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LEVEL OF FATTY ACIDS, SELECTED QUALITY TRAITS OF *LONGISSIMUS DORSI* AND *SEMIMEMBRANOSUS* MUSCLES AND THEIR RELATIONSHIP WITH FATTENING AND SLAUGHTER PERFORMANCE IN POLISH LANDRACE PIGS*

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Abstract

The aim of this study was to perform a comprehensive analysis of the level of fatty acids and selected meat quality traits, as well as their association with fattening and slaughter performance in Polish Landrace pigs. The study was conducted for two muscles: *musculus longissimus dorsi* and *musculus semimembranosus*. The study used 100 Polish Landrace gilts. The experimental animals originated from nucleus farms located in Poland. Their parents were animals with a known status of the RYR1 genotype (all animals were dominant homozygotes). Pigs were fattened, slaughtered and evaluated postmortem in piggeries of the Experimental Stations of the National Research Institute of Animal Production using test station procedures. After reaching 100 kg body weight, pigs were slaughtered and their half-carcasses dissected. Fattening and slaughter parameters were determined. Meat samples were analysed for crude fat using the Soxhlet method. The composition of higher fatty acids was determined by gas chromatography. Research results indicate that saturated fatty acids found in *m. longissimus dorsi* and *m. semimembranosus* were positively correlated to *n-3* and *n-6* PUFA. A similarly high correlation was observed between the level of UFA and *n-6* and *n-3* PUFA in the loin and ham. The fact that the proportions of some acids (e.g. *n-6/n-3* PUFA) fail to meet WHO standards requires making efforts to improve them. Likewise, selection work is necessary to improve IMF levels in meat. The low correlations between meat quality traits and fattening and slaughter performance suggest that quality parameters should be regarded as independent traits in pig improvement models. In order to limit meat quality traits in pig improvement models, it is necessary to make use of the correlations between them.

Key words: pigs, fatty acids, meat quality, slaughter performance

Polish Landrace is the main breed of pigs raised in Poland, accounting for 50% of the breeding population. In addition to Polish Large White, the pigs of this breed are predominantly used as female parents in breeding programmes. The consider-

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able contribution of these breeds to pork production requires paying attention to the quality traits represented by these genotypes, because they are important for the meat industry and the consumers. In the light of current knowledge, there is justification for incorporating the most important parameters of meat quality into the evaluation of genetic merit of the active pig population in Poland. From the viewpoint of health-promoting, culinary and technological properties, it is justified to investigate the content and composition of fats, and the stability of lipid oxidation products in pork to determine the risk of their consumption and to improve the taste of this type of meat. Finding the relationships between quality traits of pork and between these traits and slaughter performance of pigs will make it possible to modify breeding work methods aimed at improving the quality of raw material obtained from pigs while maintaining optimum slaughter performance. When discussing the quality parameters of pig meat, it is essential to recognize the importance of intramuscular fat (IMF) content, which is an important characteristic from a consumer perspective. Being one of the principal indicators of culinary meat quality, it is accounted for in breeding programmes in many European Union countries. This indicator is positively correlated to many other traits of meat quality (Wood et al., 1994; Tyra and Żak, 2013). It should be noted that intramuscular fat content of meat, the optimum level of which is most often considered to range from 2.5% to 3% (Florowski et al., 2007), largely determines the taste qualities of meat. In addition to the IMF content of pork, which has a high economic weight in the breeding programmes used in many countries, there are several quality traits that determine the technological suitability of the raw material and are, therefore, important for the meat industry. These include pH value, water holding capacity, colour, electrical conductivity (EC), and drip loss of meat (Melody et al., 2004; Bee et al., 2007). Aside from the meat quality parameters mentioned above, a significant role in shaping the sensory and technological traits is played by the content of individual fatty acids. According to FAO/WHO recommendations, the human diet should have an *n-6/n-3* fatty acid ratio of 5:1. In pork fat, the optimum composition of fatty acids is characteristic of stearic acid (C18:0) at a level of at least 12%, while the total content of linoleic (C18:2) and linolenic (C18:3) acids should not exceed 15% (Migdał and Pieszka, 2007). The level of stearic (C18:0) and linoleic acids (C18:2) is strictly related to meat tenderness, firmness and juiciness. Extensive research conducted to determine the effect of fatty acid composition on meat taste has shown that this trait correlates positively with saturated and monounsaturated fatty acids, and negatively with unsaturated fatty acids (Wood et al., 1994; Jacyno et al., 2002). It can therefore be stated that polyunsaturated fatty acids are highly desirable from the consumer perspective because they improve the dietetic quality of meat, but their excessive quantities in animal fat have a negative effect on the sensory properties (flavour, aroma) of meat and its storability (Lauridsen and Jakobsen, 1997). Pig meat is characterized by high energy value and considerable content of cholesterol and saturated fatty acids, which, considering its high consumption (approx. 60% of total meat consumption in Poland) may increase the incidence of cardiac and cardiovascular diseases among consumers. Reducing the content of fat and producing a more beneficial composition of fatty acids in intramuscular and intermuscular fat are among the goals of today's pork producers.

