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Full Length Research Paper

The influence of cross-breeding Zlotnicka Spotted native breed sows with boars of Duroc (D) and Polish Large White (PLW) breeds on meat quality

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The aim of the study was to investigate the influence of cross-breeding of Zlotnicka Spotted sows with Duroc and Polish Large White boars on the quality of meat of crossbred fatteners. The investigation was done on 50 carcasses of fatteners from four genetic groups: Zlotnicka Spotted x Zlotnicka Spotted (n = 20), Zlotnicka Spotted x Polish Large White (n = 10), Zlotnicka Spotted x Duroc (n = 10) and Zlotnicka Spotted x (Zlotnicka Spotted x Duroc, n = 10). The analysis of pH in the longissimus and semimembranosus muscles in all the genetic groups revealed typical values of meat without qualitative deviations. No statistically significant differences between the groups were observed. Pale, soft and exudative (PSE) meat was found in one carcass of Zlotnicka Spotted x Zlotnicka Spotted group and two carcasses of Zlotnicka Spotted x Polish Large White group. The results of evaluation of physiochemical characteristics indicate very good quality of meat in all the groups of animals. The highest content of intramuscular fat, that is, 3.80%, was observed in the carcasses of the Zlotnicka Spotted x (Zlotnicka Spotted x Duroc) group. Statistical differences were found between this group and Zlotnicka Spotted x Polish Large White, in which the intramuscular fat content was 2.95%. The meat of all the genetic groups of pigs was characterised by desirable and the same colour in the profile of the longissimus muscle. However, similarly to many native breeds, this muscle was characterised by lesser lightness than breeds with high meat content. Also, the results of evaluation of sensory quality determinants, that is, flavour, juiciness, tenderness and palatability, which were higher than four points on average (one to five scale), confirmed perfect quality of the meat. To sum up, it is possible to say that the raw meat of Zlotnicka Spotted pigs and their cross-breeds with Duroc and Polish Large White breeds is characterised by good quality and because of its considerable intramuscular fat content, it has a high culinary and processing value, especially for ripening products.

Key words: Pigs, Złotnicka Spotted, cross-breeds, meat quality.

INTRODUCTION

Studies on native breeds of pigs in many European countries show that the breeds are characterised by low values of fattening and slaughter traits (Labroue et al., 2000; Acciaioli et al., 2002; Szulc et al., 2006; Franci and Pugliese, 2007). However, their meat is characterised by good quality and valuable flavour (Labroue et al., 2000; Pugliese et al., 2004; Franci and Pugliese, 2007; Serrano et al., 2008; Babicz et al., 2009). Among Polish native breeds, the Zlotnicka Spotted pig breed is distinguished by its good meat quality (Buczyński et al., 2001; Kapelański et al., 2006; Olkiewicz et al., 2006; Grześkowiak et al., 2009). However, the breed is less

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Table 1. Proximate composition of diets.

Item	Diet		
	Starter	Grower	Finisher
Spring barley (%)	26.00	20.00	21.00
Triticale (%)	-	20.00	39.80
Winter wheat (%)	30.40	16.10	-
Maize (%)	20.00	13.00	12.00
Soybean meal 46 (%)	16.00	13.00	7.40
Rapeseed meal “00” 34 (%)	-	5.00	2.00
Wheat bran (%)	-	10.00	15.00
[1]Ekonomix T (%)	2.40	1.50	1.30
Fodder chalk (%)	1.10	1.40	1.50
[2]Zinteral (%)	0.10	-	-
[3]Substimel 950 (%)	4.00	-	-
Dry matter (%)	90.29	90.28	90.56
Energy (MJ/kg)	13.46	12.63	12.46
Crude protein (%)	16.26	17.31	14.79
Digestible protein (%)	13.65	14.65	12.65
Lysine (%)	1.11	0.99	0.79

[1]Mineral feeding stuff; [2]additive of Zn; [3]additive of whey.

useful in commodity production, because it has low content of meat (about 46%), considerable thickness of fat and low fattening growths (Buczyński et al., 2001; Szulc et al., 2006; Grześkowiak et al., 2009).

Since the early 1990s, the main aim of selection in pigs is to improve the meat content. However, higher content of meat in the carcass leads to considerably reduced content of subcutaneous and intramuscular fat (Morrisey et al., 1998; Newcom et al., 2004). On the other hand, intramuscular fat (IMF) is an important marker of meat quality, because higher IMF content has a positive effect on the sensory characteristics, technological and culinary usefulness of meat (Wood et al., 1999; Buczyński et al., 2005; Świtoński et al., 2010). IMF is particularly, an important trait in relation to raw meat used for ripening products. It is an element that causes normal course of ripening processes and a factor responsible for the favourable development of sensory characteristics of these products (Daszkiewicz et al., 2005; Olkiewicz et al., 2006). Apart from the fat content, the colour of meat may also be a significant determinant in the evaluation of pork quality (Faustman and Cassens, 1990).

