

ANIMAL SCIENCE

Title: Selection for increased intramuscular fat and its effect on other quality traits and the fatty acid composition of pork - **NPB #06-191**

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Industry Summary

Long-term selection for increased lean has come at the expense of meat quality traits, namely IMF percentage, objective loin color, and eating quality traits such as flavor and off-flavor. Results obtained in the current study suggest that the fatty acid composition of *longissimus dorsi* muscle IMF is correlated genetically with production and meat quality traits. It has been suggested that the fatty acid composition of intramuscular fat is greatly influenced by dietary feed content, and to a lesser extent, the effect of genetics (Cameron et al., 2000). Heritability estimates in the current study are moderate to high for the major fatty acids found in the intramuscular fat of the *longissimus dorsi* muscle. The greatest heritability estimates were found for lauric acid (C12:0), palmitoleic acid (C16:1n7), stearic acid (C18:0), linoleic acid (C18:2n6), and α -Linolenic acid (C18:3n3) which were 0.73, 0.40, 0.36, 0.33, and 0.26, respectively. Genetic correlations between IMF content and C16:0, C18:0, and C18:1 did not differ from zero. However, negative genetic correlations between IMF and C17:0, and between IMF and C18:2 were found (-0.61 and -0.80, respectively). Loin muscle area was positively correlated with C18:2 concentration (0.75) and tenth-rib backfat was negatively correlated (-0.62) with C18:2. Monounsaturated fat concentrations from IMF were negatively correlated with LMA (-0.70), but positively correlated with BF10 (0.77). No significant genetic correlations were found in the current study between sensory panel scores (flavor and off-flavor) and the respective fatty acids. The change in fatty acid composition of IMF is a correlated response to selection for increased quantity of IMF. Therefore, when selection for IMF is executed, we must understand the possible changes that may occur in fatty acid composition of the various adipose tissues. Understanding the response in fatty acid composition to selection for IMF is more important than directly selecting for individual fatty acids.

Scientific Abstract

Selection was practiced for seven generations and based on estimated breeding value for IMF from fitting a two-trait animal model and the full relationship matrix in MATVEC. A randomly mated, unselected control line (CL) was maintained in the population. The two traits emphasized were IMF estimated on the carcass and IMF predicted using real-time ultrasound on the live animal. Longissimus muscle samples (LM) (n=663, 357 in CL, 306 in SL) collected from pigs in generations 3 through 7 and adipose tissue samples from pigs in generations 6 and 7 were used to determine the fatty acid composition of IMF and adipose tissue. Total

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lipids were extracted from trimmed LM samples and tenth-rib subcutaneous adipose tissue and methylated directly with acetyl chloride and methanol. Triacylglycerols (TAG) were separated from phospholipids (PL) in IMF by thin-layer chromatography. All fatty acid methyl esters were quantified by using gas chromatography. Pigs in the SL had more backfat, less loin muscle area, and consequently, lower carcass lean percentage when compared with pigs in the CL. Control line pigs had more favorable objective color measures. Select line pigs had more flavor and less off-flavor, and were generally more desirable for sensory panel scores when compared with pigs from the control line. Additionally, SL pigs had more total SFA in adipose tissue and more MUFA in the intramuscular fat than pigs in the control line. Total PUFA was higher in CL pigs, regardless of fat depot. The greatest heritability estimates were found for lauric acid (C12:0), palmitoleic acid (C16:1n7), stearic acid (C18:0), linoleic acid (C18:2n6), and α -Linolenic acid (C18:3n3) which were 0.73, 0.40, 0.36, 0.33, and 0.26, respectively. Genetic correlations between IMF content and C16:0, C18:0, and C18:1 did not differ from zero. However, negative genetic correlations between IMF and C17:0, and between IMF and C18:2 were found (-0.61 and -0.80, respectively). Loin muscle area was positively correlated with C18:2 concentrations (0.75), and tenth-rib backfat was negatively correlated (-0.62) with C18:2. Monounsaturated fat concentrations from IMF were negatively correlated with LMA (-0.70), but positively correlated with BF10 (0.77). Intramuscular fat PUFA concentrations were negatively correlated with IMF and BF10, but positively correlated with LMA. No significant genetic correlations were found in the current study between eating quality traits (flavor score and off-flavor score) and the respective fatty acids. Results suggest that the fatty acid composition of fat depots in pigs is a correlated response to selection for quantity of IMF. When selection for IMF is executed, attention to the correlated response in fatty acid composition must be accounted for when looking at the overall meat and eating quality traits of pork. Understanding changes in fatty acid composition as a correlated response to selection for IMF is more important than direct selection for fatty acid composition.

Introduction

Total lipid content of pork skeletal muscle has been shown to have a role in sensory traits such as tenderness and juiciness of the cooked meat product. The role of IMF is of particular interest in pigs because selection for carcass lean percentage over the last decade has significantly decreased marbling fat to below 1% of muscle weight in pork (Wood et al., 2004a). Selection for increased lean content in pig carcasses has been associated with lower meat and fat quality (Scott et al., 1981a, b). Fatty acid composition of intramuscular and subcutaneous adipose tissue is not only an indicator of carcass fat quality, but it also can dramatically influence the eating quality of the meat. Improving meat quality, namely intramuscular fat (IMF), has been one the main objectives of producers, processors, retailers, and researchers. The increase in demand for superior quality pork from foreign markets has increased the pressure to produce a higher quality product in the United States. Japanese consumers primarily consume pork as fresh meat; so it is imperative to have high fat quality, and the quality of fat is determined by its fatty acid composition (Gatlin et al., 2002; Wood et al., 2004b). Large variation exists in the melting point of specific fatty acids; therefore, the composition directly affects the firmness or softness of subcutaneous adipose and IMF firmness and/or softness (Pitchford et al., 2002).

Traditionally, meat fatty acid composition research has concentrated on adipose tissue, the body's major lipid storage depot. However, more emphasis has recently been placed on muscle because of the greater impact on further processing of food products (Wood et al., 2008). In addition, fatty acids present in the fat depots of pigs with a genetic predisposition for obesity were more saturated than those from pigs selected for leaner backfat thickness (Scott et al., 1981b; Wood, 1984; Wood et al., 1978). Fat deposition in various depots, namely subcutaneous adipose tissue and skeletal muscle, is influenced by energy balance between intake and energy expenditure, as well as energy intake and energy mobilization (Nurnberg et al., 1998). Because IMF content seems to be highly heritable (Newcom et al., 2003; Suzuki et al., 2005) and the fatty acid composition of muscle lipid is moderate to highly heritable (Cameron and Enser, 1991; Suzuki et al., 2006), attention must be placed on the fatty acid composition of pork (IMF and subcutaneous adipose tissues) if selection for increased IMF is practiced.

Previous studies indicate that fatty acid composition of *longissimus dorsi* muscle is related to the overall eating quality of the pork, with polyunsaturated fatty acids having a negative impact on pork flavor while

saturated and monounsaturated acids are positively correlated with eating quality (Cameron and Enser, 1991). Pork flavor, flavor preference, and overall acceptability were positively correlated with the concentrations of monounsaturated fatty acids, C16:1 and C18:1 (Cameron et al., 2000). Phospholipids, which are the main structural component of all tissue membranes, are proportionally rich in PUFA, and are susceptible to oxidation and the formation of off-flavors (Warnants et al., 1996; Wood and Enser, 1997). Therefore, the objective of this study was to determine genetic parameters for fatty acid composition and meat and eating quality traits of the *longissimus dorsi* muscle and adipose tissue from Duroc pigs selected for increased IMF after seven generations.

Objectives

- Evaluate the relationships among fatty acid composition of pork and other important measures of pork quality.
- Evaluate the effect of percentage of intramuscular fat (IMF) on the fatty acid profile of pork.
- Estimate genetic and phenotypic correlations of IMF content with other measures of pork quality and determine if these correlations differ by percentage of IMF.

