Phenotypic correlations of backfat thickness with meatiness traits, intramuscular fat, *longissimus* muscle cholesterol and fatty acid composition in pigs

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Abstract

The aim of the present study was to determine the phenotypic correlations of backfat thickness with meatiness traits and intramuscular fat, cholesterol and fatty acid composition in the *longissimus* muscle of pigs. For this study, 60 barrows and 60 gilts (Pietrain × Duroc boars and Polish Large White crossbred sows) were slaughtered at 100 kg bodyweight. Lean meat percentage (LMP), loin muscle area (LMA), backfat thickness measured at five locations and average backfat thickness (ABF), and intramuscular fat (IMF), cholesterol (CHLM) and fatty acid composition in the *longissimus* muscle were determined. Phenotypic correlations of individual backfat thickness measured at five locations and ABF with LMP, LMA and polyunsaturated fatty acids (PUFAs), including C18 :2n-6, were negative and moderate to high, while with monounsaturated fatty acids (MUFAs), including C16:1 and C18:1 were positive and very low. Correlations of individual backfat thickness and ABF with saturated fatty acids (SFAs) and C16:0 were positive (0.29 to 0.56), while for C18:0 were low (0.10 to 0.23). Correlations of IMF and CHLM with LMP, LMA and PUFAs, especially C18:2n-6, were negative and high, while with SFAs and MUFAs were positive and moderate to high. Correlation between IMF and CHLM was high (0.74). The results of the present study indicate that increased IMF content results a significant decrease in carcass meatiness (LMP and LMA) and of PUFAs content and an increase in backfat thickness and contents of SFAs, MUFAs and CHLM.

Keywords: Intramuscular chemical compositions, muscle, MUFA, PUFA, swine
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Introduction

Intramuscular fat (IMF) content and fatty acid composition in pig meat have received considerable interest in view of their implications for human health (Williams, 2000) and for meat quality characteristics (Wood *et al*., 2003). Intramuscular fat content is an important parameter that influences the sensory characteristics of fresh pork (Fernandez *et al*., 1999). It has a positive effect on flavour, juiciness, tenderness/firmness and overall acceptability (Fortin *et al*., 2005; Gao & Zhao, 2009; Schwab *et al*., 2009). Some authors consider that levels of 2.5% to 3% IMF are required to ensure a desirable quality of fresh pork (De Vol *et al*., 1988), while other studies have reported positive relationship between IMF and sensory traits up to 3.5% IMF (Fernandez *et al*., 1999). Currently, IMF levels in the majority of modern commercial breeds have decreased below 1.5% (Gjerlaug-Enger *et al*., 2010; Hamill *et al*., 2012). This is largely owing to long-term intensive genetic selection for lean growth and decreased backfat thickness (Sonesson *et al*., 1998).

The genetic and phenotypic correlations between subcutaneous backfat depth and IMF content show moderate positive values (Newcom *et al*., 2005). This indicates that reductions in carcass fatness are likely to be accompanied by lower intramuscular fat levels in meat. Variation in fat content in meat has an effect on fatty acid composition (De Smet *et al*., 2004), since fat deposition is determined by *de novo* fatty acid synthesis and the uptake of exogenous fatty acids supplied by the diet (Kloareg *et al*., 2007). Meat of pigs with a higher intramuscular fat content has a higher level of saturated fatty acids (SFA) and monounsaturated fatty acids (MUFA), and a lower level of polyunsaturated fatty acids (PUFA) (Rauw *et al*., 2012).

The aim of the present study was to determine the phenotypic correlations of individual subcutaneous backfat thickness with meatiness traits and intramuscular fat, cholesterol and fatty acid composition in the *longissimus* muscle of pigs.

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Materials and Methods

A total of 120 crossbred pigs (Pietrain × Duroc boars and Polish Large White sows), comprising 60 gilts and 60 barrows, were used in this study. The animals were housed in 20 pens (six pigs per pen). Feed was supplied ad libitum, and water was provided by nipple drinkers.