The aim of this study was to perform a comprehensive analysis of the level of fatty acids and selected meat quality traits, as well as their association with fattening and slaughter performance in Polish Landrace pigs. The study was conducted for two muscles, i.e. *m. longissimus dorsi* and *m. semimembranosus*.

Material and methods

The study used 100 Polish Landrace (PL) gilts. The experimental animals originated from nucleus farms located in Poland. Their parents were animals with a known status of the RYR1 genotype (all animals were dominant homozygotes). Pigs were fattened, slaughtered and evaluated postmortem in piggeries of the Experimental Stations of the National Research Institute of Animal Production using test station procedures (Różycki, 1996). Fattening performance was tested from 30 kg body weight. Animals were kept in individual pens equipped with nipple drinkers under the same hygienic conditions and fed *ad libitum* two feed mixtures: a complete diet containing 13.50 MJ ME/kg and 180 g CP/kg until 80 kg body weight, and a diet containing 13.00 MJ ME/kg and 170 g CP/kg from 80 to 100 kg body weight. After reaching 100 kg body weight, pigs were slaughtered and their half-carcasses dissected according to the test station methodology (Różycki, 1996). Fattening and slaughter parameters were determined. A sample of approx. 150–200 g meat was collected from *m. longissimus dorsi* over the last 3 thoracic vertebrae to determine IMF levels and water holding capacity. Meat samples were analysed for crude fat using the Soxhlet method (Soxtherm 600, Gerhardt). Water holding capacity was determined by the Grau and Hamm method (1953). To analyse the composition of fatty acids, two meat samples were collected from each experimental animal, one from *m. longissimus dorsi* (from the breast portion – *longissimus thoracis*), and another from ham muscle (*m. semimembranosus*). The samples were immediately preserved and stored at –19°C until analysis. The composition of higher fatty acids was determined by gas chromatography. Samples were extracted with chloroform-methanol (2:1, v/v) according to the method of Folch et al. (1957). Then 1 g of meat samples was mixed with 15 mL chloroform–methanol mixture and homogenized for 10 min at 5000 rpm, and after 5 min pause – 5 min at 1000 rpm using homogenizer MPW-120 (Mechanika Precyzyjna, Warszawa, Poland). The mixture was then filtered through filter paper to the regular cylinder and completed with extraction mixture up to 15 mL. Next, 3 mL of 0.74% KCl solution was added to 15 mL of filtrate. The alcohol–water phase was removed, and the chloroform phase was washed 3 times using 2 mL solution of chloroform:methanol:0.74% KCl (3:48:47, v/v/v). Subsequently the chloroform phase was recovered, dehydrated with anhydrous sodium sulphate (Na_2SO_4) and dried using nitrogen at 45°C. To the sample (about 10 mg) was added 0.5 ml 0.5 N KOH in methanol and heated at 85°C; next, 1 mL 12% BF3 in methanol was added and the sample was again heated at 85°C. After cooling in room temperature 1 mL hexane and 5 mL saturated solution of NaCl were added. Fatty acid methyl esters profile in one µl samples at the split ratio of 10:1 were separated by gas chromatography on a TRACE GC ULTRA gas chromatograph, equipped with 30 m capillary column SUPELCOWAX 10 of 0.25 mm inner diameter and coating thickness of 0.25 µm (30 m × 0.25 mm × 0.25 um). Operating conditions were as follows: helium was used as a carrier gas, flow 1 ml/min, split flow 10 ml/min, injector temperature 220°C, detector temperature 250°C, initial column temperature 160°C. Fatty acid content was expressed as percent of total fatty acids. The results were analysed statistically using one-way analysis of variance (ANOVA) and Tukey's test. Correlations were also estimated between the analysed meat quality parameters and slaughter traits, using Statgraphics Centurion XVI package (2012). The data were tested at P<0.05 and P<0.01 levels of significance. Basic statistical values (mean, $\bar{x}$; standard deviation, SD) were also calculated for individual trait values and given in tables (Żuk, 1989).

