PAPER

COMPARISON OF THE FATTY ACID PROFILE IN THE MEAT OF PIGS AND WILD BOARS

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ABSTRACT

The aim of the study was to compare the fatty acid profile of the *longissimus lumborum muscle* from organically raised pigs: 20 samples from Złotnicka Spotted pigs, 20 samples from F_1 crossbred pigs (Polish Large White x Polish Landrace) and 16 samples from wild boar. The content of saturated fatty acids in the meat of animals from all the groups was similar. Statistically significant differences were calculated for monounsaturated fatty acids and polyunsaturated fatty acids. The meat of wild boar had the highest content of arachidonic acid but the lowest content of palmitoleic acid, oleic acid and α-linolenic acid.

Keywords: fatty acid profile, meat, pigs, wild boar

1. INTRODUCTION

Due to its content of many nutrients, meat plays an important role in the human diet. Meat provides our bodies with high value protein, essential amino acids, as well as trace elements, B-group and antioxidant vitamins and fatty acids (FA). The composition of fatty acids, especially the ratio of polyunsaturated fatty acids (PUFA) to saturated fatty acids (SFA), is significant for human health (STRAZDINA *et al*., 2013). According to SERRANO *et al*. (2007), saturated fatty acids are regarded as the cause of cardiovascular diseases, as they increase blood pressure and the concentration of the LDL fraction of cholesterol, while monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) decrease the concentration of bad cholesterol (LDL) and increase the concentration of the good cholesterol (HDL), which results in reducing the risk of heart diseases and atherosclerosis (GARCIA REBOLLO *et al*., 1998; GERHARD *et al*. ,2004).
Compared to beef, pork is characterised by a favourable fatty acid profile, i.e. lower SFA content and higher PUFA content. In comparison with poultry meat, pork (despite a lower total PUFA content) shows a much more beneficial n-6 to n-3 fatty acids ratio (BLICHARSKI *et al*., 2013; IVANOVIĆ *et al*., 2013).
Recently, more and more consumers have been paying attention not only to the quality and safety of food, but also to the environmental aspects of its production. The main regulations regarding organic food production are included in the following legal acts: Council Regulation (EC) No. 834/2007 and Regulation (EC) No. 889/2008. According to these regulations, livestock should be fed with plant feeds and feed produced in accordance with the principles of organic farming. At the same time, the laws take into account the possibility of using additives containing some trace elements, vitamins and minerals (SUNDRUM *et al*., 2000). In organic farms, plant protection products or veterinary medicines should not be used. Organically raised animals are fed diets without synthetic additives and GMO preparations. These requirements undoubtedly affect the quality of the product obtained. The meat quality of domestic animals, which were bred in natural conditions means greater food safety for the consumer (SKOBRÁK *et al*., 2011). According to GRELA and KOWALCZUK (2009), organic meat products derived from fattening pigs are characterised by a higher content of nutrients. Pork obtained from pigs reared in the organic system contains higher amounts of intramuscular fat and more unsaturated fatty acids (ANGOOD *et al*., 2008; SUNDRUM *et al*., 2000; HANSEN *et al*., 2006).
In turn, the main source of feed for wild boar living in their natural habitats is plants (grasses, leaves, roots, shrubs, seeds, forest fruits) and, less frequently, avian eggs, snails, insects, earthworms, larvae and beetles (SKOBRÁK *et al*., 2011; ROŻMAITE *et al*., 2012). Due to the natural environment in which wild animals live, venison is often defined as an organic food.
The aim of the study was to compare the fatty acid profile of the *longissimus lumborum muscle* from organically raised Złotnicka Spotted and F_1 crossbred pigs (Polish Large White × Polish Landrace) and from wild boar.

2. MATERIALS AND METHODS

2.1. Animals

The study used 20 Złotnicka Spotted pigs, 20 F_1 crossbred pigs (Polish Large White × Polish Landrace) and 16 wild boar (hogs and gilts in equal amounts). In each group, the gender ratio of the tested animals was close to 1:1. The pigs originated from an organic