Materials and Methods

Population

Experimental protocols for this study were approved by the Iowa State University Institutional Animal Care and Use Committee. A selection project was initiated in 1998 through the purchase of 40 registered Duroc gilts from 10 Midwest Duroc breeders. By using semen from Duroc boars available in regional U.S. boar studs, two generations of random mating were conducted to expand the population and to produce the base generation of 56 litters. Littermate pairs of gilts from the base generation were designated randomly to either the control (CL) or select line (SL). Littermate pairs of females were mated to the same boar (via natural mating or AI) to establish sufficient genetic ties between lines before selection was initiated. At weaning, up to four boars in each SL litter (when available) were selected randomly to remain intact to maintain selection intensity. Selection was based on the estimated breeding value (EBV) for IMF by fitting a two-trait animal model (carcass intramuscular fat and ultrasonically predicted intramuscular fat) and the full relationship matrix in MATVEC (Wang et al., 2003). In the SL, the top 10 boars and top 50% of gilts were used to produce the next generation. One boar from each sire family and 50 gilts representing all sire families were randomly selected each generation to maintain the CL. In subsequent generations, up to four boars in each SL litter (when available) were selected randomly to remain intact to increase selection intensity.

Performance and Carcass Measurements

Finishing pigs were housed in fully slatted, mechanically ventilated, curtain-sided finishing buildings and were provided a minimum of 0.77 m² of floor space with 20 to 25 pigs per pen from 34 kg until they reached an average off test weight of 110 kg. A 17.5% CP, 1.15% lysine corn-soy diet was provided ad libitum from 34 to 68 kg, followed by a 16.0% CP, 0.85% lysine corn-soy diet from 68 to 91 kg, and a 15.0% CP, 0.70% lysine corn-soy diet from 91 kg until market weight. Dietary fatty acid analysis of the typical last diet fed in the finishing phase in all generations is presented in Table 1.

Upon completion of the performance test period, all available barrows and randomly selected gilts were harvested at a commercial abattoir (Hormel Foods, Austin, MN). Carcass measurements were obtained by Iowa State University personnel 24 h post-mortem. Standard carcass collection procedures as outlined in Pork Composition and Quality Assessment Procedures (NPPC, 2000) were followed to obtain measurements of 10th rib backfat (BF10) and loin muscle area (LMA). A section of bone-in *longissimus dorsi* containing the 10th to 12th ribs was excised from the carcass and transported to the Iowa State University Meat Laboratory. A 3.2 mm slice from the 10th rib face was removed and utilized for lipid content analysis. Carcass pH was measured 48 h post-mortem on the 10th rib face of the longissimus muscle by using a pH star probe (SFK Ltd, Hvidovre, Denmark). Hunter L* score and Minolta Reflectance were measured on the 10th rib face of the loin by using a Minolta CR-310 (Minolta Camera Co., Ltd., Osaka, Japan) with a 50-mm-diameter aperture, D65 illuminant,

and calibrated to the white calibration tile. The 11th and 12th rib sections were cut into 2.54 cm samples and set cut side up for 10 min to allow the sample to bloom. Subjective measures of color (1 = pale pinkish gray to white; 6 = dark purplish red), marbling (1 = 1% IMF; 10 = 10% IMF), and firmness (1 = soft; 3 = very firm) were evaluated on the 11th rib face according to NPPC (2000) by personnel trained in meat quality evaluation. Water holding capacity was measured on the 11th rib face by using the filter paper method described by Kauffman et al. (1986). Longissimus muscle samples (n=663) collected from generation 3 through 7 pigs (Table 2) in the CL (n=357) and SL (n=306) were used to determine fatty acid profiles of IMF.

Fatty acid analysis

Trimmed loin samples (Generations 3 through 7) and all layers of adipose tissue (Generation 6 and 7) from the *longissimus dorsi* at the 10-11th rib were utilized for fatty acid determination. Total lipid was extracted from IMF samples with a chloroform and methanol (2:1, vol:vol) mixture and quantified gravimetrically (Folch et al., 1957). Triacylglycerols (TAG) were separated from phospholipids (PL) by thin-layer chromatography with hexane and ethyl acetate (4:1, vol:vol). Fatty acids in each lipid were derivatized to methyl esters according to Lepage and Roy (1986). Fatty acid methyl ester (FAME) from both subcutaneous adipose tissue and IMF were analyzed by gas chromatography (GC; model 3400, Varian, Palo Alto, CA) equipped with a Supelco SP-2560 column (100 m x 0.25 mm x 0.2 µm film thickness) and a flame ionization detector. The column started at a temperature of 100°C and was increased to 170°C at a rate of 2°C per min, followed by an increase to 180°C at 0.5°C per min and to 250°C at 10°C per minute. Total run time was 77 min and the detector was maintained at 220°C. Based on fatty acid composition, the atherogenic index (AI) was calculated following Ulbricht and Southgate (1991):

$$AI = \frac{C12 : 0 + (4 \times C14 : 0) + C16 : 0}{\Sigma MUFA + \Sigma PUFA}$$

Sensory Evaluation

Two 2.54-cm chops from the 10th to 12th rib section were vacuum packaged and taken to Iowa State University Food Science Laboratory (McKay Hall, Iowa State University) where samples were refrigerated at 0°C for 7 d. Both rib sections were cooked to 71°C in an electric broiler (Amana model ARE 640, Amana, IA), with sample temperature monitored with Chromega/Alomega thermocouples attached to an Omega digital thermometer (DSS-650, Omega Engineering, Inc., Stamford, CT). Weights prior to and immediately after cooking were used to calculate weight and percentage of cooking loss. A 3-member trained sensory panel evaluated cooked loin samples for quality attributes (Huff-Lonergan et al., 2002) on three 1.3 cm³ cubes from the center of the 11th and 12th rib samples. Eating quality evaluations for juiciness (1 = dry; 10 = juicy), tenderness (1 = tough; 10 = tender), flavor (1 = little pork flavor; 10 = extremely flavorful, abundant pork flavor), and off-flavor (1 = no off-flavor; 10 = abundant non-pork flavor) were recorded by using an end-anchored, 10-point scoring system (AMSA, 1995). Individual booths with red overhead lighting were provided for each panelist. Sample evaluations were averaged across panelists for analysis. The 12th rib section was evaluated for tenderness by using an Instron Universal Testing Machine (Model 1122; Instron Corp., Canton, MA) fitted with a circular, 5-point star probe (9 mm diameter with 6 mm between points) (Oltrogge-Hammernick and Prusa, 1987).

Statistical Analysis

Line differences for meat and eating quality traits and fatty acid composition through generation 7 were assessed by using the MIXED procedure of SAS (SAS Inst., Cary, NC). A mixed model with fixed effects of line, gender, generation, and carcass contemporary group, and interactions of line × sex and line × generation was utilized to estimate least squares means (±SE) for all dependent variables. A random effect of sire nested within line, and a covariate of hot carcass weight were included in all analyses. Least squares means within fixed effects were compared by using pair-wise *t*-tests (*pdiff* option in SAS) and declared to be different at *P* < 0.05.

The statistical software package DMU (Madsen and Jensen, 2000), with the average information restricted maximum likelihood procedure DMUAI, was used to estimate genetic parameters from an animal

model. All known pedigree relationships back to the animals used to initiate the population were included. The number of animals in the pedigree with a non-zero inbreeding coefficient was 5,101.

Bivariate Analysis

Each trait was analyzed with a two-trait model to obtain initial estimates for components of variance due to animal additive genetic, common environment of birth litter, and residual effects. Convergence criterion of the norm update vector was 1.0×10^{-7} for all bivariate analyses. To account for selection, IMF was included in each bivariate analysis (Meyer, 1989). Heritability estimates were calculated as the ratio of animal genetic variance to the sum of additive genetic, common environmental, and residual variances.