Results

Table 1 presents basic characteristics (means, standard deviation) for selected slaughter and fattening parameters, and physicochemical traits of meat.

Table 1. Characteristics of the experimental material

Item	IMF *m.l.d.* (%)	Water holding capacity *m.l.d.* (%)	Mean backfat thickness (cm)	Loin eye area (cm^2)	Carcass meat content (%)	Daily weight gain (30–100 kg) (g)
			n = 100			
$\bar{x}$	1.29	33.30	1.33	55.63	59.54	883.0
SD	0.19	8.38	0.37	4.71	2.80	111.4

Table 2 shows the mean values of individual fatty acids in *longissimus dorsi* and *semimembranosus* muscles, taking into account minimum and maximum values. Among the saturated fatty acids, palmitic (C16:0) and stearic acids (C18:0) predominated (23 and 10%, respectively) in both loin and ham muscle. As regards the level of monounsaturated fatty acids (MUFA), they were significantly higher in *m. longissimus dorsi* compared to *m. semimembranosus* (42.08 vs. 37.05%, P<0.00001) (Table 3). Among the MUFA, significantly higher levels were found in loin vs. ham muscle for oleic acid (C18:1 *n-9*; 33.78 vs. 29.27%; P<0.00001) and eicosenic acid (C20:1; 0.478 vs. 0.424%; P<0.00001). With regard to the polyunsaturated fatty acids (PUFA), they were significantly higher in *m. semimembranosus* (28.03%) compared to *m. longissimus dorsi* (21.83%; P<0.00001). Significantly higher levels of hypercholesterolemic acids (OFA) (C14:0+C16:0) were found in *m. longissimus dorsi* compared to *m. semimembranosus* (25.41 vs. 24.65%; P<0.00001). Different relationships were observed for the content of hypocholesterolemic acids (DFA) (UFA+C18:0), which were significantly higher in ham (75.11%) compared to loin (74.39%) (P<0.00001). Likewise, *n-6* and *n-3* PUFA were significantly higher in ham compared to loin muscle: 25.95 vs. 20.11% (P<0.00001) and 1.60 vs. 1.30% (P<0.00001).

Table 2. Composition of fatty acids in *m. longissimus dorsi (m.l.d.)* and *m. semimembranosus (s.m.)* of PL pigs

Trait	Parameter	*m.l.d.* (n = 100)	*s.m.* (n = 100)
1	2	3	4
C10:0	$\bar{x}$	0.080	0.070
	SD	0.020	0.021
C12:0	$\bar{x}$	0.070	0.060
	SD	0.020	0.018
C14:0	$\bar{x}$	1.037	0.900
	SD	0.200	0.220
C14:1	$\bar{x}$	0.024	0.024
	SD	0.013	0.013
C15:0	$\bar{x}$	0.050	0.060
	SD	0.026	0.023
C16:0	$\bar{x}$	23.85	23.20
	SD	1.050	1.070
C16:1 *n-9*	$\bar{x}$	0.419	0.442
	SD	0.069	0.066
C16:1 *n-7*	$\bar{x}$	2.520	2.210
	SD	0.580	0.630
C17:0	$\bar{x}$	0.183	0.228
	SD	0.050	0.060
C17:1	$\bar{x}$	0.155	0.167
	SD	0.060	0.070
C18:0	$\bar{x}$	10.480	10.020
	SD	0.980	0.770
C18:1 *n-9*	$\bar{x}$	33.780	29.270
	SD	4.750	5.410
C18:1 *n-7*	$\bar{x}$	4.700	4.500
	SD	1.050	0.910
C18:2 *n-6*	$\bar{x}$	16.250	20.570
	SD	4.240	4.760
C18:3 *n-6*	$\bar{x}$	0.103	0.120
	SD	0.050	0.050
C18:3 *n-3*	$\bar{x}$	0.550	0.660
	SD	0.150	0.180
CLA	$\bar{x}$	0.047	0.048
	SD	0.019	0.020
C20:0	$\bar{x}$	0.117	0.096
	SD	0.020	0.020
C20:1	$\bar{x}$	0.474	0.424
	SD	0.112	0.125

