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THE RELATION BETWEEN INTRAMUSCULAR FAT LEVEL IN THE *LONGISSIMUS* MUSCLE AND THE QUALITY OF PIG CARCASSES AND MEAT*

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Abstract

This study evaluated the effect of intramuscular fat (IMF) content on the quality of pig carcass and meat. One hundred and twenty right half-carcasses of crossbred pigs (Pietrain × Duroc boars and Polish Large White × Polish Landrace sows) from a commercial farm were divided into two groups depending on the content of IMF in the *longissimus* muscle (LM): LIMF – lower content (mean 2.05% IMF; 28 gilts and 30 barrows) and HIMF – higher content (mean 3.08% IMF; 32 gilts and 30 barrows) were used. Pigs with a higher IMF content in LM (HIMF group) had a significantly lower (P≤0.01) percentage of lean meat in carcass, loin muscle area, level of polyunsaturated fatty acids (PUFAs) and PUFAs/SFAs ratio, whereas backfat thickness, content of cholesterol in LM, levels of saturated fatty acids (SFAs) and monounsaturated fatty acids (MUFAs) were significantly greater (P≤0.01) than those in pigs with lower IMF content (LIMF group).

Key words: pigs, intramuscular fat, meat quality, carcass traits

Pig selection over the last few decades has mainly focused on increased lean meat production, however, one result has been a decrease in quality. One of the most important traits influencing the sensory characteristics of fresh pork is intramuscular fat (IMF) content (Verbeke et al., 1999). This has a positive effect on flavour, juiciness, tenderness/firmness and overall acceptability of pork (Fortin et al., 2005; Schwab et al., 2009). Because lean meat content and IMF content are negatively correlated (Eggert, 1998; Newcom et al., 2005; Bahelka et al., 2007) the selection for increased lean efficiency has led to a decrease in IMF to levels below those recommended. Currently, IMF levels in the majority of modern commercial breeds have decreased below 1.5% (Gjerlaug-Enger et al., 2010; Hamill et al., 2012) while ensuring desirable fresh pork levels of 2 to 3%, which are required (DeVol et al., 1988).

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Currently, improving overall consumer satisfaction and healthfulness of pork is one of the most important goals for pork producers. Schwab et al. (2009) have shown that long-term selection for increased IMF content in Duroc pigs improved the sensory characteristics of meat, but resulted in a significant reduction in loin muscle area and backfat thickness increase. A variation in fat content affected fatty acid composition, independent of species, breed and dietary factors (De Smet et al., 2004). The meat of pigs with a higher IMF content has higher levels of saturated fatty acids (SFAs) and monounsaturated fatty acids (MUFAs), and lower levels of polyunsaturated fatty acids (PUFAs) (Burkett, 2009; Yang et al., 2010; Rauw et al., 2012). The fatty acid composition of muscle affects the quality and nutritional value of meat (Wood et al., 2008). Increased SFA content has a positive effect on the firmness and oxidative stability of meat (Teye et al., 2006), but negatively affects human health (Chizzolini et al., 1999). Dietary SFAs are related to an increased risk of coronary heart disease, whereas replacing SFAs with unsaturated fatty acids has been shown as effective in lowering the risk (Hu et al., 2001). Pork flavour has been positively correlated with a concentration of MUFAs (Cameron et al., 2000). In contrast, a greater content of PUFAs has a negative impact on pork flavour (Wood and Enser, 1997; Martin et al., 2008).

The aim of this study was to evaluate the effect of IMF content on carcass traits (percentage of lean meat, loin muscle area, subcutaneous backfat thickness) and pig meat quality (cholesterol, fatty acid composition and pH).

Material and methods

Materials

The study material consisted of the right half-carcasses of 120 pigs (60 gilts and 60 barrows) of the same genetic origin (Pietrain × Duroc boars and Polish Large White × Polish Landrace sows) from a commercial farm. The pig carcasses were divided into two groups, depending on the content of IMF in LM: LIMF – lower content (1.76–2.31%) and HIMF – higher content (2.33–4.32%), to determine its effect on carcass and meat quality. The LIMF group contained 28 gilts and 30 barrows, and HIMF group was made up of 32 gilts and 30 barrows.

