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CHEMICAL COMPOSITION OF MEAT FROM THE PULAWSKA BREED PIGS, DEPENDING ON THEIR SLAUGHTER WEIGHT*

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Abstract

Meat, including pork, is a source of nutritious proteins, fat and other ingredients required in the human diet. Currently, breeding and feeding works are carried out to obtain a product of the desired quality. The aim of the study was to determine the effect of the slaughter weight of pigs on the content of basic and mineral ingredients and the fatty acid profile in the *longissimus lumborum* and *semimembranosus* muscles. The research material was composed of 30 samples of both muscles from the Pulawska breed pigs. At the end of the fattening period lasting 114 days, pigs were slaughtered and classified to 3 groups according to the slaughter weight: 100 ± 2.5 kg – group I, 105 ± 2.5 kg – group II and 110 ± 2.5 kg – group III, and then 10 *longissimus lumborum* and 10 *semimembranosus* muscles were taken from each group. There was no statistically significant impact of the pig slaughter weight on the content of basic ingredients in both muscles, with the exception of intramuscular fat (IF) in the *semimembranosus*. Most IF was determined in the *semimembranosus* pig muscle with the highest (110 ± 2.5 kg) slaughter weight and the difference was significant ($p \leq 0.05$) compared to the lightest pigs (100 ± 2.5 kg). Although the slaughter weight did not affect significantly the overall content of mineral compounds (ash) in muscles, some influence of this factor on certain elements was found. Meat from the lightest pigs contained less Zn and Cu in comparison to meat from the heaviest ones ($p \leq 0.05$). The lipids of both muscles of lighter pigs (group I and II) were richer in PUFA than the lipids of muscles of the heaviest pigs ($p \leq 0.05$). The results give rise to the recommendation of slaughtering Pulawska pigs with the body weight of 100 ± 2.5 kg to 105 ± 2.5 kg, as this provides meat with less intramuscular fat, and whose profile of fatty acids is more favourable to the human body.

Keywords: pigs, meat, slaughter weight, basal nutrients, macroelements, microelements, fatty acids.

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INTRODUCTION

Currently, one of the major objectives of pig breeding is to improve the quality of slaughter pork to suit the requirements of the modern consumer. More and more attention is being paid to the nutritional value of meat products as one of the major components of the human diet. This is due to the fact that meat provides nutritious proteins and vitamins, easily assimilated minerals and bioactive compounds (taurine, carnosine, ubiquinone, creatine, etc.). In terms of the nutritional value, the fat content and the profile of fatty acids, with a significant share of saturated fatty acids, are also very important (MILCZAREK, OSEK 2006, ŻAK et al. 2014, KUNACHOWICZ et al. 2017). The nutritional value of raw pork is the combined result of a number of genetic and environmental factors such a breed, sex, feeding, age and weight at slaughter and others (CORREA et al. 2006, CZARNIECKA-SKUBINA et al. 2007, RAJ et. al. 2010, LECHOWSKI et al. 2013, WIĘCEK et al. 2015). The research (BABICZ et al. 2009, PIÓRKOWSKA et al. 2010, KASPRZYK et al. 2013) showed that Pulawska pig meat stands out in terms of the physical and chemical properties shaping its high quality. One of the important elements is the high content of intramuscular fat (IMF), which exceeds 2% in the longest muscle and ham (FLOROWSKI et al. 2006, MILCZAREK and OSEK 2006, BABICZ et al. 2009, PIÓRKOWSKA et al. 2010). This level of intramuscular fat guarantees the optimum sensory parameters of meat and its products (VIRGILI et al. 2003, OLKIEWICZ et al. 2006). The research (ROSENVOLD, ANDERSEN 2003, CORREA et al. 2006, MAIORANO et al. 2007, MIGDAŁ et al. 2007) shows that the amount of fat increases with the age and weight of slaughtered animals, while LO FIEGO et al. (2010), LUKAČ et al. (2015) and SZULC et al. (2018) reported different results. The impact of slaughter weight on the content of mineral compounds and the profile of the fatty acids of the meat is another interesting issue.

The aim of the study was to determine the effect of the slaughter weight of pigs on the chemical composition and nutritional value of the *longissimus lumborum* and *semimembranosus* muscles.

