies after only 14 d of consuming a diet formulated with sardine oil, whereas Warnants et al. (1999) noted that more than 60% of the change in MUFA and PUFA concentrations in pork backfat occurred within 28 d of replacing full-fat soybeans with beef tallow. It is plausible that the rate at which fatty acid composition of pork adipose changes may be related to the saturation of the dietary fat source, the dietary inclusion amount of a particular fat source, or both. The subcutaneous fat of pigs has 3 individual layers, with the outer layer developing the earliest and consistently having a greater proportion of unsaturated fatty acids than the other 2 layers (Koch et al., 1968; McDonald and Hamilton, 1976; Malmfors et al., 1978). Conversely, depths of the middle (Moody and Zobrisky, 1966; Fortin, 1986; Leymaster and Mersmann, 1991) and inner (Newcom et al., 2005) backfat layers increase at a faster rate than the outer layer, and the middle subcutaneous layer has greater lipogenic activity (Anderson et al., 1972b; Camara et al., 1996; Warnants et al., 1999), resulting in greater deposition of SFA (Chris- tie et al., 1972; Villegas et al., 1973; Whittington et al., 1986) and smaller iodine values (IV; Irie and Sakimoto, 1992) than the outer subcutaneous layer. However, previous research has not reported any interactive effect of dietary fat or oil and time on feed on fatty acid compositional changes; therefore, the objective of this experiment was to test the interactive effects, if any, of dietary fat sources incorporated into diets at 5% and slaughter weight on the fatty acid composition of the growing-finishing pigs.

**MATERIALS AND METHODS**

Before beginning this research trial, animal care and experimental protocols were approved by the University of Arkansas Interdepartmental Animal Care and Use Committee.

**Animals and Diets**

Crossbred barrows and gilts (n = 288) from the mating of EB boars to line 348 dams (Monsanto Choice Genetics, St. Louis, MO), with an average initial BW of 28.1 kg, were blocked by BW into 9 blocks of 32 pigs/block. Pigs within blocks were allotted randomly to pens (8 pigs/pen) and stratified across sex and litter origin. Within each block, pens were randomly assigned to 1 of 4 dietary treatments, including control (Ctrl), corn-soybean meal grower and finisher diets with no added fat, or grower and finisher diets supplemented with 5% of either beef tallow (BT), poultry fat (PF), or soybean oil (SBO). Pigs were fed a 4-phase diet with transition from grower-I to grower-II, grower-II to finisher-I, and finisher-I to finisher-II when the mean BW of each block was 45.5, 68.1, and 90.9 kg, respectively. All diets were formulated to meet or exceed NRC (1998) AA, energy, and other nutrient requirements of growing-finishing swine [refer to Apple et al. (2009) for feedstuff, calculated nutrient, and fatty acid compositions of the grower and finisher diets]. Additionally, the calculated IV product (Madsen et al., 1992) ranged from 33.9 to 38.5, 57.1 to 61.8, 72.5 to 77.1, and 100.0 to 104.7 for the Ctrl, BT, PF, and SBO diets, respectively. Pigs were housed in a curtain-sided building with 1.5 × 3 m pens on totally slatted concrete floors. Each pen was equipped with a single-opening feeder and cup waterers, allowing pigs ad libitum access to feed and water.

**Pig Slaughter and Carcass Dissection**

Immediately after treatment allotment (and before penning), 1 pig from each pen was randomly selected for slaughter at the University of Arkansas Red Meat Research Abattoir for initial carcass composition. Additionally, 1 pig was chosen at random from each pen when block BW averaged 45.5, 68.1, 90.9, and 113.6 kg. Pigs were electrically stunned and slaughtered according to industry standards, weighed, and chilled for 48 h at 1°C. Within 1 h postmortem, a 5.0 × 5.0 cm section of backfat was removed from the left sides between the 4th and 8th thoracic vertebra, and subsequently separated into the inner, middle, and outer fat layers. Each layer was placed in Whirl-Pak bags identified with the identification number and backfat layer of the pig and immediately frozen at –20°C.

**Fatty Acid Sample Collection and Analysis**

Approximately 5 g of frozen subcutaneous fat from each backfat layer was weighed and placed in 30-mL beakers, and beakers were then placed into vacuum flasks attached to the manifold of a Labconco freeze-dryer (model 4.5, Labconco Corp., Kansas City, MO) with a temperature setting of –50°C and a vacuum of less than 10 mmHg. Dissected backfat layers were freeze-dried for 60 h before duplicate 30-ml freeze-dried samples were subjected to direct transesterification by incubating in 2.0 mL of 0.2 M methanolic potassium hydroxide in 16 × 125-mm screw-capped tubes at 50°C for 30 min with vortex mixing 2 to 3 times/min until tissues were dissolved (Murrieta et al., 2003). Tubes were allowed to cool to room temperature, and 1 mL of saturated sodium chloride was added to each tube. A 1-mL quantity of a hexane solution containing an internal standard [glyceryl tridecanoic acid (13:0)] was then added to each tube, and the hexane was evaporated before tubes were vortexed and subsequently centrifuged for 5 min at 1,100 × g and 20°C to separate phases. A portion of the hexane layer containing the fatty acid methyl esters was transferred to GLC vials that contained a 1.0-mm bed of anhydrous sodium sulfate.
Separation of fatty acid methyl esters was achieved by GLC (Model HP 5890 Series II GC, with an HP-7673 automatic injector and HP-3365 software; Hewlett-Packard, Avondale, PA) equipped with a 100-m capillary column (0.25-mm i.d.; Model 2560 fused-silica capillary column; Supelco Inc., Bellefonte, PA) and helium as the carrier gas at 0.5 mL/min (1:50 split ratio). Oven temperature was maintained at 175°C for 35 min, increased at 5°C/min to 215°C, and then increased at 10°C/min to 235°C, whereas injector and detector temperatures were maintained at 250°C. Identification of peaks was accomplished by using purified standards obtained from Nu-Chek Prep (Elysian, MN), Matreya (Pleasant Gap, PA), and Supelco.

The total proportion of SFA included palmitic (16:0) and stearic (18:0) acids, as well as the minor SFA [capric (10:0), lauric (12:0), myristic (14:0), pentadecanoic (15:0), margaric (17:0) and arachidic (20:0) acids], whereas the total proportion of MUFA was calculated by summing the weight percentages of palmitoleic acid (16:1c, where c = cis), oleic acid (18:1c9) and cis-vaccenic acid (18:1c11), as well as the minor MUFA [myristoleic (14:1), palmitelaidic (16:1t, where t = trans), 10-trans-heptadecenoic (17:1t), all 18:1 fatty acids, and gadoleic (20:1c11) acids]. Additionally, the total percentage of PUFA included linoleic acid (18:2n-6) and α-linolenic acid (18:3n-3), along with the minor PUFA [CLA (18:2c9t11), γ-linolenic (18:3n-6), eicosadienoic (20:2), dihomogamma-linolenic (20:3n-6), eicosatrienoic (20:3n-3), arachidonic (20:4n-6), docosapentaenoic (22:5n-3), and docosahexaenoic (22:6n-3) acids]. Iodine values were calculated according to the AOCS (1998) equation \(0.95 \times [\Sigma 16:1] + 0.86 \times [\Sigma 18:1] + (1.732 \times [\Sigma 18:2]) + (2.616 \times [\Sigma 18:3]) + (0.785 \times [20:1c11]),\) where the brackets in the equation indicate the concentration of the specific fatty acid.