In the fattening period (30 ± 3.1 - 100 ± 4.2 kg body weight), animals were fed a grower diet (from 30 to 60 kg bodyweight) and a finisher diet (from 60 to 100 kg body weight). The ingredient composition and nutrient contents of the diets are given in Table 1.

Table1 Ingredient composition and nutrient contents of the grower and finisher diets

Item	Grower (30 - 60 kg)	Finisher (60 – 100 kg)
Ingredients (g/kg)		
Barley	350	150
Triticale	226	428
Wheat	150	150
Wheat bran	50	100
Soybean meal	120	54
Rapeseed meal	60	90
Soybean oil	15	-
Mineral, vitamin and amino acid premix[1]	29	29
Nutrients (g/kg; analysed results)		
Metabolizable energy (MJ/kg)[2]	12.8	12.6
Crude protein	177	156
Crude fibre	32.0	32.9
Crude fat	32.4	21.4
Crude ash	53.4	38.6
Lysine	9.4	7.7
Methionine and cystine	6.1	5.1
Threonine	6.6	5.4
Calcium	7.3	5.3
Phosphorus	5.9	4.5

[1] Premix supplied the following per kg diet: Mn, 60 mg; Zn, 130 mg; Cu, 25 mg; I, 0.5 mg; Se, 0.3 mg; Fe, 85 mg; vitamin A, 9000 IU; vitamin D_3, 1000 IU; vitamin E, 87.5 mg; vitamin K, 2 mg; vitamin B_{12}, 25 µg; biotin, 25 µg; niacin, 20 mg; folic acid, 1 mg; choline chloride, 125 mg; pantothenic acid, 20 mg; lysine, 2.4 mg; methionine, 0.6 mg; threonine, 1.1 mg.
[2] Calculated from Polish Norms for Pig Nutrition (1993).

Animals were slaughtered at 100 ± 4.2 kg bodyweight. Carcass evaluation was conducted according to the Polish Pig Testing Station's methodology (Różycki & Tyra, 2010). After chilling at 4 ºC for 24 h, the carcasses were weighed and the right half-carcass was measured. Subcutaneous backfat thickness was measured by Vernier calliper to the nearest 0.1 cm, at five locations: at the thickest point over the shoulder (BFOS), on the back between the last thoracic and first lumbar vertebrae (BFB), at three points on the sacrum – above the rostral edge (BFS I), above the middle (BFS II) and above the caudal edge of the gluteal muscle section (BFS III). These measurements were used to calculate average backfat thickness (ABF) from 5 measurements. Next, the right half-carcasses were dissected and the components were weighed and measured. The height and width of the *longissimus* muscle at the last rib were measured by Vernier calliper. The loin muscle area (LMA) was determined by the height × width × 0.8, and meat content was calculated as follows (Różycki & Tyra, 2010):

$$y = 1.745x_1 + 0.836x_2 + 0.157x_3 – 1.884$$

where y is weight of meat of right half-carcass (kg); x_1 is weight of fatless ham (kg); x_2 is weight of *longissimus* muscle (kg); and x_3 is double width + height of *longissimus* muscle (cm). The weight of the meat of the half-carcass was used to calculate the lean meat percentage in the carcass (LMP). The samples (300 g) of the *longissimus* muscle were taken from the right half-carcass, in the region of the last rib. Samples were minced, vacuum packed and stored at −20 ºC, pending analysis of IMF, fatty acids and cholesterol concentrations.

The basic chemical composition in the diet was determined by standard methods (AOAC, 2006), while amino acids in the diet were assayed with the Beckman 6300 Amino Acid Analyser (Beckman Instruments, Palo Alto, Calif, USA). Phosphorus was determined via the vanadium-molybdenum colorimetric method (Cavell, 1955) and calcium by emission spectrometry on BUCK Scientific's 210 VGP Atomic Emission Spectrophotometer.