MATERIAL AND METHODS

The research material was sampled from 54 Pulawska castrated male pigs fed for 114 days with a complete balanced feed in accordance with the recommendations of the Standards of Pig Nutrition (2015). The mixture were prepared from barley (39%), triticale (38.5%), extracted soybean meal (10%), low-tannin faba bean (10%) and premix (2.5%), and 1 kg of the mixture contained 12.8 MJ ME, 16% crude protein, 0.91% lysine, 0.60% Ca, 0.22% P available. The fatteners were kept in the same environmental conditions with an unrestricted access to feed and water. At the end of the fattening, the animals were slaughtered and classified to 3 groups according to the slaughter weight: 100 ± 2.5 kg – group I, 105 ± 2.5 kg – group II and 110 ± 2.5 kg – group III. Then, 10 *longissimus lumborum* and *semimembranosus* muscles were sampled from each group of pigs in order to perform analyses of the chemical composition. In both muscles, the content of the following was determined: dry weight, mineral compounds in the form of ash, total proteins and fat – by AOAC International (2011). The energy value of meat was calculated on the basis of the content and physical equivalents of calorific values of protein (5.65 kcal g^{-1}) and fat (9.45 kcal g^{-1}). The content of the selected minerals was determined having mineralised a meat sample at 550°C for 16 h, after which the ash generated by mineralisation was placed in a 50 cm^3 flask together with 10 cm^3 of 10% HCl. The solution was assayed for the total content of elements, determined by atomic emission spectrometry with excitation in the inductively-coupled plasma (ICP-AES) using an Optima 3200RL camera (Perkin Elmer, USA). The composition and amount of individual fatty acids in the muscle lipid fraction were measured after the fatty acids had been converted to methyl esters by gas chromatography using a Varian 450-GC chromatograph (Varian Inc., USA) equipped with a flame-ionizing detector (air - hydrogen). A Select™ Biodiesel for FAME capillary column was used (30 m × 0.32 mm × 0.25 µm), filled with Select Biodiesel for FAME Fused Silica. The temperature of the injection chamber was 250°C, the detector – 300°C and the columns – 200°C (initial) and 240°C (final). Helium flowing at a rate of 2.5 ml min^{-1} served as the carrier gas. Based on the percentage (% of the total fatty acids) of fatty acids, we calculated the atherogenic (AI) and thrombogenic (TI) indices as well as the hypocholesterolemic-to-hypercholesterolemic fatty acids ratio (HH) according to Ulbricht and Southgate (1991) and Santos-Silva et al. (2002):

$$AI = (C12{:}0+4\times C14{:}0+C16{:}0)\,/[\Sigma MUFA+\Sigma(n\text{-}6)+\Sigma(n\text{-}3)];$$

$$TI = (C14{:}0+C16{:}0+C18{:}0)\,/[0.5\times\Sigma MUFA+0.5\times\Sigma(n\text{-}6)+3\times\Sigma(n\text{-}3)+\Sigma(n\text{-}3)\,/\Sigma(n\text{-}6)];$$

$$HH = [(C18{:}1n\text{-}9+C18{:}2n\text{-}6+C20{:}4n\text{-}6+C18{:}3n\text{-}3+C20{:}5n\text{-}3+C22{:}5n\text{-}3+ +C22{:}6\text{-}n)/(C14{:}0+C16{:}0)].$$

The results were developed by the ANOVA method using a one-way analysis of variance ($p \leq 0.05$) and calculating the mean values for the groups and the standard error of the mean (SEM). The significance of differences between mean values of the analysed characteristics was determined by the Duncan test (*post-hoc*) with Statistica 12.5 software (StatSoft Inc., 2015).

RESULTS AND DISCUSSION

The content of essential nutrients and the energy value of the *longissimus lumborum* and *semimembranosus* muscles are given in Table 1.