Multivariate Analysis

A multivariate analysis was performed to evaluate measures of fatty acid composition, meat and eating quality, and production traits. An 8-trait analysis was performed that included carcass composition, production, and eating quality traits, as well as one of the major fatty acids. Since selection was based on EBV for IMF, this trait was included in the model to account for selection (Meyer, 1989). A multi-trait convergence criterion of 10^{-5} was designated to determine (co)variance estimates. After initial convergence was attained, three cold starts were performed to ensure global convergence, as determined when (co)variance estimates did not change to the second decimal.

Results

Carcass Composition and Meat Quality

Least squares means for carcass composition and meat quality traits are presented in Table 3. Select line pigs had 5.80 mm ($P < 0.001$), 3.17 mm ($P < 0.001$), and 3.18 mm ($P < 0.001$) more tenth rib, last-rib, and last lumbar backfat, respectively, when compared to control line pigs. Additionally, pigs in the SL had less loin muscle area ($P < 0.001$) and combined with more overall fat, were less desirable in percentage lean ($P < 0.001$). The direct response to selection for IMF corresponded to 1.66% increase in total lipid in the select line ($P < 0.001$). No significant line differences were observed in the current study for pH measured at 24 h, 48 h, or 7 d post mortem. Additionally, water holding capacity and cook loss were not different between lines ($P > 0.05$).

Selection for quantity of IMF resulted in a correlated response in objective color estimates. Select line pigs had a 1.84 unit, 1.82 unit, 2.17 unit, and 2.19 unit increase in 24 h and 48 h Minolta reflectance and 24 h and 48 h Hunter L values, respectively.

Correlated Responses in Eating Quality

Least square means for sensory panel scores are presented in Table 4. Sensory panel evaluation, including juiciness, chewiness, and tenderness scores did not differ ($P < 0.05$) between lines. However, loin samples from select line pigs had more flavor ($P < 0.001$) and less off-flavor ($P < 0.05$) than did samples from control line pigs.

Fatty Acid Composition -- Longissimus dorsi total lipid

Least squares means for fatty acid composition of LM total lipids are presented in Table 5. The main effect of line was a significant source of variation for total MUFA and PUFA, but was not significant for total saturated fatty acids. Saturated fatty acids, including C12:0 ($P < 0.05$), C15:0 ($P < 0.001$), C17:0 ($P < 0.001$), and C22:0 ($P < 0.001$) were more abundant in loins from pigs in the CL, whereas C18:0 ($P < 0.01$) and C20:0 ($P < 0.01$) were more prevalent in loins from SL pigs. Monounsaturated fatty acids C18:1 n -9 ($P < 0.05$) and C24:1 ($P < 0.05$), and total MUFA ($P < 0.001$) were more abundant in SL samples when compared to those in the CL. Conversely, PUFA, including C18:2 n -6 ($P < 0.001$), C20:3 n -6 ($P < 0.05$), C20:4 n -6 ($P < 0.001$), and C22:5 n -3 ($P < 0.001$), and total PUFA were more abundant in the CL loin samples. Loin samples from SL pigs had more α -linolenic (C18:3 n 3) ($P < 0.001$) and γ -linolenic acid (C18:3 n 6) ($P < 0.05$) than those from CL pigs.

Fatty Acid Composition -- Longissimus dorsi phospholipid

Least squares means by concentration of individual fatty acids in the phospholipid fraction of IMF samples are reported in Table 6. There were no line differences ($P > 0.05$) in total saturated, total MUFA, and total PUFA in the phospholipid fraction; however, loin samples from SL pigs had more C15:0 than samples from pigs in the CL ($P < 0.05$). The CL loin samples had a greater percentage of C18:0 ($P < 0.05$), C20:4 n -6 ($P < 0.05$), and C22:5 n -3 ($P < 0.01$).

Fatty Acid Composition -- Longissimus dorsi neutral lipid

Least squares means for concentration of individual fatty acids in the neutral lipid fraction of IMF samples are presented in Table 7. Loin samples from pigs in the CL had more C12:0 ($P < 0.05$), C24:0 ($P < 0.05$), and C18:2n-6 ($P < 0.01$) in neutral lipid, while loin samples from SL pigs had more C18:0 ($P < 0.001$), C20:0 ($P < 0.001$), C20:1n-9 ($P < 0.001$), C24:1 ($P < 0.001$), and C22:4n-6 ($P < 0.001$). Overall, there were no differences ($P > 0.05$) in total saturated and total MUFA.

Fatty Acid Composition -- Subcutaneous adipose tissue

Least squares means for fatty acid composition of tenth rib-subcutaneous adipose tissue (all layers combined) (Generation 6 and 7 only) are presented in Table 8. Adipose tissue from pigs in the SL had more C14:0 ($P < 0.01$), C16:0 ($P < 0.001$), and saturated fatty acids ($P < 0.001$) when compared to those in the CL. Control line pigs, however, had more C18:2n-6 ($P < 0.001$), C18:3n-3 ($P < 0.001$), C20:2 ($P < 0.001$), C22:6n-3 ($P < 0.05$), and total PUFA ($P < 0.001$) present in adipose tissue when compared to pigs in the SL.

Heritability Estimates for Fatty Acid Composition

Heritability estimates for fatty acid composition of total lipid in intramuscular fat are presented in Table 9. The greatest heritability estimates were found for lauric acid (C12:0), palmitoleic acid (C16:1n7), stearic acid (C18:0), linoleic acid (C18:2n6), and α -Linolenic acid (C18:3n3) (0.73, 0.40, 0.36, 0.33, and 0.26, respectively).

Genetic Correlations of Fatty Acid Composition and Meat and Eating Quality Traits

Genetic correlations among fatty acid composition and meat and eating quality traits are presented in Tables 10 and 11. Genetic correlations between IMF content and C16:0, C18:0, and C18:1 did not differ from zero. However, negative genetic correlations between IMF and C17:0, and IMF and C18:2 were found (-0.61 and -0.80, respectively). Loin muscle area was positively correlated with C18:2 concentrations (0.75) and tenth-rib backfat was negatively correlated (-0.62) with C18:2 concentrations. Monounsaturated fat concentrations from IMF were negatively correlated with LMA (-0.70), but positively correlated with BF10 (0.77). Total PUFA concentrations in intramuscular fat were negatively correlated with IMF and BF10, but positively correlated with LMA. No significant genetic correlations were found in the current study between eating quality traits (flavor score and off-flavor score) and individual fatty acids.

Discussion

Observed color differences may be influenced by quantity of IMF on the exposed loin muscle surface, rather than by true differences in lean tissue color. This effect is one possible pitfall to using objective color reflectance measures on exposed lean tissue with high levels of IMF. An evaluation of color, independent of IMF, such as myoglobin concentration, may be required to determine the true pigmentation of lean tissue and true color differences.

Carcass lean percentage is under genetic control and is potentially influenced by numerous traits. When intense selection pressure is placed on percentage of lean, unfavorable correlated responses in the form of decreased meat and fat quality may result. Long-term selection response for increased carcass leanness has been at the expense of meat quality traits, namely IMF percentage (Wood et al., 2004a), objective measures of tenderness (Schwab et al., 2006), and color scores (both objective and subjective measures) (Schwab et al., 2006).

Flavor has been reported to have a relatively strong relationship with IMF content (Van Oeckel et al., 1999), although there have been reports of little to no association between eating quality and IMF (Channon et al., 2004; Fernandez et al., 1999; van Laack et al., 2001). Off-flavor scores (flavor perceived as inappropriate) were not influenced by IMF (Fortin et al., 2005); however, in the current study, samples with increased IMF (i.e., SL pigs) had the lowest sensory off-flavor scores. This result is significant because Risvik (1994) identified that the absence of off-flavors is critical for pork consumer acceptance.