Animals and feeding

The animals used in this study were housed in twenty pens (six pigs per pen). Fattening was carried out on a larger group of pigs (192) with an equal sex ratio. After slaughter, only the carcasses with intramuscular fat content in *longissimus* muscle in the range of 1.76–2.31% and 2.33–4.32% were chosen from this group of animals, taking into account a similar share of gilts and barrows in individual ranges. Feed was supplied *ad libitum*, and water was provided by nipple drinkers.

In the fattening period (30±3.4–100±5.3 kg body weight), animals were fed a grower diet (from 30 to 60 kg body weight) and a finisher diet (from 60 to100 kg body weight). The ingredients and nutrient contents of the diets are given in Table 1.

Table 1. Ingredients and nutrient contents of grower and finisher diets

Item	Grower (30 to 60 kg)	Finisher (60 to 100 kg)
Ingredients (g/kg)		
barley	212	170
wheat	320	320
rye	159	279.3
maize	80	-
wheat bran	-	60
soybean meal, CP 47%	190	140
rapeseed oil	5	5
dicalcium phosphate	1	0.7
premix[1]	30	25
acidifier	3	-
Nutrients (g/kg; analysis results)		
metabolizable energy (MJ /kg)[2]	13.2	13.0
crude protein	175	157
crude fibre	32.7	35.7
lysine	9.8	8.2
methionine + cystine	6.5	5.6
threonine	7.0	5.8
tryptophan	2.1	1.8
Ca	6.9	6.0
P	5.9	4.9

[1]The premix supplied the following per kg diet: vitamin A – 8000 IU; vitamin D_3 – 1000 IU; vitamin E – 60 mg; vitamin K_3 – 2 mg; vitamin B_1 – 2 mg; vitamin B_2 – 4 mg; vitamin B_6 – 4 mg; vitamin B_{12} – 25 µg; biotin – 100 µg; pantothenic acid – 10 mg; niacin – 20 mg; folic acid – 400 µg; choline chloride – 600 mg; Fe – 80 mg; Mg – 400 mg; Mn – 40 mg; Zn – 100 mg; Cu – 10 mg; I – 0.8 mg; Co – 0.4 mg, Se – 0.3 mg, lysine – 2.4 g; methionine – 0.6 g; threonine – 1.1 g.

[2]Calculated from Polish Pig Feeding Standards (1993).

Carcass measurements

Animals were slaughtered at a body weight of 100±5.3kg. Carcass evaluation was conducted according to Polish Pig Testing Station methodology (Różycki and Tyra, 2010). After 24-h chilling at 4°C, the carcasses were weighed and the right half was measured. pH measurements were taken in the LM (between the last thoracic vertebra and first lumbar vertebra) 45 min (pH_{45}) and 24 h (pH_{24}) after slaughter using a Matthäus, pH-Star CPU (Matthäus, Pöttmes, Germany) pH-meter with a glass electrode standardized for pH 4.6 and 7.0.

Subcutaneous backfat thickness was measured by a calliper to the nearest 0.1 cm, at five locations: at the thickest point over the shoulder (BFTOS), on the back over the joint between last thoracic and first lumbar vertebrae (BFTB), and at three points over the edge of the cross-sectional area of the gluteus muscle (loin region): the rostral part (BFTLI), middle part (BFTLII) and caudal part (BFTLIII). These measurements were used to calculate average backfat thickness from 5 measurements (ABFT). Next, the right half-carcasses were dissected and then these dissected components were weighed and measured. The height and width of LM at the

last rib were measured by calliper. The loin muscle area (LMA) was determined by the height × width × 0.8. Backfat thickness at point C1 (BFTC1) was measured on a vertical line extending from the height of the loin eye muscle. The cuts obtained (loin and ham) were dissected into tissues to estimate carcass meat percentage, based on a regression equation calculated according to the testing station method (Różycki and Tyra, 2010). The weight of the half-carcass meat was used to calculate the lean meat percentage in carcass (LMP).