**Statistical Analyses**

Data were analyzed as a randomized complete block design, with pen as the experimental unit and blocks based on initial pig BW. Analysis of variance was generated by using the mixed-model procedure (SAS Inst. Inc., Cary, NC). Fatty acid composition data were analyzed as repeated measures, with the initial models including backfat layer, dietary fat source, slaughter weight (repeated measure), and all 2- and 3-way interactions as fixed effects, and block included in the model as a random effect. However, because there were no \(P \geq 0.96\) 3-way interactions, fatty acid data were reanalyzed within backfat layers as repeated measures, with fat source, slaughter weight, and the fat source × slaughter weight interaction as the fixed effects included in the statistical model. Least squares means were computed for all 2-way interactive effects and were separated statistically by using the PDIFF option (SAS Inst. Inc.) when a significant \(P \leq 0.05\) F-test was detected.

**RESULTS**

**SFA**

During the first 17.4 kg of BW gain, percentages of all SFA increased in backfat from pigs fed the Ctrl and BT diets but decreased in backfat from pigs fed the PF and SBO diets (fat source × slaughter weight, \(P < 0.01\); Figure 1). Even though total SFA percentages increased as slaughter weight increased from 45.5 to 113.6 kg, subcutaneous fat from SBO-fed pigs had the least \((P < 0.05)\) proportions of all SFA when slaughtered at 45.5, 90.9 and 113.6 kg, whereas subcutaneous fat from pigs fed the Ctrl diets had the greatest \((P < 0.05)\) proportions of SFA at slaughter weights of 68.1 and 113.6 kg. Interestingly, backfat from BT-fed pigs had greater \((P < 0.05)\) percentages of SFA than that from PF- and SBO-fed pigs when slaughtered at 45.5, 68.1, 90.9, and 113.6 kg.

Even though the proportions of palmitic acid (16:0) did not \((P > 0.05)\) differ between 28.1 and 45.5 kg in subcutaneous fat from pigs fed the Ctrl, BT and PF diets, the proportion of 16:0 decreased \((P < 0.05)\) by 1.7 percentage units in SBO-fed pigs during the first 17.4 kg of BW gain (fat source × slaughter weight, \(P < 0.01\); Figure 2A). When slaughtered at BW between 45.5 and 113.6 kg, subcutaneous fat from Ctrl-fed pigs had the greatest \((P < 0.05)\) and subcutaneous fat from SBO-fed pigs had the least \((P < 0.05)\), percentages of 16:0, whereas 16:0 concentrations in backfat were similar \((P > 0.05)\) between pigs fed the BT and PF diets and slaughtered at 45.5, 90.9, and 113.6 kg.

Approximately 68.8, 77.4, 32.4, and 95.5% of the total increase \((P < 0.05)\) in stearic acid (18:0) in pigs fed the Ctrl, BT, PF, and SBO diets occurred between 28.1 and 68.1 kg, respectively, whereas percentages of 18:0 were greater \((P < 0.05)\) in subcutaneous fat from pigs fed the Ctrl and BT diets than in PF- and SBO-fed pigs slaughtered at 45.5, 68.1, and 90.9 kg (fat source × slaughter weight, \(P < 0.01\); Figure 2B). Additionally, when pigs were slaughtered at 113.6 kg, the proportion of 18:0 was greatest \((P < 0.05)\) in Ctrl-fed pigs and least \((P < 0.05)\) in SBO-fed pigs, with subcutaneous fat from BT- and PF-fed pigs having similar \((P > 0.05)\) percentages of 18:0.

**SFA Differences Among Backfat Layers**

In general, the inner backfat layer had the greatest \((P < 0.05)\) proportions of all SFA as well as 16:0 and 18:0, whereas the outer backfat layer had the least \((P < 0.05)\) percentages of 16:0, 18:0, and all SFA (Table 1). Additionally, interactive effects \((P < 0.05)\) of fat source and slaughter weight on percentages of all SFA, 16:0, and 18:0 were observed in the inner \((P \leq 0.051)\), middle \((P \leq 0.028)\), and outer \((P \leq 0.015)\) backfat layers (Table 2).

Between 28.1 and 45.5 kg, total SFA and 18:0 increased \((P < 0.05)\) in the inner backfat layer of Ctrl-fed
pigs, but only 18:0 was increased \((P < 0.05)\) in the inner layer of BT-fed pigs during the first 17.4 kg of BW gain (Table 2). However, approximately 29.1 to 79.8% of the increase \((P < 0.05)\) in all SFA as well as 41.8 to 89.1% of the increase \((P < 0.05)\) in 18:0 occurred between 28.1 and 68.1 kg in pigs fed diets formulated without fat (Ctrl) or with BT and PF. Furthermore, in comparison with the other dietary treatments, Ctrl-fed pigs had the greatest \((P < 0.05)\) proportions of 16:0 when slaughtered at 45.5, 68.1, 90.9, and 113.6 kg, whereas concentrations of all SFA and 18:0 were greatest \((P < 0.05)\) in pigs fed the Ctrl diets when slaughtered at 68.1 and 90.9 kg. Percentages of all SFA and 16:0 in SBO-fed pigs were 9.1 to 16.9%, 7.4 to 12.6%, and 13.2 to 24.8% less \((P < 0.05)\) than Ctrl-, BT-, or PF-fed pigs, respectively.

Approximately 60.0, 75.1, and 50.8% of the increases \((P < 0.05)\) in the proportions of all SFA, 16:0, and 18:0 in the outer backfat layer of Ctrl-fed pigs, respectively, occurred between 28.1 and 45.5 kg (Table 2). When compared with the other dietary treatments, pigs fed the Ctrl diets had greater \((P < 0.05)\) proportions of all SFA at 68.1 and 113.6 kg, 16:0 at 68.1 and 90.9 kg, and 18:0 at only 113.6 kg. Even though concentrations of 16:0 did not \((P > 0.05)\) differ between BT- and PF-fed pigs, regardless of slaughter weight, the middle layer from pigs fed the BT diets had greater \((P < 0.05)\) proportions of all SFA and 18:0 than the middle layer from pigs fed the PF or SBO diets when slaughtered at 68.1 and 90.9 kg. Furthermore, when pigs were slaughtered at 113.6 kg, percentages of all SFA, 16:0, and 18:0 in SBO-fed pigs were 9.1 to 16.9%, 7.4 to 12.6%, and 13.2 to 24.8% less \((P < 0.05)\) than Ctrl-, BT-, or PF-fed pigs, respectively.