Increased concentrations of C18:2n6 have been shown to have a negative correlation with objective color measures (Cameron and Enser, 1991). In the current study, loin samples from CL pigs had more C18:2n6 and more desirable objective color measures. Select line loin samples had more α -linolenic (C18:3n3) ($P < 0.001$) and γ -linolenic acid (C18:3n6) ($P < 0.05$) than those from the control line. This increase in essential

fatty acids is beneficial from a human health aspect, but poses increased risk for product shelf life due to oxidative stability of fat (Martin et al., 2008; Wood and Enser, 1997).

Fatty acid profiles of IMF in the present study are similar to those presented by Enser et al. (1996), who compared random samples from commercially available retail display counters for pork, lamb, and beef. Because pigs do not synthesize linoleic and linolenic acids, tissue content reflects the amount of these fatty acids present in the diets fed to pigs producing the meat (Gatlin et al., 2003). In the present study, pigs in each generation were fed diets formulated to have identical nutrient composition, however, raw materials of the diet ingredients are produced each year; thus, diets for each generation could potentially be slightly different. To account for potential year to year variation in dietary ingredient composition, differences were accounted for by including generation as a fixed effect in the model used to analyze the data. Significant line differences were found for total lipid content of pork skeletal muscle and intramuscular adipose lipids. Further research into possible differences in the genetic control of fatty acid transport mechanisms and binding proteins is needed because these variables could influence PUFA content of IMF and ultimately, the healthfulness of pork for consumers.

In a study conducted by Wood et al. (1996), the inverse correlation between unsaturated fatty acid concentration and lipid content was absent for C18:2 n -3, which suggests different metabolic controls for C18:2 n -6 and C18:2 n -3, both of which are entirely dietary derived and compete for inclusion into lipid depots in pigs. Because of the increase in overall C18:2 n -6 and C18:2 n -3 in CL loin samples, one would expect an increased synthesis of the longer chain PUFA, which are the n -3 fatty acids involved in potential health benefits (Wood and Enser, 1997). Additionally, subsequent increases in these fatty acids have elicited a high proportion of negative comments on flavor in bacon derived from pigs fed diets supplemented with ground flaxseed (high in n -3 fats) for 25 d (Romans et al., 1995a; Romans et al., 1995b).

As expected, only minor line differences were found for PL concentration, due to the conservation of lipids found in membranes and their important role in membrane integrity (Farkas et al., 2000). Pork flavor has been reported to have a negative correlation with the amount of PUFA, suggesting that a higher concentration of PUFA may result in an increased incidence of off-flavor appearance (Cameron et al., 2000; Cameron and Enser, 1991). A negative correlation between pork flavor and neutral lipid PUFA (C18:2, C18:3, C20:3, C20:4, C20:5, C22:5, and C22:6) was reported by Cameron et al. (2000), but the authors reported a positive correlation with MUFA of the neutral lipid (C16:1 and C18:1). Although differences in flavor and off-flavor were found in the current study, the only difference in neutral fatty acid composition between lines was increased C18:2 in the CL, which could explain the increased incidence of sensory off-flavor scores observed in this line.

A positive relationship between carcass leanness and the ratio of PUFA:SFA of adipose tissue has been previously reported (Scott et al., 1981b). This can be explained by the smaller contribution of *de novo* synthesis and larger contribution of dietary fatty acids to total fat composition in genetically leaner pigs. The dietary intake of C18:2 n 6 was identical in the two lines in the current study; however its proportion increases in the CL pigs. These modifications have antagonistic effects on adipose tissue when further processing of pork occurs (decreased melting point and increased susceptibility to oxidation). However, these have positive implications on human health when incorporated into the diet (essential fatty acid supply) (Sheard et al., 2000).

Decreased PUFA concentration in the SL pigs was a correlated response to seven generations of selection for increased IMF in that line. Pigs with increased backfat have been shown to have greater saturation present in adipose tissue (Scott et al., 1981b). Greater saturation of subcutaneous backfat and skeletal adipose tissue (IMF) may have resulted from selection for greater *de novo* synthesis, lower lipolytic rate (thus lower turnover), preferential incorporation of saturated fatty acids during TAG biosynthesis, lower desaturase activity, or some combination of these factors.

Sellier (1998) reported mean heritability estimates of 0.51 (0.42 to 0.57) for C18:0 and 0.58 (0.47 to 0.70) for C18:2 of subcutaneous fat. Heritability estimates for fatty acids of subcutaneous fat analyzed using near-infrared spectroscopy were reported by Fernández et al. (2003). The greatest heritability estimate (0.41) was found for stearic acid (C18:0) with C18:2, C18:1 and C16:0 having heritability estimates of 0.29, 0.31, and 0.31, respectively. A study conducted by Suzuki et al. (2006), showed that the percentage of C18:2 present in intramuscular fat was half that of the inner and outer layers of subcutaneous fat, suggesting that the genetic

control of fatty acid accumulation is different for subcutaneous and intramuscular fats. It has been suggested that the fatty acid composition of intramuscular fat is greatly influenced by dietary feed content, and to a lesser extent, by genetics (Cameron et al., 2000). However, heritability estimates in the current study were moderate to high for the major fatty acids found in the intramuscular fat of the *longissimus dorsi* muscle.

Fernandez et al. (2003) estimated that the genetic correlations between IMF content and C16:0, C18:0, C18:1, and C18:2 were nearly zero (-0.06 to 0.09). In the present study, genetic correlations between IMF content and C16:0, C18:0, and C18:1 did not differ from zero.

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Table 1. Fatty acid composition of the phase 3 finishing diet fed to pigs in a selection project for intramuscular fat content[†]

Trait	Formula	Phase 3 Diet ¹
Fat, %		6.26
Saturated fatty acids (wt %)		
Lauric acid	C12:0	0.01
Myristic acid	C14:0	0.76
Pentadecanoic acid	C15:0	0.00
Palmitic acid	C16:0	22.18
Margaric acid	C17:0	0.25
Stearic acid	C18:0	8.65
Arachidic acid	C20:0	0.36
Behenic acid	C22:0	0.09
Lignoceric acid	C24:0	0.00
Total saturated		32.30
Monounsaturated fatty acids (wt %)		
Myristoleic acid	C14:1	0.04
Palmitoleic acid	C16:1 <i>n</i> -7	1.45
<i>cis</i> -Heptadecenoic acid	C17:1 <i>n</i> -10	0.13
Oleic acid	C18:1 <i>n</i> -9	17.20
<i>trans</i> -Vaccenic acid	C18:1 <i>n</i> -7	1.39
Eicosanoic acid	C20:1 <i>n</i> -9	0.74
Nervonic acid	C24:1	0.08
Total MUFA		21.03
Polyunsaturated fatty acids (wt %)		
Linoleic acid	C18:2 <i>n</i> -6	44.35
α -Linolenic acid	C18:3 <i>n</i> -3	1.56
γ -Linolenic acid	C18:3 <i>n</i> -6	0.01
Eicosadienoic acid	C20:2 <i>n</i> -6	0.00
Eicosatrienoic acid	C20:3 <i>n</i> -6	0.08
Arachidonic acid	C20:4 <i>n</i> -6	0.21
Eicosapentaenoic acid	C20:5 <i>n</i> -3	0.00
Docosatetraenoic acid	C22:4 <i>n</i> -6	0.01
Docosapentaenoic acid	C22:5 <i>n</i> -3	0.01
Docosahexaenoic acid	C22:6 <i>n</i> -3	0.00
Total PUFA		46.23

[†]Presented as a percentage of total lipid in the feed on an as-fed basis.

¹Phase 3 Finisher Diet – 91 kg to market weight.