Table 1

Basic nutrients (g 100 g^{-1}) and energy value (kcal 100 g^{-1}) of muscles

Item	Groups*			SEM	*P*
	I *n* = 10	II *n* = 10	III *n* = 10		
Longissimus lumborum					
dry matter	27.28	26.94	27.30	0.603	0.261
crude ash	1.120	1.100	1.110	0.176	0.682
crude protein	23.12	22.90	23.10	0.500	0.370
crude fat	3.040	2.940	3.080	0.636	0.133
energy value	159.4	157.2	159.7	1.836	0.509
Semimembranosus					
dry matter	27.03	27.48	27.19	0.678	0.083
crude ash	1.100	1.080	1.090	0.173	0.386
crude protein	22.14	22.49	22.06	0.703	0.221
crude fat	3.770^{b}	3.910^{ab}	4.030^{a}	0.105	0.045
energy value	159.7	164.0	162.8	1.761	0.073

a, *b* – values in a row with different letters differ significantly at $p \leq 0.05$
* I – 100 ± 2.5 kg, II – 105 ± 2.5 kg, III – 110 ± 2.5 kg slaughter weight

There was no statistically significant impact of the pig slaughter weight on the content of basic ingredients in both muscles, with the exception of the intramuscular fat (IF) in the ham muscle. A significantly ($p \leq 0.05$) greater IF level was recorded in the *semimembranosus* muscle of the heaviest pigs (110 ± 2.5 kg) compared to lighter ones (100 ± 2.5 kg). Regardless of the body weight, the level of IF in this muscle should be considered as high because it exceeded 3-3.5%, which is the upper level for intramuscular fat acceptable by consumers and not having a negative impact on the processing technology of such material (FERNANDEZ et. al. 1999, CZARNIECKA-SKUBINA et al. 2007). The lack of impact of the slaughter weight of pigs on the content of IF in the *longissimus* muscle confirms the results obtained by CORREA et al. (2006), LO FIEGO et al. (2010), LUKAČ et al. (2015) and SZULC et al. (2018). CORREA et al. (2006) showed that different slaughter body weight: 107 kg, 115 kg or 125 kg, of Duroc x (Landrace x Yorkshire) crossbred pigs did not influence the intramuscular fat content (1.6-2.2%) in the *longissimus* muscle. Camborough/PIC hybrids investigated by LO FIEGO et al. (2010) did not exhibit significant differences in the intramuscular fat content depending on the body weight on the day of slaughter. LUKAČ et al. (2015) did not prove the impact of the slaughter body weight: 100-110 kg, 111-120 kg and 121-130 kg of Landrace and Yorkshire crossbreed pigs on IF in loin (2.78-3.60%) and ham (2.41-2.72%). In the studies by SZULC et al. (2018), Zlotnicka Spotted x Duroc fatteners from all slaughter weight groups (<110 kg; ≥110 ≤120 kg, >120 kg) were characterised by high IF content (3.57%), although the differences were not significant.

The levels of protein in the muscle of 3 groups of pigs determined in this experiment are similar to the results obtained by ELLIS and BERTOL (2001), LATORRE et al. (2004), LUKAČ et al. (2015). In the research by LATORRE et al. (2004), the *longissimus* muscle of crossbred pigs (Pietrain x Large White) x (Landrace x Large White) with the slaughter body weight of 116 kg, 124 kg and 133 kg contained from 23.7% to 24.0% of crude protein. Likewise, LUKAČ et al. (2015) obtained results for the crude protein content in the range from 22.33% to 22.54% in loin and from 20.60% to 21.01% in ham, regardless of the body weight at slaughter (100-110 kg 111-120 kg and 121-130 kg), in an experiment on Landrace and Yorkshire crossbreed pigs. Significantly ($p \leq 0.05$) less crude protein in the *longissimus* muscle of heavier (≥110 ≤120 kg, >120 kg slaughter weight) *vs.* light (<110 kg slaughter weight) Zlotnicka Spotted x Duroc fatteners was determined by SZULC et al. (2018). The increased content of protein in the muscles concurrent with an increase of the pig's body weight (from 107 kg to 115 kg) was demonstrated by CORREA et al. (2006). In turn, MIGDAŁ et al. (2007) showed a rise in both protein and fat in the *longissimus* and *semimembranosus* muscles of PL. In our study, no impact of pigs' slaughter weight on the energy value of the assessed muscles was found. Due to its higher intramuscular fat content, the ham muscle had a higher calorific value than the loin. A similar energy value of the *longissimus lumborum* muscle for Pulawska pigs was found by KASPRZYK et al. (2013).