farm in the Kujawsko-Pomorskie province, where they were fed a diet containing 12.6 MJ metabolisable energy and 156 g total protein. The feed was comprised of 25% triticale, 20% rye, 10% barley, 10% wheat, 10% oats, 10% lupin, 5% pea, 5% rapeseed and 5% vitamin-mineral mixture. The piggery m*et al*l the conditions of welfare defined by Polish law (Regulation of the Minister of Agriculture and Rural Development, 2010). At the end of fattening, when Złotnicka Spotted pigs reached 106.2±3.66 kg of body weight (aged 5.5-6 month) and F_1 crosses reached 114.25±2.59 kg (aged 6.5-7 month), the animals were slaughtered under uniform standard production conditions in accordance with Polish law and standards in place. From the right halves of the carcasses, samples of the *longissimus lumborum muscle* were collected (between the 1st and the 4th lumbar vertebra).
In turn, two-year-old wild boar (weighing 38-60 kg on average) were shot in the Podkarpackie province during the hunting season by different hunters, in accordance with Regulation No. 45 and No. 48 of the Minister of the Environment. The samples were removed from the *longissimus lumborum* approximately at the level of the 1-2 lumbar vertebra of the carcasses. Local hunters provided all samples within 24 hours after shooting.

2.2. Samples and fatty acid analysis

For further analyses, samples were placed in sterile, tightly sealed bags, chilled to 4°C and transported to a laboratory. After freeze-drying (Lyovac GT2, Finn-Aqua), the samples were analysed for fatty acids through extraction with a chloroform and methanol solution in accordance with the method described by FOLCH *et al*. (1956). The fatty acid profile of methyl esters was determined by gas chromatography (Varian 3800 GC, USA) with a flame ionisation detector, using a Supelcowax 10 column (30 m × 0.32 mm × 0.25 μm). The temperature of the injector was 230°C, and that of the detector was 250°C. The volume of the injected sample was 1μl (split 1:50). The carrier gas was helium at a flow rate of 1.5 $cm^3 min^{-1}$. The analyses were performed at a temperature range of 90 to 225°C (11°C min^{-1}), 225°C for 6 min, and then an increase from 225 to 240°C (6°C min^{-1}) and 240°C for 19 min. The fatty acid methyl esters were identified with Supelco PUFA-2 Animal Source and Supelco 37 Component Fame Mix standards (Supelco, USA). The composition of fatty acids was expressed as a percentage of total fatty acids.
In addition, the indices of fatty acid metabolism were specified. The elongase index was calculated as the ratio of C18:0 to C16:0. The thioesterase index was calculated as the ratio of C16:0 to myristic acid (C14:0). The 9-desaturase index was calculated as 100 times the ratio of the palmitoleic acid (C16:1) percentage to the sum of acids: C16:1 and C16:0. The 9-desaturase index was calculated as 100 times the ratio of oleic acid (C18:1) to the sum of acids: C18:1 and C18:0 (ZHANG *et al*., 2007).

2.3. Statistical analysis

The results were statistically analysed with Statistica 8.0, and the means and standard deviations are provided in the table. One-way analysis of variance (ANOVA) and the post-hoc Scheffe test were used to compare the proportion of different fatty acids in the *longissimus lumborum muscle* of the animals. The normality of data distribution and the homogeneity of variance were tested with the Shapiro-Wilk and Levene tests, respectively. The correlations between the analysed fatty acids were determined based on the coefficients of Pearson's correlation. Differences were considered significant at $P < 0.05$.

3. RESULTS AND DISCUSSION

The percentage of different fatty acids in the *longissimus lumborum muscle* of the animals, depending on genetic type and species, is presented in Table 1.

Table 1. Fatty acid profile (% of total FA) of fat from the *m. longissimus lumborum* of the studied animals.

	ZS n=20	PLW x PL n=20	WILD BOAR n=16
C14:0	1.02±0.21[a]	1.26±0.27[a]	1.80±0.39[b]
C16:0	26.88±1.48[a,b]	28.22±0.91[a]	25.14±4.21[b]
C18:0	14.91±2.82[a]	13.29±1.60[a]	15.36±0.85[a]
C16:1 n7	3.05±0.45[a]	3.64±0.74[c]	1.30±0.68[b]
C18:1 n9	41.65±2.58[a]	40.76±3.38[a]	31.59±6.17[b]
C18:3 n3	2.09±0.66[a]	2.03±0.59[a]	0.79±0.16[b]
C20:4 n6	10.40±1.87[a]	10.80±2.99[a]	24.01±3.15[b]
SFA	42.81±3.50[a]	42.78±0.95[a]	42.31±3.93[a]
MUFA	44.70±2.81[a]	44.40±3.90[a]	32.90±5.77[b]
PUFA	12.48±2.34[a]	12.83±3.36[a]	24.80±3.10[b]
n3/n6	0.20±0.05[a]	0.19±0.05[a]	0.03±0.01[b]
n6/n3	5.34±1.46[a]	5.62±1.87[a]	32.03±9.89[b]
thioesterase index[1]	27.07±4.35[a]	23.23±4.63[a]	14.88±5.24[b]
elongase index[2]	0.55±0.10[a,b]	0.47±0.07[a]	0.63±0.12[a]
Δ^9 desaturase (C16) index[3]	10.10±1.35[a]	11.35±1.88[a]	4.74±1.95[b]
Δ^9 desaturase (C18) index[4]	73.69±4.48[a]	75.32±3.52[a]	66.79±4.27[b]

