Original scientific paper
DOI: /10.5513/JCEA01/19.1.2029
Journal of Central European Agriculture, 2018, 19(1), p.102-113

Pork quality with special emphasis on colour and its changes during storage

Jakość mięsa wieprzowego ze szczególnym uwzględnieniem barwy i jej zmian w trakcie przechowywania

Maria BOCIAN, Hanna JANKOWIAK*, Patrycja RESZKA and Sandra BANASZAK

Department of Pig Breeding and Horses, UTP University of Science and Technology in Bydgoszcz, 85-084 Bydgoszcz, Mazowiecka 28, Poland, *correspondence: jankowiak@utp.edu.pl

Abstract

The aim of the study was to evaluate the quality of pork meat, including its colour after 24, 48, and 72 hours from the slaughter and its changes during storage. The meat was obtained from 52 crossbreed porkers F_1 (Polish Large White x Polish Landrace), gilts and hogs in equal amounts. The assessment of the quality of the meat was performed in 48 hours after slaughter on the samples of the *longissimus lumborum* muscle. The meat was analysed in respect to its acidity (pH_{45} and pH_{48h}), technological properties, and the level of the muscle colours. The sensory evaluation of the meat was conducted in terms of the intensity of colour, marbling, and firmness. The chemical composition of the meat and its tenderness was also evaluated. The colour of meat was measured by the use of the Minolta CR-300 apparatus in CIE *L*a*b** system (*L** - lightness, *a** - participation of redness, *b** - participation of yellowness), where the saturation of colour *C** was calculated as well as the hue angle h^o after 24, 48, and 72 hours from the slaughter. The changes (Δ) of colour parameters after 24 h and 48 h of storage were calculated. Results demonstrated that the examined pork had the proper technological properties, it was tender (41.93 N/cm), and low in collagen (0.89%). During the storage of meat after 24, 48, and 72 hours from the slaughter, many significant changes appeared in the parameters of meat colour that is in *L**, *a**, *b**, in saturation with *C** and in the hue *h*° ($P<0.01$). The values of colour *L** were changing into lighter ($P<0.01$), whereas the participation of colour red *a**, yellow *b** and the saturation of colour *C** and its hue h^o showed an increasing trend during storage ($P<0.01$). It was noticed that there are significant correlation coefficients between the colour parameters *L**, *a**, *b**, its saturation *C**, and hue h^o, and the technological quality characteristics, the sensory intensity of colour, the content of muscle pigments at 24, 48 and 72 h after slaughter ($P<0.01$; $P<0.05$).

Keywords: colour of meat and its changes, meat quality, pork

Streszczenie

Celem pracy była ocena jakościowa mięsa wieprzowego, w tym barwy mierzonej 24, 48 i 72 h po uboju oraz jej zmiany w trakcie przechowywania. Mięso do badań pozyskano od 52 tuczników mieszańców F_1 (wielka biała polska x polska biała zwisłoucha), w połowie loszki i wieprzki. Oceny jakości mięsa dokonano 48 h po uboju na próbach mięśnia *longissimus lumborum*. W mięsie oznaczono kwasowość (pH_{45} i pH_{48h}), właściwości technologiczne mięsa oraz zawartość barwników mięśniowych. Na plastrze mięsa surowego dokonano oceny sensorycznej mięsa: określono intensywność barwy, marmurkowatość i jędrność-twardość. Oceniono skład chemiczny mięsa oraz jego kruchość. Barwę mięsa mierzono aparaturowo w systemie CIE *L*a*b** (*L** - jasność, *a** - udział barwy czerwonej, *b** - udział barwy żółtej), wyliczono nasycenie barwy *C** oraz h^o ton barwy, po 24, 48 i 72 h od uboju. Wyliczono zmiany (Δ) parametrów barwy po 24 h i 48 h przechowywania. W pracy wykazano, iż oceniane mięso wieprzowe cechowało się prawidłowymi właściwościami technologicznymi, było kruche (41,93 N/cm), o niskiej zawartości kolagenu (0,89%). W trakcie przechowywania mięsa po 24, 48 i 72 h od uboju nastąpiły istotne zmiany w parametrach barwy mięsa, tj. *L*, a*, b**, nasyceniu *C** oraz tonie barwy *h°* (P<0,01). Wartości barwy *L** zmieniały się w kierunku jaśniejszym (P<0,01), natomiast udział barwy czerwonej *a**, żółtej *b** oraz nasycenie barwy *C** i jej ton h^o wykazywały tendencję wzrostową w czasie przechowywania mięsa (P<0,01). Wykazano, istotne współczynniki korelacji między parametrami barwy *L**, *a**, *b**, jej nasyceniem *C** i tonem h^o a cechami jakości technologicznej, intensywnością barwy ocenianą sensorycznie, zawartością barwników mięśniowych w czasie 24, 48 i 72 h po uboju (P<0,01; P<0,05).