Table 2. Distribution of records by generation and line from a selection experiment for increased intramuscular fat in Duroc swine

Trait Category	Generation					Total
	3	4	5	6	7	
	No. of observations					
Contol Line¹						
Gilts	14	5	14	17	6	56
Barrows	67	66	87	60	21	301
Select Line²						
Gilts	8	24	24	32	12	100
Barrows	56	53	46	40	11	206
Total						
Gilts	22	29	38	49	18	156
Barrows	123	119	133	100	32	507
Carcass	145	148	171	149	50	663

¹Control line = unselected, randomly mated population.

²Select line = selected for 7 generations for increased IMF based on a 2-trait animal model that included IMF measured on the carcass and IMF predicted via real-time ultrasound.

Table 3. Least squares means (\pm SE) for carcass composition and meat quality traits from Duroc pigs in a selection experiment for increased intramuscular fat

Item	Line		Difference between Control and Select	P-Value
	Control ¹	Select ²		
Carcass composition				
Length, cm	82.15 \pm 0.16	82.49 \pm 0.16	-0.34 \pm 0.22	0.1279
Tenth rib backfat, mm	19.71 \pm 0.50	25.51 \pm 0.48	-5.80 \pm 0.68	<0.0001
Last rib backfat, mm	23.69 \pm 0.40	26.86 \pm 0.39	-3.17 \pm 0.54	<0.0001
Last lumbar backfat, mm	18.65 \pm 0.42	21.83 \pm 0.40	-3.18 \pm 0.57	<0.0001
Loin muscle area, cm ²	44.19 \pm 0.40	38.29 \pm 0.39	5.90 \pm 0.54	<0.0001
Percentage lean, (% wet basis)	39.63 \pm 0.25	36.04 \pm 0.24	3.59 \pm 0.34	<0.0001
Intramuscular fat, (% wet basis)	3.02 \pm 0.12	4.68 \pm 0.12	-1.66 \pm 0.16	<0.0001
Meat quality				
24 h pH	5.72 \pm 0.01	5.73 \pm 0.01	0.01 \pm 0.01	0.8527
48 h pH	5.66 \pm 0.01	5.68 \pm 0.01	0.02 \pm 0.01	0.3581
7 d pH	5.70 \pm 0.01	5.71 \pm 0.01	-0.01 \pm 0.01	0.6072
24 h Minolta reflectance	22.77 \pm 0.22	24.61 \pm 0.22	-1.84 \pm 0.30	<0.0001
48 h Minolta reflectance	21.72 \pm 0.20	23.54 \pm 0.20	-1.82 \pm 0.28	<0.0001
24 h Hunter L value	47.40 \pm 0.24	49.57 \pm 0.24	-2.17 \pm 0.33	<0.0001
48 h Hunter L value	46.34 \pm 0.25	48.53 \pm 0.24	-2.19 \pm 0.34	<0.0001
Water holding capacity, mg	57.07 \pm 1.77	57.85 \pm 1.71	-0.78 \pm 2.37	0.7422
Cooking loss, %	17.99 \pm 0.22	18.29 \pm 0.22	-0.30 \pm 0.29	0.3071
Instron tenderness, kg	5.78 \pm 0.06	5.49 \pm 0.06	0.29 \pm 0.08	0.0006

¹Control line = unselected, randomly mated population.

²Select line = selected for 7 generations for increased IMF based on a 2-trait animal model that included IMF measured on the carcass and IMF predicted via real-time ultrasound.

Table 4. Least squares means (\pm SE) for sensory panel traits from pigs in Generations 3 through 7 of a selection experiment for increased intramuscular fat in Duroc swine

Item ¹	Line		Difference between		P-Value
	Control ²	Select ³	Control and Select		
Juiciness score	6.33 \pm 0.09	6.43 \pm 0.08	-0.10 \pm 0.12		0.4368
Chewiness score	3.04 \pm 0.09	3.02 \pm 0.08	0.02 \pm 0.12		0.8225
Tenderness score	6.44 \pm 0.11	6.43 \pm 0.10	0.01 \pm 0.15		0.9337
Flavor score	2.63 \pm 0.09	3.17 \pm 0.08	-0.54 \pm 0.13		<0.0001
Off-flavor score	2.46 \pm 0.11	2.17 \pm 0.10	0.29 \pm 0.15		0.0494

¹Trained sensory panel evaluations of juiciness (1 = dry; 10 = juicy), chewiness (1 = not chewy; 10 = very chewy), tenderness (1 = tough; 10 = tender), flavor (1 = little pork flavor, bland; 10 = very flavorful, abundant pork flavor), and off-flavor (1 = no off-flavor, 10 = abundant non-pork flavor).

²Control line = unselected, randomly mated population.

³Select line = selected for 7 generations for increased IMF based on a 2-trait animal model that included IMF measured on the carcass and IMF predicted via real-time ultrasound.

Table 5. Least squares means (\pm SE) for total fatty acid composition of intramuscular fat from pigs in Generation 3 through 7 of selection project for intramuscular fat in Duroc swine[†]

Fatty acid	Formula	Line						Difference between Control and Select	P-value		
		Control ¹			Select ²						
Saturated											
Lauric acid	C12:0	0.08	\pm	0.00	0.07	\pm	0.00	0.01	\pm	0.01	0.0200
Myristic acid	C14:0	1.41	\pm	0.02	1.48	\pm	0.02	-0.07	\pm	0.03	0.0564
Pentadecanoic acid	C15:0	0.51	\pm	0.03	0.34	\pm	0.03	0.17	\pm	0.04	<0.0001
Palmitic acid	C16:0	26.11	\pm	0.26	26.42	\pm	0.24	-0.31	\pm	0.36	0.4042
Margaric acid	C17:0	0.26	\pm	0.01	0.19	\pm	0.01	0.07	\pm	0.02	<0.0001
Stearic acid	C18:0	12.97	\pm	0.14	13.47	\pm	0.12	-0.50	\pm	0.19	0.0082
Arachidic acid	C20:0	0.08	\pm	0.00	0.10	\pm	0.00	-0.02	\pm	0.01	0.0026
Behenic acid	C22:0	0.06	\pm	0.00	0.05	\pm	0.00	0.01	\pm	0.01	0.0299
Lignoceric acid	C24:0	0.02	\pm	0.00	0.02	\pm	0.00	0.00	\pm	0.00	0.3273
Total saturated		41.53	\pm	0.31	42.14	\pm	0.28	-0.61	\pm	0.42	0.1479
Monounsaturated											
Myristoleic acid	C14:1	0.02	\pm	0.00	0.02	\pm	0.00	0.00	\pm	0.00	0.8633
Palmitoleic acid	C16:1 <i>n</i> -7	3.31	\pm	0.05	3.45	\pm	0.05	-0.14	\pm	0.07	0.0543
<i>cis</i> -Heptadecenoic acid	C17:1 <i>n</i> -10	0.06	\pm	0.02	0.10	\pm	0.01	-0.04	\pm	0.02	0.0996
Oleic acid	C18:1 <i>n</i> -9	40.94	\pm	0.38	42.37	\pm	0.35	-1.43	\pm	0.52	0.0064
<i>trans</i> -Vaccenic acid	C18:1 <i>n</i> -7	2.44	\pm	0.28	2.68	\pm	0.25	-0.24	\pm	0.33	0.5219
Eicosanoic acid	C20:1 <i>n</i> -9	0.15	\pm	0.01	0.16	\pm	0.01	-0.01	\pm	0.02	0.7086
Nervonic acid	C24:1	0.04	\pm	0.00	0.03	\pm	0.00	0.01	\pm	0.00	0.0108
Total MUFA		47.06	\pm	0.26	48.89	\pm	0.26	-1.83	\pm	0.39	<0.0001
Polyunsaturated											
Linoleic acid	C18:2 <i>n</i> -6	8.88	\pm	0.15	6.92	\pm	0.13	1.96	\pm	0.20	<0.0001
α -Linolenic acid	C18:3 <i>n</i> -3	0.70	\pm	0.02	0.78	\pm	0.02	-0.08	\pm	0.02	0.0005
γ -Linolenic acid	C18:3 <i>n</i> -6	0.04	\pm	0.00	0.06	\pm	0.00	-0.02	\pm	0.00	0.0202
Eicosadienoic acid	C20:2 <i>n</i> -6	0.27	\pm	0.01	0.27	\pm	0.01	0.00	\pm	0.01	0.9578
Eicosatrienoic acid	C20:3 <i>n</i> -6	0.15	\pm	0.01	0.13	\pm	0.01	0.02	\pm	0.01	0.0283
Arachidonic acid	C20:4 <i>n</i> -6	0.51	\pm	0.04	0.34	\pm	0.03	0.17	\pm	0.05	0.0005
Eicosapentaenoic acid	C20:5 <i>n</i> -3	0.01	\pm	0.00	0.01	\pm	0.00	0.00	\pm	0.00	0.5076
Docosatetraenoic acid	C22:4 <i>n</i> -6	0.09	\pm	0.01	0.07	\pm	0.01	0.02	\pm	0.01	0.2045
Docosapentaenoic acid	C22:5 <i>n</i> -3	0.07	\pm	0.01	0.05	\pm	0.01	0.02	\pm	0.01	0.0012
Docosahexaenoic acid	C22:6 <i>n</i> -3	0.01	\pm	0.00	0.01	\pm	0.00	0.00	\pm	0.00	0.1963
Total PUFA		10.73	\pm	0.17	8.63	\pm	0.16	2.10	\pm	0.24	<0.0001