Within the middle backfat layer, percentages of all SFA and 16:0 in SBO-fed pigs decreased \((P < 0.05)\) by approximately 7.6 and 8.6%, respectively, whereas percentages of 18:0 increased \((P < 0.05)\) by approximately 13.6 and 12.8% in the middle layer of Ctrl- and BT-fed pigs, respectively, as slaughter weight increased from 28.1 to 45.5 kg (Table 2). When compared with the other dietary treatments, pigs fed the Ctrl diets had greater \((P < 0.05)\) proportions of all SFA at 68.1 and 113.6 kg, 16:0 at 68.1 and 90.9 kg, and 18:0 at only 113.6 kg. Even though concentrations of 16:0 did not \((P > 0.05)\) differ between BT- and PF-fed pigs, regardless of slaughter weight, the middle layer from pigs fed the BT diets had greater \((P < 0.05)\) proportions of all SFA and 18:0 than the middle layer from pigs fed the PF or SBO diets when slaughtered at 68.1 and 90.9 kg. Furthermore, when pigs were slaughtered at 113.6 kg, percentages of all SFA, 16:0, and 18:0 in SBO-fed pigs were 9.1 to 16.9%, 7.4 to 12.6%, and 13.2 to 24.8% less \((P < 0.05)\) than Ctrl-, BT-, or PF-fed pigs, respectively.

Approximately 60.0, 75.1, and 50.8% of the increases \((P < 0.05)\) in the proportions of all SFA, 16:0, and 18:0 in the outer backfat layer of Ctrl-fed pigs, respectively, occurred between 28.1 and 45.5 kg (Table 2). Conversely, percentages of all SFA and 16:0 in SBO-fed pigs were reduced \((P < 0.05)\) by 10.1 and 9.8%, respectively, during the first 17.4 kg of BW gain, whereas percentages of all SFA and 16:0 were 5.8 and 5.2% less \((P < 0.05)\) in PF-fed pigs between 28.1 and 45.5 kg, respectively. Pigs fed the Ctrl diets had greater \((P < 0.05)\) proportions of 16:0 than pigs from all other dietary treatments when slaughtered at 68.1, 90.9, and 113.6 kg, but proportions of all SFA and 18:0 were greater \((P < 0.05)\) in Ctrl- and BT-fed pigs than in PF- and SBO-fed pigs when slaughtered at 68.1 and 90.9 kg. Additionally,
PF-fed pigs had greater ($P < 0.05$) percentages of all SFA at 45.5, 90.9, and 113.6 kg, and greater ($P < 0.05$) percentages of 16:0 at each slaughter weight between 45.5 and 113.6 kg; however, the percentage of 18:0 was greater ($P < 0.05$) only in the outer backfat layer of pigs fed the PF diets compared with pigs fed the SBO diets when slaughtered at 113.6 kg.

**MUFA**

The proportions of all MUFA in subcutaneous fat from BT-fed pigs increased ($P < 0.05$) by 6.1% during the first 17.4 kg of BW gain, with an additional 3.0% increase between 68.1 and 90.9 kg, yet MUFA percentages in SBO-fed pigs decreased ($P < 0.05$) by 9.1% be-

Figure 2. Interactive effect of dietary fat source (Ctrl = control diets with no added fat; BT = 5% beef tallow; PF = 5% poultry fat; and SBO = 5% soybean oil) and slaughter weight ($P < 0.001$) on percentages of A) palmitic (16:0) and B) stearic (18:0) acids in subcutaneous fat. a–iLeast squares means lacking common letters differ, $P < 0.05$. 

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Between 28.1 and 45.5 kg, by 3.8% between 45.5 and 68.1 kg, and by 4.4% between 68.1 and 90.9 kg (fat source × slaughter weight, P < 0.001; Figure 3). As expected, subcutaneous fat from pigs fed BT diets therefore had the greatest (P < 0.05) percentages of all MUFA when slaughtered at 45.5, 90.9, and 113.6 kg, whereas subcutaneous fat from pigs fed the SBO diets had the least (P < 0.05) MUFA percentages at every slaughter weight between 45.5 and 113.6 kg. Moreover, percentages of all MUFA were greater (P < 0.05) in PF- than Ctrl-fed pigs when slaughtered at 68.1 and 113.6 kg.

Almost 65.3, 61.2, and 41.6% of the increase (P < 0.05) in oleic acid (18:1\text{c}) occurred during the first 17.4 kg of BW gain in subcutaneous fat from pigs fed the Ctrl, BT, and PF diets, respectively, whereas 91.2 and 87.8% of the increase (P < 0.05) in 18:1\text{c} was observed between 28.1 and 68.1 kg in subcutaneous fat from pigs fed the BT and PF diets, respectively (fat source × slaughter weight, P < 0.001; Figure 4A). Moreover, subcutaneous fat from BT-fed pigs had greater (P < 0.05) proportions of 18:1\text{c} than subcutaneous fat from Ctrl- and PF-fed pigs slaughtered at 45.5, 90.9, and 113.6 kg, and although subcutaneous fat from PF-fed pigs had greater (P < 0.05) proportions of 18:1\text{c} than Ctrl-fed pigs at 45.5 kg, concentrations of 18:1\text{c} did not (P > 0.05) differ between PF- and Ctrl-fed pigs when slaughtered at heavier BW. Interestingly, when compared with the other dietary treatments, percentages of 18:1\text{c} were least (P < 0.05) in SBO-fed pigs at 45.5, 68.1, 90.9, and 113.6 kg.

The proportions of cis-vaccenic acid (18:1\text{c}11) decreased (P < 0.05) by 9.8 and 13.8% between 28.1 and 45.5 kg in BT- and SBO-fed pigs, respectively, whereas between 28.1 and 68.1 kg, percentages of 18:1\text{c}11 decreased (P < 0.05) in Ctrl-fed pigs but increased (P < 0.05) by 16.0% in PF-fed pigs (fat source × slaughter weight, P < 0.001; Figure 2B). When slaughtered at 45.5 kg, subcutaneous fat from PF- and Ctrl-fed pigs had greater (P < 0.05) proportions of 18:1\text{c}11 than subcutaneous fat from BT-fed pigs; however, subcutaneous fat from pigs fed PF had the greatest (P < 0.05) proportions of 18:1\text{c}11 at 68.1, 90.9, and 113.6 kg, and subcutaneous fat from pigs fed SBO had the least (P < 0.05) proportions of 18:1\text{c}11 from 45.5 to 113.6 kg. In addition, even though 18:1\text{c}11 concentrations were similar (P > 0.05) in subcutaneous fat from Ctrl- and BT-fed pigs slaughtered at 68.1 kg, Ctrl-fed pigs had greater (P < 0.05) proportions of 18:1\text{c}11 than BT-fed pigs slaughtered at 90.9, but had smaller (P < 0.05) proportions when slaughtered at 113.6 kg.

### MUFA Differences Among Backfat Layers

Percentages of all MUFA, 18:1\text{c}9, and 18:1\text{c}11 were greatest (P < 0.05) in the outer backfat layer, whereas the inner layer had greater (P < 0.05) proportions of all MUFA, 18:1\text{c}9, and 18:1\text{c}11 than the middle layer (Table 1). Moreover, dietary fat source × slaughter weight interactions (P < 0.001) were noted for the MUFA within the inner, middle, and outer backfat layers (Table 3). Between 28.1 and 45.5 kg, more than 96 and 73% of the total increases (P < 0.05) in all MUFA and 18:1\text{c}9, respectively, as well as 54.8% of the total decrease (P < 0.05) in 18:1\text{c}11, were observed in the inner backfat layer of BT-fed pigs, yet 76.1 and 60.8% of the total decreases (P < 0.05) in concentrations of all MUFA and 18:1\text{c}11 in the inner layer of SBO-fed pigs also occurred.

