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Influence of crossing Polish and foreign pig breeds on physicochemical traits of longissimus lumborum muscle

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Abstract: The aim of this study was an assessment of physicochemical traits characterizing the longissimus lumborum muscle in fatteners originating from an application of various variants of commodity crossbreeding with a contribution of 2 Polish and 2 foreign breeds. The research material was collected from the right half-carcass from 180 crossbred fatteners selected randomly from a technological group (60 heads in each), with a division of gilts and hogs. The meat was subjected to laboratory examinations according to the procedures and requirements of the Association of Official Agricultural Chemists International. Pig breeds used in the crossbreeding affected the values of the examined physicochemical traits significantly from a culinary and technological point of view. Crossbred fatteners from the backcrossing, compared to 4-breed single crossing, were characterized by statistically significantly higher dry matter content in the longissimus lumborum muscle and higher water-holding capacity. In terms of fat and collagen content in the muscle, the crossbred fatteners from the backcrossing demonstrated poorer parameters compared to 4-breed crossbreds. Statistically significant differences in the range of muscle color determinants were noted between the groups of fatteners. The most profitable parameters were observed in crossbred fatteners ¾ PLW ¼ PL and ¾ PL ¼ PLW.

Key words: Fatteners, commodity crossbreeding, physicochemical traits, longissimus lumborum muscle

1. Introduction

Pork meat is of high significance in human feeding all over the world. The arrangement and size of pig populations depend on 2 factors, i.e. denominational aspect and fodder resources, essential for this animal species.

The potentate in pig breeding and pork production is China. Besides China, the main breeding regions include western and central Europe, the European part of Russia, the northern United States, and eastern Brazil.

Up to the beginning of the 1970s, the state of the pig population in Poland depended on the number of these animals maintained on peasant holdings and was in a range of several millions of heads on average. Rapid and clear increase in pig population up to over 20 million heads was noted after 1970, when large national farms of commodity fattener production started to operate in the country.

The period of political transformation in Poland considerably affected the state of the pig population after 2000. An important role was played by the market based on obeying the law of pig livestock demand and supply. Currently, the pig population in Poland has decreased to the level of about 11 million heads. Despite this, due to culinary traditions, pork meat attracts special attention.

One of the possibilities of musculature degree improvement in fatteners is the crossbreeding of Polish and foreign pig breeds. Having in mind maintenance of good quality slaughter material, each new fattener genotype obtained should be examined (1–6). Quantitative and qualitative features of meat tissue determine consumption and technological usefulness of pork meat (1,7). The aim of this study was an assessment of the indices characterizing the longissimus lumborum muscle in fatteners that were the product of an application of various variants of commodity crossbreeding using 2 Polish and 2 foreign breeds.

2. Materials and methods

Animal material originated from a commodity farm producing 40,000 pigs annually aimed for slaughter.

The experimental animals were crossbred fatteners originating from single backcrossing: in the first group,

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crossbred sows (PLW × PL) with PLW breed boars; in the second group, crossbred sows (PL × PLW) with PL boars; and in the third group, 4-breed single-crossing of crossbred sows (PLW × PL) with crossbred boars (Duroc × Pietrain). The research material was collected from 180 crossbred fatteners randomly selected from a technological group in amounts of 60 heads from each, with division of gilts and hogs (30 heads in a group). The scheme of the experiment is presented in Table 1.

Meat samples weighing approximately 200 g were collected 24 h after slaughter of fatteners, cutting from the right half-carcass from the lumbar segment of the longissimus dorsi muscle. These samples were cut off at the height of the first and second lumbar vertebrae. The material was preserved in the slaughterhouse and then it was transported to the laboratory and subjected to analysis according to the procedures and requirements of the Association of Official Agricultural Chemists International (8).

The measurements of pH_{45min} were performed using the PM-600 pH-meter coupled with a EuroSensor electrode at the first hour after slaughter in the longissimus lumborum muscle at the height of the third and fourth lumbar vertebrae. The value of pH_{24} was examined at the same point.