[†]Presented as percentage of total lipid in the lean tissue.

¹Control line = unselected, randomly mated population.

²Select line = selected for 7 generations for increased IMF based on a 2-trait animal model that included IMF measured on the carcass and IMF predicted via real-time ultrasound.

Table 6. Least squares means (\pm SE) for phospholipid composition of intramuscular fat from pigs in Generations 3 through 7 of a selection project for intramuscular fat in Duroc swine[†]

Fatty acid	Formula	Line				Difference between Control and Select	P-value	
		Control ¹		Select ²				
Saturated								
Lauric acid	C12:0	1.51	\pm 0.19	1.50	\pm 0.19	0.01	\pm 0.28	0.9586
Myristic acid	C14:0	0.49	\pm 0.08	0.47	\pm 0.09	-0.02	\pm 0.13	0.8808
Pentadecanoic acid	C15:0	6.77	\pm 0.22	7.64	\pm 0.19	-0.87	\pm 0.29	0.0027
Palmitic acid	C16:0	20.05	\pm 0.45	21.18	\pm 0.40	-1.13	\pm 0.53	0.0615
Margaric acid	C17:0	3.45	\pm 0.14	3.15	\pm 0.13	0.30	\pm 0.19	0.1207
Stearic acid	C18:0	9.32	\pm 0.21	8.72	\pm 0.19	0.60	\pm 0.25	0.0400
Arachidic acid	C20:0	0.17	\pm 0.06	0.22	\pm 0.05	-0.05	\pm 0.08	0.5495
Behenic acid	C22:0	0.07	\pm 0.02	0.09	\pm 0.01	-0.02	\pm 0.02	0.4664
Lignoceric acid	C24:0	0.09	\pm 0.03	0.04	\pm 0.03	0.05	\pm 0.03	0.2438
Total saturated		41.93	\pm 0.51	43.00	\pm 0.46	-1.07	\pm 0.12	0.1247
Monounsaturated								
Myristoleic acid	C14:1	0.40	\pm 0.08	0.32	\pm 0.08	0.08	\pm 0.11	0.4918
Palmitoleic acid	C16:1 <i>n</i> -7	0.45	\pm 0.09	0.52	\pm 0.08	-0.07	\pm 0.11	0.5752
<i>cis</i> -Heptadecenoic acid	C17:1 <i>n</i> -10	1.95	\pm 0.28	1.56	\pm 0.25	0.39	\pm 0.38	0.2993
Oleic acid	C18:1 <i>n</i> -9	10.47	\pm 0.33	10.91	\pm 0.30	-0.44	\pm 0.44	0.3227
<i>trans</i> -Vaccenic acid	C18:1 <i>n</i> -7	1.75	\pm 0.11	1.95	\pm 0.11	-0.20	\pm 0.17	0.2577
Eicosanoic acid	C20:1 <i>n</i> -9	0.14	\pm 0.13	0.30	\pm 0.12	-0.16	\pm 0.18	0.3836
Nervonic acid	C24:1	0.15	\pm 0.03	0.09	\pm 0.03	0.06	\pm 0.04	0.1376
Total MUFA		15.28	\pm 0.46	15.62	\pm 0.42	-0.34	\pm 0.62	0.5866
Polyunsaturated								
Linoleic acid	C18:2 <i>n</i> -6	31.89	\pm 0.59	31.94	\pm 0.53	-0.05	\pm 0.79	0.9457
α -Linolenic acid	C18:3 <i>n</i> -3	0.16	\pm 0.04	0.11	\pm 0.04	0.05	\pm 0.05	0.4422
γ -Linolenic acid	C18:3 <i>n</i> -6	0.24	\pm 0.06	0.20	\pm 0.06	0.04	\pm 0.08	0.6158
Eicosadienoic acid	C20:2 <i>n</i> -6	0.24	\pm 0.20	0.19	\pm 0.18	0.05	\pm 0.26	0.8469
Eicosatrienoic acid	C20:3 <i>n</i> -6	0.69	\pm 0.07	0.59	\pm 0.06	0.10	\pm 0.09	0.2854
Arachidonic acid	C20:4 <i>n</i> -6	5.10	\pm 0.28	4.18	\pm 0.26	0.92	\pm 0.26	0.0166
Eicosapentaenoic acid	C20:5 <i>n</i> -3	0.11	\pm 0.05	0.15	\pm 0.04	-0.04	\pm 0.06	0.5327
Docosatetraenoic acid	C22:4 <i>n</i> -6	0.38	\pm 0.04	0.42	\pm 0.04	-0.04	\pm 0.06	0.5292
Docosapentaenoic acid	C22:5 <i>n</i> -3	0.30	\pm 0.03	0.19	\pm 0.03	0.11	\pm 0.04	0.0105
Docosahexaenoic acid	C22:6 <i>n</i> -3	0.11	\pm 0.06	0.09	\pm 0.05	0.02	\pm 0.08	0.8071
Total PUFA		39.40	\pm 0.65	38.16	\pm 0.58	1.24	\pm 0.87	0.1551

[†]Presented as percentage of total phospholipid in the lean tissue.

¹Control line = unselected, randomly mated population.

²Select line = selected for 7 generations for increased IMF based on a 2-trait animal model that included IMF measured on the carcass and IMF predicted via real-time ultrasound.