Results were expressed as means±SD. Values marked in the same row with different letters (a,b) are statistical significantly different at $P < 0.05$. SFA, MUFA, PUFA, n6, n3 = sum of all saturated (SFA), monounsaturated (MUFA), polyunsaturated (PUFA), n6 and n3 fatty acids, ZS - Złotnicka Spotted pigs, PLW x PL - crossbred pigs (Polish Large White × Polish Landrace), [1]Calculated as 16:0/14:0, [2]Calculated as 18:0/16:0, [3]Calculated as 100 × [16:1n-9/(16:1n-9 + 16:0)], [4]Calculated as 100 × [18:1n-9/(18:1n-9 + 18:0)]

Among saturated fatty acids (SFA), the presence of myristic (C14:0), palmitic (C16:0) and stearic acids (C18:0) was found. Compared to pig muscle, the wild boar muscle had a significantly highest content of C14:0 (approx. 1.8%). In turn, the muscle of PLW x PL crossbreeds contained statistically more C16:0 acid than wild boar muscle (approx. 3.08%). Unlike JANKOWIAK *et al*. (2010), the present statistical analysis showed no significant differences in the content of palmitic acid between the meat of Złotnicka Spotted pigs and F_1 crossbreeds (PLW × PL). Despite the differences in the content of individual fatty acids, the total SFA in the meat of the animals in each group did not exceed 43%. The obtained result was confirmed in the studies of other authors (PETROVIĆ *et al*., 2014; GRELA and KOWALCZUK, 2009).

While SFA content remained at the same level in all the groups, considerable differences occurred in the group of monounsaturated fatty acids (MUFA). The lowest concentration of MUFA was observed in wild boar muscle, in which the content of palmitoleic (C16:1 n7) and oleic acids (C18:1 n9) differed significantly from that determined for the pig muscle from both study groups. Compared to other authors, the content of acids (C16:1 n7 and

C18:1 n9) determined in the present study was very similar, although the content of MUFA was lower by 4.81% for organically raised pigs (GRELA and KOWALCZUK, 2009) and by 3.9% for wild boar (IVANOVIĆ *et al*., 2013). This difference is caused by the presence of additional acids (C18:1 n7).

The highest total PUFA (24.8% of all fatty acids) was determined in wild boar muscle. This value was confirmed in the research of other authors (SALES and KOTRBA, 2008). The high level of these acids translates into an appropriate PUFA/SFA ratio, which, according to WOOD *et al*. (2003), should exceed 0.4. For wild boar muscle, this ratio is 0.5861. The present level was slightly lower than published by DANNENBERGER *et al*. (2013) for wild boar living in the northern part of Germany (0.65÷1.05). In our study, the content of PUFA in wild boar meat was twice as high as the values obtained for the muscles of the pigs from both study groups. Their PUFA level was similar to the values published by CEBULSKA *et al*. (2018), for Złotnicka Spotted pigs, and by GRZEŚKOWIAK *et al*. (2010), who determined the fatty acid profile of the muscle of Polish Landrace × Polish Large White pigs. In the present study, arachidonic acid (C20:4 n6) showed the highest percentage among PUFA. Likely, the high content of C20:4 n6 is due to the absence of C18: 2 n6. This was significantly higher in wild boar muscle compared to pig muscle. Statistical analysis did not reveal significant differences in the content of this acid between the meat from Złotnicka Spotted and PLW × PL pigs. The second determined PUFA acid was α-linolenic acid (C18:3 n3; ALA). The muscles of pigs from both study groups contained similar amounts of this acid, which formed approx. 2% of total fatty acids. In contrast, the wild boar meat was less abundant in this acid (only 0.79%). In comparison with other authors, the ALA acid content determined in our own research was higher. According to PEDRAZZOLI *et al*. (2017), meat of wild boars up to 2 years should contain on average 1.47% of this acid (0.62% more than in the muscle of pigs), while the meat of older wild boars only 0.99% (0.2% more than in the present study).