The samples of LM (between the last thoracic and first lumbar vertebra) were taken from the right half-carcass. Samples were minced, vacuum-packed and stored at –20ºC until analysis was made of IMF and fatty acids.

Chemical analyses

The basic chemical composition of the diet was determined by standard methods (AOAC, 2006) and amino acids using the Beckman 6300 Amino Acid Analyser (Beckman Instruments, Palo Alto, CA, USA). Phosphorus was determined by the vanadium-molybdenum colorimetric method (Cavell, 1955), calcium measured by the emission spectrometry method on a Buck Scientific 210 VGP Atomic Absorption Spectrophotometer. The IMF content in LM was determined by means of Soxhlet apparatus according to the Weibull and Stoldt method (AOAC, 1997). Fatty acids composition in the lipid extracts was determined with the use of a gas chromatography method after transesterification using a solution of 14% boron trifluoride (BF_3) in methanol. A fatty acid analysis was performed on a Hewlett Packard GC 5890, series II gas chromatograph. Muscle cholesterol content (CHLM) was determined according to Rhee et al. (1982).

Statistical analysis

The results are presented as least squares means ± standard error of the mean (SEM). The data were subjected to a one-way analysis of variance (ANOVA). The statistical model used in the calculations was as follows:

$$Y_{ijk} = \mu + a_i + b_j + e_{ijk}$$

where:

Y_{ijk} – ijk^{th} observation,
μ – overall mean,
a_i – IMF group effect,
b_j – sex effect,
e_{ijk} – random effect.

The significance of difference (P) between means was determined by using paired t-tests. Correlation coefficients, including significance (P), between IMF content and traits of carcass and meat quality in IMF groups were calculated. Statistical data analysis was carried out using Statistica computational software (Statistica PL, version 10).

Results

The effects of IMF on carcass traits of pigs have been presented in Table 2. The mean IMF content in LM in the HIMF group was 1.03% (P≤0.01) higher than in the LIMF group. Pigs with a higher IMF content in LM (HIMF group) had lower LMP (by 3.85%; P≤0.01) and LMA (by 7.48 cm^2; P≤0.01), whereas backfat thickness measured at five locations, ABFT and BFTC1 were greater (from 0.31 to 0.52 cm; P≤0.01) compared to pigs with a lower IMF content (LIMF group).

The LM of pigs with a higher content of IMF (HIMF group) contained significantly more cholesterol in LM (CHLM) (by 5.78 mg/100 g; P≤0.01) compared to the LM of pigs from the LIMF group (Table 2). The values of pH_{45} and pH_{24} (measured 45 min and 24 h postmortem, respectively) in LM were similar in both groups of pigs, regardless of IMF content.

Table 2. Least squares means and respective standard errors (SEM) for carcass traits, the contents of IMF and CHLM, and pH_{45} and pH_{24} in the LM of both groups

Item[2]	IMF groups[1]				HIMF – LIMF
	LIMF (n= 59)		HIMF (n= 61)		
	mean	SEM	mean	SEM	
IMF(%)	2.05	0.03	3.08	0.09	1.03**
LMP (%)	58.63	0.72	54.79	0.55	–3.85**
LMA (cm^2)	52.73	0.83	45.24	0.69	–7.48**
BFTOS (cm)	3.33	0.06	3.64	0.05	0.31**
BFTB (cm)	2.01	0.06	2.44	0.06	0.43**
BFTLI (cm)	2. 15	0.08	2.59	0.06	0.44**
BFTLII (cm)	1.40	0.05	1.73	0.06	0.33**
BFTL III (cm)	2.13	0.08	2.49	0.08	0.36**
ABFT (cm)	2.25	0.05	2.62	0.06	0.37**
BFTC1 (cm)	1.43	0.04	1.95	0.05	0.52**
CHLM (mg/100 g)	58.92	0.49	64.70	0.78	5.78**
pH_{45}	6.23	0.05	6.44	0.04	0.21
pH_{24}	5.46	0.02	5.48	0.01	0.02

[1]IMF groups: LIMF – lower (1.76≤2.31) and HIMF – higher (2.33≤4.32) IMF content in LM.