### Table 1. Comparison of fatty acid composition (reported as weight percentages) among the individual backfat layers

<table>
<thead>
<tr>
<th>Fatty acid, %</th>
<th>Inner</th>
<th>Middle</th>
<th>Outer</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>All SFA\textsuperscript{1}</td>
<td>34.29\textsuperscript{a}</td>
<td>33.49\textsuperscript{a}</td>
<td>30.60\textsuperscript{a}</td>
<td>0.213</td>
</tr>
<tr>
<td>Palmitic acid (16:0)</td>
<td>21.19\textsuperscript{a}</td>
<td>20.81\textsuperscript{a}</td>
<td>20.12\textsuperscript{a}</td>
<td>0.155</td>
</tr>
<tr>
<td>Stearic acid (18:0)</td>
<td>11.14\textsuperscript{a}</td>
<td>10.71\textsuperscript{a}</td>
<td>8.46\textsuperscript{a}</td>
<td>0.109</td>
</tr>
<tr>
<td>All MUFAs\textsuperscript{2}</td>
<td>43.06\textsuperscript{a}</td>
<td>42.35\textsuperscript{a}</td>
<td>44.41\textsuperscript{a}</td>
<td>0.240</td>
</tr>
<tr>
<td>Oleic acid (18:1\text{c})</td>
<td>36.33\textsuperscript{a}</td>
<td>35.68\textsuperscript{a}</td>
<td>36.86\textsuperscript{a}</td>
<td>0.176</td>
</tr>
<tr>
<td>cis-vaccenic acid (18:1\text{c}11)</td>
<td>2.44\textsuperscript{a}</td>
<td>2.34\textsuperscript{a}</td>
<td>2.64\textsuperscript{a}</td>
<td>0.024</td>
</tr>
<tr>
<td>All PUFAs\textsuperscript{3}</td>
<td>20.35\textsuperscript{a}</td>
<td>21.77\textsuperscript{a}</td>
<td>22.33\textsuperscript{a}</td>
<td>0.333</td>
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<tr>
<td>Linoleic acid (18:2\text{c}6-2)</td>
<td>17.86\textsuperscript{a}</td>
<td>19.17\textsuperscript{a}</td>
<td>19.54\textsuperscript{a}</td>
<td>0.287</td>
</tr>
<tr>
<td>Linolenic acid (18:3\text{c}n-3)</td>
<td>1.02\textsuperscript{a}</td>
<td>1.09\textsuperscript{a}</td>
<td>1.14\textsuperscript{a}</td>
<td>0.037</td>
</tr>
<tr>
<td>Iodine value\textsuperscript{4}</td>
<td>71.2\textsuperscript{x}</td>
<td>73.1\textsuperscript{z}</td>
<td>75.8\textsuperscript{x}</td>
<td>0.45</td>
</tr>
</tbody>
</table>

\textsuperscript{1}Within a row, least squares means lacking common superscript letters differ, P < 0.05.
\textsuperscript{2}Includes the weight percentages of capric (10:0), lauric (12:0), myristic (14:0), pentaenoic (15:0), margaric (17:0), and arachidic (20:0) acids, as well as 16:0 and 18:0.
\textsuperscript{3}Includes the weight percentages of palmitoleic (16:1\text{c}), palmitoleic (16:1\text{t}), oleic (18:1\text{c}), cis-9, trans-11, and trans-11, cis-9 oleic acids, and gadoleic (20:1\text{c}11) acids, as well as 18:1\text{c}9 and 18:1\text{c}11 (where cis and trans are defined as cis and trans, respectively).
\textsuperscript{4}Iodine value = (0.95 × [Σ 16:1]) + (0.86 × [Σ 18:1]) + (1.732 × [Σ 18:2]) + (2.616 × [Σ 18:3]) + (0.785 × [Σ 20:1]).

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Table 2. Interactive effects of dietary fat source\(^1\) and slaughter weight on the SFA composition (reported as weight percentages) of the individual backfat layers

<table>
<thead>
<tr>
<th>Slaughter wt, kg</th>
<th>Inner backfat layer</th>
<th>Middle backfat layer</th>
<th>Outer backfat layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ctrl</td>
<td>BT</td>
<td>PF</td>
<td>SBO</td>
</tr>
<tr>
<td>Ctrl</td>
<td>BT</td>
<td>PF</td>
<td>SBO</td>
</tr>
<tr>
<td>Ctrl</td>
<td>BT</td>
<td>PF</td>
<td>SBO</td>
</tr>
</tbody>
</table>

- **All SFA**
  - **16:0**
    - P = 0.002 and SEM = 0.662\(^2\)
    - P = 0.003 and SEM = 0.753\(^2\)
    - P = 0.001 and SEM = 0.594\(^2\)
  - **18:0**
    - P = 0.051 and SEM = 0.362\(^2\)
    - P = 0.028 and SEM = 0.405\(^2\)
    - P = 0.015 and SEM = 0.339\(^2\)

Within a specific fatty acid and backfat layer, least squares means lacking common superscript letters differ, \(P < 0.05\).

\(^1\)Ctrl = control diets with no added fat; BT = 5% beef tallow; PF = 5% poultry fat; and SBO = 5% soybean oil.

\(^2\)The probability value and SEM for the specific dietary fat source × slaughter weight interaction.

\(^3\)Palmitic acid.

\(^4\)Stearic acid.
during the first 17.4 kg of BW gain (Table 3). Moreover, the inner layer of pigs fed SBO diets had the least \((P < 0.05)\) proportions of all MUFA, 18:1\(c_9\), and 18:1\(c_{11}\), regardless of slaughter weight, and, even though total MUFA and 18:1\(c_9\) percentages were greater \((P < 0.05)\) in the inner layer of BT-fed compared with Ctrl- and PF-fed pigs at 45.5 kg, neither total MUFA at 68.1 and 90.9 kg nor 18:1\(c_9\) at 68.1 kg nor 18:1\(c_{11}\) at 68.1 kg differed \((P > 0.05)\) among pigs fed the Ctrl, BT, and PF diets. When pigs were slaughtered at 113.6 kg, concentrations of all MUFA in those fed the Ctrl diets were less \((P < 0.05)\) than in either BT- or PF-fed pigs, whereas the inner layer of BT-fed pigs had greater \((P < 0.05)\) proportions of 18:1\(c_9\) than the inner layer of either Ctrl- or SBO-fed pigs. Conversely, the proportions of 18:1\(c_{11}\) in the inner backfat layer from PF-fed pigs were greater than the inner backfat layer from BT-fed pigs at 45.5 kg \((P < 0.05)\) and were greater than the inner backfat layer from both Ctrl- and BT-fed pigs at 68.1, 90.9, and 113.6 kg \((P < 0.05)\); however, Ctrl-fed pigs had more \((P < 0.05)\) 18:1\(c_{11}\) than BT-fed pigs when slaughtered at 90.9 and 113.6 kg.