Table 2 – contd.

1	2	3	4
C20:2	$\bar{x}$	0.352	0.424
	SD	0.107	0.122
C20:3 *n-6*	$\bar{x}$	0.320	0.421
	SD	0.120	0.141
C20:4 *n-6*	$\bar{x}$	3.050	4.380
	SD	1.360	1.580
C20:5 *n-3*	$\bar{x}$	0.134	0.183
	SD	0.063	0.088
C22:4 *n-6*	$\bar{x}$	0.391	0.454
	SD	0.200	0.160
C22:5 *n-3*	$\bar{x}$	0.480	0.582
	SD	0.210	0.200
C22:6 *n-3*	$\bar{x}$	0.144	0.174
	SD	0.085	0.107
SFA	$\bar{x}$	35.89	34.67
	SD	1.76	1.550
UFA	$\bar{x}$	63.910	65.090
	SD	1.740	1.570
MUFA	$\bar{x}$	42.080	37.050
	SD	5.370	6.270
PUFA	$\bar{x}$	21.830	28.030
	SD	6.100	6.600
PUFA *n-6*	$\bar{x}$	20.110	25.950
	SD	5.730	6.290
PUFA *n-3*	$\bar{x}$	1.310	1.600
	SD	0.380	0.390
DFA	$\bar{x}$	74.390	75.110
	SD	1.160	1.230
OFA	$\bar{x}$	25.410	24.650
	SD	1.180	1.210
UFA/SFA	$\bar{x}$	1.780	1.880
	SD	0.130	0.120
DFA/OFA	$\bar{x}$	2.930	3.050
	SD	0.180	0.190
MUFA/SFA	$\bar{x}$	1.170	1.070
	SD	0.140	0.180
PUFA/SFA	$\bar{x}$	0.614	0.812
	SD	0.190	0.200
PUFA *n-6/n-3*	$\bar{x}$	15.660	16.450
	SD	2.990	3.330

Table 4 shows the coefficients of simple correlation between selected meat quality traits, slaughter and fattening traits, and main groups of fatty acids in *longissimus dorsi* and *semimembranosus* muscles. A significant correlation was found between the level of unsaturated fatty acids (UFA) and water holding capacity of *longissimus dorsi* muscle (P<0.05). For the *semimembranosus* muscle, significant correlations were observed between loin eye area and the level of UFA, as well as highly significant correlations between backfat thickness and the level of *n-3* PUFA (P<0.01). In addition, there were highly significant coefficients of correlation between SFA, UFA, *n-6* PUFA and *n-3* PUFA for their content in both ham and loin muscle (P<0.01).

Table 3. Comparison of the fatty acid profile of *m. longissimus dorsi* and *m. semimembranosus* in PL pigs

Trait	Muscle		SE	P
	m. longissimus dorsi (m.l.d.)	*m. semimembranosus (s.m.)*		
SFA	35.89	34.67	0.114	0.0000
UFA	63.91	65.09	0.113	0.0000
MUFA	42.08	37.05	0.393	0.0000
PUFA	21.83	28.03	0.435	0.0000
PUFA *n-6*	20.11	25.95	0.411	0.0000
PUFA *n-3*	1.31	1.60	0.025	0.0000
DFA	74.39	75.11	0.079	0.0000
OFA	25.41	24.65	0.080	0.0000
UFA/SFA	1.78	1.88	0.008	0.0000
DFA/OFA	2.93	3.05	0.012	0.0000
MUFA/SFA	1.17	1.07	0.010	0.0000
PUFA/SFA	0.61	0.81	0.013	0.0000
PUFA *n-6/n-3*	15.66	16.45	0.206	0.06