[2]IMF – intramuscular fat; LMP – lean meat percentage; LMA – loin muscle area; BFT – backfat thickness: OS – over the shoulder (at the thickest point), B – on the back between the last thoracic and first lumbar vertebrae, at three points over the edge of the cross-sectional area of the gluteus muscle (loin region): the rostral part (LI), middle part (LII) and caudal part (LIII); ABFT – average backfat thickness from five measurements; BFTC1 – backfat thickness at point C1 (at a vertical line extending from the height of the loin muscle); CHLM – cholesterol in LM; IMF – intramuscular fat in LM; pH_{45} and pH_{24} – 45 min and 24 h postmortem, respectively.

*P≤0.05; **P≤0.01.

The least square means for fatty acid composition in the LM of pigs by IMF groups have been presented in Table 3. The LM of pigs from the HIMF group had a greater content of SFAs (P≤0.01), including C14:0 and C16:0 (P≤0.01), and a smaller content of C18:0 and C20:0 than pigs from the LIMF group (not statistically confirmed). The muscles of pigs with a higher content of IMF (HIMF group) had

more MUFAs (P≤0.01), including C16:1 (P≤0.05) and C18:1 (P≤0.01) than the pigs of LIMF group. Pigs with a higher IMF content in the LM (HIMF group) had a significantly (P≤0.01) lower level of PUFAs, including C18:2*n-6* and C18:3*n-3* (P≤0.01 and P≤0.05, respectively) and had a smaller ratio of C18:2*n-6*/C18:3*n-3* compared to pigs in the LIMF group. The PUFAs/SFAs ratio was significantly (P≤0.01) lower and *n-6/n-3* ratio slightly (non-significantly) lower in the HIMF than LIMF group.

Table 3. The least squares means and respective standard errors (SEM) for fatty acid composition (% of total fatty acids) in the LM of pigs by IMF groups

Fatty acids[1]	IMF groups				HIMF –LIMF
	LIMF (n=59)		HIMF (n=61)		
	mean	SEM	mean	SEM	
C14:0	1.29	0.01	1.43	0.02	0.14**
C16:0	23.23	0.13	25.93	0.12	2.8**
C18:0	11.47	0.12	10.99	0.14	–0.48
C20:0	0.19	0.01	0.17	0.02	–0.02
SFAs	36.12	0.21	38.52	0.23	2.42**
C16:1	3.48	0.06	3.70	0.05	0.22*
C18:1	41.66	0.24	43.77	0.22	2.14**
C20:1	0.69	0.02	0.66	0.04	–0.03
MUFAs	45.87	0.23	48.13	0.19	2.28**
C18:2*n-6*	12.67	0.17	10.30	0.16	–2.30**
C20:2*n-6*	0.45	0.02	0.44	0.02	–0.01
C18:3*n-3*	0.77	0.01	0.68	0.02	0.09*
C18:3*n-6*	0.37	0.02	0.36	0.03	–0.01
C20:3*n-6*	0.39	0.02	0.26	0.01	–0.13**
C20:4*n-6*	1.24	0.05	0.91	0.05	–0.33**
C20:5*n-3*	0.19	0.01	0.15	0.01	–0.04**
PUFAs	16.15	0.24	13.10	0.25	–3.05**
n-6/n-3	15.75	0.17	14.79	0.16	0.95
PUFAs/SFAs	0.44	0.01	0.35	0.01	–0.09**

[1]Fatty acids: SFAs – saturated fatty acids (C14:0 + C16:0 + C18:0 + C20:0); MUFAs – monounsaturated fatty acids (C16:1 + C18:1 + C20:1); PUFAs – polyunsaturated fatty acids C18:2*n-6* + C20:2*n-6* + C18:3*n-3* + C18:3*n-6* + C20:3*n-6* + C20:4*n-6* + C20:5*n-3*).

*P≤0.05; ** P≤0.01.