The middle backfat layer from SBO-fed pigs had the least \((P < 0.05)\) proportions of all MUFA, 18:1\(c_1\), and 18:1\(c_{11}\), and percentages of all MUFA and 18:1\(c_{11}\) decreased \((P < 0.05)\) by 8.7 and 12.9\% between 28.1 and 45.5 kg, respectively, in SBO-fed pigs (Table 3). Proportions of total MUFA and 18:1\(c_9\) were greater \((P < 0.05)\) in the middle layer from BT-fed pigs than in the middle layer from Ctrl- and PF-fed pigs at 45.5 and 113.6 kg, and although concentrations of 18:1\(c_9\) were not \((P > 0.05)\) different among pigs fed the Ctrl, BT, and PF diets at 68.1 kg, total MUFA percentages were greater \((P < 0.05)\) in BT- and PF-fed pigs than in Ctrl-fed pigs slaughtered at 68.1 kg. Furthermore, when slaughtered at 90.9 kg, percentages of all MUFA were greater \((P < 0.05)\) in BT-fed pigs than in Ctrl-fed pigs, whereas greater \((P < 0.05)\) percentages of 18:1\(c_9\) were observed in BT-fed pigs compared with Ctrl- and PF-fed pigs. On the other hand, the middle backfat layer from pigs consuming the Ctrl or BT diets at each slaughter weight between 45.5 and 113.6 kg.

In accordance with the observations from the middle backfat layer, proportions of all MUFA, 18:1\(c_9\), and 18:1\(c_{11}\) were the least in the outer layer of pigs consuming the SBO diets, and percentages of all MUFA and 18:1\(c_{11}\) decreased \((P < 0.05)\) by 7.7 and 11.2\%, respectively, between 28.1 and 45.5 kg, with additional decreases \((P < 0.05)\) of 8.8 and 15.6\%, respectively, between 45.5 and 90.9 kg (Table 3). In addition, even though concentrations of 18:1\(c_9\) in the outer layer of SBO-fed pigs were reduced \((P < 0.05)\) by only 4.9\% between 28.1 and 90.9 kg, percentages of total MUFA, 18:1\(c_9\), and 18:1\(c_{11}\) actually increased \((P < 0.05)\) by 7.6, 7.4, and 11.0\%, respectively, during the last 22.7 kg of BW gain. When pigs were slaughtered at 45.5 kg, the outer layer of PF-fed pigs had less \((P < 0.05)\) total MUFA and 18:1\(c_9\) than the outer layer of BT-fed

Figure 3. Interactive effect of dietary fat source (Ctrl = control diets with no added fat; BT = 5% beef tallow; PF = 5% poultry fat; and SBO = 5% soybean oil) and slaughter weight \((P < 0.001)\) on percentages of all MUFA in subcutaneous fat. a–kLeast squares means lacking common letters differ, \(P < 0.05\).
pigs, whereas the proportion of 18:1c11 in the outer layer of BT-fed pigs was considerably less ($P < 0.05$) than in either Ctrl- or PF-fed pigs. Moreover, percentages of all MUFA and 18:1c9 did not ($P > 0.05$) differ among pigs consuming the Ctrl, BT, and PF diets at 68.1 kg, but proportions of all MUFA were less ($P < 0.05$) in Ctrl-fed pigs than in BT-fed pigs slaughtered at 90.9 kg and were less than in BT- and PF-fed pigs at 113.6 kg. Concentrations of 18:1c9 were greater ($P < 0.05$) in the outer layer of pigs consuming the BT diets than in those consuming the Ctrl and PF diets at 90.9 and 113.6 kg; however, the outer layer of PF-fed pigs had greater ($P < 0.05$) proportions of 18:1c11 than the outer layer of pigs fed the Ctrl or BT diets at 68.1, 90.9, and 113.6 kg. Pigs fed the Ctrl diets had greater ($P < 0.05$) percentages of 18:1c11 than did BT-fed pigs.

Figure 4. Interactive effect of dietary fat source (Ctrl = control diets with no added fat; BT = 5% beef tallow; PF = 5% poultry fat; and SBO = 5% soybean oil) and slaughter weight ($P < 0.001$) on percentages of A) oleic (18:1c9) and B) cis-vaccenic (18:1c11) acids in subcutaneous fat. Least squares means lacking common letters differ, $P < 0.05$. 

A

B

Oleic acid (18:1c9), %

Vaccenic acid (18:1c11), %

Slaughter wt, kg

Slaughter wt, kg
Table 3. Interactive effects of dietary fat source\(^1\) and slaughter weight on the MUFA composition (reported as weight percentages) of the individual backfat layers

<table>
<thead>
<tr>
<th>Slaughter wt, kg</th>
<th>Inner backfat layer</th>
<th></th>
<th>Middle backfat layer</th>
<th></th>
<th>Outer backfat layer</th>
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<tbody>
<tr>
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<td>PF</td>
<td>SBO</td>
<td>Ctrl</td>
<td>BT</td>
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<td></td>
</tr>
<tr>
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<td>42.88(^{de})</td>
<td>43.42(^{cde})</td>
<td>42.32(^{d})</td>
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<td>42.97(^{cde})</td>
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<tr>
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<td>46.06(^{b})</td>
<td>44.75(^{bcd})</td>
<td>36.95(^{d})</td>
<td>43.13(^{d})</td>
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<td>113.6</td>
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<td>46.34(^{a})</td>
<td>45.32(^{bc})</td>
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<td>2.35(^{g})</td>
<td>3.01(^{a})</td>
<td>1.92(^{bc})</td>
<td>2.25(^{f})</td>
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<td>2.22(^{f})</td>
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<td>113.6</td>
<td>2.05(^{ef})</td>
<td>2.29(^{g})</td>
<td>2.76(^{bc})</td>
<td>1.88(^{bc})</td>
<td>1.93(^{e})</td>
<td>2.29(^{e})</td>
</tr>
</tbody>
</table>

\(^a\)Within a specific fatty acid and backfat layer, least squares means lacking common superscript letters differ, \(P < 0.05\).

\(^1\)Ctrl = control diets with no added fat; BT = 5% beef tallow; PF = 5% poultry fat; and SBO = 5% soybean oil.

\(^2\)The probability value and SEM for the specific dietary fat source × slaughter weight interaction.

\(^3\)Oleic acid.

\(^4\)\(\text{Cis-vaccenic acid.}\)
slaughtered at 68.1 but had smaller \((P < 0.05)\) percentages than BT-fed pigs slaughtered at 113.6 kg.

**PUFA**

Although percentages of all PUFA in the subcutaneous fat from SBO-fed pigs increased \((P < 0.05)\) by 39.9% between 28.1 and 45.5 kg and by 5.8% between 68.1 and 90.9 kg, total PUFA percentages in subcutaneous fat from BT-fed pigs decreased \((P < 0.05)\) by 12.6 and 14.6% as slaughter weight increased from 28.1 to 45.5 kg and 68.1 to 90.9 kg, respectively (fat source \(\times\) slaughter weight, \(P < 0.001\); Figure 5). More importantly, regardless of slaughter weight, the proportions of all PUFA were greatest \((P < 0.05)\) in pigs fed the SBO diets and were least \((P < 0.05)\) in pigs fed the BT diets. After an initial 10.5% increase \((P < 0.05)\) in PUFA percentages in PF-fed pigs, the proportions of all PUFA decreased \((P < 0.05)\) by 13.7% between 45.5 and 68.1 kg, and 90.9 kg, respectively (fat source \(\times\) slaughter weight, \(P < 0.001\); Figure 5). On the other hand, proportions of 18:2n-6 in BT-fed pigs decreased \((P < 0.05)\) by 12.2% between 28.1 and 45.5 kg, with another reduction \((P < 0.05)\) of 14.1% between 68.1 and 90.9 kg, and subcutaneous fat from BT-fed pigs possessed the smallest \((P < 0.05)\) proportions of 18:2n-6 when slaughtered at 45.5, 90.9, and 113.6 kg. Moreover, the subcutaneous fat from pigs consuming the PF diets had greater \((P < 0.05)\) concentrations of 18:2n-6 than the subcutaneous fat from pigs fed the Ctrl diets when slaughtered at 45.5, 68.1, and 90.9 kg.

