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RELATIONSHIP BETWEEN SELECTED QUALITY CHARACTERISTICS AND LEVELS OF WATER-SOLUBLE PROTEINS IN PORCINE *LONGISSIMUS* MUSCLE

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ABSTRACT

This study comprised 136 meat samples (*m. longissimus lumborum*) from 136 pork carcasses of six-month-old crossbred porkers derived from ♀ (Polish Large White×Polish Landrace)×♂ (Duroc×Pietrain), with an average carcass weight of 85.8 ±8.5 kg, slaughtered on an industrial processing line. The pH_1, pH_{24}, pH_{48}, WHC, colour parameters (L^*, a^*, b^*), moisture content, crude protein, intramuscular fat, and water-soluble protein content were determined. Significantly high correlation coefficients between the proportion of water-soluble proteins in meat and crude protein and pH_{48}, WHC, and lightness (L^*) were recorded, with pH_{48} (measured in water extracts of meat) having the greatest effect on the proportion of water-soluble protein fractions in the meat and crude protein. In contrast, the basic chemical composition of the meat, i.e. moisture, crude protein, and intramuscular fat content, had no significant effect on the levels of water-soluble proteins. The results indicate that water-soluble proteins are a useful indicator of the quality of pork *longissimus* muscle.

Key words: pork quality, pH, water-soluble proteins

INTRODUCTION

Proteins play a major role in shaping the quality of meat. They largely determine the external appearance, colour, juiciness, and texture. Among the most important functional characteristics of proteins are their solubility and ability to hold water, both of which are significantly influenced by pH and temperature. Disruptions in the course of post-slaughter glycolysis, involving too rapid a decrease in pH and an increase in muscle temperature, cause denaturation of proteins, which leads to a deterioration in the water-holding capacity and a decrease in their technological functionality, resulting in PSE (pale, soft, exudative) meat.

The water-soluble fraction of meat proteins are sarcoplasmic proteins. In 1962, Bendall and Wismer-Pedersen [1962] found that in PSE meat, a fraction of sarcoplasmic proteins denature and precipitate on myofibrillar proteins, leading to a reduction in solubility and thus reduced drip loss and discolouration of the meat. Bendall and Lawrie [1964] showed that reduced solubility of muscle proteins is associated not only with the precipitation of denatured sarcoplasmic proteins on myofibrils, but also with partial denaturation of the two most important myofibrillar proteins – actin and myosin. In particular, denaturation of myosin is one of the most dramatic early postmortem events in muscle [Barbut et al. 2008]. According to Liu et al. [2016], the precipitation and aggregation of sarcoplasmic proteins occur in parallel with myofibrillar protein denaturation and improve the water holding capacity by counteracting the effect of denaturation of myofibrillar proteins. In a recent study, [Yang et al. 2022] showed that in PSE, sarcoplasmic proteins are denaturated in a very unique way. Proteomic analysis is proving helpful in better understanding the mechanisms of PSE meat formation, and some sarcoplasmic proteins may be potential biomarkers in assessing meat quality [Przybylski et al. 2016, Zequan et al. 2021].

Some authors [Kotik 1974, Lopez-Bote et al. 1989] consider the content of water-soluble proteins in pork as

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an important quality characteristic differentiating normal meat (RFN) from defective meat (PSE and DFD). The content of these proteins in muscle tissue is significantly correlated with other meat quality traits shaped during post-slaughter transition [Kortz 1986, Karamucki et al. 2004]. This is especially true for pH. The pH of muscle tissue decreases in successive hours *post mortem* and has a significant impact on the formation of its technological qualities, with the dynamics of this process being greatest during the first hour. The denaturation of myofibrillar and sarcoplasmic proteins in PSE meat and the accompanying decrease in water absorption is caused by both a rapid decrease in pH and a simultaneous increase in temperature inside the muscle [Kim et al. 2014]. The amount of water-soluble proteins extracted from meat correlates with the rate (pH_1) or extent (pH_{24}, pH_{48}) of the post-slaughter pH decrease. For example, the least water-soluble proteins are extracted from PSE meat, in which the rate of pH drop in the first hour *post mortem* is the greatest. In contrast, more of them are extracted from RFN (red, firm, non-exudative) meat, which has a lower rate of pH decrease in the first hour *post mortem*, and most of these proteins are extracted from DFD (dark, firm, dry) meat, in which *post mortem* glycogenolysis was the least intense [Lopez-Bote et al. 1989].