Intramuscular fat content in the *longissimus* muscle was determined by the Soxhlet extraction method (AOAC, 2006). The fatty acid composition in the lipid extracts was determined by gas chromatography after transesterification using a solution of 14% boron trifluoride (BF_3) in methanol. The fatty acid analysis was performed on a Hewlett Packard GC 5890 series II gas chromatograph. Total cholesterol content in the muscle was determined through the methods of Rhee *et al*. (1982).

Basic statistical characteristics of the results in this arithmetic means (Mean), standard error of means (SEM) and correlation coefficients, including significance (*P*), were calculated using statistical computational software (Statistica PL, version 8.0).

Results and Discussion

Descriptive statistics for intramuscular fat and cholesterol in the *longissimus* muscle and slaughter traits of the pigs are shown in Table 2. The values presented in Table 2 are characterized by great variability. The lean meat percentage of pigs in this study ranged from 51.0% to 62.4% (mean 56.6%), while ABF ranged from 1.72 cm to 2.95 cm (mean 2.28 cm). These values are representative of the commercial pig population. In this study, the average IMF content of the *longissimus* muscle was 2.5% (ranging from 1.73% to 4.14%). This content is in the range of values (2.5% - 3.5%) that has been indicated as being sufficient to provide meat with the marbling characteristics appreciated by the consumers and to improve the sensory aspects of meat quality (De Vol *et al*., 1988; Fernandez *et al*., 1999). Hwang *et al*. (2005) and Kim *et al*. (2008) found the average IMF content in the range of 2% - 3% in the *longissimus* muscle of commercial pig breeds. This value is consistent with the results of our study.

Table 2 Descriptive statistics for intramuscular fat and cholesterol in *longissimus* muscle and slaughter traits of the pigs[3] (n = 120)

Traits[1]	Mean	SEM[2]	Min	Max
LMP (%)	56.6	0.39	51.0	62.4
BFOS (cm)	3.3	0.04	2.39	3.96
BFB (cm)	2.1	0.05	1.05	3.01
BFS I (cm)	2.4	0.06	1.10	3.51
BFS II (cm)	1.4	0.04	0.65	2.53
BFS III (cm)	2.2	0.06	1.14	3.23
ABF (cm)	2.3	0.04	1.72	2.95
LMA (cm^2)	49.1	0.69	38.5	61.4
CHLM (mg/100 g)	60.0	0.57	50.0	70.0
IMF (%)	2.5	0.07	1.73	4.14

[1] Traits: LMP: lean meat percentage; BFOS: backfat thickness over the shoulder; BFB: backfat thickness between the last thoracic and first lumbar vertebrae; BFS I: backfat thickness above the rostral edge; BFS II: backfat thickness above the middle; BFS III: backfat thickness above the caudal edge; ABF: average backfat thickness from five measurements; LMA: loin muscle area; CHLM: cholesterol in *longissimus* muscle; IMF: intramuscular fat in *longissimus* muscle.
[2] SEM: standard error of mean.
[3] Animals were slaughtered at 100 ± 4.2 kg of bodyweight.

Table 3 Descriptive statistics for fatty acid composition (% of total fatty acids) of *longissimus* muscle of the pigs (n = 120)

Fatty acid	Mean	SEM[4]	Min	Max
C14:0	1.3	0.01	1.14	1.57
C16:0	23.5	0.11	21.5	25.3
C18:0	11.6	0.09	10.0	13.4
C20:0	0.5	0.01	0.02	0.89
SFAs[1]	37.0	0.17	34.0	40.7
C16:1	4.7	0.04	3.81	5.54
C18:1	44.6	0.17	41.5	48.2
C20:1	1.2	0.03	0.71	1.87
MUFAs[2]	50.5	0.17	46.8	53.4
C18:2n-6	9.5	0.16	6.94	11.98
C20:2	0.4	0.01	0.01	0.81
C18:3n-3	0.6	0.01	0.27	0.94
C18:3n-6	0.3	0.02	0.05	0.62
C20:3	0.3	0.01	0.07	0.56
C20:4n-6	1.1	0.04	0.44	1.97
PUFAs[3]	12.1	0.22	8.41	15.68

[1] SFAs: saturated fatty acids; [2] MUFAs: monounsaturated fatty acids; [3] PUFAs: polyunsaturated fatty acids.
[4] SEM: standard error of the mean.