Correlations of IMF content in the LM of all pigs with LMP and LMA were negative and high (P≤0.01), positive and high (P≤0.01) with CHLM and BFTC1, positive and moderate (P≤0.05) with ABFT, and nearly zero with pH_{45} and pH_{24} (Table 4). Similar relationships were found in both IMF groups, however, lower correlation values in the LIMF than in the HIMF groups were observed.

Correlation coefficients between IMF and the major fatty acids in the *longissimus* muscle of pigs are presented in Table 5. Correlations between IMF in the LM of all pigs used in this study and SFAs, including the C16:0, and MUFAs, including the C16:1 and C18:1 were positive and moderate (0.31; P≤0.05 to 0.43; P≤0.01), whereas between IMF and PUFAs or individual PUFA were negative and moderate to high (–0.28; P≤0.05 to –0.61; P≤0.01). Similar correlation tendencies between IMF and

SFA, MUFA and PUFA were observed in the LIMF and HIMF groups of pigs, but greater correlations (positive or negative) were noted in the HIMF group. Selection for an increase in the intramuscular fat content, will result in an increase in the content of MUFAs and a lower level of desired PUFAs. It has been well established that increasing the IMF content will have a positive effect on the sensory characteristics of meat. However, the estimated correlation between the content of IMF and selected features in the HIMF and LIMF groups indicate that an increase of IMF above 2.3% has a more negative affect on carcass traits, cholesterol content and fatty acid profile.

Table 4. Correlation coefficients between IMF content and selected traits

Traits[1]	Total (n=120)	IMF – groups	
		LIMF (n=59)	HIMF (n=61)
LMP	–0.61**	–0.43**	–0.55**
LMA	–0.64**	–0.55**	–0.64**
ABFT	0.31*	0.22	0.33*
BFTC1	0.55**	0.34*	0.48**
CHLM	0.62**	0.45**	0.57**
pH_{45}	0.15	0.13	0.24
pH_{24}	–0.03	–0.02	–0.06

[1]For abbreviations see Table 2.
*P≤0.05; **P≤0.01.

Table 5. Correlation coefficients between IMF content and the major fatty acids in the LM of pigs

Fatty acids[1]	Total (n=120)	IMF groups	
		LIMF (n=59)	HIMF (n=61)
C16:0	0.43**	0.26	0.35*
C18:0	0.20	0.23	0.25
SFAs	0.34**	0.25	0.35*
C16:1	0.31*	0.18	0.26
C18:1	0.38**	0.28*	0.37**
MUFAs	0.43**	0.29*	0.39**
C18:2*n-6*	–0.58**	–0.31*	–0.46**
C20:2*n-6*	–0.28*	–0.24	–0.27*
C18:3*n-3*	–0.35**	–0.26	–0.32*
C20:4*n-6*	–0.60**	–0.45**	–0.52**
PUFAs	–0.61**	–0.43**	–0.54**

[1]For abbreviations see Table 3.
*P≤0.05; **P≤0.01.

Discussion

The average IMF content in the groups of pigs under study (LIMF and HIMF) was in a lower and upper range of values, respectively (2–3%). The content of IMF

at this level is sufficient to provide marbling meat appreciated by consumers and improve the sensory aspects of meat quality (DeVol et al., 1988). However, Tyra and Żak (2010) observed that the level of IMF in the two most popular breeds in Poland (Polish Large White and Polish Landrace) was below the acceptable level for good quality meat (1.84% and 1.76%, respectively).

In this study, pigs with a higher IMF content in LM had significantly lower LMP and LMA, whereas backfat thickness was significantly greater compared to pigs with a lower IMF content. Burkett (2009) found that long-term selection for IMF increased its content (by 1.66%) in LM of pigs, but resulted in a significant decrease in LMA and LMP ($P \leq 0.001$) and an increase in backfat thickness ($P \leq 0.001$). Similarly, Schwab et al. (2009) reported that the selection of Duroc pigs for 6 generations increased IMF by 88% (4.53% in selected line vs 2.41% in control line). In addition, pigs of a selected line had smaller loin muscle area (by 7.43 cm^2) and significantly greater backfat thickness measured at the 10th rib compared with the control line. These results are consistent with the results of our study. Other studies have also shown that increasing the content of IMF in LM of pigs was accompanied by a decrease of LMP (Bahelka et al., 2007) and LMA (Eggert, 1998; Newcom et al., 2005), but an increase in backfat thickness (Newcom et al., 2005; Bahelka et al., 2007; Yang et al., 2010).