The purpose of this study was to analyze the relationship between selected quality characteristics of raw *longissimus lumborum* muscle (pH_1, pH_{24}, pH_{48}, WHC, colour parameters – L^*, a^*, b^*, moisture content, crude protein and intramuscular fat) obtained from porkers and the levels of water-soluble proteins.

MATERIAL AND METHODS

The material for the study consisted of *longissimus lumborum* muscle samples taken from 136 pork carcasses of six-month-old porkers (average weight 85.8 ±8.5 kg) from an industrial processing line. The porkers were derived from crossbreeding a ♀ (Polish Large White × Polish Landrace) × ♂ (Duroc × Pietrain).

The carcasses had been chilled in two stages (cooled for 60 minutes at –20°C and stored for 24 hours at 4°C), after which samples (approx. 1 kg meat with bone) were dissected from the right half-carcass between the 1st and 4th lumbar vertebrae for examination.

A CyberScan 10 pH meter (Eutech Cybernetics Pte Ltd., Singapore) was used together with a glass composite electrode ERH12–6 (HYDROMET S.C.). Calibration of the electrode was performed using pH 7.0 and pH 4.0 buffers.

The pH_1 was measured on the processing line about 45 minutes after slaughter in the *longissimus* muscle in the section between the 4th and 5th lumbar vertebrae of the right half-carcass.

After cooling for 24 hours, the *longissimus* muscle (with bone) was sampled from the 1–4 lumbar vertebrae of the right half-carcass while the carcass was dissected and packed in plastic bags, after which they were transported in thermoses to the laboratory.

The pH_{24} was measured in the laboratory in the center of a cross-section of the *longissimus* muscle on the side of the 4th lumbar vertebra, after which the samples were placed at 4°C and left until the following day.

Approximately 48 hours after slaughter, the samples were separated from the bones, the fat and flesh were removed, and the meat was ground twice on a wolf using a mesh with a spacing of 4 mm. The ground meat was used for further determinations, i.e. pH_{48}, WHC, colour parameters (L^*, a^*, b^*), moisture, crude protein, intramuscular fat, and water-soluble protein levels.

The pH_{48} was measured in water extract (distilled water) with a 1:1 meat to water ratio, after one hour of extraction.

The water holding capacity (WHC) of meat was determined as the percentage of bound water in total water using the Grau and Hamm method [Grau and Hamm 1952] as modified by Pohja and Niinivaara [1957]. A sample of meat weighing 0.3 g was placed on Whatman 1 blotting paper between two glass plates and subjected to a load of 2 kg for 5 minutes. Then, the surface areas of infiltration and the meat sample were drawn onto the glass plates. After drying the filter paper, both surfaces were planimetered (cm^2) and then the difference between surface areas was divided by the sample weight, thus calculating the percentage of free water in the meat. The resulting value was divided by the percentage of total water content in the meat, and after deducing this value from 100 the percentage of water holding capacity of the meat was obtained.

Colour measurements were carried out using a MiniScan XE Plus 45/0 spectrophotometer, with a measuring port diameter of 31.8 mm, equipped with an attachment for measuring the colour of ground meat. Instrument standardization was carried out using a black glass standard and a white tile standard with the following parameters: $X = 78.5$, $Y = 83.3$, and $Z = 87.8$ (for D65 illuminant and 10° observer). Samples of ground meat were placed in measuring dishes, the surface was leveled, and then held for 20 minutes at 4°C to oxidize the myoglobin in the surface layer [Krzywicki 1979]. They were then placed in a spectrophotometer attachment and colour was measured using the CIELAB scale [CIE 1976] and the illuminant/observer D65/10° system recommended for meat colour measurements [Honikel 1998].

Proximate measurements. The following chemical constituents were determined in samples of the ground meat according to official AOAC [2003] methods of analysis, namely: moisture content by oven drying a ca. 2 g sample at 102°C to a constant weight (950.46 B,

see p. 39.1.02); lipid (crude) content by petroleum ether extraction using a Soxhlet apparatus (960.39 (a), see p. 39.1.05); and crude protein content by the classical macro-Kjeldahl method (981.10, see p. 39.1.19).