The pig body weight differentiated the content of macro- and microelements in the *longissimus lumborum* and *semimembranosus* muscles (Table 2).

In both muscles, as the slaughter weight increased, so did the Zn and Cu levels, and the difference between groups I and III was confirmed statistically ($p \leq 0.05$). Significantly more Fe was found in the *longissimus* muscles of the heaviest pigs (group III) in comparison to the others. In the ham muscle of heavier animals, more Na and Mg were determined ($p \leq 0.05$) (without muscle of the heaviest pigs) in comparison to the lightest weight pigs (group I). Similar quantities of P, Mg and Fe, less K, Na and Cu but more Ca in comparison with our determinations were found in the raw loin by KUNACHOWICZ et al. (2017). In turn, LECHOWSKI et al. (2013) found a higher overall content of mineral compounds in the *adductor femoris* muscle of pigs, which included similar amounts of Mg, less K, Ca, Na and more Fe and Zn.

The dietary value of meat also depends on the composition and amount of fatty acids in the meat lipid fraction (Tables 3 and 4).

In the current study, the impact of the slaughter weight of pigs on the lipid profile of the *longissimus lumborum* and *semimembranosus* muscles

Table 2

Content of macro- and microelements (mg 100 g^{-1}) of pig muscles

Element	Groups*			SEM	*P*
	I $n = 10$	II $n = 10$	III $n = 10$		
Longissimus lumborum					
P	199.7	199.7	202.3	2.883	0.874
K	385.3	381.9	387.3	4.048	0.894
Ca	7.102	6.801	6.408	1.554	0.614
Mg	24.50	23.52	23.10	1.144	0.574
Na	45.10	45.30	45.30	1.628	0.796
Fe	0.840^{b}	0.874^{b}	1.080^{a}	0.493	0.039
Zn	1.232^{b}	1.343^{ab}	1.474^{a}	0.675	0.045
Mn	0.015	0.012	0.015	0.083	0.619
Cr	0.014	0.016	0.043	0.066	0.675
Co	0.007	0.009	0.002	0.033	0.188
Cu	0.082^{b}	0.086^{b}	0.153^{a}	0.240	0.032
Mo	0.020	0.010	0.017	0.111	0.296
Semimembranosus					
P	195.5	211.8	237.2	5.976	0.205
K	359.8	395.8	390.4	8.418	0.167
Ca	6.700	5.900	7.100	1.717	0.566
Mg	22.85^{b}	25.30^{a}	23.80^{ab}	2.133	0.038
Na	47.70^{b}	56.40^{a}	53.70^{a}	3.422	0.029
Fe	1.075	1.054	1.035	0.649	0.471
Zn	1.329^{b}	1.773^{a}	1.800^{a}	0.658	0.027
Mn	0.014	0.015	0.018	0.101	0.820
Cr	0.023	0.013	0.016	0.127	0.572
Co	0.002	0.001	0.002	0.041	0.781
Cu	0.111^{b}	0.160^{a}	0.152^{a}	0.282	0.026
Mo	0.009	0.008	0.009	0.071	0.865

a, *b* – values in a row with different letters differ significantly at $p \leq 0.05$
* I – 100 ± 2.5 kg, II – 105 ± 2.5 kg, III – 110 ± 2.5 kg slaughter weight

was found. Significantly more necessary unsaturated fatty acids, such as linoleic and linolenic acids, were found in the *longissimus lumborum* muscles of lighter pigs (group I and II) in comparison to the heart muscle of pigs from group III. A similar trend was observed in the lipid profile of the *semimembranosus* muscle. As a result, more ($p \leq 0.05$) PUFA was found in muscles of pigs in groups I and II. A decrease in PUFA parallel to the increasing

Table 3

Fatty acid profile (% of the total fatty acids) and AI, TI and HH indices of the *longissimus lumborum* muscles