The results of our study showed that the meat of pigs with higher IMF content had much more CHLM. Dorado et al. (1999) revealed a high positive correlation ($r=0.88$) between IMF content and cholesterol levels. In contrast, Rauw et al. (2012) reported a low correlation between IMF and CHLM ($r=0.10$). The cholesterol intake in meat is positively related with plasma cholesterol levels in humans (Sacks et al., 1981), and these levels are thought to be implicated in the occurrence of coronary artery disease (Djoussé and Gaziano, 2009). Therefore, it is necessary to decrease cholesterol content in animal products.

In our study we observed a small and insignificant relationship between IMF content and pH value in LM of pigs, with similar results being reported by Sellier (1998). Also, other authors found no significant relationship between pH measured at 24 h, 48 h and 7 d postmortem and IMF content in the LM of pigs (Schwab et al., 2006; Burkett, 2009).

In the present study, the muscles of pigs with a higher IMF content had higher levels of SFAs, including C14:0 and C16:0, and a lower content of C18:0 and C20:0 than muscles with a lower IMF content. Similar tendencies were confirmed in a study carried out by Rauw et al. (2012). An increased intake of SFA is associated with obesity, increased plasma cholesterol, and cardiovascular diseases in humans (Chizzolini et al., 1999). The greatest risk factor for these diseases is an increase in the content of C14:0 and C16:0, whereas C18:0 has little to no detrimental effect on human health (Bonanome and Grundy, 1988).

We found that the muscles of pigs with a higher content of IMF had more MUFAs, including C16:1 and C18:1, which is consistent with the results of Burkett (2009), Yang et al. (2010) and Rauw et al. (2012). The concentration of MUFA, C16:1 and C18:1 have been positively correlated with pork flavour, flavour preference, and overall acceptability (Cameron et al., 2000). Furthermore, MUFA have beneficial

effects on human health (Rudel et al., 1995), however, an increase in MUFA, especially C18:1, is associated with increased fat deposition (Yang et al., 2010).

The results presented in our study showed that pigs with greater IMF content in muscles had smaller percentages of PUFAs and a smaller ratio of C18:2*n-6*/C18:3*n-3* than those with lower IMF content, which is consistent with the results of Burkett (2009) and Yang et al. (2010). A greater content of PUFAs in meat is beneficial from the point of view of human health, but poses an increased risk for shelf life due to the low oxidative stability of the fat (Wood and Enser, 1997; Martin et al., 2008). De Smet et al. (2004) reported that, for a given diet, the C18:2*n-6*/C18:3*n-3* ratio in very lean meat will be higher than in meat with a higher fat level, which is consistent with our results. In the present study, the *n-6/n-3* ratio was slightly lower in the LIMF than in the HIMF group, but in both groups *n-6/n-3* values were very high. Nutritional recommendations for a healthy diet suggest that the ratio of *n-6* to *n-3* should be 4.0 or lower (Department of Health, 1994), whereas today this ratio is about 20–30:1, which indicates that human diets are deficient in n-3 fatty acids (Simopoulos, 1999).

The content of PUFA increases with fatness, as do SFA and MUFA, but at a slower rate, resulting in a decreased proportion of PUFA and a decrease in the PUFAs/SFAs ratio (De Smet et al., 2004). In the present study, LM with a higher IMF had a higher level of SFAs and MUFAs, a lower level of PUFAs and consequently a lower PUFAs/SFAs ratio, which was lower than the recommended 0.4 and over (Wood et al., 2003).

The results of our study indicate that a genetic selection for increased IMF content can result in a decrease in carcass meatiness (LMP and LMA) and an increase in backfat thickness. High negative correlations between IMF and LMP were also found by Bahelka et al. (2007) and Eggert (1998). Newcom et al. (2005), Bahelka et al. (2007) and Yang et al. (2010) reported a correlation between IMF and subcutaneous backfat thickness in the range of 0.26 to 0.33, which confirms our own data.