The content of water-soluble proteins in meat was determined using the method of Kotik [1974] as follows: 25 g of distilled water were added to 15 g of ground meat and homogenized. The samples were then cooled for 30 minutes at 4–6°C and centrifuged for 20 minutes at 2000 rpm, after which they were filtered through soft strainers. Then, 0.5 ml of filtrate was taken into tubes, 4.5 ml of distilled water and 5 ml of biuret reagent were added and mixed. After 30 min, the extinction coefficient at 540 nm was determined on a spectrophotometer against a control sample consisting of 5 ml of distilled water and 5 ml of biuret reagent. The extinction coefficient was converted to soluble protein content on the basis of a previously prepared standard curve which was obtained by previously making parallel determinations of protein concentrations in a series of solutions using the Kjeldahl method and the colorimetric method. The biuret reagent was obtained by dissolving 45 g of potassium sodium tartrate ($NaKC_4H_4O_6$) in 200 ml of 0.2 M sodium hydroxide (NaOH) solution, in a 1000 ml volumetric flask. Then 5 g of copper sulfate ($CuSO_4 \cdot 5\,H_2O$) was added and made up to 1000 ml with 0.2 M sodium hydroxide (NaOH) solution in a volumetric flask.

Statistical analysis

Statistical analyses were performed using STATISTICA v13.3 (TIBCO Software Inc.). Means and standard deviations were calculated. In addition, simple correlation coefficients (Pearson's r) and adjusted coefficients of determination (R^2) were calculated and their significance was estimated for probability levels $P \leq 0.01$ and $P \leq 0.001$.

RESULTS AND DISCUSSION

Table 1 shows the number of samples in each pH range in the first hour and at 24 and 48 hours after slaughter. The results indicate that the pH value decreased in many cases during the second 24 hours after slaughter. After 48 hours after slaughter, three meat samples in the range of $5.0 < pH \leq 5.2$ were recorded. In addition, the number of meat samples in the range of $5.2 < pH \leq 5.4$ increased, especially $5.4 < pH \leq 5.6$, and decreased the number of meat samples primarily in the pH range of $5.6 < pH \leq 5.8$, as well as $5.8 < pH \leq 6.0$. This indicates that 24 hours after slaughter, meat quality was not yet fully formed.

Table 2 shows the means and standard deviations of the meat quality traits studied. The results indicate that the highest standard deviations for meat pH were recorded in the first hour after slaughter (pH_1). In contrast, the standard deviations for pH measured 24 hours (pH_{24}) and 48 hours (pH_{48}) after slaughter were lower.

Table 3 shows the simple correlation coefficients (r) between the studied meat quality traits and the proportion of water-soluble proteins in meat and crude protein. With the increase in meat and crude protein of water-soluble proteins, the pH_1, pH_{24}, and pH_{48} and WHC increased significantly, while the colour parameters (L^*, a^*, b^*) decreased significantly. There were no significant correlation coefficients between moisture and intramuscular fat. The correlation coefficients between water-soluble protein and crude protein in meat were also statistically insignificant. However, it was found that as the crude protein in meat increased, the proportion of water-soluble proteins in meat significantly decreased (r = –0.249**), which is consistent with the results of previous studies [Karamucki et al. 2004]. The highest correlation coefficients were recorded for pH_{48}, WHC, and lightness (L^*) and yellowness (b^*) of colour, with higher correlation coefficients for water-soluble protein content for meat than for crude protein. This is consistent with the results of Joo et al. [1999], who noted that as the solubility of sarcoplasmic and myofibrillar proteins increased, the pHu increased, and drip loss and colour parameters (L^*, a^*, b^*) decreased significantly, with the solubility of sarcoplasmic proteins having a greater effect on the formation of these quality traits. Those authors found that pork colour strongly correlated with the precipitation of sarcoplasmic proteins, while WHC was affected by the denaturation of myofibrillar proteins (PSE samples) and lower ultimate pH (PSE and RSE (reddish, soft, exudative) samples).