The optimal pH_{24} ranging between 5.6 and 5.8, water holding capacity and a wide range of other physio-chemical determinants are very important for meat used to form ripening product. Such raw meat is obtained from heavy pigs, traditionally (extensively) bred, with the slaughter weight of about 120 kg (Olkiewicz et al., 2006). In many countries, native breeds of pigs are the source of this meat, e.g. the Italian Mora Romagnolia and Spanish Iberico. Various authors also indicate the Duroc breed as a source of excellent quality meat (Morcuende et al., 2007). In the Polish conditions, there are possibilities to produce raw pork on the basis of some native breeds, e.g. Pulawska, Zlotnicka Spotted or their cross-breeds with other breeds, whose meat are useful in ripening products (Olkiewicz et al., 2006; Babicz et al., 2009; Grześkowiak et al., 2009). In order to prevent the loss of important qualitative values of the meat of porkers from crossbreeding of native breeds, it is very important to select appropriate crossbreeding components.

The aim of this study was to investigate the influence of cross-breeding of Zlotnicka Spotted sows with Duroc and Polish Large White boars on the quality of meat from crossbreeding.

MATERIALS AND METHODS

The specimens for investigation were 50 carcasses of fatteners from four genetic groups: ZS x ZS, Zlotnicka Spotted (n = 20); purebred fatteners: ZS x PLW, Zlotnicka Spotted x Polish Large White (n = 10); ZS x D, Zlotnicka Spotted x Duroc (n = 10); ZS x (ZS x D), Zlotnicka Spotted x (Zlotnicka Spotted x Duroc, n = 10).

The animals were divided into four experimental groups with equal numbers of sows and boars. All the animals were tattooed and ear-marked. Experimental animals with the average weight of 20 kg were selected and the experiment ended when the animals attained a slaughter weight of about 120 kg (113.0 to 123.6 kg).

The experiment was divided into the starter (20 to 30 kg), grower (30 to 80 kg) and finisher (over 80 kg) rations. Table 1 shows the proximate composition of diets. The rations in all the three stages were similar for all of the three genotypes. The fatteners were kept in collective pens of 35 animals, on shallow bedding. The animals were fed *ad libitum* with total mixed rations and had constant

Table 2. Mean pH values and the share of quality defects in the meat of porkers under analysis.

Characteristic		Genetic group			
		ZS x ZS	ZS x PLW	ZS x D	ZS x (ZS x D)
pH_{45} LD muscle	Mean	6.39	6.42	6.38	6.26
	SD	0.31	0.26	0.25	0.36
pH_{45} SEM muscle	Mean	6.32	6.32	6.26	6.12
	SD	0.28	0.27	0.26	0.30
pH_{24} LD muscle	Mean	5.50	5.40	5.41	5.51
	SD	0.09	0.09	0.08	0.17
pH_{24} SEM muscle	Mean	5.76	5.62	5.68	5.74
	SD	0.20	0.22	0.17	0.18
PSE meat	(n)	1 carcass	2 carcasses	No carcasses	No carcasses
DFD meat	(n)	no carcass	No carcass	No carcass	No carcass

No significant differences were found; LD, longissimus dorsi muscle; SEM, semimembranosus muscle; PSE, pale, soft and exudative; DFD, dark, firm and dry. ZS x ZS, Zlotnicka Spotted; ZS x PLW, Zlotnicka Spotted x Polish Large White; ZS x D, Zlotnicka Spotted x Duroc; ZS x (ZS x D), Zlotnicka Spotted x (Zlotnicka Spotted x Duroc).

access to water.

After the final fattening, the animals were transported from the farm to the abattoir located at a distance of about 50 km. The animals were rested for about two hours before slaughtering. The fatteners were stunned prior to slaughter.