Color L*a*b*, tint, and color saturation of the longissimus lumborum muscle were determined using a Minolta CR-200b reflecting colorimeter. Dry matter content in the meat tissue was determined using the oven-drying method. Crude protein was determined using the Kjeldahl method and fat content with the Soxhlet method. Fat from the samples dried to solid mass was extracted with petroleum ether. Water-holding capacity was examined using the Grau and Hamm method (9). The content of collagen was determined based on the colorimetric examination of hydroxyproline content (read from the standard curve), based on the hydroxyproline to collagen conversion factor. The measurement of hydrolyzed samples' extinction was performed at a wavelength of λ = 560 nm, using a DU spectrophotometer manufactured by Beckman. Meat weight losses were established on tissue samples of dimensions 4 × 4 × 4 cm, which were weighed with an accuracy of 0.001 g and then were subjected to heat processing in a water bath at a temperature of 90 °C. The samples were heated until reaching a temperature of 70 °C in the geometric center. After the samples were heat-treated and cooled to temperature of 20 °C in the geometric center, they were weighed. Meat weight losses after the samples' heat treatment were calculated based on the differences. Shear force was examined on samples of dimensions of 5 × 5 × 40 mm after heat treatment, using an Instron strength device. These samples were subjected to an activity of shearing strength mediated by the head equipped with a knife of a shape of a reversed V, acting perpendicularly to the course of the muscle fibers. The rate of the head movement was 50 mm/min, and the activity of shear force was stopped after complete breaking of the muscle fibers.

The collected results of the study were analyzed statistically using StatSoft STATISTICA ver. 9. The results obtained were elaborated using one-factor analysis of variance (ANOVA), and significance of the differences between group means was evaluated using Duncan's multiple range test.

3. Results

The results of this study as presented in the tables show that physicochemical traits of the longissimus lumborum muscle to a high degree depend on genotype and fattener's sex. Significant differences between mean values of dry matter, protein, collagen, fat, color, water-holding capacity, and shear force were noted depending on the genotype (Table 2). Higher content of dry matter and the differences in longissimus lumborum muscle color were noted in the fatteners originating from the backcrossing of Polish pig breeds comparing to 4-breed crossbreds with a share of Polish and foreign origin breeds. The lowest content of dry matter in the muscle was characteristic for hogs from a single commodity crossing, with 4 breeds' contribution.

Table 1. Experimental design.

Specification	Groups		
	I	II	III
Sows	PLW × PL	PL × PLW	PLW × PL
Boars	PLW	PL	D × P
Progeny	(PLW × PL) × PLW	(PL × PLW) × PL	(PLW × PL) × (D × P)
No. of animals	60 (30♀ + 30♂)	60 (30♀ + 30♂)	60 (30♀ + 30♂)

Polish Large White - PLW; Polish Landrace - PL; Duroc - D; Pietrain - P.

Table 2. Physicochemical traits of longissimus lumborum muscle of fatteners.

Traits	Groups I (Mean ± SE)	Groups II (Mean ± SE)	Groups III (Mean ± SE)
Dry matter (%)	28.44 ± 0.08[a]	28.50 ± 0.10[a]	27.65 ± 0.09[b]
Crude protein (%)	23.19 ± 0.11[b]	24.20 ± 0.08[a]	23.20 ± 0.02[b]
Collagen (%)	1.98 ± 0.07[b]	1.71 ± 0.05[b]	2.68 ± 0.03[a]
Crude fat (%)	1.89 ± 0.09[b]	2.20 ± 0.04[b]	2.78 ± 0.07[a]
Lightness (L*)	52.26 ± 0.20[a]	53.04 ± 0.19[a]	50.85 ± 0.22[b]
Redness (a*)	8.60 ± 0.21	7.73 ± 0.25	8.30 ± 0.18
Yellowness (b*)	6.35 ± 0.23[a]	6.34 ± 0.25[a]	4.76 ± 0.25[b]
Tint	36.31 ± 1.02[a]	36.91 ± 0.89[a]	28.89 ± 1.28[b]
Saturation	11.01 ± 0.22[a]	9.85 ± 0.33	9.40 ± 0.25[b]
pH_{45min}	6.14 ± 0.05	6.25 ± 0.06	6.03 ± 0.03
pH_{24}	5.42 ± 0.02	5.46 ± 0.01	5.48 ± 0.01
Water-holding capacity (%)	53.83 ± 0.14[a]	53.41 ± 0.46[a]	51.13 ± 0.12[b]
Thermal drip (%)	18.86 ± 0.49	22.81 ± 0.61	16.96 ± 0.45
Shear force (N)	14.74 ± 0.10[a]	11.61 ± 0.31[b]	12.46 ± 0.27