The ALA (α-linolenic acid, C18: 3 n3) and LA (linoleic; C18: 2 n6) acids supplied with food may undergo enzymatic transformation. Elongase enzymes lengthen carbon chains, and desaturases produce additional double bonds, resulting in the formation of polyunsaturated fatty acids with lengths of at least 20 C atoms (ACHREMOWICZ and SZARY-SWORST, 2005). In fatty acid synthesis, thioesterase is responsible for terminating the reaction and releasing the newly synthesised fatty acid. The thioesterase index (C16:0/C14:0), which indicates a catalysis of palmitic acid synthesis from miristic, was higher ($P < 0.05$) in pig muscle than in wild boar, while the elongase index, as an indicator of C18:0 synthesis from C16:0 (C18:0/C16:0), remained at the same level (0.47-0.63) in all the groups. Δ^9-desaturase catalyses the conversion of C16:0 and C18:0 to C16:1 and C18:1, the 2 major MUFA of pork lipids. Greater index values mean greater desaturase activity. The highest Δ^9-desaturase (C16) and (C18) indexes were found in pig muscle. These results agree with those obtained by DAZA et.al. (2017) and ZHANG *et al*. (2007).

Between the analysed fatty acids, 11 correlations were found for the meat of ZS pigs and 16 correlations for the meat of PLW × PL pigs. Statistically significant relationships recurred between myristic acid and palmitic, palmitoleic and arachidonic acids, between palmitoleic acid and stearic and oleic acids, and between stearic acid and oleic and arachidonic acids (Tables 2-3).

Table 2. Coefficients of correlation (r_{xy}) between fatty acids determined in the *m. longissimus lumborum* of ZS pigs.

C16:0	0.81*					
C16:1	0.56*	0.18				
C18:0	–0.22	0.21	–0.57*			
C18:1	–0.10	–0.45*	0.43*	–0.68*		
C18:3	0.05	–0.16	–0.02	–0.40*	–0.19	
C20:4	–0.44*	–0.56*	–0.19	–0.43*	–0.02	0.64*
	C14:0	C16:0	C16:1	C18:0	C18:1	C18:3

* significant at $P < 0.05$

Table 3. Coefficients of correlation (r_{xy}) between fatty acids determined in the *m. longissimus lumborum* of F_1 crossbred pigs (PLW × PL).

C16:0	0.77*					
C16:1	0.82*	0.66*				
C18:0	–0.81*	–0.77*	–0.95*			
C18:1	0.63*	0.38	0.65*	–0.67*		
C18:3	–0.87*	–0.50	–0.58*	0.57	–0.61*	
C20:4	–0.63*	–0.45	–0.63*	0.64*	–0.98*	0.56
	C14:0	C16:0	C16:1	C18:0	C18:1	C18:3

* significant at $P < 0.05$

Contrary to pig meat, only 5 correlations were found for wild boar meat (Table 4). The only correlation shared by the analysed fatty acids for all study groups was a negative correlation between palmitoleic acid and stearic acid (r= -0.57 for ZS; r= -0.95 for PLW × PL; r= -0.76 for wild boar; $P < 0.05$).

Table 4. Coefficients of correlation (r_{xy}) between fatty acids determined in the *m. longissimus lumborum* of wild boar.

C16:0	–0.15					
C16:1	0.10	0.73*				
C18:0	–0.27	–0.34	–0.76*			
C18:1	0.23	–0.90*	–0.63*	0.29		
C18:3	0.05	0.02	–0.01	0.25	0.10	
C20:4	–0.33	0.38	0.24	–0.20	–0.74*	–0.35
	C14:0	C16:0	C16:1	C18:0	C18:1	C18:3

* significant at $P < 0.05$

To ensure normal function of the human body, it is particularly important to maintain the proper PUFA n6 to PUFA n3 ratio, which should range between 1:1 and 4:1 (SIMOPOULOS, 2002). In both pig groups under study, this ratio was slightly higher (5.3:1

and 5.6:1), while in the case of wild boar muscle, it was by the highest (32.03:1). According to MARCINIAK-ŁUKASIK (2011), excess n6 fatty acids in the diet inhibits the metabolism of n3 fatty acids, which disrupts the physiological balance of the biologically active compounds obtained from them.

4. CONCLUSIONS

Wild boar meat does not differ significantly in SFA content from the meat of organically raised pigs of the ZS breed and F_1 crossbreds (PLW × PL). Statistically significant differences were noted in the MUFA and PUFA content. Wild boar muscle proved the richest in polyunsaturated fatty acids.
The appropriate amounts of individual fatty acids determined in the pig muscles translate into a more health-promoting ratio of n6 to n3 acids. The n6 to n3 fatty acids ratio determined in wild boar muscle was the highest, but the least desirable.

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