The content of fatty acids in the IMF of *longissimus* muscle of the pigs was variable (Table 3, SEM). The *longissimus* muscle fat contained about 62.5% unsaturated fatty acids. The mean MUFAs content was 50.5% (range = 46.8% to 53.4%), while PUFAs was 12.13% (range = 8.41% to 15.68%). Similar values were reported by Kim *et al*. (2008).

Phenotypic correlations (Table 4) of subcutaneous backfat thickness measured at five locations (BFOS, BFB, BFS I, BFS II BFS III) and ABF with LMP and LMA were negative (−0.48 to −0.69; P <0.01, and −0.37 to −0.57; P <0.01, respectively). Bahelka *et al*. (2007) found that the correlation between ABF and LMP was −0.50, which is substantially smaller than in our study (−0.69). Also, the phenotypic correlations between the three individual subcutaneous backfat layers and LMA reported by Newcom *et al*. (2005) were considerably smaller (−0.18 to −0.23) than in the present study.

Correlations between backfat thickness and CHLM were positive and differed (P <0.01) from zero, except for BFS I and BFS II with CHLM. Correlations of five individual subcutaneous backfat thickness and ABF with IMF were 0.32 to 0.50 (P <0.01), respectively. Newcom *et al*. (2005) and Yang *et al*. (2010) reported smaller correlations between the individual subcutaneous backfat layers and IMF (0.26 to 0.34). The value for the correlation between ABF and IMF reported by Bahelka *et al*. (2007) (0.33) is also substantially smaller than that observed in the present study (0.49). Substantially greater correlations of individual backfat layers at the 10th rib (outer, middle, and inner) with IMF for Duroc-sired pigs (0.66, 0.76 and 0.71, respectively) were reported by Eggert (1998). Newcom *et al*. (2005) suggested that the contradictory results may be because of differences in the populations of pigs that were studied (pure bred vs. cross bred pigs), measurement methods and the mean values of these traits.

Correlations of CHLM and IMF with LMP and LMA were negative and high (P <0.01). Eggert (1998) and Newcom *et al*. (2005) reported smaller correlations between IMF and LMA (−0.56 and −0.22, respectively, vs. −0.72 in our study). Bahelka *et al*. (2007) reported a correlation between IMF and LMP of −0.53, which is smaller than −0.71 obtained in our study. Loin muscle area is an indicator of lean meat content in a pig carcass; thus, the correlation between IMF and LMP can have a value similar to that between IMF and LMA, which was observed in the present study.

The results of the present study indicate that genetic selection for increased IMF content can result in a decrease in carcass meatiness and an increase in backfat thickness. Schwab *et al*. (2009) showed that long-term selection for intramuscular fat in Duroc pigs yielded decreased loin muscle area and increased

Table 4 Phenotypic correlations of backfat thickness, cholesterol and intramuscular fat in *longissimus* muscle with lean meat percentage, loin muscle area, cholesterol, intramuscular fat in *longissimus* muscle and major fatty acid composition of intramuscular fat