In 45 min (pH_{45}) and 24 h (pH_{24}) after the slaughter, pH was measured in the longissimus (L) muscle at the last rib and in the semimembranosus muscle (SEM) by means of an integrated electrode pH meter Radiometr PHM 80 Portable. Samples from the lumbar section of the L muscle were collected for laboratory investigation. The following items were labelled in the raw meat samples:

1. Water content according to the standard PN-ISO 1442:2000,
2. Fat content according to the standard PN-ISO 1444:2000,
3. Protein content with the Kjeldahl method using Kjeltec System 1002 Distilling Unit (PN-75/A-04018),
4. Water holding capacity (WHC) with the Grau and Hamm method (1952) modified by Pohja and Niinivaara (1957),
5. Drip loss: After measurement of weight, about 100 g sample of the longissimus dorsi muscle was placed in a plastic bag and stored in a refrigerator at temperature of 4°C for 48 h. After that time, the samples were weighed and the results were computed from the weight difference,
6. Cooking loss: The samples were heated to reach the internal temperature of 75°C in the geometric centre of the sample. The results were computed from the differences between the weight before and after cooking (Baryłko-Pikielna, 1975),
7. Meat colour was determined by means of a Minolta Chroma CR 400 apparatus, where the colour parameters were determined in the CIE system: L*, lightness value; a*, redness value; b*, yellowness value,
8. Meat marbling: The degree of meat fat was specified in the scale of one to four points, according to the Canadian and American standards, where one point refers to slight fat content, whereas four points refers to high fat content (Wise, 1981; Kauffman et al., 1992),
9. Shear force of the cooked longissimus dorsi (LD) muscle was specified with a Warner-Bratzler apparatus. The same muscle samples that were used to determine the cooking loss were used for assessment of WB. The muscle samples were refrigerated (4°C) and stored over-night before WB was determined. A load cell of 500 kN and crosshead speed of 100 mm/min was attached to the model ZWICK/ROELL Z0.5 texture machine. Mean maximum shear force values were calculated from the recorded shear force values for seven cylindrical cores (wide 25.4 mm) cut parallel to the fibers from each muscle sample.

Cylindrical meat samples of about 2.5 cm diameter were cut out. A trained team of five people made sensory evaluation of cooked meat in the scale of one to five points. The following traits were evaluated: flavour, juiciness, tenderness and palatability (PN-ISO 4121:1998). Based on the pH_{45} ($pH \leq 5.8$) and pH_{24} ($pH > 6.3$) value of the carcass content with pale, soft and exudative (PSE) and dark, firm and dry (DFD) meat was determined, respectively.

The obtained results were statistically processed by means of the statistical package Statistica PL v. 9.1. In order to calculate the differences in the analysed characteristics between the genetic groups of pigs, one-way ANOVA was applied. The significance of the differences between the mean values was verified by means of Tukey's test (Stanisz, 1998).

RESULTS AND DISCUSSION

Table 2 shows the results of pH measurements in the longissimus and semimembranosus muscles in the fatteners of the four compared genetic groups in 45 min and 24 h after the slaughter. On the other hand, Table 3 contains the physiochemical characteristics of the longissimus muscle of the animals under investigation. Table 4 presents the results of sensory assessment and measurements of the shear force of the cooked longissimus muscle.

The analysis of the pH_{24} of the longissimus and semimembranosus muscles proved low values of the characteristic in all the genetic groups and no statistically significant differences were found between them. In the group of purebred animals (ZS x ZS), the pH_{24} of the longissimus muscle was 5.50, whereas for the semi-membranosus, it was 5.76. Other authors noted similar pH_{24} values for the L and SEM muscles of the ZS breed (Florowski et al., 2005; Kapelański et al., 2006; Grześkowiak et al., 2009). However, Kasprzyk et al. (2010) observed lower pH_{24} in the native Pulawska breed (Pul); it was 5.41 for the longissimus muscle and 5.50 for

Table 3. The physiochemical characteristics of the LD muscle in the genetic groups of pigs under analysis.

Characteristic		Genetic group			
		ZS x ZS	ZS x PLW	ZS x D	ZS x (ZS x D)
Water content (%)	Mean	71.74	71.59	71.18	69.65
	SD	2.01	1.32	1.24	1.93
Fat content (%)	Mean	3.44	2.95[a]	3.52	3.80[b]
	SD	0.92	0.32	0.76	1.54
Total protein content (%)	Mean	24.54	24.32	24.19	25.41
	SD	1.42	1.24	1.11	1.07
WHC[1] (%)	Mean	32.66	32.60	32.04	31.12
	SD	2.87	2.20	3.20	3.84
Drip loss (%)	Mean	2.36	2.31	2.94	1.76
	SD	1.14	1.12	1.40	0.41
Cooking loss (%)	Mean	27.91	28.28	27.70	27.04
	SD	4.02	3.24	2.78	2.73
L* - value Lightness	Mean	46.43	47.12	47.33	46.05
	SD	5.46	1.74	4.15	6.71
a* - value Redness	Mean	8.17	6.67	6.87	7.98
	SD	0.99	0.70	1.54	1.46
b* - value Yellowness	Mean	2.89	2.17	2.93	2.86
	SD	1.88	0.62	1.80	1.65
Marbling (points)	Mean	1.94	2.19	2.52	2.22
	SD	0.73	0.44	0.50	0.93