Table 7. Least squares means (\pm SE) for fatty acid composition of neutral lipids of intramuscular fat from pigs in Generations 3 through 7 of a selection project for intramuscular fat in Duroc swine[†]

Fatty acid	Formula	Line		Difference between Control and Select	P-value
		Control ¹	Select ²		
Saturated					
Lauric acid	C12:0	0.26 \pm 0.05	0.13 \pm 0.04	0.13 \pm 0.06	0.0367
Myristic acid	C14:0	1.87 \pm 0.06	1.76 \pm 0.06	0.11 \pm 0.09	0.1942
Pentadecanoic acid	C15:0	0.11 \pm 0.04	0.03 \pm 0.03	0.08 \pm 0.05	0.1135
Palmitic acid	C16:0	28.27 \pm 0.36	27.96 \pm 0.32	0.31 \pm 0.48	0.5153
Margaric acid	C17:0	0.09 \pm 0.02	0.11 \pm 0.02	-0.02 \pm 0.02	0.4234
Stearic acid	C18:0	12.55 \pm 0.19	13.32 \pm 0.17	-0.77 \pm 0.25	0.0029
Arachidic acid	C20:0	0.11 \pm 0.01	0.16 \pm 0.01	-0.05 \pm 0.01	0.0004
Behenic acid	C22:0	0.004 \pm 0.006	0.008 \pm 0.005	-0.004 \pm 0.008	0.5733
Lignoceric acid	C24:0	0.05 \pm 0.01	0.02 \pm 0.01	0.03 \pm 0.01	0.0246
Total saturated		43.32 \pm 0.41	43.50 \pm 0.37	-0.18 \pm 0.56	0.7509
Monounsaturated					
Myristoleic acid	C14:1	0.08 \pm 0.03	0.02 \pm 0.03	0.06 \pm 0.04	0.1339
Palmitoleic acid	C16:1 <i>n</i> -7	3.83 \pm 0.07	3.84 \pm 0.06	-0.01 \pm 0.09	0.9324
<i>cis</i> -Heptadecenoic acid	C17:1 <i>n</i> -10	0.07 \pm 0.01	0.09 \pm 0.01	-0.02 \pm 0.01	0.1689
Oleic acid	C18:1 <i>n</i> -9	42.95 \pm 0.57	42.22 \pm 0.51	0.73 \pm 0.76	0.3382
<i>trans</i> -Vaccenic acid	C18:1 <i>n</i> -7	3.41 \pm 0.33	4.22 \pm 0.30	-0.81 \pm 0.44	0.0699
Eicosanoic acid	C20:1 <i>n</i> -9	0.54 \pm 0.02	0.66 \pm 0.02	-0.12 \pm 0.03	0.0003
Nervonic acid	C24:1	0.001 \pm 0.003	0.013 \pm 0.003	-0.012 \pm 0.004	0.0029
Total MUFA		50.88 \pm 0.43	51.07 \pm 0.39	-0.19 \pm 0.58	0.7490
Polyunsaturated					
Linoleic acid	C18:2 <i>n</i> -6	5.02 \pm 0.10	4.63 \pm 0.09	0.39 \pm 0.13	0.0038
α -Linolenic acid	C18:3 <i>n</i> -3	0.23 \pm 0.04	0.24 \pm 0.03	-0.01 \pm 0.05	0.8738
γ -Linolenic acid	C18:3 <i>n</i> -6	0.07 \pm 0.02	0.02 \pm 0.02	0.05 \pm 0.02	0.0843
Eicosadienoic acid	C20:2 <i>n</i> -6	0.19 \pm 0.01	0.18 \pm 0.01	0.01 \pm 0.02	0.8255
Eicosatrienoic acid	C20:3 <i>n</i> -6	0.05 \pm 0.03	0.06 \pm 0.02	-0.01 \pm 0.03	0.6866
Arachidonic acid	C20:4 <i>n</i> -6	0.05 \pm 0.01	0.07 \pm 0.01	-0.02 \pm 0.01	0.3356
Eicosapentaenoic acid	C20:5 <i>n</i> -3	0.12 \pm 0.02	0.12 \pm 0.02	0.00 \pm 0.03	0.8273
Docosatetraenoic acid	C22:4 <i>n</i> -6	0.004 \pm 0.002	0.013 \pm 0.002	-0.009 \pm 0.003	0.0009
Docosapentaenoic acid	C22:5 <i>n</i> -3	0.002 \pm 0.001	0.004 \pm 0.001	-0.002 \pm 0.002	0.2504
Docosahexaenoic acid	C22:6 <i>n</i> -3	0.02 \pm 0.02	0.02 \pm 0.02	0.00 \pm 0.02	0.9211
Total PUFA		5.77 \pm 0.13	5.40 \pm 0.12	0.37 \pm 0.17	0.0335

[†]Presented as percentage of total neutral lipid in the lean tissue.

¹Control line = unselected, randomly mated population.

²Select line = selected for 7 generations for increased IMF based on a 2-trait animal model that included IMF measured on the carcass and IMF predicted via real-time ultrasound.

Table 8. Least squares means (\pm SE) for fatty acid composition of tenth-rib subcutaneous adipose tissue (all layers combined) from pigs in Generations 6 and 7 of a selection project for intramuscular fat in Duroc swine[†]

Fatty acid	Formula	Line		Difference between Control and Select	P-value
		Control ¹	Select ²		
Saturated					
Lauric acid	C12:0	0.053 \pm 0.005	0.055 \pm 0.005	-0.002 \pm 0.007	0.7784
Myristic acid	C14:0	1.34 \pm 0.03	1.44 \pm 0.03	-0.10 \pm 0.04	0.0084
Pentadecanoic acid	C15:0	0.033 \pm 0.004	0.030 \pm 0.004	0.003 \pm 0.005	0.5873
Palmitic acid	C16:0	23.78 \pm 0.27	25.58 \pm 0.24	-1.80 \pm 0.37	<0.0001
Margaric acid	C17:0	0.45 \pm 0.02	0.43 \pm 0.02	0.02 \pm 0.03	0.4968
Stearic acid	C18:0	12.51 \pm 0.20	12.88 \pm 0.18	-0.37 \pm 0.27	0.1786
Arachidic acid	C20:0	0.17 \pm 0.01	0.18 \pm 0.01	-0.01 \pm 0.01	0.3501
Behenic acid	C22:0	0.015 \pm 0.003	0.015 \pm 0.002	0.000 \pm 0.003	0.9727
Lignoceric acid	C24:0	0.04 \pm 0.02	0.02 \pm 0.02	0.02 \pm 0.03	0.3568
Total saturated		38.41 \pm 0.42	40.65 \pm 0.38	-2.24 \pm 0.57	0.0003
Monounsaturated					
Myristoleic acid	C14:1	0.02 \pm 0.01	0.02 \pm 0.01	0.00 \pm 0.01	0.7897
Palmitoleic acid	C16:1 <i>n</i> -7	1.99 \pm 0.04	2.20 \pm 0.04	-0.21 \pm 0.05	0.0005
<i>cis</i> -Heptadecenoic acid	C17:1 <i>n</i> -10	0.25 \pm 0.01	0.25 \pm 0.01	0.00 \pm 0.02	0.7781
Oleic acid	C18:1 <i>n</i> -9	38.93 \pm 0.51	39.20 \pm 0.48	-0.27 \pm 0.70	0.6901
<i>trans</i> -Vaccenic acid	C18:1 <i>n</i> -7	2.33 \pm 0.37	1.63 \pm 0.36	0.70 \pm 0.52	0.1785
Eicosanoic acid	C20:1 <i>n</i> -9	0.61 \pm 0.02	0.59 \pm 0.02	0.02 \pm 0.03	0.4392
Nervonic acid	C24:1	0.048 \pm 0.003	0.043 \pm 0.003	0.005 \pm 0.004	0.2481
Total MUFA		44.13 \pm 0.36	43.93 \pm 0.33	0.20 \pm 0.49	0.6778
Polyunsaturated					
Linoleic acid	C18:2 <i>n</i> -6	15.32 \pm 0.36	13.58 \pm 0.33	1.74 \pm 0.49	0.0009
α -Linolenic acid	C18:3 <i>n</i> -3	0.93 \pm 0.02	0.82 \pm 0.02	0.11 \pm 0.03	0.0008
γ -Linolenic acid	C18:3 <i>n</i> -6	0.015 \pm 0.005	0.013 \pm 0.005	0.002 \pm 0.007	0.7781
Eicosadienoic acid	C20:2 <i>n</i> -6	0.75 \pm 0.02	0.65 \pm 0.02	0.10 \pm 0.02	<0.0001
Eicosatrienoic acid	C20:3 <i>n</i> -6	0.10 \pm 0.03	0.07 \pm 0.03	0.03 \pm 0.04	0.4316
Arachidonic acid	C20:4 <i>n</i> -6	0.15 \pm 0.01	0.14 \pm 0.01	0.01 \pm 0.01	0.2786
Eicosapentaenoic acid	C20:5 <i>n</i> -3	0.005 \pm 0.001	0.005 \pm 0.001	0.000 \pm 0.002	0.9479
Docosatetraenoic acid	C22:4 <i>n</i> -6	0.05 \pm 0.01	0.05 \pm 0.01	0.00 \pm 0.01	0.8001
Docosapentaenoic acid	C22:5 <i>n</i> -3	0.030 \pm 0.005	0.025 \pm 0.005	0.005 \pm 0.007	0.4621
Docosahexaenoic acid	C22:6 <i>n</i> -3	0.001 \pm 0.001	0.00 \pm 0.00	0.001 \pm 0.001	0.0417
Total PUFA		17.35 \pm 0.40	15.35 \pm 0.36	2.00 \pm 0.54	0.0005