Item[1]	BFOS	BFB	BFS I	BFS II	BFS III	ABF	CHLM	IMF
LMP	−0.67**	−0.52**	−0.51**	−0.64**	−0.48**	−0.69**	−0.68**	−0.71**
LMA	−0.49**	−0.39**	−0.39**	−0.57**	−0.37**	−0.54**	−0.65**	−0.72**
CHLM	0.33**	0.37**	0.19	0.44**	0.15	0.33**	-	0.74**
IMF	0.37**	0.50**	0.33**	0.49**	0.32**	0.49**	0.74**	-
C16:0	0.52**	0.55**	0.36**	0.56**	0.34**	0.55**	0.36**	0.50**
C18:0	0.23	0.22	0.10	0.23	0.12	0.22	0.16	0.20
SFAs	0.51**	0.48**	0.30*	0.53**	0.29*	0.47**	0.33**	0.44**
C16:1	0.04	0.15	0.14	0,13	0.16	0.17	0.36**	0.31**
C18:1	0.09	0.15	0.11	0.05	0.02	0.11	0.53**	0.38**
MUFAs	0.07	0.18	0.15	0.09	0.07	0.15	0.54**	0.43**
C18:2n-6	−0.44**	−0.46**	−0.29*	−0.41**	−0.27*	−0.41**	−0.70**	−0.65**
C20:2	−0.33**	−0.26*	−0.24*	−0.30**	−0.27*	−0.37**	−0.42**	−0.44**
C18:3n-3	−0.31**	−0.28*	−0.25*	−0.29*	−0.23*	−0.24*	−0.41**	−0.40**
C18:3n-6	−0.28*	−0.18	−0.16	−0.32**	−0.24*	−0.32**	−0.58**	−0.50**
C20:3	−0.47**	−0.40**	−0.35**	−0.46**	−0.28*	−0.51**	−0.51**	−0.52**
C20:4n-6	−0.36**	−0.43**	−0.34**	−0.45**	−0.27*	−0.44**	−0.63**	−0.60**
PUFAs	−0.46**	−0.47**	−0.33**	−0.46**	0.30**	−0.47**	−0.73**	−0.68**

[1] BFOS: backfat thickness over the shoulder; BFB: backfat thickness between the last thoracic and first lumbar vertebrae; BFS I: backfat thickness above the rostral edge; BFS II: backfat thickness above the middle; BFS III: backfat thickness above the caudal edge; ABF: average backfat thickness from five measurements; CHLM: cholesterol in *longissimus* muscle; IMF: intramuscular fat in *longissimus* muscle; LMP: lean meat percentage; LMA: loin muscle area; SFAs: saturated fatty acids; MUFAs: monounsaturated fatty acids; PUFAs: polyunsaturated fatty acids.
* P <0.05; ** P <0.01.

backfat thickness. De Vries *et al*. (1994) reported that increasing the lean meat content of pig carcasses by 1% is associated with a reduction in IMF content by 0.07%. In this study, higher content of IMF was associated with a higher content of CHLM (r = 0.74; P <0.01). A previous study Dorado *et al*. (1999) showed a significantly high relationship between IMF content and cholesterol levels (r = 0.88). In contrast, Rauw *et al*. (2012) reported a comparatively low correlation (0.10) between IMF and CHLM.

A greater ratio of SFA to PUFA improves most aspects of meat quality, particularly pork flavour, although this may have a negative effect on the nutritional value of the meat (Teye *et al*., 2006). Increased intake of SFA is associated with obesity, increased plasma cholesterol and cardiovascular diseases in humans (Chizzolini *et al*., 1999). Increased palmitic acid (C16:0) is one of the main risk factors for these diseases, whereas stearic acid (C18:0) has little to no benefit to human health (Bonanome & Grundy, 1988). Thus, an increase in the proportion of C18:0 in pork would be preferred in view of human health and pork palatability. Our study has shown that a decrease in percentages of SFAs, especially C16:0 in the *longissimus* muscle, was associated with significantly smaller carcass fatness and a lower content of IMF and CHLM, while there were low correlations between C18:0 and BF (from 0.10 to 0.23), IMF (0.20) and CHLM (0.16). Phenotypic correlations of SFAs and C16:0 with BF ranged from 0.29 to 0.53 (P <0.05 and P <0.01), and 0.34 to 0.56 (P <0.01), respectively. Correlations of SFAs and C16:0 with IMF and CHLM were 0.44 and 0.50 (P <0.01), and 0.33 and 0.36 (P <0.01), respectively. Similar tendencies of phenotypic correlations of C16:0 and C18:0 with BF were confirmed by Suzuki *et al*. (2006) and Yang *et al*. (2010), while correlations of SFAs, C16:0 and C18:0 with IMF were confirmed in the studies of Yang *et al*. (2010) and Rauw *et al*. (2012).

