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Microstructure of *longissimus lumborum* Muscle in Pigs of several Breeds and Its Relation to Meat Quality Traits

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A total of 190 animals, representing Polish Landrace, Pietrain, Złotniki Spotted pigs and Pietrain (Polish Large White Polish Landrace) crosses were investigated. Samples of *longissimus lumborum* muscle were taken for histological tests and frozen in liquid nitrogen. After microscopic preparations were made, they were subjected to histochemical reactions to identify muscle fibre types differing in metabolism, and to determine the percentage of intramuscular fat and glycogen in the analysed muscle. The analysis of *longissimus lumborum* structure showed that Pietrain pigs had the largest proportion of FTG fibres and the smallest proportion of STO fibres that are the most beneficial in terms of meat quality characteristics. The greatest diameters of all muscle fibre types were in the muscle of Pietrain (Polish Large White Polish Landrace) crosses, which were also found to contain the lowest number of fibres in the muscle cross-section area. The least favourable meat quality traits were shown by Pietrain pigs. Their meat was characterized by considerable acidification 45 minutes postmortem, lightest colour and the least favourable water holding capacity.

Key words: Microstructure, pigs, *longissimus lumborum* muscle, meat quality.

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Pig meatiness is one of the major problems for both Polish and foreign pig breeders. In recent years, however, the problem of pork quality and technological suitability has gained in importance because negative relationships between the quantity and quality of meat deposited in carcasses are increasingly common.

The knowledge of muscle tissue microstructure, with the use of simple methods of its differentiation, may become an important element of appropriate and objective evaluation of meat quality or a method used to validate or complement the existing assessment methods. Relationships between the microstructure and physiological and biochemical properties of muscle, such as oxidative or glycolytic enzyme activity and the kinetics of muscle fibre spasm – in addition to great cognitive value – may be of great practical significance. They can explain the basis of meatiness and the occurrence of undesirable meat properties. (HENCKEL *et al*. 1997; KŁOSOWSKA *et al*. 1998a, 1998b; ČANDEK-POTOKAR *et al*. 1999).

The aim of the present study was to compare the microstructure of *longissimus lumborum* muscle of purebred and crossbred pigs, taking into consideration the relationships between individual types of muscle fibres and their mutual proportions in the muscle, and some meat quality traits.

Material and Methods

The study involved 190 pigs representing four groups: Polish Landrace – PL (30), Pietrain – P (30), Złotniki Spotted – ZS (30) and three-breed crosses ♂P × ♀F_1 (Polish Large White × Polish Landrace) – P × (PLW × PL) (100 pigs). Animals were kept under the same conditions of AGRO-WRONIE pedigree farm in Wronie near Wąbrzeźno, Poland. They were fed *ad libitum* from automatic feeders.

At approximately 105 kg body weight, all animals were slaughtered according to meat industry standards. At 45 minutes postmortem, the degree of *longissimus lumborum* muscle acidity (pH_{45}) was measured with a portable pH-meter (Matthäus). Muscle samples were also taken from the lumbar region, between the 4th and 5th vertebrae.

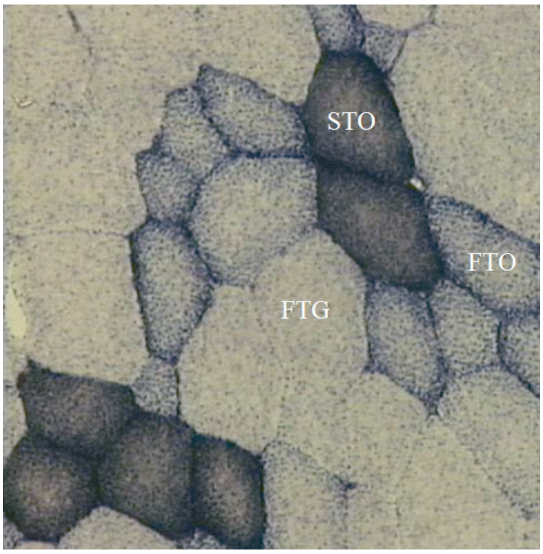

Fig. 1. Cross-section of *m. longissimus lumborum* of PL pig no. 4, ×125. Small diameters of muscle fibres.