Percentages of linolenic acid (18:3n-3) were elevated \((P < 0.05)\) by 115.2% during the first 17.4 kg of BW gain in subcutaneous fat from SBO-fed pigs, with subsequent increases \((P < 0.05)\) of 9.4 and 9.9% when pigs were slaughtered at 68.1 and 90.9 kg, respectively (fat source \(\times\) slaughter weight, \(P < 0.001\); Figure 6B). More importantly, the subcutaneous fat from SBO-fed pigs had considerably greater \((P < 0.05)\) proportions of 18:3n-3 than the subcutaneous fat from pigs fed the other dietary treatments, and, with the exception that 18:3n-3 concentrations were greater \((P < 0.05)\) in the subcutaneous fat from Ctrl-fed pigs compared with Ctrl- and BT-fed pigs at 45.5 kg, proportions of 18:3n-3 were similar \((P > 0.05)\) among pigs consuming the Ctrl, BT, and PF diets when slaughtered at 68.1, 90.9, and 113.6 kg.
Even though the middle and outer backfat layers had greater \( (P < 0.05) \) percentages of all PUFA and 18:2n-6 than the inner layer, the outer backfat layer had greater \( (P < 0.05) \) proportions of 18:3n-3 than the inner layer, with the middle layer possessing intermediate proportions of 18:3n-3 (Table 1). In addition, data analysis indicated interactive effects of dietary fat source and slaughter weight \( (P < 0.001) \) on the percentages of all PUFA, 18:2n-6, and 18:3n-3 within the inner, middle, and outer backfat layers (Table 4).

Proportions of all PUFA, especially 18:2n-6 and 18:3n-3, were robustly increased \( (P < 0.05) \) in the inner backfat layer from SBO-fed pigs between 28.1 and 45.5 kg, and percentages of the PUFA were greater \( (P \)
< 0.05) than in pigs fed all other dietary treatments between 45.5 and 113.6 kg (Table 4). Furthermore, despite reductions (P < 0.05) in the percentages of the PUFA in the inner layer from PF-fed pigs between 45.5 and 68.1 kg, proportions of all PUFA, 18:2n-6, and 18:3n-3 were greater (P < 0.05) in PF-fed pigs than in Ctrl- and BT-fed pigs when slaughtered at 45.5 to 113.6 kg. Even though percentages of PUFA did not (P > 0.05) differ between pigs fed the Ctrl and BT diets, 18:2n-6 from the inner fat layer declined (P < 0.05) by 17.5% between 45.5 and 68.1 kg in Ctrl-fed pigs and by more than 18.0 and 16.5% in BT-fed pigs at slaughter weights of 28.1 to 68.1 kg and 68.1 to 90.9 kg, respectively. Conversely, percentages of 18:3n-3 in the inner fat layer of Ctrl-fed pigs decreased (P < 0.05) by 37.5 to 43.2% as slaughter weights increased from 28.1 to 68.1 and 90.9 kg, respectively, whereas 18:3n-3 concentrations in the inner layer of BT-fed pigs were reduced (P < 0.05) by 40.4 and 44.9% as slaughter weights increased from 28.1 to 90.9 and 113.6 kg, respectively.

Percentages of all PUFA, 18:2n-6, and 18:3n-3 were increased (P < 0.05) by 39.2, 37.5, and 119.4%, respectively, during the first 17.4 kg of BW gain in the middle backfat layer from SBO-fed pigs, and proportions of PUFA were the greatest (P < 0.05) at slaughter weights heavier than 28.1 kg; however, across the last 22.7 kg of BW gain, the 9.1% reduction (P < 0.05) in concentrations of all PUFA within the middle layer of SBO-fed pigs was a reflection of the 13.7% decrease (P < 0.05) in 18:3n-3 percentages (Table 4). Similar to the inner fat layer results, percentages of all PUFA and 18:2n-6 were greater (P < 0.05) in the middle fat layer of PF-fed pigs compared with BT-fed pigs between 45.5 and 113.6 kg, but with the exception of pigs slaughtered at 45.5 kg, concentrations of 18:3n-3 in the middle layer did not (P > 0.05) differ among pigs fed the Ctrl, BT, and PF diets. In addition, concentrations of all PUFA and 18:2n-6 in the middle layer of Ctrl-fed pigs declined (P < 0.05) by 16.4 and 14.4%, respectively, as slaughter weight increased from 28.1 to 90.9 kg. Although percentages of 18:3n-3 were similar (P < 0.05) between Ctrl- and BT-fed pigs, the proportion of all PUFA in the middle fat layer from BT-fed pigs was 21.6% less (P < 0.05) than in Ctrl-fed pigs at 113.6 kg, whereas the proportions of 18:2n-6 in BT-fed pigs were 16.8 and 22.5% less (P < 0.05) than in Ctrl-fed pigs slaughtered at 90.9 and 113.6 kg, respectively.

In the outer backfat layer, 75.0, 74.7, and 68.5% of the total increase (P < 0.05) in the proportions of all PUFA, 18:2n-6, and 18:3n-3, respectively, occurred between 28.1 and 45.5 kg in pigs fed the SBO diets, and even though percentages of PUFA in the outer layer of SBO-fed pigs were greater (P < 0.05) than in the other dietary treatments, percentages of total PUFA, 18:2n-6, and 18:3n-3 declined (P < 0.05) by 9.5, 9.3, and 13.4%, respectively, during the last 22.7 kg of BW gain (Table 4). Percentages of all PUFA and, in particular, 18:2n-6 in the outer fat layer of PF-fed pigs were less (P < 0.05) at 113.6 than at 28.1 kg and were less (P < 0.05) at 68.1, 90.9, and 113.6 than at 45.5 kg, whereas the outer layer from BT-fed pigs had smaller (P < 0.05) percentages of total PUFA and 18:2n-6 at 68.1, 90.9, and 113.6 than at 28.1 kg, and again at 90.9 and 113.6 kg when compared with 45.5 kg. Moreover, concentrations of all PUFA and 18:2n-6 in the outer layer of Ctrl-fed pigs did not (P > 0.05) change with increasing slaughter weight, yet proportions of these PUFA were greater (P < 0.05) in PF- and Ctrl-fed pigs than in BT-fed pigs when slaughtered at 90.9 and 113.6 kg. Interestingly, percentages of 18:3n-3 were similar (P > 0.05) in the outer fat layer of pigs consuming the Ctrl, BT, and PF diets, regardless of slaughter weight, in spite of the reductions (P < 0.05) in 18:3n-3 between 28.1 and 90.9 to 113.6 kg in BT-fed pigs and between 45.5 and 90.9 to 113.6 kg in PF-fed pigs.