The coefficients of determination (R^2) in Table 4 indicate that the effect of pH_1 helped explain only 34.31% (R^2 = 0.3431) of the variation in meat content and 33.24% (R^2 = 0.3324) of the content in crude protein of water-soluble proteins. Similarly, for pH_{24} these were 44.13% and 40.40%, and for pH_{48} they were 67.19% and 64.14%. So, the pH at 48 hours after slaughter measured in the meat extracts had the greatest effect on the variation of water-soluble protein content in meat (expressed both as % in meat and as % in crude protein). The highest coefficients of determination (R^2) for the meat and crude protein content of water-soluble proteins were recorded for the combined effect of $pH_1 + pH_{48}$ (R^2 = 0.7176 and R^2 = 0.6869), $pH_1 + pH_{24} + pH_{48}$ + WHC (R^2 = 0.7467 and R^2 = 0.6925), $pH_1 + pH_{24} + pH_{48} + L^*$ (R^2 = 0.7677 and R^2 = 0.7232), $pH_1 + pH_{24} + pH_{48} + a^*$ (R^2 = 0.7409 and R^2 = 0.7286), $pH_1 + pH_{24} + pH_{48} + b^*$ (R^2 = 0.7303 and R^2 = 0.7071), $pH_1 + pH_{24} + pH_{48} + L^* + a^* + b^*$ (R^2 = 0.7695 and R^2 = 0.7285), $pH_1 + pH_{24} + pH_{48}$ + WHC + L^* (R^2 = 0.7741 and R^2 = 0.7210), and $pH_1 + pH_{24} + pH_{48}$ + WHC + $L^* + a^* + b^*$ (R^2 = 0.7756 and R^2 = 0.7267). The combined effect of only the three most important quality traits (pH_{48} + WHC + L^*) accounted for as much as 75.93% and 68.54% (R^2 = 0.7593 and R^2 = 0.6854) of the variation in the proportion of water-

Table 1. Number of meat samples with different pH depending on pH_1, pH_{24}, and pH_{48}

pH value	pH_1 (n=136)	pH_{24} (n=136)	pH_{48} (n=136)
6.8 < pH ≤ 7.0	12		
6.6 < pH ≤ 6.8	35		
6.4 < pH ≤ 6.6	30		
6.2 < pH ≤ 6.4	20		
6.0 < pH ≤ 6.2	16	5	5
5.8 < pH ≤ 6.0	15	12	11
5.6 < pH ≤ 5.8	7	47	32
5.4 < pH ≤ 5.6	1	59	71
5.2 < pH ≤ 5.4		13	14
5.0 < pH ≤ 5.2			3

Table 2. Mean and standard deviation (SD) for meat quality traits (n=136)

Trait	Mean	SD
pH_1	6.41	0.35
pH_{24}	5.61	0.16
pH_{48}	5.55	0.20
WHC	75.32	9.00
L^*	55.30	3.41
a^*	8.16	1.25
b^*	16.59	1.17
Moisture content, %	74.12	0.88
Intramuscular fat, %	2.60	0.94
Crude protein, %	22.13	0.67
Water-soluble protein, % in meat	9.06	0.91
Water-soluble protein, % in crude protein	40.94	4.28

soluble proteins in meat and crude protein, respectively. The coefficients of determination (R^2) had a higher value when water-soluble protein content was expressed as % in meat. There was no significant effect of moisture, intramuscular fat and crude protein on the proportion of water-soluble proteins in meat, or of moisture and intramuscular fat on the proportion of these proteins in crude protein. The proportion of water-soluble proteins in crude proteins depended significantly on the crude protein content in meat (R^2 = 0.0552).

In addition, the results indicate that the content of water-soluble proteins (expressed both as % in meat and % in crude protein) in the *longissimus* muscle of fattening pigs depended less on the dynamics of pH decrease *post mortem* (pH_1) than on the extent of pH decrease (pH_{24} and pH_{48}), with pH_{48} showing a greater effect on the content of these proteins than pH_{24}. When analyzing the obtained results, it should be taken into account that measuring pH directly in the muscle (here pH_1 and pH_{24}) allows determining the pH value only at the site of measurement, while measuring in aqueous extracts is more representative as it uses minced muscle, which was also used to determine the water-soluble protein proportion in the meat, as well as crude protein and moisture and intramuscular fat.

In summary, the results obtained indicate that the pH in the first hour *post mortem* (pH_1) had the least effect on the content (%) of the water-soluble protein fraction in meat and crude protein, with a greater effect of pH at 24 hours post slaughter (pH_{24}), and the greatest effect of pH at 48 hours post slaughter (pH_{48}).