Mean values marked in rows with different letters differ significantly at P≤0.05; [1]WHC, water holding capacity. ZS x ZS, Zlotnicka Spotted; ZS x PLW, Zlotnicka Spotted x Polish Large White; ZS x D, Zlotnicka Spotted x Duroc; ZS x (ZS x D), Zlotnicka Spotted x (Zlotnicka Spotted x Duroc).

the semimembranosus muscle. Also, Babicz et al. (2009) noted similar pH values for the Pul breed, that is, pH_{24} of the L and SEM amounted to 5.40 and 5.34, respectively.

Earlier studies on the quality of meat of ZS pigs showed that the defect of PSE meat is very rare (Rak et al., 1997). Later studies by Florowski et al. (2006) and Kapelański et al. (2006) also confirmed this fact. It may be attributed to the fact that the ZS breed is only slightly burdened with the mutation of *RYR1* gene, which is responsible for the occurrence of the defect and excessive stress proneness of the animals (Buczyński et al., 2006; Florowski et al., 2006). In the authors' own research, PSE meat was found only in one carcass of ZS x ZS and two carcasses of ZS x (ZS x D) cross-breeds. The cases of PSE meat may have been the effect of unfavourable conditions before slaughter, including electrical stunning (Grześkowiak et al., 2009).

Research on fatness characteristics, including the content of intramuscular fat is very important in relation to food sciences and breeding. Świtoński et al. (2010) pointed out that fatness traits affected the quality of meat and fattening effectiveness. There are numerous papers on the influence of genetic and environmental factors on pig fatness in the literature (Acciaioli et al., 2002; Gondret and Lebert, 2002; Mason et al., 2005; Stachowiak et al., 2010). Some authors indicated that the meat of restrictively fed animals contains less intramuscular fat as compared to the meat of pig fed *ad libitum* and it is characterised by slightly bad taste and little juiciness (Gondret and Lebert, 2002; Mason et al., 2005). As showed by Acciaioli et al. (2002), the method of maintenance of animals also influences their fatness. The breed is an important factor that has significant influence on the content of intramuscular fat. As indicated by

Table 4. The results of sensory evaluation (points) and shear force (N) of the cooked LD muscle in the genetic groups of pigs under analysis

Characteristic		Genetic group			
		ZS x ZS	ZS x PLW	ZS x D	ZS x (ZS x D)
Flavour	Mean	4.37	4.41	4.35	4.38
	SD	0.16	0.16	0.16	0.13
Juiciness	Mean	4.12	4.23	4.09	4.22
	SD	0.27	0.27	0.20	0.43
Tenderness	Mean	4.16[a]	4.36[b]	4.02[a]	4.32[b]
	SD	0.24	0.22	0.20	0.21
Palatability	Mean	4.30[a]	4.50[b]	4.46[a]	4.45[a]
	SD	0.18	0.15	0.18	0.18
Shear force	Mean	63.14	60.78	74.11	55.40
	SD	18.48	14.17	15.03	11.52

Mean values marked in rows with different letters differ significantly at P≤0.05. ZS x ZS, Zlotnicka Spotted; ZS x PLW, Zlotnicka Spotted x Polish Large White; ZS x D, Zlotnicka Spotted x Duroc; ZS x (ZS x D), Zlotnicka Spotted x (Zlotnicka Spotted x Duroc).

Newcom et al. (2004), some breeds of pig differed significantly in the content of intramuscular fat. The mentioned authors found the highest content of intramuscular fat in the Chester White (3.41%) and Duroc (3.30%) breeds, than in Landrace (1.90%) and Yorkshire (1.98%). However, the content of IMF ranging between 2.0 and 3.5% is recognised as the most favourable to achieve sensory attractiveness of products (Wood et al., 1994; Olkiewicz et al., 2006). These authors also think that the use of porkers with the share of Duroc blood from 25 to 50% in commodity production has positive influence on the IMF.