Means within the same column with different superscripts are significantly different (P < 0.05).
I - (PLW × PL) × PLW; II - (PL × PLW) × PL; III - (PLW × PL) × (D × P).

Sex also affected the level of protein, fat, and collagen in the longissimus lumborum muscle (Tables 3 and 4). Water-holding capacity is related to raw material usefulness for meat processing. The examined samples of meat of 4-breed crossbred fatteners were characterized by lower water-holding capacity compared to the muscle samples of 2-breed crossbred fatteners. Both gilts and hogs from group III were characterized by lower degree of water-holding capacity compared to those from groups I and II (Tables 3 and 4). With respect to thermal drip, differences were observed between the groups and within sexes; however, they were insignificant statistically. The highest shear force was characteristic for the muscle of crossbred fatteners from group I, and this result differed statistically from that obtained in group II (Table 2). The muscle of gilts and hogs from group I required higher shear force compared to that from groups II and III. The differences were significant statistically.

4. Discussion

The examined muscle tissue of crossbred fatteners from backcrossing based entirely on Polish pig breeds was characterized by nearly 1% higher dry matter content compared to the meat obtained from single 4-breed crossing with a contribution of Polish and foreign breeds pigs. The highest protein content was observed in the meat of fatteners from group II, and the difference between the mean value for this group and other means from groups I and III was significant statistically (Table 2). Differences in dry matter content were also noted between the gilts and hogs within fatteners groups (Tables 3 and 4). It was observed in previous studies conducted by Wajda et al. (10) that dry matter content in the longissimus lumborum muscle was 25% to 26% depending on fattener genotype. The study performed by Migdał et al. (11) confirmed high levels of dry matter in the longissimus dorsi muscle in fatteners of PLW, PL, and Duroc breeds, from 26.85% to 27.33%. Higher values of dry matter in the longissimus lumborum muscle were obtained in this study in fatteners originating from backcrossing with a share of entirely Polish pig breeds PLW and PL (groups I and II). It may be concluded based on the results of this study that commodity crossbreeding with a contribution of Polish pig breeds profitably affects the content of dry matter in the longissimus lumborum muscle.

Table 3. Physicochemical traits of longissimus lumborum muscle of gilts.

Traits	Groups		
	I	II	III
	(Mean ± SE)	(Mean ± SE)	(Mean ± SE)
Dry matter (%)	28.66 ± 0.11	28.81 ± 0.15	28.01 ± 0.13
Crude protein (%)	23.02 ± 0.13[b]	23.97 ± 0.07[a]	23.06 ± 0.02[b]
Collagen (%)	1.83 ± 0.09[c]	1.44 ± 0.09[b]	2.82 ± 0.02[a]
Crude fat (%)	1.92 ± 0.13[b]	2.12 ± 0.14	2.76 ± 0.10[a]
pH_{45min}	6.14 ± 0.06	6.32 ± 0.07[a]	6.02 ± 0.03[b]
pH_{24}	5.40 ± 0.03[b]	5.47 ± 0.01[a]	5.47 ± 0.01[a]
Water-holding capacity (%)	53.85 ± 0.27[a]	53.04 ± 0.76	50.35 ± 0.12[b]
Thermal drip (%)	18.42 ± 0.69	24.48 ± 0.85	19.11 ± 0.85
Shear force (N)	16.56 ± 0.85[a]	13.05 ± 0.72[b]	14.10 ± 1.02

Means within the same column with different superscripts are significantly different ($P < 0.05$).
I - (PLW × PL) × PLW; II - (PL × PLW) × PL; III - (PLW × PL) × (D × P).