Boler et al. [2010] state that pHu is one of the most important traits that determines the quality of meat by affecting WHC, the structure of meat, and the oxidation and reduction processes, which in turn affect the relative proportions of the chemical forms of myoglobin in the surface layer of meat. The results obtained confirm that the pHu was the most important trait determining the qual-

Table 3. Simple correlation coefficients (r) between the studied traits and the content of water-soluble proteins (n=136)

Trait	Water-soluble protein, % in meat	Water-soluble protein, % in crude protein
pH_1	0.590**	0.581**
pH_{24}	0.642**	0.612**
pH_{48}	0.821**	0.803**
WHC	0.799**	0.731**
*L**	–0.769**	–0.715**
*a**	–0.240*	–0.192
*b**	–0.689**	–0.653**
Moisture content, %	0.056	0.143
Intramuscular fat, %	–0.065	0.063
Crude protein, %	0.044	–0.249*
Water-soluble protein, % in meat	–	0.948**

* significant at P ≤ 0.01; ** significant at P ≤ 0.001.

Table 4. Coefficients of determination R^2 (adjusted) for meat quality traits (n=136)

Trait	Water-soluble protein, % in meat	Water-soluble protein, % in crude protein
pH_1	0.3431**	0.3324**
pH_{24}	0.4413**	0.4040**
pH_{48}	0.6719**	0.6414**
WHC	0.6361**	0.5308**
*L**	0.5888**	0.5079**
*a**	0.0511*	0.0298
*b**	0.4701**	0.4222**
Moisture, %	0.0000	0.0131
Intramuscular fat, %	0.0000	0.0000
Crude protein, %	0.0000	0.0552*
$pH_1 + pH_{24}$	0.5747**	0.5383**
$pH_1 + pH_{48}$	0.7176**	0.6869**
$pH_1 + pH_{24} + pH_{48}$	0.7177**	0.6898**
$pH_1 + pH_{24} + pH_{48}$ + WHC	0.7467**	0.6925**
$pH_1 + pH_{24} + pH_{48} + L^*$	0.7677**	0.7232**
$pH_1 + pH_{24} + pH_{48} + a^*$	0.7409**	0.7286**
$pH_1 + pH_{24} + pH_{48} + b^*$	0.7303**	0.7071**
$pH_1 + pH_{24} + pH_{48} + L^* + a^* + b^*$	0.7695**	0.7285**
$pH_1 + pH_{24} + pH_{48}$ + WHC + L^*	0.7741**	0.7210**
pH_{48} + WHC + L^*	0.7593**	0.6854**
$pH_1 + pH_{24} + pH_{48}$ + WHC + L^* + a* + b*	0.7756**	0.7267**

* significant at P ≤ 0.01; ** significant at P ≤ 0.001.

ity of meat. The pH_1 value is primarily a good indicator of the rate of change occurring in the muscle in the first hour after slaughter, helpful in distinguishing PSE meat from normal and DFD meat [Kortz 1986]. The quality of the meat is not yet fully developed at that time, so the pH_1 measurement is not closely related to the final quality of the meat, and the denaturation of muscle proteins in the first hour *post mortem* is not the main determinant of the proportion of water-soluble protein fractions in meat. The amounts are also affected by the further decrease in pH during the first and second hours *post mortem*. This is confirmed by the results of Karamucki et al. [2004] in analyzing the proportion of water-soluble proteins in the samples of *longissimus lumborum* muscle from pork carcasses classified into different classes of the EUROP system, and found no significant simple correlation coefficients between pH_1 and the proportion of water-soluble proteins in meat and crude protein.

However, they noted significant positive simple correlation coefficients between pH measured 48 hours after slaughter and the content of these proteins in meat and crude protein (r = 0.63** and r = 0.70**, respectively). Similarly, also for WHC, the authors recorded significant positive simple correlation coefficients (r = 0.52** and r = 0.53**, respectively). At the same time, as the proportion of water-soluble proteins in meat and crude protein increased, the technological quality of meat increased significantly.

It is known that the WHC of meat depends on the ability of various protein fractions to retain water, including water-soluble protein fractions. WHC is affected by both denaturing changes in proteins and structural changes associated with shrinkage of the spaces between filaments [Irving et al. 1990, Swatland 2004, Huff-Lonergan and Lonergan 2005]. In the material studied, the WHC of meat depended 63.61% and 53.08% on the variation in the proportion of water-soluble proteins in meat and crude protein, respectively.