Item	Groups*			SEM	*P*
	I $n = 10$	II $n = 10$	III $n = 10$		
C 14:0	0.540	0.604	0.646	0.307	0.828
C 16:0	27.10	27.60	28.39	1.026	0.388
C 16:1	3.400	3.852	3.930	0.141	0.278
C 18:0	8.164	7.940	8.766	0.890	0.631
C 18:1	58.16	56.96	56.15	1.156	0.386
C 18:2	2.332^{a}	2.678^{a}	1.840^{b}	1.020	0.019
C 18:3	0.020^{b}	0.032^{a}	0.010^{c}	0.140	0.016
C 20:0	0.041	0.040	0.038	0.001	0.182
C 20:1	0.122	0.144	0.114	0.154	0.229
C 20:2	0.014	0.014	0.014	0.070	0.495
C 20:4	0.048	0.054	0.036	0.143	0.397
Others	0.059	0.082	0.066	0.004	0.137
SFA	35.845	36.184	37.840	1.303	0.456
MUFA	61.682	60.956	60.194	1.144	0.464
PUFA	2.414^{a}	2.778^{a}	1.900^{b}	1.033	0.019
AI	4.950	5.579	4.906	0.262	0.539
TI	28.70	28.45	29.32	0.300	0.111
HH	2.200	2.122	1.977	0.375	0.307

a, *b*, *c* – values in a row with different letters differ significantly at $p \leq 0.05$
* I – 100 ± 2.5 kg, II – 105 ± 2.5 kg, III – 110 ± 2.5 kg slaughter weight
SFA – saturated fatty acids, UFA – unsaturated fatty acids, MUFA – monounsaturated fatty acids, AI – atherogenic index, TI – thrombogenic index, HH – hypocholesterolemic-to-hypercholesterolemic fatty acids ratio

slaughter weight in the *longissimus* muscle of four (Belgian Landrace, Duroc, Hampshire, Pietrain) breeds of pigs was found by RAJ et al. (2010). The authors found significantly ($p \leq 0.01$) less PUFA in the meat lipids of pigs with the body weight of 130 kg compared to 90 kg or 110 kg. In turn, WIĘCEK et al. (2015) have not noticed any significant effect of the slaughter weight (≤100 kg or >100 kg) on the sum of individual fatty acid groups in the *longissimus lumborum* muscles of pigs (PL x WPL) x Duroc.

The fatty acid profiles we identified provided the data for an evaluation of atherogenicity (AI) and thrombogenictity (TI) indices, and consequently the ratios of hypocholesterolemic and hypercholesterolemic fatty acids (HH) could be determined. According to TURAN et al. (2007), nutritional quality indices can indicate the meat's potential for plaque aggregation There were

Table 4

Fatty acid profile (% of the total fatty acids) and AI, TI and HH indices of the *semimembranosus* muscles

Item	Groups*			SEM	*P*
	I $n = 10$	II $n = 10$	III $n = 10$		
C 14:0	0.462	0.558	0.546	0.289	0.163
C 16:0	25.484	25.718	26.588	0.917	0.099
C 16:1	3.560	4.110	3.888	0.121	0.194
C 18:0	7.236	6.450	7.118	0.877	0.256
C 18:1	60.204	60.088	59.494	1.052	0.610
C 18:2	2.736	2.742	2.074	0.806	0.204
C 18:3	0.020^{a}	0.012^{b}	0.010^{b}	0.101	0.044
C 20:0	0.032	0.036	0.034	0.001	0.848
C 20:1	0.116	0.134	0.094	0.167	0.081
C 20:2	0.012	0.018	0.014	0.090	0.546
C 20:4	0.068	0.056	0.058	0.153	0.735
Others	0.070	0.078	0.082	0.005	0.762
SFA	33.214	32.762	34.286	1.156	0.210
MUFA	63.880	64.332	63.476	1.050	0.541
PUFA	2.836^{a}	2.828^{a}	2.156^{b}	0.821	0.021
AI	5.003	5.386	4.687	0.173	0.247
TI	26.16	26.47	27.35	0.238	0.100
HH	2.432	2.399	2.273	0.355	0.125

Explanations see Table 3

no significant differences in the indices, but at a higher slaughter weight the hypocholesterolemic potential decreased in both muscles, which proves their lower dietary value.

CONCLUSION

The results justify the recommendation to slaughter Pulawska pigs with the body weight of 100 ± 2.5 kg to 105 ± 2.5 kg, as their carcasses can provide meat with less intramuscular fat content, whose composition of fatty acids is more favourable to the human body.

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