Table 4. Simple correlations between selected meat quality traits, slaughter and fattening performance, and main groups of fatty acids *in longissimus dorsi (m.l.d.)* and *semimembranosus* muscles *(s.m.)*

Trait	SFA		UFA		PUFA *n-6*		PUFA *n-3*	
	m.l.d.	*s.m.*	*m.l.d.*	*s.m.*	*m.l.d.*	*s.m.*	*m.l.d.*	*s.m.*
IMF	0.0069	not tested	–0.0019	not tested	–0.0882	not tested	–0.1308	not tested
Water holding capacity	0.2729	not tested	0.2662 *	not tested	–0.2052	not tested	–0.2338	not tested
Backfat thickness	0.0717	0.0914	–0.0712	–0.0976	0.0688	–0.0965	–0.1311	–0.3244 **
Loin eye area	–0.1728	–0.2389	0.1827	0.2761 *	–0.0643	–0.0501	0.1054	0.1745
Carcass meat content	–0.1031	–0.1905	0.1095	0.210	–0.0573	0.1386	–0.0090	0.1141
Daily weight gain	0.0425	–0.0438	–0.0465	0.0409	0.0207	–0.0234	–0.0207	–0.0727
SFA			0.998 **	0.9919 **	–0.6202 **	–0.3943 **	–0.6194 **	–0.4921 **
UFA	0.998 **	0.9919 **			0.6017 **	0.4036 **	0.5955 **	0.5028 **
PUFA *n-6*	–0.6202 **	–0.3943 **	0.6017 **	0.4036 **			0.8234 **	0.6721 **
PUFA *n-3*	–0.6194 **	–0.4924 **	0.5955 **	0.5028 **	0.8234 **	0.6791 **		

Discussion

Pork production has been an important element in the agricultural economy of many countries, including – for many decades – Poland. This is probably due to the many advantages of pig meat and the tradition of its consumption. It is suitable not only as a product intended for direct consumption but also for manufacture of quality cured meats and other processed products. The consumption of pork is high compared to the meat obtained from other animal species. Per capita consumption of pork ranges from 25.1 to 63.0 kg in the member countries of the European Union, and exceeds 40 kg in Poland. The relatively high consumption of pig meat and the annually increasing percentage of the population suffering from cardiac and cardiovascular diseases make it necessary to find ways of producing healthier pork by reducing carcass fatness, changing the chemical composition of fat, adding biologically active substances (e.g. fat-soluble vitamins, conjugated linoleic acid) to fat, and decreasing cholesterol (especially LDL cholesterol) in meat (Migdał et al., 2008). Healthier pork is one with a relatively low content of fat and proper composition of fatty acids, intramuscular and intermuscular fat, in particular the right content and proportion of *n-3* and *n-6* PUFA, and the right PUFA to SFA ratio. The nutritional value of meat and meat products is strictly related to the fat content and lipid composition. Intramuscular fat content is a trait significantly correlated with the sensory properties of meat, namely tenderness, juiciness, and odour profile. Wood (1990) reports that although the coefficients of heritability for IMF and adipose tissue are 0.50 and 0.69, respectively, the genetic correlations between these traits are low ($r_G = 0.11$). This leaves limited opportunity for increasing IMF content in the tissues of high-lean pigs. In the most recent study, Tyra and Żak (2013) estimated the coefficient of correlation between mean backfat thickness and IMF in PL pigs to be $r_G = 0.186$. Novakofski (1987) found that the low level of IMF is unfavourable for the taste of meat. However, the same author holds that IMF levels exceeding the optimum range of 2.5%–3.0% do not guarantee a linear, beneficial effect of improved meat flavour. Other authors concluded that very good scores for meat taste can be given for various IMF levels. Excellent scores can be awarded when IMF level is around 2% in one group of meat samples but also when it is 2.5% in another group of samples. This depends on the range of IMF content represented by the analysed samples, as well as on the effects of breed, age of animals, pre- and post-slaughter conditions, and differences in the sensitivity of panel members (Brewer et al., 2001).