[†]Presented as percentage of total lipid from tenth-rib adipose tissue.

¹Control line = unselected, randomly mated population.

²Select line = selected for 7 generations for increased IMF based on a 2-trait animal model that included IMF measured on the carcass and IMF predicted via real-time ultrasound.

Table 9. Phenotypic variance (σ_p), animal genetic variance (σ_a), common environmental variance of litter (σ_l), and heritability (h^2 , \pm SE) estimates from a bivariate animal model evaluation of purebred Duroc swine (n=637)^a

Trait	Formula	σ_p	σ_a	σ_l	h^2
Lauric acid	C12:0	0.0023	0.0017	0.0006	0.73 \pm 0.21
Myristic acid	C14:0	0.0815	0.0185	0.0002	0.23 \pm 0.10
Pentadecanoic acid	C15:0	0.1233	0.0051	0.0004	0.04 \pm 0.06
Palmitic acid	C16:0	8.3580	0.2972	0.9449	0.04 \pm 0.08
Palmitoleic acid	C16:1n-7	0.3534	0.1425	0.0034	0.40 \pm 0.12
Margaric acid	C17:0	0.0240	0.0057	0.0007	0.24 \pm 0.10
Stearic acid	C18:0	2.4780	0.8883	0.1709	0.36 \pm 0.12
Oleic acid	C18:1n-9	21.7476	0.4547	3.1301	0.02 \pm 0.06
Linoleic acid	C18:2n-6	2.8828	0.9649	0.0203	0.33 \pm 0.09
α -Linolenic acid	C18:3n-3	0.0355	0.0091	0.0019	0.26 \pm 0.13
SFA ^b		12.0339	3.2143	0.2313	0.27 \pm 0.11
MUFA ^c		11.8274	1.8441	1.0636	0.16 \pm 0.08
PUFA ^d		3.8837	1.1115	0.0011	0.29 \pm 0.08
AI ^e		0.0329	0.0004	0.0028	0.01 \pm 0.06
Iodine value ^f		12.8441	4.3329	0.0008	0.34 \pm 0.11

^aAll estimates obtained from a 2-trait model which included IMF and each individual trait in order to account for selection (Meyer, 1989).

^bSFA = Total saturated fatty acids

^cMUFA = Total monounsaturated fatty acids

^dPUFA = Total polyunsaturated fatty acids

^eAI = Atherogenic index calculated as (C12:0+4×C14:0+C16:0)/(Σ MUFA+ Σ PUFA).

^fIodine Value =

(C16:1n7*0.95)+((C18:1n9+18:1n7)*0.86)+(C18:2n6*1.732)+((C18:3n3+C18:3n6)*2.616)+(C20:1*0.785)+(C22:1*0.723)

Table 10. Genetic (r_G) and phenotypic (r_P) correlations between individual saturated fatty acids and intramuscular fat, composition traits, meat quality, and eating quality traits in pigs from a selection project after seven generations of selection for intramuscular fat in Duroc swine.^a

Trait	C12:0		C14:0		C15:0		C16:0		C17:0		C18:0		SFA	
	r_G	r_P	r_G	r_P	r_G	r_P	r_G	r_P	r_G	r_P	r_G	r_P	r_G	r_P
Intramuscular fat, (%)	-0.17	-0.07	0.50	0.10	-0.57	-0.27	0.65	0.05	-0.61	-0.21	0.22	0.21	0.40	0.08
Tenth-rib backfat, (mm)	-0.02	-0.01	0.20	0.09	-0.23	-0.09	0.15	0.14	-0.18	-0.09	-0.25	0.81	0.01	0.16
Loin muscle area, (cm ²)	0.16	0.01	-0.10	-0.07	0.44	0.10	-0.24	-0.09	0.47	0.14	0.03	0.24	-0.12	-0.13
48 h pH	0.29	0.05	0.43	0.04	-0.21	-0.07	0.19	-0.01	-0.06	-0.10	0.19	0.08	0.09	0.00
Cook loss, (%)	-0.18	0.06	-0.17	0.09	0.00	-0.05	-0.05	0.01	-0.21	-0.03	0.02	0.01	-0.10	-0.01
Flavor score ^b	0.07	-0.01	0.53	0.06	-0.07	-0.14	0.34	-0.01	-0.41	-0.11	0.20	0.15	0.26	0.04
Off-flavor score ^b	-0.20	-0.06	-0.69	-0.11	0.08	0.09	-0.36	-0.09	0.25	0.06	0.01	0.06	-0.15	-0.07

^aGenetic correlation estimates that differ more than $1.96 \times SE$ from zero ($P < 0.05$) are presented in bold.

^bTrained sensory panel evaluations of flavor (1= little pork flavor, bland; 10 = extremely flavorful, abundant pork flavor), off-flavor (1 = no off-flavor; 10 = abundant non-pork flavor)

Table 11. Genetic (r_G) and phenotypic (r_P) correlations between individual unsaturated fatty acids and intramuscular fat, composition traits, meat quality, and eating quality traits in pigs from a selection project after seven generations of selection for intramuscular fat in Duroc swine.^a

Trait	C16:1		C18:1		C18:2		C18:3n3		MUFA		PUFA	
	r_G	r_P	r_G	r_P	r_G	r_P	r_G	r_P	r_G	r_P	r_G	r_P
Intramuscular fat	0.32	0.10	-0.18	0.14	-0.80	-0.51	0.01	0.11	0.27	0.27	-0.84	-0.49
Tenth-rib backfat, (mm)	0.35	0.12	0.51	0.07	-0.62	-0.42	-0.09	-0.05	0.77	0.79	-0.73	-0.41
Loin muscle area, (cm ²)	-0.02	-0.05	-0.66	-0.05	0.75	0.33	0.00	0.01	-0.70	0.30	0.78	0.31
48 h pH	-0.35	-0.03	-0.66	0.06	-0.04	-0.11	-0.14	0.00	-0.26	0.04	-0.07	-0.08
Cook loss, (%)	0.37	0.12	0.76	0.03	-0.18	-0.07	0.24	0.01	0.39	0.93	-0.18	-0.08
Flavor score ^b	0.04	0.07	-0.65	0.04	-0.40	-0.22	-0.41	0.04	0.00	0.29	-0.41	-0.20
Off-flavor score ^b	-0.39	-0.14	0.81	-0.01	0.09	0.21	0.33	0.01	0.19	0.30	0.18	0.20

^aThe genetic correlation estimates that differ more than $1.96 \times SE$ from zero ($P < 0.05$) are presented in bold.

^bTrained sensory panel evaluations of flavor (1= little pork flavor, bland; 10 = extremely flavorful, abundant pork flavor), off-flavor (1 = no off-flavor; 10 = abundant non-pork flavor)