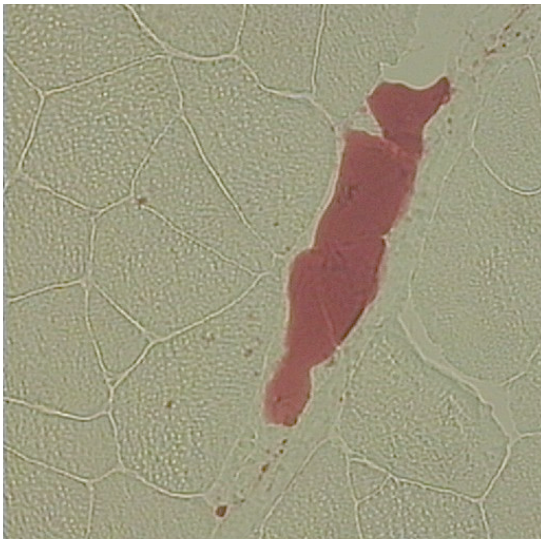

Fig. 2. Cross-section of *m. longissimus lumborum* of P × (PLW × PL) pig no. 43, × 125. Large diameters of muscle fibres.

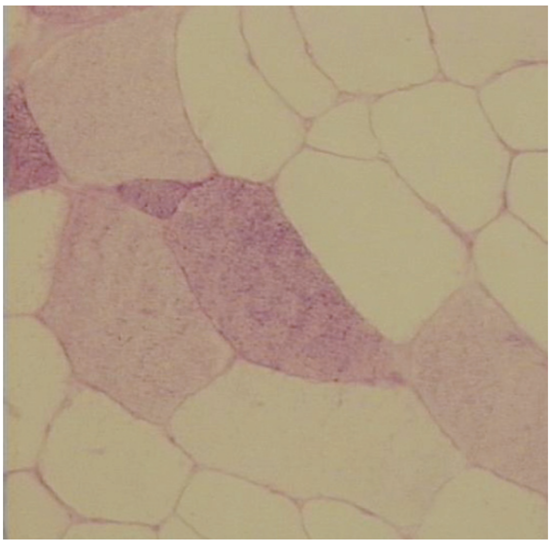

Fig. 3. Cross-section of *m. longissimus lumborum* of ZS pig no. 17 with small fat surface area, × 125.

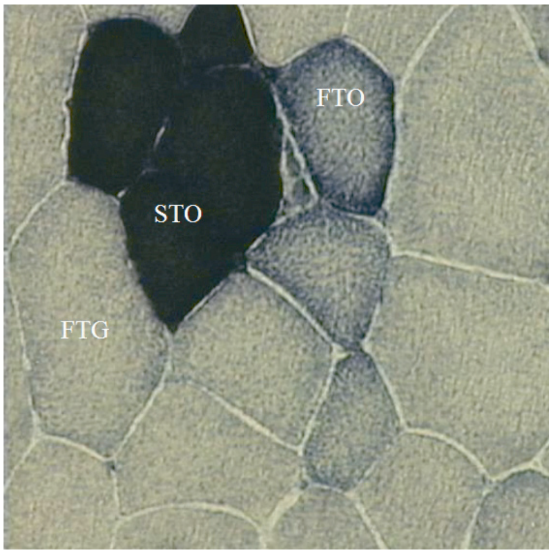

Fig. 4. Cross-section of *m. longissimus lumborum* of P × (PLW × PL) pig no. 67 with large fat surface area, × 125.

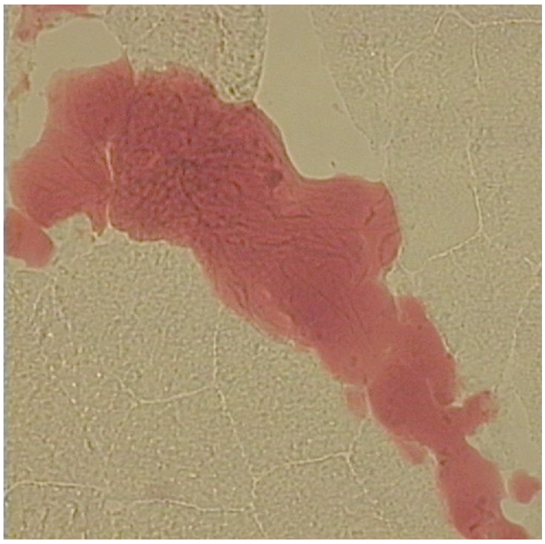

Fig. 5. Cross-section of *m. longissimus lumborum* of P × (PLW × PL) pig no. 6 with small glycogen content, × 125.