### IV

Across the first 17.4 kg of BW gain, IV in the subcutaneous fat from SBO-fed pigs increased (P < 0.05) from a mean IV of 73.5 at 28.1 kg to 85.2 at 45.5 kg, and subcutaneous fat IV of pigs fed SBO remained elevated (P < 0.05) in comparison with their contemporaries fed the Ctrl, BT or PF diets at each subsequent slaughter weight (fat source × slaughter weight, P < 0.001; Figure 7). Additionally, IV for the subcutaneous fat from Ctrl- and BT-fed pigs decreased (P < 0.05) between 28.1 and 113.6 kg, whereas after an initial increase (P < 0.05) in IV of subcutaneous fat from PF-fed pigs, IV decreased (P < 0.05) as slaughter weight increased from 45.5 to 113.6 kg (Table 5).

The greatest (P < 0.05) IV were noted in the outer backfat layer, whereas the least (P < 0.05) IV were observed in the inner backfat layer (Table 1), and there were fat source × slaughter weight interactions (P < 0.001) on IV in each backfat layer (Table 5). Iodine values increased (P < 0.05) by 15.5, 16.0, and 16.4% in the inner, middle, and outer fat layers of SBO-fed pigs, respectively, between 28.1 and 45.5 kg and remained relatively unchanged thereafter, yet the IV values of SBO-fed pigs were dramatically greater (P < 0.05) than the IV values of pigs fed other dietary treatments, independent of slaughter weight or backfat layer. Moreover, after increases (P < 0.05) of 5.0 (inner layer) to 6.8% (middle layer) in IV of PF-fed pigs during the first 17.4 kg of BW gain, IV of the inner, middle, and outer fat layers decreased (P < 0.05) by 11.0, 10.9, and 8.3%, respectively, with increasing slaughter weights between 45.5 and 113.6 kg. In addition, IV remained greater (P < 0.05) in pigs fed PF diets than in those fed BT diets, regardless of slaughter weight, and in pigs fed Ctrl diets between 45.5 and 90.9 kg. Even though IV of the inner, middle, and outer layers did not (P > 0.05) differ between Ctrl- and BT-fed pigs, IV were reduced (P < 0.05) in the inner and middle fat layers of Ctrl-fed pigs by 11.1 and 7.8%, respectively, and in the inner, mid-
Table 4. Interactive effects of dietary fat source\(^1\) and slaughter weight on the PUFA composition (reported as weight percentages) of the individual backfat layers

<table>
<thead>
<tr>
<th>Slaughter wt, kg</th>
<th>Ctrl</th>
<th>BT</th>
<th>PF</th>
<th>SBO</th>
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<td>(18:3\text{n-3})</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28.1</td>
<td>0.88(\text{d})</td>
<td>0.89(\text{d})</td>
<td>0.93(\text{c})</td>
<td>0.96(\text{c})</td>
</tr>
<tr>
<td>45.5</td>
<td>0.75(\text{d})</td>
<td>0.72(\text{d})</td>
<td>1.05(\text{b})</td>
<td>2.10(\text{a})</td>
</tr>
<tr>
<td>68.1</td>
<td>0.55(\text{d})</td>
<td>0.57(\text{d})</td>
<td>1.33(\text{a})</td>
<td>2.20(\text{a})</td>
</tr>
<tr>
<td>90.9</td>
<td>0.50(\text{d})</td>
<td>0.53(\text{d})</td>
<td>0.65(\text{d})</td>
<td>2.36(\text{d})</td>
</tr>
<tr>
<td>113.6</td>
<td>0.66(\text{d})</td>
<td>0.49(\text{d})</td>
<td>0.60(\text{d})</td>
<td>2.08(\text{d})</td>
</tr>
</tbody>
</table>

\(^1\)Within a specific fatty acid and backfat layer, least squares means lacking common superscript letters differ, \(P < 0.05\).

\(^2\)The probability value and SEM for the specific dietary fat source \(\times\) slaughter weight interaction.

\(^3\)Linoleic acid.

\(^4\)α-Linolenic acid.
dle, and outer fat layers of BT-fed pigs by 12.3, 11.2, and 7.5%, respectively, as slaughter weight increased from 45.5 to 113.6 kg.

DISCUSSION

The largest changes in the fatty acid composition of pork subcutaneous fat in response to dietary fat sources, inclusion amounts, or both occurred soon after introduction of the diet. Warnants et al. (1999) reported that more than 50% of the total increase in 18:2n-6 and all PUFA of pork subcutaneous fat was produced within the first 2 wk after replacing 2.5% BT with 15% full-fat soybeans; however, it took 60 d to increase the proportion of 18:0 by almost 60% in pork backfat when full-fat soybeans were replaced with 2.3% BT. Furthermore, approximately two-thirds of the total change in the PUFA composition of subcutaneous fat associated with the dietary inclusion of a polyunsaturated fat source occurred rapidly, between 14 d (Irie and Sakimoto, 1992; Wiseman and Agunbiade, 1998) and 17 d (Fontanillas et al., 1998). However, the rate at which the fatty acid composition of porcine adipose tissue was altered may be a response to the saturation of the dietary fat source, dietary inclusion amount of a particular fat source, or both. For example, more than 75% of the total changes in SFA of backfat from Ctrl- and BT-fed pigs occurred within the first 40 kg of BW gain, whereas less than 12% of the total change in SFA had occurred within the subcutaneous fat of pigs fed the PF and SBO diets. Likewise, slightly less than 25% of the total change in all MUFA occurred in backfat from PF-fed pigs during the first 17.4 kg of BW gain, whereas more than 55% of the total change in all MUFA occurred between 28.1 and 45.5 kg in pigs fed the Ctrl, BT and SBO diets in the present study. In addition, more than 66% of the total change in PUFA was observed in subcutaneous fat from PF- and SBO-fed pigs between 28.1 and 45.5 kg, but between 20 and 45% of the total change in PUFA was noted in backfat from pigs fed the Ctrl and BT diets and slaughtered at 45.5 kg.

Results of the present study also demonstrated that the IV of pork subcutaneous fat was increased by almost 12 points during the first 17.4 kg of BW in pigs fed the SBO diets, and, more importantly, that value decreased by only 2.6 points between 45.5 and 113.6 kg. It has been hypothesized that replacing high concentrations of a polyunsaturated fat source with BT or withdrawing any added fat would substantially reduce the IV of subcutaneous fat. However, across the entire trial, feeding BT reduced IV by only 7.5 points, whereas feeding a diet devoid of added fat reduced IV by only 5.2 points between 28.1 and 113.6 kg. It has been hypothesized that replacing high concentrations of a polyunsaturated fat source with BT or withdrawing any added fat would substantially reduce the IV of subcutaneous fat. However, across the entire trial, feeding BT reduced IV by only 7.5 points, whereas feeding a diet devoid of added fat reduced IV by only 5.2 points between 28.1 and 113.6 kg. Given these results, coupled with the knowledge that the half-life of 18:3n-3 in subcutaneous fat is approximately 300 d (Anderson et al., 1972a), it seems unlikely that removing all added fat or replacing fat with a saturated source during the last 30 d on feed or the last 25 kg of BW gain could reduce the IV of subcutaneous fat by more than 1 or 2 points.
In agreement with several published studies, the inner backfat layer was the most saturated, having the greatest proportions of all SFA, 16:0 and 18:0 (Sink et al., 1964; McDonald and Hamilton, 1976; Wiseman and Agunbiade, 1998), whereas the outer subcutaneous fat layer was the least saturated of the individual fat layers (Koch et al., 1968; Christie et al., 1972; Malmfors et al., 1978). In addition, the outer backfat layer had the greatest proportions of MUFA, whereas the middle layer contained the least amount of MUFA (Irie and Sakimoto, 1992). As expected, the proportion of 18:3n-3 was greater in the outer than inner backfat layers (Villegas et al., 1973; Wiseman and Agunbiade, 1998); however, the fatty acid composition of the inner subcutaneous fat layer was composed of less PUFA, particularly, 18:2n-6, than either the outer or middle backfat layers (Villegas et al., 1973; Wood et al., 1978; Whittington et al., 1986), which had similar compositions of PUFA. Moreover, Irie and Sakimoto (1992) reported that the IV of the the outer subcutaneous fat layer was greater than the IV of the inner layer (72.4 vs. 66.3), which concurs with the results of this study, in which the IV of the outer layer was greater than the IV of either the middle or inner subcutaneous fat layer (75.8 vs. 73.1 or 71.2).