Our study has shown positive moderate relationships of IMF with SFAs and MUFAs, and negative moderate to high with PUFAs. This indicates that increasing IMF results in an unfavourable fatty acid profile for consumption. Correlations between IMF and SFA, MUFA and PUFA noted in our study are comparable to the values estimated by other authors (Yang et al., 2010; Rauw et al., 2012).

Conclusions

The selection of pigs for increased IMF is receiving greater attention in breeding programs due to its the positive effect on the sensory characteristics of meat. A minimal level of IMF is required to maintain the overall acceptance of meat by consumers, however, further increase may have negative health implications. The results of this study indicate that an increase of IMF above 2% (indicated minimum level) caused a significant decrease in carcass meatiness (LMP and LMA), an increase in backfat thickness and content of CHLM and unfavourable fatty acid profile for consumption (higher levels of SFAs and MUFAs, lower level of PUFA and lower ratio of PUFAs/SFAs).

References

AOAC (1997). Official Methods of Analysis of AOAC International (16th ed.). AOAC Official Method 991.36, Fat (Crude) in Meats and Meat Products, AOAC International, Gaithersburg, MD, (Chapter 39).

AOAC (2006). Official Methods of Analysis (18th ed.). Gaithersburg, MD: Association of Official Analytical Chemists.

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.

Burkett J.L. (2009). The effect of selection for intramuscular fat on fatty acid composition in Duroc pigs. Graduate Theses and Dissertations. Iowa State University.

Cameron N.D., Enser M., Nute G.R., Whittington F.M., Penman J.C., Fisken A.C., Perry A.M., Wood J.D. (2000). Genotype with nutrition interaction on fatty acid composition of intramuscular fat and the relationship with flavour in pig meat. Meat Sci., 55: 157–195.

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.

Department of Health (1994). Nutritional aspects of cardiovascular disease. Report on health and social subjects no. 46. Her Majesty's Stationery Office Publ., London, UK.

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.

DeVol 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.

Djoussé L., Gaziano J.M. (2009). Dietary cholesterol and coronary artery disease: a systematic review. Curr. Atheroscler. Rep., 11: 418–422.

Dorado M., Martín Gómez E.M., Jiménez-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. Ph.D. Thesis, Purdue University Univ., West Lafayette, IN.

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.

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.

Hu F.B., Manson J.E., Willett W.C. (2001). Types of dietary fat and risk of coronary heart disease: a review. J. Am. Coll. Nutr., 20: 5–19.

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.

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 (in Polish). IZ PIB, Kraków, XXVIII: 93–117.

Rudel L.L., Park J.S., Sawyer J.K. (1995). Compared with dietary monounsaturated and saturated fat, polyunsaturated fat protects African green monkeys from coronary artery atherosclerosis. Arterioscler. Thromb. Vasc. Biol., 15: 2101–2110.

Sacks F.M., Donner A., Castelli W.P., Gronemeyer J., Pletka P., Margolius H.S., Landsberg L., Kass E.H. (1981). Effects of ingestion of meat on plasma cholesterol of vegetarians. JAMA, 246: 640–644.

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.

Sellier P. (1998). Genetics of meat and carcass traits. In: The Genetics of the Pig, Rothschild M.F., Ruvinsky A. (eds). CAB International, New York, pp. 463–510.

Simopoulos A.P. (1999). Essential fatty acids in health and chronic disease. Am. J. Clin. Nutr., 70: 560–569.

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.

Tyra M., Żak G. (2010). Characteristics of the Polish breeding population of pigs in terms of intramuscular fat (IMF) content of m. *longissimus* dorsi. Ann. Anim. Sci., 10: 241–248.

Verbeke W., Van Oeckel M.J., Warnants N., Viaene J., Boucque C.V. (1999). Consumer perceptions, facts and possibilities to improve acceptability of health and sensory characteristics of pork. Meat Sci., 53: 77–99.

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.

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