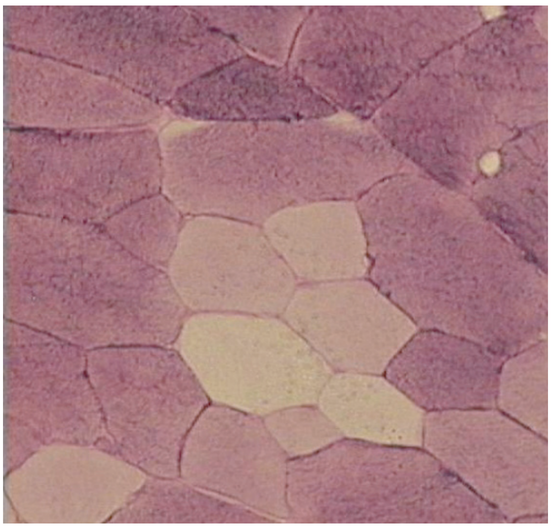

Fig. 6. Cross-section of *m. longissimus lumborum* of ZS pig no. 8 with large glycogen content, × 125.

Directly after taking, the samples were frozen in liquid nitrogen and transported to the laboratory of the Department of Animal Histology at the University of Technology and Agriculture in Bydgoszcz. Frozen meat samples were cut into 10 μm sections using a Leica cryostat. Then the sections were placed on glass slides and stained. The following histochemical reactions were performed:

1. combined NADH-TR and myofibrillar ATP-ase reaction to identify three types of muscle fibres (STO – red, FTO – intermediate, FTG – white) (ZIEGAN 1979),

2. Periodic Acid Schiff (PAS) reaction to show the level of glycogen in muscle fibres (DUBOVITZ *et al*. 1973),

3. Oil Red staining to determine the level of intramuscular fat (DUBOVITZ *et al*. 1973).

Muscle fibre diameters were measured, and percentages of STO, FTO and FTG fibres and the number of fibres per 1.089 mm^2 area were determined, using a Leica Q 500 MC image analysis system. The same system was used to determine the percentage of intramuscular fat per 2.178 mm^2 area. The level of glycogen in muscle tissue per 1.089 mm^2 area was measured using computer software (ŚRUTEK & KŁOSOWSKA 2002).

During the dissection of one half-carcass, meat samples were taken from the lumbar part of the *longissimus lumborum* muscle according to Pig Testing Station methodology (RÓŻYCKI 1996) and moved to a meat laboratory of the Department of Pig Breeding at the University of Technology and Agriculture in Bydgoszcz to perform meat quality analyses that included:

– sensory evaluation of meat colour, wateriness and firmness by a panel of 5 judges on a scale of 1 to 5 (CLAUSEN & THOMSEN 1956). The score of 3 was optimal and the range of 2.0-3.2 corresponded to good quality meat;

– physico-chemical evaluation of meat water holding capacity expressed as percentage of loose water in meat (GRAU & HAMM 1952) and meat colour saturation and lightness determined with a Spekol 11 spectrophotometer (RÓŻYCZKA *et al*. 1968). Ultimate meat acidity (pH_u) was determined again 24 h postmortem.

Each trait was analysed statistically by calculating the arithmetic mean ($\bar{x}$) and standard deviation (s). Significant differences between the groups were tested using variance analysis and Duncan's test. All the calculations were made using STATISTICA PL software (1995).

Results and Discussion

The evaluation of muscle tissue microstructure in the analysed group of pigs is illustrated in Table 1 and microscopic images show the characteristic pattern of histochemically different muscle fibres (Figs 1-2), the distribution of intramuscular fat (Figs 3-4) and the differences in the glycogen content of muscle fibres (Figs 5-6).

The percentage of STO fibres in particular pig genotypes ranged from 12.84 to 16.53%. Most STO fibres in the *longissimus lumborum* muscle were found in three-breed crosses Pietrain × (Polish Large White × Polish Landrace) and the least in Pietrains. Differences between the analysed groups were significant or highly significant. A low content of red fibres in Pietrain pigs was also observed by KŁOSOWSKA (1973).

Significant differences between the groups were also found for FTO fibres (P<0.01), which were the least abundant in the muscle of Polish Landrace (14.43%) and the most abundant in Złotniki Spotted pigs (23.71%).

Most FTG fibres in the muscle were found in Pietrain (70.50%) and Polish Landrace (70.16%), and the least in Złotniki Spotted pigs (62.46%).

A lower proportion of glycolytic fibres is related to more favourable quality traits of meat, as observed by KŁOSOWSKA (1973) for Złotniki Spotted, Pietrain and the their crossbreds.

Measurements of muscle fibre showed the greatest fibre diameters in the *longissimus lumborum* muscle of the crossbreds (48.16 μm for STO, 47.92 μm for FTO, and 62.63 μm for FTG).