High content of intramuscular fat is typical for local breeds of pigs. As indicated by Serrano et al. (2008), the muscles of the Spanish breed Iberico are characterised by particularly high content of fat (8.8%). Considerable intramuscular fat ranging from 3.32 to 4.27% in the L muscles was noted for the native Italian breed of Nero Siciliano (Pugliese et al., 2004). On the other hand, Čandek-Potokar et al. (2003) determined the content of IMF in the Slovenian Krškopolje pig breed at 3%. The results of research on the IMF in Polish native pigs are diversified. Rak et al. (1997) determined the content of intramuscular fat in ZS pigs at 1.02 to 2.07%. Grześkowiak et al. (2009) noted the mean content of intramuscular fat of 2.04% in ZS pigs and 1.87% in the Zlotnicka White breed. However, the intramuscular fat content in ZS pigs observed in the research by Florowski et al. (2005) was higher and amounted to 3.1%. In the authors' own research, the intramuscular fat content in ZS x ZS fatteners was 3.44%. The highest intramuscular fat content of 3.80% was noted for the fatteners from the ZS x (ZS x D) group. The animals from the ZS x PLW group were characterised by the smallest fat content, where it reached the value of 2.95%. The differences observed between the groups were statistically significant (P≤0.05). Babicz et al. (2009) determined the intramuscular fat content of 2.53% in the longissimus of the Pul breed. Simultaneously, they noted a higher significant increase in the intramuscular fat content of 3.05% in the cross-breeds of the Pul and Duroc breeds, when compared with the purebred animals.

Following the results of assessment of the technological quality of the meat of ZS pigs and their cross-breeds with the Duroc and PLW breeds, it is shown that their raw meat is characterised by high processing usefulness, which is expressed by small amount of natural exudation, favourable water holding capacity and small loss of weight during thermal processing.

Next analysed trait of meat quality was its colour. It is worth mentioning that this trait characteristic is one of the most important criteria of consumers' assessment of pork (Faustman and Cassens, 1990). However, as the research proved, some consumers prefer a darker colour of pork (Newcom et al., 2004). Measurements of the parameters for the colours L*, a*, b* showed that the meat of all the genetic groups of pigs was characterised by very desirable and same colour in the muscle section. The lightness of colour (L*) fluctuated from 46.05 to 47.33. In earlier studies, Florowski et al. (2005) and Grześkowiak et al. (2009) obtained similar L* values for ZS pigs (43.8 to 47.9). Pugliese et al. (2004) obtained

similar results of evaluation of the meat colour in the Italian breed of Nero Siciliano, where L* was 46.7. On the other hand, Newcom et al. (2004) observed similar results of colour evaluation for the Berkshire (44.40), Chester White (44.80) and Duroc (45.70) breeds. Serrano et al. (2008) observed a darker colour in the Iberico breed. In the research by these authors, the mean L* value amounted to 39.8. On the other hand, in the native Krškopolje pig breed, a lighter colour of the longissimus muscle was found, where the mean L* value was as high as 54.1 (Čandek-Potokar et al., 2003). The results of evaluation of meat marbling in the authors' own research ranged between 1.94 (ZS x ZS) and 2.52 points (ZS x D), but no statistical differences in the value of this characteristic were observed between the individual genetic groups of pigs. By comparison, Grześkowiak et al. (2009) proved higher marbling in the meat ZS x ZS pigs, which was 2.34 points.

The results of sensory evaluation obtained in this study confirm good quality of meat from the porkers of all the genetic groups. The mean grade for each of the determinants, that is, flavour, juiciness, tenderness and palatability, was more than four points. However, the meat of the animals from the ZS x (ZS x D) and ZS x PLW (4.32 and 4.36 pts) pig groups was characterised by significantly higher tenderness than the meat from the fatteners from the ZS x ZS and ZS x D groups (4.16 and 4.02 points). As far as palatability is concerned, the meat from the fatteners from the ZS x PLW group (4.50 points) was distinguished. This characteristic in the ZS x PLW group was different from that in the other groups, where significantly lower palatability was noted. Similarly, Florowski et al. (2005) and Grześkowiak et al. (2009) obtained the results of sensory evaluation for purebred ZS pigs, which showed perfect quality of the meat. Kasprzyk et al. (2010) noted a slightly better assessment of the juiciness and tenderness of the meat from the native Pul pigs.

The last evaluated trait was the shear force, which fluctuated from 55.4 to 74.1 N. However, no statistically significant differences between the individual genetic groups were observed for this characteristic.

Conclusion

The meat of the native breed of Zlotnicka Spotted pigs and its cross-breeds with the Duroc and Polish Large White breeds was characterised by very good quality. It was proved by a small amount of natural exudation from the muscle tissue, desirable meat colour, favourable water holding capacity and loss of weight during thermal processing, and positive sensory evaluation. Also, the considerable content of intramuscular fat indicates that raw meat from ZS pigs and their cross-breeds with the Duroc and Polish Large White breeds has high culinary and processing values, especially for production of ripening products.

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