Table 4. Physicochemical traits of longissimus lumborum muscle of hogs.

Traits	Groups		
	I	II	III
	(Mean ± SE)	(Mean ± SE)	(Mean ± SE)
Dry matter (%)	28.22 ± 0.12[a]	28.17 ± 0.16[a]	27.28 ± 0.14[b]
Crude protein (%)	23.37 ± 0.20[b]	24.44 ± 0.16[a]	23.35 ± 0.05[b]
Collagen (%)	2.13 ± 0.10	1.98 ± 0.06[b]	2.53 ± 0.05[a]
Crude fat (%)	1.87 ± 0.12[b]	2.33 ± 0.07	2.81 ± 0.11[a]
pH_{45min}	6.15 ± 0.09	6.18 ± 0.09	6.04 ± 0.05
pH_{24}	5.43 ± 0.01	5.46 ± 0.01	5.48 ± 0.02
Water-holding capacity (%)	53.85 ± 0.13[a]	53.79 ± 0.54	51.91 ± 0.22[b]
Thermal drip (%)	19.30 ± 0.68	21.13 ± 0.88	14.82 ± 0.77
Shear force (N)	12.92 ± 1.06[a]	10.17 ± 0.16[b]	10.81 ± 0.47

Means within the same column with different superscripts are significantly different ($P < 0.05$).
I - (PLW × PL) × PLW; II - (PL × PLW) × PL; III - (PLW × PL) × (D × P).

Meat of fatteners from group II was characterized by the highest protein content (Table 2). The highest contribution of protein in meat was noted in hogs from group II, and the lowest in hogs in groups I and III (the differences between these means were confirmed statistically). Gilts from group II also differed statistically significantly in terms of protein content from gilts from the other groups (Tables 3 and 4). Low protein content (22.03%) in the longissimus lumborum muscle of crossbred fatteners from PLW × Duroc crossing was demonstrated by Falkowski et al. (12). Definitely higher content of crude protein, in the range of 23.10% to 23.77%, was characteristic in the muscle of PLW, PL, and Duroc fatteners in the study conducted by Migdał et al. (11). In the case of this study, the protein level in the muscle of crossbred fatteners from groups I and III was similar to that obtained by Sieczkowska et al. (13).

Fatteners that were progeny of crossbred boars, especially fleshy ones, were characterized by definitely higher collagen content in the loin (group III). Collagen contribution in the longissimus lumborum muscle of fatteners from groups I and II was definitely lower compared to group III, and the differences were confirmed statistically (Table 2). The content of collagen in muscle was high both in gilts and hogs from group III. Its lowest value was seen for the muscles of gilts and hogs from group II (Tables 3 and 4). Statistically significant differences were observed between the mean values of the examined trait in the gilts. The content of connective tissue in animals muscles, and thus also collagen content, is sometimes differentiated, which was confirmed in the studies of Krasnowska and Čandek-Potokar et al. (14,15). It should also be mentioned that motorically active muscles contain higher amounts of collagen compared to static ones. The high collagen level noted in the longissimus lumborum muscle of 4-breed crossbred fatteners from group III would have been related to individual selections during crossing. Wojciechowski et al. (16), examining longissimus lumborum muscles of fatteners from 5 different interbreed crossing variants, demonstrated collagen content on a level from 1% to 1.3%, suggesting that it depends on the fattener's genotype.