The smallest diameter of red fibres was observed in Pietrain (44.25 μm) and Polish Landrace (44.30 μm), with highly significant differences shown between the analysed groups of pigs. As regards the thickness of particular fibre types, purebred animals showed similar diameters of intermediate fibres (42.03 μm in Polish Landrace, 43.00 μm in Pietrain and 41.56 μm in Złotniki Spotted) and white fibres (55.89, 56.96 and 57.43 μm, respectively) and were significantly different (P<0.01) from those of the crossbreds. A much greater diameter of FTG fibres compared to other fibre types and a significant effect of pig breed on the thickness of muscle fibres were shown by many authors (GAJEWCZYK & KANIAK-POLOK 2002; KŁOSOWSKA *et al*. 1998a, 1998b, 2002).

There were also significant differences between the analysed groups in the number of fibres per 1.089 mm^2 area. The greatest number of fibres was characteristic of the muscles of Polish Landrace (259.93) and Złotniki Spotted (258.33) pigs. The smallest number of fibres was observed in the crosses of Pietrain boars and F_1 Polish Large White × Polish Landrace sows (193.17), in which all fibre types had the greatest diameter.

Table 1

Musculus longissimus lumborum microstructure in pigs of the analysed groups

Trait			Group			
			PL	P	ZS	P × (PLW × PL)
Proportion of fibres, %	STO	x	15.41^{ab}	12.84^{Bc}	13.83^{bc}	16.53^{Aa}
		s	3.40	3.89	3.60	4.67
	FTO	x	14.43^{B}	16.66^{B}	23.71^{A}	16.55^{B}
		s	4.44	5.48	3.01	5.75
	FTG	x	70.16^{Aa}	70.50^{Aa}	62.46^{Bc}	66.92^{Ab}
		s	4.56	5.93	4.15	7.52
Fibre diameter, μm	STO	x	44.30^{B}	44.25^{B}	47.85^{A}	48.16^{A}
		s	4.14	6.60	3.62	5.94
	FTO	x	42.03^{B}	43.00^{B}	41.56^{B}	47.92^{A}
		s	3.56	4.95	3.34	6.49
	FTG	x	55.89^{B}	56.96^{B}	57.43^{B}	62.63^{A}
		s	4.96	6.52	4.89	7.25
Number of fibres per 1.089 mm^2 area		x	259.93^{A}	227.40^{B}	258.33^{A}	193.17^{C}
		s	26.30	39.97	25.24	36.05
Intramuscular fat,%		x	3.22	3.48	2.96	2.62
		s	2.09	2.26	2.36	2.57
Glycogen, %		x	40.48	39.09	43.12	36.31
		s	16.11	21.26	13.97	17.14

Values marked with different letters differ significantly; capital letters at P<0.01, small letters at P<0.05;
PL – Polish Landrace, P – Pietrain, ZS – Złotniki Spotted, PLW – Polish Large White.

Table 2

Meat quality traits of pigs of the analysed groups

Trait		Group			
		PL	P	ZS	P × (PLW × PL)
pH_1	x	6.65^{Aa}	5.73^{Cc}	6.51^{AaB}	6.30^{Bb}
	s	0.30	0.30	0.46	0.44
pH_u	x	5.45^{B}	5.40^{B}	5.42^{B}	5.52^{A}
	s	0.06	0.06	0.06	0.13
Colour, pts	x	2.5^{A}	1.8^{B}	2.7^{A}	2.6^{A}
	s	0.4	0.3	0.5	0.5
Wateriness, pts	x	2.7^{A}	1.9^{B}	2.8^{A}	2.7^{A}
	s	0.3	0.3	0.4	0.4
Firmness, pts	x	2.8^{A}	2.2^{B}	2.7^{A}	2.7^{A}
	s	0.3	0.4	0.4	0.4
Lightness of colour, %	x	24.07^{Bb}	27.35^{Aa}	22.35^{Bc}	22.54^{Bbc}
	s	2.18	3.62	4.43	3.49
Saturation with colour, %	x	20.70^{BCcd}	23.88^{Aa}	22.17^{Bb}	19.49^{Cd}
	s	1.94	3.54	3.57	2.46
Water holding capacity (WHC) – % loose water	x	21.12^{BCc}	23.97^{Aa}	22.58^{ABb}	19.88^{Cc}
	s	2.93	2.71	3.79	2.61

Values marked with different letters differ significantly; capital letters at P<0.01, small letters at P<0.05.

Fatty tissue found in the muscles is a specialized variety of connective tissue, which develops relatively late in the body and only when the amount of nutrients exceeds their requirement for the building of cells. In recent years breeding selection, aimed at increasing the meat content of carcasses, has decreased the content of intramuscular fat. Fat content is positively correlated with pork quality and especially its tenderness, juiciness and palatability.