Correlations of MUFAs, including C16:1 and C18:1 with BF, were positive and very low, while those with CHLM and IMF were significant (P <0.01; r = 0.54, 0.36 and 0.53, and 0.43, 0.31 and 0.38, respectively). Similar correlations between C18:1 and BF have been reported by other authors (Cameron *et al*., 1990; Piedrafita *et al*. 2001). Suzuki *et al*. (2006) found that the phenotypic correlations of BF and IMF with C16:1

and C18:1 were almost zero (−0.02 to 0.07). Correlations between MUFAs and IMF reported by Yang *et al*. (2010) and Rauw *et al*. (2012) were 0.42 and 0.47, respectively, which are similar to the estimated correlations in the present study.

The results presented in Table 4 indicate that pigs with greater fat deposition tended to have smaller percentages of PUFAs in the *longissimus* muscle, as in the results of Cameron & Enser (1991). Correlations of PUFAs and individual PUFAs with all backfat were negative and moderate and were similar to the values reported by Yang *et al*. (2010). The main PUFA is C18:2n-6 (9.5%; Table 3), which is an essential fatty acid in mammalian nutrition. Suzuki *et al*. (2006) found a moderate negative correlation between C18:2n-6 in LM and BF (−0.43), and similar correlations were estimated in our study. Also, Wood *et al*. (2008) reported that the proportions of C18:2n-6 decline in LM as fat deposition increases. A greater content of PUFAs in the meat is beneficial from a human health aspect, but poses increased risk for its shelf life owing to oxidative stability of fat (Wood & Enser, 1997; Martin *et al*., 2008).

In the present study, the LM with a greater content of IMF contains less PUFAs. Intramuscular fat content was negatively correlated with PUFAs and individual PUFA (from −0.40 to −0.68; P <0.01). Yang *et al*. (2010) and Rauw *et al*. (2012) found high negative correlations of IMF with PUFAs and C18:2n-6 (−0.54 and −0.52, and −0.48 and −0.48, respectively), although these were smaller than in the present study (−0.68 and −0.65; P <0.01, respectively). Negative relationships of CHLM in the LM with PUFAs and individual PUFA (r = −0.41 to −0.73; P <0.01) were estimated in this study. In contrast, Rauw *et al*. (2012) reported almost zero correlations between CHLM and all fatty acids (PUFA, MUFA and SFA).

Conclusions

The results of the present study indicate that increased IMF content results in a significant decrease in carcass meatiness (LMP and LMA) and of PUFAs content, and an increase in backfat thickness and contents of SFAs, MUFAs and CHLM**.** Intramuscular fat content in pork is receiving greater attention in breeding programmes owing to its role in the sensory aspects of meat quality. A minimal level of IMF is required to maintain the overall acceptance of meat by consumers. However, further increases in the content of IFM may have negative health implications.

References

AOAC, 2006. Official Methods of Analysis (18th ed.). Association of Official Analytical Chemists. Washington, D.C., USA.

Bahelka, I., Hanusová, E., Peškovičová, D. & Demo, P., 2007. The effect of sex and slaughter weight on intramuscular fat content and its relationship to carcass traits of pigs. Czech J. Anim. Sci. 52, 122-129.

Bonanome, A. & Grundy S., 1988. Effect of dietary stearic acid on plasma cholesterol and lipoprotein concentrations. N. Engl. J. Med. 318, 1244-1248.

Cameron, N.D. & Enser, M.B., 1991. Fatty-acid composition of lipid in longissimus dorsi muscle of Duroc and British landrace pigs and its relationship with eating quality. Meat Sci. 29, 295-307.