Fat is a very important determinant characterizing pork meat quality. It may be concluded from the data presented in Table 2 that fat content in the longissimus lumborum muscle was differentiated and was highest in group III. Statistically significant differences in fat content in the muscle were noted between group III and groups I and II. The highest fat share was noted in gilts and hogs from group III (Tables 3 and 4). This was probably affected by the Duroc breed constituting the male component. It may be concluded from many other studies (1–4,10,17–19) that, together with an increase in carcass musculature degree, the content of intramuscular fat is subject to a decrease, even to below 1%, which clearly deteriorates raw material quality and its taste value.

Meat color is an important feature characterizing its quality. Lightness L*, redness a*, yellowness b*, tint, and saturation of the longissimus lumborum muscle in fatteners was differentiated in the groups and subgroups. With respect to color lightness L*, the muscle of fatteners from group III differed statistically from the muscles of fatteners from groups I and II, which were lighter. Meat color is also related to determination of normal or defective meat (PSE, DFD). It may be noted based on the study conducted by Doroszewski (20) that PSE meat is observed when the L* parameter has a value from 48.1 to 52.0, with pH_{45min} below 6.0. In turn, Reichert (17) reported that DFD meat is observed with L* on the level of 45.0 and PSE with L* higher than 58.0. According to that author, meat for which the L* value is within the range of 50.0 to 55.0 is considered as normal. Van Oeckel et al. (21) claimed, in turn, that meat with DFD failure is characterized by color lightness L* lower than 43.0, and PSE with L* lower than 50.0. It may be supposed, accepting the results of the studies conducted by Van Oeckel et al. and Honikel (21,22), that the longissimus lumborum muscle of fatteners from group III would have been characterized by PSE failure. The data contained in Table 2 demonstrate that the lowest contribution of redness a* was characteristic for the meat of fatteners from group II. The differences between the groups in the case of parameter a* appeared to be insignificant statistically. The share of yellowness b* exhibited the lowest value in group III and differed statistically significantly from the means of this feature in groups I and II. It was demonstrated in the study conducted by Reichert (17) that when the b* parameter value is below 2.5, we have good quality of meat. Slightly poorer quality was noted with b* values from 2.5 to 4.3, and definitely poor quality with b* values of higher than 4.3. Comparing these values of the b* parameter with those obtained in the present study, it may be concluded that the muscles of fatteners originating from the pigs from 3 various crossbreeding schemes did not fulfill the recommended standards elaborated by Reichert (17) for desirable quality meat. With respect to color tint and saturation, the highest values were obtained in the meat of fatteners from groups I and II, and the lowest in individuals from group III. These differences were confirmed statistically.

The results concerning pH_{45min} and pH_{24} obtained in this study point to a proper process of slaughter and meat seasoning.

Statistically significant differences in the case of most of the examined traits such as dry matter, crude protein, collagen, crude fat content, color components, water-holding capacity, and shear force of the longissimus lumborum muscle were proven between the gilts and hogs in the experimental groups (Tables 3 and 4). This study points to distinct differentiation in the range of physicochemical traits of longissimus lumborum muscles between genotypes and fattener sexes.

The following conclusions may be drawn:

1. Pig breeds used in crossbreeding affected the values of the examined physicochemical traits, important from culinary and technological points of view.
2. Fatteners crossbred from commodity backcrossing, compared to crossbreds from single commodity crossing with a contribution of 4 breeds, were characterized by higher content of dry matter in the longissimus lumborum muscle and higher water-holding capacity.

3. In terms of fat and collagen content in the muscle, crossbred fatteners from commodity backcrossing were characterized by worse parameters compared to 4-breed crossbreds.
4. Statistically significant differences between the fattener groups were noted in the range of muscle color determinants, which were the most profitable in ¾ LPW ¼ PL and ¾ PL ¼ LPW crossbred fatteners.
5. The highest shear force of the muscle was noted in ¾ PLW ¼ PL crossbred fatteners.

This study allows for selection of the best variant of pig outbreeding on commodity farms. The best advisable value for consumers and meat processing plants was demonstrated for fattener crossbreds of ¼ LPW ¼ PL ¼ Duroc ¼ Pietrain.

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