Many authors hold that the content of intramuscular fat in today's high-meat pigs is too low. In this experiment, the level of fat in the meat of pigs of all groups was also small and did not exceed 3.07% on average.

In the histochemically tested content of intramuscular fat, no significant differences were found between particular groups of pigs. Intramuscular fat was equalized and ranged from 2.62% in the crossbreds to 3.48% in Pietrain pigs.

In the present experiment, glycogen content was determined in histological preparations using the PAS method, as adapted by ŚRUTEK and KŁOSOWSKA (2002) to determine the level of glycogen in the muscle sample tested. Statistical analysis did not show significant differences between the genetic groups. Mean percentages of glycogen-containing fibres ranged from 36.31% in the crossbreds to 43.12% in Złotniki Spotted pigs.

The evaluation of meat quality in the analysed animals is given in Table 2. The data clearly point to significant and highly significant differences in meat quality traits of the analysed pig breeds, to the disadvantage of the Pietrain breed. The meat of Pietrain pigs was characterized by considerable acidity 45 min postmortem. The mean value of this trait was 5.73, which may suggest the incidence of PSE meat. The low pH_1 of the meat of Pietrain pigs was also shown by other authors (ORZECHOWSKA *et al.* 1996; POSPIECH *et al.* 1998). pH_1 of meat of Polish Landrace and Złotniki Spotted pigs was much higher – 6.65 and 6.51 respectively. Slightly lower acidity 45 min postmortem (6.30) was noted in Pietrain × (Polish Large White × Polish Landrace) pigs. The high pH_1 of meat in the Złotniki Spotted breed (6.57) was also shown by WAJDA and RATAJSZCZAK (1988).

The meat of Pietrain pigs also showed the lowest ultimate pH measured 24 h postmortem (pH_u), which was 5.40 for this group of animals. A similar result was obtained by ORZECHOWSKA *et al.* (1996). The highest pH_u of meat was found in crossbreds (5.52) and differed highly significantly from the meat of purebred animals. However, such a high value of ultimate pH is considered typical of normal meat (GRAJEWSKA *et al.* 1984).

The next three traits of meat (colour, wateriness and firmness), evaluated sensorily, were the least favourable in Pietrain pigs ($P<0.01$). There were no statistically significant differences between the other groups of pigs. The results of sensory evaluation were close to or better than the results reported by other authors (GRZEŚKOWIAK 1995; MICHALSKA *et al.* 2000; RAK *et al.* 1993).

In addition to pH_1, colour lightness is the main criterion used to evaluate meat quality. PSE meat always has lighter colour than normal meat. As expected, the lightest meat colour was found in the meat of Pietrain pigs (27.35%). Likewise, ORZECHOWSKA *et al.* (1996) observed the lightest meat colour in Pietrains. The meat of Złotniki Spotted pigs showed the darkest colour (22.35%), but the average values of this trait were still within the usual range for normal meat (GRAJEWSKA *et al.* 1984).

The most favourable saturation of meat colour (19.49%) was obtained in Pietrain × (Polish Large White × Polish Landrace) crosses. Similarly as for the previously discussed traits, the least favourable result was obtained for Pietrain pigs (23.88%).

An important criterion of meat quality classification is its water holding capacity (WHC), which indicates the suitability of raw meat for further processing. Water holding capacity was expressed as percentage of loose water in meat. It was the lowest (most favourable) in the meat of Pietrain × (PLW × Polish Landrace) crosses – 19.88%. A less favourable result (23.09%) for the meat of Pietrain × (Polish Large White × Polish Landrace) crosses was obtained by ŁYCZYŃSKI *et al.* (2000). As could be expected, the highest WHC value was noted in the meat of Pietrain pigs (23.97%). Differences between the groups were confirmed statistically. RAK *et al.* (1993) showed 24.7% of loose water in the meat of Pietrain pigs.

In conclusion, Pietrain pigs had the highest proportion of FTG (white) fibres and the lowest proportion of STO (red) fibres that are most beneficial in terms of meat quality characteristics. Pietrain pigs also showed the least favourable traits of meat quality. Their meat was characterized by considerable acidity 45 min postmortem, the lightest colour, and the least favourable water holding capacity. The greatest diameter of all types of muscle fibres occurred in the muscle of three-breed crosses, and accordingly these animals had the lowest number of fibres per unit of muscle cross-section area. A greater rate of growth was therefore related to the structure of muscles with thicker fibres that had greater diameters.

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