Cameron, N.D., Warris, P.D., Porter, S.J. & Enser, M.B., 1990. Comparison of Duroc and British Landrace pigs for meat and eating quality. Meat Sci. 27, 227-247.

Cavell, A.J., 1955. The colorimetric determination of phosphorus in plant materials. J. Sci. Food Agric. 6, 479-481.

Chizzolini, R., Zanardi, E., Dorigoni, V. & Ghidini, S., 1999. Calorific value and cholesterol content of normal and low-fat meat and meat products. Trends Food Sci. Technol. 10, 119-128.

De Smet, S., Raes, K. & Demeyer, D., 2004. Meat fatty acid composition as affected by fatness and genetic factors: A review. Anim. Res. 53, 81-98.

De Vol, D.L., McKeith, F.K., Bechtel, P.J., Novakofski, J., Shanks, R.D. & Carr, T.R., 1988. Variation in composition and palatability traits and relationships between muscle characteristics and palatability in a random sample of pork carcasses. J. Anim. Sci. 66, 385-395.

De Vries, A.G., Van der Wal, P.G., Long, T., Eikelenboom, G. & Merks, J.W.M., 1994. Genetic parameters of pork Yorkshire populations. Livest. Prod. Sci. 40, 277-289.

Dorado, M., Martin Gomez, E.M., Jimenez-Colmenero, F. & Masoud, T.A., 1999. Cholestrol and fat contents of spanish commercial pork cuts. Meat Sci. 51, 321-323.

Eggert, J.M., 1998. Growth and characterization of individual backfat layers and their relationship with longissimus intramuscular fat. PhD dissertation, Purdue University, West Lafayette, IN.

Fernandez, X., Monin, G., Talmant, A., Mourot, J. & Lebret, B., 1999. Influence of intramuscular fat content on the quality of pig meat - 2. Consumer acceptability of m. *longissimus* lumborum. Meat Sci. 53, 67-72.

Fortin, A., Robertson, W.M. & Tong, A.K.W., 2005. The eating quality of Canadian pork and its relationship with intramuscular fat. Meat Sci. 69, 297-305.

Gao, S.Z. & Zhao, S.M., 2009. Physiology, affecting factors and strategies for control of pig meat intramuscular fat. Recent Pat. Food Nutr. Agric. 1, 59-74.

Gjerlaug-Enger, E., Aass, L., Odegard, J. & Vangen, O., 2010. Genetic parameters of meat quality traits in two pig breeds measured by rapid methods. Animal 4, 1832-1843.

Hamill, R.M., McBryan, J., McGee, C., Mullen, A.M., Sweeney, T., Talbot, A., Cairns, M.T. & Davey, G.C., 2012. Functional analysis of muscle gene expression profiles associated with tenderness and intramuscular fat content in pork. Meat Sci. 4, 440-450.

Hwang, I.H., Park, B.Y., Kim, J.H., Cho, S.H. & Lee, J.M., 2005. Assessment of postmortem proteolysis by gel-based proteome analysis and its relationship to meat quality traits in pig longissimus. Meat Sci. 69, 79-91.

Kim, J.H., Seong, P.N., Cho, S.H., Park, B.Y., Hah, K.H., Yu, L.L.H., Lim, D., Hwang, I.H., Kim, D.H., Lee, J.M. & Ahn, C.N., 2008. Characterization of nutritional value for twenty-one pork muscles. Asian-Aust. J. Anim. Sci. 21, 138-143.

Kloareg, M., Noblet, J. & Milgen, J., 2007. Deposition of dietary fatty acids, de novo synthesis and anatomical partitioning of fatty acids in finishing pigs. Br. J. Nutr. 97, 35-44.

Martin, D., Muriel, E., Antequera, T., Perez-Palacios, T. & Ruiz, J., 2008. Fatty acid composition and oxidative susceptibility of fresh loin and liver from pigs fed conjugated linoleic acid in combination with monounsaturated fatty acids. Food Chem. 108, 86-96.