Koch et al. (1968) noted a faster change in the fatty acid composition in the inner layer than in the outer layer, whereas Mersmann and Leymaster (1984) and Fortin (1986) observed that the depths of the inner and middle backfat layers increased at a faster rate than the outer layer, suggesting a more rapid rate of fatty acid deposition in the inner and middle layers. Moreover, Newcom et al. (2005) indicated that the middle and inner backfat layers grew at approximately the same rate, but Fortin (1986) reported that the middle layer deposited lipid at a faster rate than the inner backfat layer, which might explain the differences in the SFA and MUFA observed between these 2 layers in the present study. Furthermore, the inner and middle backfat layers have the greatest lipogenic activity when compared with the outer layer (Anderson et al., 1972b, Anderson and Kauffman, 1973; Warnants et al., 1999); thus, the more saturated composition of the inner and middle subcutaneous fat layers would be a response to enhanced de novo synthetic enzyme activity (Anderson et al., 1972b; Camara et al., 1996) associated with these backfat layers, whereas the more unsaturated composition of the outer backfat layer may be a response to preferential deposition of 18:1 and 18:2n-6 from the diet (Dahl and Persson, 1965; Koch et al., 1968; Brooks, 1971).

Feeding BT has been shown to reduced the proportions of 16:0 (Weber et al., 2006), 18:0 (McDonald and Hamilton, 1976), total SFA (McDonald and Hamilton, 1976), 18:1c9 (Brooks, 1971), 18:2n-6 (Brooks, 1971), and 18:3n-3 (McDonald and Hamilton, 1976) in porcine subcutaneous fat. Conversely, others have reported no effect of BT on proportions of SFA and 18:1c9 in the outer backfat layer (McDonald and Hamilton, 1976;
Weber et al., 2006), all MUFA in any backfat layer (Eggert et al., 1998b), 18:2n-6 in the inner and outer layers (McDonald and Hamilton, 1976; Weber et al., 2006), and all PUFA found in each backfat layer (Eggert et al., 1998b; Weber et al., 2006). Furthermore, even though percentages of 16:0 and all SFA were reduced in subcutaneous fat from pigs fed PF (Eggert et al., 1998a; Engel et al., 2001). Engel et al. (2001) failed to detect differences in 18:2n-6 or 18:3n-3 in subcutaneous fat from pigs consuming diets formulated without added fat or including 2 to 6% PF or choice white grease. On the other hand, Eggert et al. (1998a) observed increases of 38 to 46% in the percentage of all PUFA composing the outer and inner backfat layers, and, as expected, feeding swine diets formulated with SBO greatly increased the proportions of 18:2n-6 (74 to 148%) and 18:3n-3 (115 to 390%), as well as total PUFA (Brooks, 1971; Gläser et al., 2002), in backfat when compared with subcutaneous fat from pigs consuming diets free of added fat.

When comparing the effects of diets formulated with BT or SBO on fatty acid composition, subcutaneous fat from pigs fed BT had greater proportions of 16:0, 18:0, and all SFA (Monahan et al., 1992; Pfalzgraf et al., 1995), as well as 18:1c9 (Monahan et al., 1992; Pfalzgraf et al., 1995; Morel et al., 2006) and all MUFA (Morel et al., 2006). More specifically, the inner and outer backfat layers of pigs fed 5% BT were composed of greater percentages of 16:0, 18:0, 18:1c9, 18:1c11, and all MUFA than the inner and outer backfat layers of pigs fed 5% SBO (Morgan et al., 1992; Bee et al., 1999, 2002). Conversely, feeding pigs diets containing SBO elevated 18:2n-6 and 18:3n-3 percentages between 93 to 164% and 104 to 205% in the inner backfat layer, respectively, and between 143 to 200% and 139 to 187% in the outer layer, respectively, when compared with pigs fed BT (Morgan et al., 1992; Bee et al., 1999, 2002). Although Engel et al. (2001) found that the LM from pigs fed choice white grease had greater proportions of 18:1c9 than the LM of PF-fed pigs, fatty acid profiles of subcutaneous fat did not differ between pigs fed PF or choice white grease. Thus, results of the present study are the first to compare fatty acid compositions of the 3 individual backfat layers from PF-fed pigs to pigs consuming diets formulated without added fat or with SBO or BT.

When feeding swine finishing diets formulated with 0 to 8% of a tallow-soybean oil blend, Pascual et al. (2006) noted a continuous increase in the proportion of 18:0 during the 76 d of treatment, whereas Camoes et al. (1995) observed that the 18:2n-6 content of subcutaneous fat increased at a constant rate between 70 and 115 kg. Interestingly, 16:0 and 18:0 percentages appeared to increase steadily in pigs fed the Ctrl and BT diets between 28.1 and 113.6 kg, as well as in subcutaneous fat from PF- and SBO-fed pigs between 45.5 and 113.6 kg; however, PUFA concentrations in subcutaneous fat from SBO-fed pigs increased by more than 41% during the first 17.4 kg of BW gain before leveling off between 45.5 and 113.6 kg, whereas the percentages of 18:2n-6 and 18:3n-3 remained relatively unchanged between 45.5 and 113.6 kg. The pattern of observed changes in PUFA, as well as all MUFA and 18:1c9, are consistent with the exponential asymptotic responses to manipulation of PUFA and MUFA with SBO in pigs between 55 and 93 kg (Wiseman and Aguimbade, 1998) and canola oil or SBO in pigs between 26 and 95 kg (Fontanillas et al., 1998).

In summary, the fatty acid composition of the each backfat layer can be altered rather quickly depending on the polyunsaturation of the fat source incorporated into diets of growing-finishing swine. Although increasing the PUFA content of the porcine adipose tissue may provide nutritional benefits to consumers (Mattson and Grundy, 1985; Li et al., 1998; Wood et al., 2003), proportions of 18:2n-6 in each backfat layer of SBO-fed pigs exceeded 15%, the concentration of 18:2n-6 typically associated with soft pork fat (Whittington et al., 1986; Wood et al., 1986). Moreover, increased concentrations of polyunsaturation in porcine adipose tissue may negatively affect fresh pork shelf life (Pfalzgraf et al., 1995; Morel et al., 2006) and cooked pork palatability (Wood and Enser, 1997; Wiseman et al., 2000).

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