One of the positive effects of increasing the muscle tissue content of pig carcasses is the higher level of *n-6* and *n-3* PUFA, which is due to the fact that these acids are found in cell membranes and thus their muscle tissue content increases in parallel with improvements in the protein to fat ratio (Seewald et al., 1991). Conversely, when the total lipid content of muscle tissue increases, it is paralleled by a considerable decrease in the relative amount of PUFA and a reduction in the PUFA/SFA ratio. This phenomenon likely results from the fact that membrane density decreases with increasing adipose tissue deposition. Fat and fatty acids are important because of their effects on human health. It is essential to choose a pork production strategy that maximizes both the quality and health-promoting benefits of this product (Yang et al., 2010). The *n-6* to *n-3* PUFA ratio is an important determinant of the nutritive value of fat. Its value was similar in both muscles examined (15.66 in loin and 16.45 in ham). Grześkowiak et al. (2010) found similar values to ours for Polish Landrace × Polish Large White pigs. In a study of meat from purebred Polish Landrace pigs, Krzysztoforski et al. (2007) found this indicator to be higher in high-lean compared to low-lean pigs (19.89 vs. 17.31). Studies by other authors, who used different pig genotypes, found greater variations in the *n-6/n-3* PUFA ratio: from 7.2 (Enser et al., 1996) to 20.82 (Lenartowicz and Kulisiewicz, 2000). Another indicator which shows the dietetic qualities of consumed fat is the PUFA/SFA ratio, which FAO/WHO recommends to be at least 0.45. In our study, this ratio was 0.61 in *m. longissimus dorsi* and 0.81 (even more beneficial) in *m. semimembranosus*. The SFA to UFA ratio ranged from 1.78 in loin to 1.88 in ham and was similar to the findings of Krzysztoforski et al. (2007). In a study by Kondracki (2000) with Puławska and Polish Large White pigs, this ratio exceeded 2. It is worth noting that excessive amounts of polyunsaturated fatty acids in intramuscular or depot fat negatively affect the technological and qualitative (mainly sensory) properties of meat. Soft greasy fat compromises the flavour and aroma of meat, reduces its shelf life, and limits its storability. These are the basic problems associated with the increased UFA content of meat fat and meat products. When considering the quality of raw material obtained from fattening pigs slaughtered in Poland and analysing a number of related parameters, it is necessary to note the proportions of traits responsible for sensory and technological properties of meat (Cameron, 1990; Kortz et al., 2003), because they determine the optimum properties of pork that are most desirable for the consumer in terms of health-promoting benefits and taste. It is essential to find the relationships between meat quality traits to avoid situations in which selection for one trait increases or decreases another trait, thus disturbing the optimum balance between the two, and indirectly compromising raw material quality (Cameron, 1990; Cameron et al., 2000).

Due to the expectations of the meat industry to improve the meat content of pig carcasses, breeding work conducted in the second half of the 20th century focused on improving muscling and fattening traits in pigs (Sellier and Monin, 1994). The intensive breeding efforts led to considerable progress in the level of pig meatiness, but this had an adverse influence on many meat quality traits (Koćwin-Podsiadła et al., 1998). This results from a negative correlation between carcass meatiness and meat quality traits. It must be also remembered that increased meatiness contributes to a significant reduction of fat, and, just as importantly, alters the composition of fat in pork carcasses (Sellier and Monin, 1994).

In light of the research and analyses, it is concluded that when designing models for improving the active population of pigs, close attention should be paid to meat quality parameters in the context of its health-promoting and culinary qualities. Research results indicate that saturated fatty acids found in *m. longissimus dorsi* and *m. semimembranosus* were positively correlated to *n-3* and *n-6* PUFA. A similarly high correlation was observed between the level of UFA and *n-6* and *n-3* PUFA in the loin and ham. The fact that the proportions of some acids (e.g. *n-6/n-3* PUFA) fail to meet FAO/WHO standards requires making efforts to improve them. Likewise, selection work is necessary to improve IMF levels in meat. The low correlations between meat quality traits and fattening and slaughter performance suggest that quality parameters should be regarded as independent traits in pig improvement models. In order to limit meat quality traits in pig improvement models, it is necessary to make use of the correlations between them. Selection in breeding pigs should be focused on maintaining high fattening and slaughter performance as well as strong improvement of meat quality traits.

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