Newcom, D.W., Baas, T.J., Schwab, C.R. & Stalder, K.J., 2005. Genetic and phenotypic relationships between individual subcutaneous backfat layers and percentage of longissimus intramuscular fat in Duroc swine. J. Anim. Sci. 83, 316-323.

Piedrafita, J., Christian, L.L. & Lonergan, S.M., 2001. Fatty acid profiles in three stress genotypes of swine and relationships with performance, carcass and meat quality traits. Meat Sci. 57, 71-77.

Polish Norm of Pig Nutrition, 1993. Institute of Animal Physiology and Nutrition. Omnitech Press, Warsaw, Poland.

Rauw, W.M., Diaz, I., Frances, F., Corella, D., Soler, J., Tibau, J. & Gomez-Raya, L., 2012. The relationship between feed intake behaviour with intramuscular fat, cholesterol and fatty acid composition in pork. J. Anim. Breed. Genet. 129, 289-297.

Rhee, K.S., Dutson, T.R., Smith, G.C., Hostetler, R.L. & Reiser, R., 1982. Effects of changes in intramuscular and subcutaneous fat level on cholesterol content of raw and cooked beef steaks. J. Anim. Sci. 47, 716-719.

Różycki, M. & Tyra, M., 2010. Methodology for tested fattening and slaughter value at Pig Testing Station. IZ PIB, Krakow, Poland XXVIII, 93-117.

Schwab, C.R., Baas, T.J., Stalder, K.J. & Nettleton, D., 2009. Results from six generations of selection for intramuscular fat in Duroc swine using real-time ultrasound. I. Direct and correlated phenotypic responses to selection. J. Anim. Sci. 87, 2774-2780.

Sonesson, A.K., de Greef, K.H. & Meuwissen, T.H.E., 1998. Genetic parameters and trends of meat quality, carcass composition and performance traits in two selected lines of Large White pigs. Livest. Prod. Sci. 7, 23-32.

Suzuki, K., Ishida, M., Kadowaki, H., Shibata, T., Uchida, H. & Nishida, A., 2006. Genetic correlations among fatty acid compositions in different sites of fat tissues, meat production, and meat quality traits in Duroc pigs. J. Anim. Sci. 84, 2026-2034.

Teye, G.A., Sheard, P.R, Whittington, F.M., Nute, G.R., Stewart, A. & Wood, J.D., 2006. Influence of dietary oils and protein level on pork quality. 1. Effects on muscle fatty acid composition, carcass, meat and eating quality. Meat Sci. 73, 157-165.

Williams, C.M., 2000. Dietary fatty acids and human health. Ann. Zootech. 49, 165-180.

Wood, J.D. & Enser, M., 1997. Factors influencing fatty acids in meat and the role of antioxidants in improving meat quality. Br. J. Nutr. 78 (Supp. 1), 49-60.

Wood, J.D., Richardson, R.I., Nute, G.R., Fisher, A.V., Campo, M.M., Kasapidou, E., Sheard, P.R. & Enser, M., 2003. Effects of fatty acids on meat quality: A review. Meat Sci. 66, 21-32.

Wood, J.D., Enser, M., Fisher, A.V., Nute, G.R., Sheard, P.R., Richardson, R.I., Hughes, S.I. & Whittington, F.M., 2008. Fat deposition, fatty acid composition and meat quality: A review. Meat Sci. 78, 343-358.

Yang, K.X., Ma, J.W., Guo, Y.M., Guo, T.F., Zhao, Y.G., Ding, N.S., Betti, M., Plastow, G.S. & Huang, L.S., 2010. Correlations between fat depot traits and fatty acid composition in abdominal subcutaneous adipose tissue and longissimus muscle: Results from a White Duroc × Erhualian intercross F_2 population. J. Anim. Sci. 88, 3538-3545.