Other quality traits significantly correlated with the meat and crude protein content of water-soluble proteins were lightness (L^*) and yellowness (b^*). The lightness (L^*) of meat depended 58.88% and 50.79%, and the yellowness (b^*) depended in 47.01% and 42.22% on the variation in the proportion of water-soluble proteins in meat and crude protein, respectively. Also Joo et al. [1999] noted that sarcoplasmic protein solubility accounted for 71% of the variation in lightness and 64% of the variation in yellowness.

As is well known, meat lightness (L^*) and yellowness (b^*) increase as the pH decreases. Lightness (L^*) increases because the decreasing pH generates structural changes in meat such as denaturation of proteins and shrinkage of the spaces between filaments [Irving et al. 1990], contributing to an increase in the amount of light reflected from the meat surface. The yellowness (b^*) of meat increases with the decreasing pH because low pH increases the susceptibility of meat pigments to oxidation and oxidation, resulting in an increase in the relative amounts of oxymyoglobin and methymyoglobin, which have a higher yellowness (b^*) than the reduced chemical form of myoglobin. Therefore, yellowness (b^*) depends almost exclusively on the variation in the relative amount of myoglobin chemical forms in the surface layer of meat penetrated by light and oxygen [Lindahl et al. 2001, Lindahl 2005, Karamucki et al. 2013]. The coefficients for redness (a^*) are due to the fact it depends primarily on the amount of pigments in the meat layer penetrated by light, and to a lesser extent on the relative amount of chemical forms of myoglobin [Karamucki et al. 2013].

CONCLUSIONS

In this study, the proportion of water-soluble protein fraction in meat and crude protein depended most on the pH value measured 48 hours *post mortem* (pH_{48}), and less on the pH values after 24 hours (pH_{24}) and in the first hour *post mortem* (pH_1). The highest correlation coefficients (r) between the percentage of water-soluble protein in meat and crude protein were recorded for pH_{48}, WHC, and lightness (L^*). The combined effect of just these three variables accounted for as much as 75.93% and 68.54% of the variation in the percentage of water-soluble proteins in meat and crude protein, respectively. In contrast, moisture, crude protein, and intramuscular fat had no significant effect on the percentage of water-soluble proteins in meat. The results indicate that the percentage of water-soluble proteins in pork *longissimus* muscle and crude protein can be useful in assessing the quality of pork.

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ZALEŻNOŚĆ MIĘDZY WYBRANYMI CECHAMI JAKOŚCIOWYMI WIEPRZOWEGO MIĘŚNIA *LONGISSIMUS* A ZAWARTOŚCIĄ W NIM BIAŁEK ROZPUSZCZALNYCH W WODZIE

STRESZCZENIE

Badaniami objęto 136 prób mięsa (*m. longissimus lumborum*) pobranych ze 136 tusz sześciomiesięcznych tuczników mieszańców, pochodzących z krzyżowania ♀ (Polish Large White x Polish Landrace)×♂ (Duroc x Pietrain), o średniej masie tuszy 85,80 kg ±8,49, ubijanych na przemysłowej linii technologicznej. Określono pH_1, pH_{24}, pH_{48}, WHC, parametry barwy (L^*, a^*, b^*) mięsa oraz procentową zawartość w nim wody, białka ogólnego, tłuszczu śródmięśniowego i białek rozpuszczalnych w wodzie. Odnotowano istotne wysokie wartości współczynników korelacji między udziałem białek rozpuszczalnych w wodzie, zarówno w odniesieniu do mięsa, jak i białka ogólnego, a pH_{48}, wodochłonnością (WHC) i jasnością barwy (L^*), przy czym wartość pH_{48} (zmierzona w ekstraktach wodnych mięsa) miała największy wpływ na zawartość w mięsie i w białku ogólnym frakcji białek rozpuszczalnych w wodzie. Natomiast podstawowy skład chemiczny mięsa, tj. zawartość wody, białka ogólnego i tłuszczu śródmięśniowego, nie miał istotnego wpływu na zawartość w nim badanych białek. Wyniki wskazują, że zawartość białek rozpuszczalnych w wodzie w wieprzowym mięśniu *longissimus* jest cechą przydatną w ocenie jakości wieprzowiny.

Słowa kluczowe: jakość mięsa wieprzowego, pH, białka rozpuszczalne w wodzie

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