Słowa kluczowe: barwa mięsa i jej zmiany, jakość mięsa, mięso wieprzowe

Introduction

The requirements of pork consumers are concentrated (Novotni-Danko et al., 2015; Balogh et al., 2016), among other things, on the colour of meat, which is an important criterion for its qualitative assessment. The consumers prefer light pink-red coloured meat (Karamucki, 2008; Pospiech, 2016). The meat colour is a sensation perceived by the senses, depending on the ability to absorb or reflect the light of different wavelengths by colourful chemical compounds (Kortz, 1970; Lindahl et al., 2001). It is more stable when the meat is characterized by lower saturation, darker colour, and higher pH and higher water holding capacity. During the storage of meat, its colour changes (Kortz, 1970; Bocian et al., 2015).

The colour lightness is a quantitative feature which determines the degree of the light reflection or absorption. The intensity of meat colour depends on the content of muscle pigments (Pisula, 2011), and the composition and texture of meat (Karamucki, 2008). Pisula (2011) states that young animals are characterized by lighter colour of meat due to the lower content of their muscle pigments. Karamucki (2008) showed that the sex of animals influences the colour formation, while the meat of gilts is of darker colour than barrows. The breed of animals also matters. The pigs of the Złotnicka Spotted and Puławska breeds are characterized by a darker and

therefore more favourable colour of meat (Bogucka and Kapelański, 2016). A higher content of the intramuscular fat and the marbling in meat causes that the meat is lighter (Czarniecka-Skubina et al., 2007).

The meat colour is closely related to other characteristics of the technological suitability of pork meat, affecting the assessment of the consumer quality and the processing efficiency (Van Laack et al., 2001; Kajak et al., 2007; Strzyżewski et al., 2008; Bocian et al., 2015).

The aim of the study was to assess the quality of pork meat, the colour measured 48 and 72 h after the slaughter and its changes during storage.

Materials and methods

The meat for the study was obtained from 52 fatteners of the F1 crossbreed (Polish Large White x Polish Landrace), half gilts and half barrows, bought in the area of the Kuyavian-Pomeranian area. The meat quality evaluations were performed 48 h after slaughter on the samples of the *longissimus lumborum* muscle, which were kept refrigerated at 4-6 ^{o}C. The acidity (pH_{45} and pH_{48h}) was determined in the meat by means of the pH meter-Elmetron CP-401 with a stick electrode. The apparatus was calibrated using pH 7 and pH 4 buffer from Elmetron.

Assessment of water holding capacity was determined by the method of Grau and Hamm (1952), modified by Pohja and Niinivaara (1957). A sample of 300 mg finely ground meat was applied to Whatman 1 paper, placed between two glass plates and subjected to an even loading of 2 kg for 5 min. From the size of the outflow area, the percentage of free water in the meat was calculated, assuming that 1 cm^2 of the outflow corresponded to 10 mg of water. A smaller area of the outflow (the amount of free water) indicated the greater water holding capacity of the meat.

The free flow of meat juice during 48 h of storage was determined according to Honikel (1987) on slices about 2.5 cm thick together with the perimysium. The sample was placed in a foil bag and weighed. The bag was cut several times at its bottom to allow the flow of the muscle juice. Then, the sample was placed in the second bag and suspended so that the leaking juice was not in contact with the meat sample. The samples were stored in a hanging position under refrigerated conditions at 2-4 °C for 48 h. After this time, the samples were re-weighed. From the difference in weight before the storage and after 48 h of the storage calculated the amount of free outflow of meat juice.

The size of the thermal drip was done 48 h after the slaughter by the Walczak (1959) method. The sample of the finely ground meat (20 g) was placed in a hygroscopic gauze and heated in a water bath at 85 ^{o}C for 10 min. After removing the sample, removing the gauze and cooling down to 4 ^{o}C, the sample was reweighed. From the difference in weight of meat before the processing and after the heat treatment calculated the percentage of loss.

The content of muscle pigments was determined colorimetrically according the Hornsey (1956) method. The finely ground meat samples (10 g) were filled with 40 ml of acetone:water:concentrated HCl, in a ratio of 40:2:1 and extracted for 1 hour. After filtration, the absorbance of the tested solution was measured with the Marcel Media

spectrometer at a wavelength of 640 nm. The optical density value (E) was multiplied by factor 680 to obtain the appropriate hematine concentration express as micrograms of hematin per 1 g of meat.

The measurement of meat tenderness was performer using the INSTRON 3342 strength tester with Warner-Bratzler attachment, according to the method provided by Szalata et al. (1999). A meat sample of about 120 g was heated in a water bath to reach 70 °C inside. The heat treatment was conducted in 0.85% NaCl solution. Then, according to course of muscle fibres, 10 mm x 10 mm posts were cut, which were cut perpendicularly to their course. The results were read as the maximum shear force, expressed in N.

The analysis of the chemical composition of meat i.e. water, total protein, intramuscular fat and collagen, was conducted in accordance with norms (PN-A 82109:2010) with the use of the near-infrared spectrometry (NIT) using an artificial neural network (ANN) calibration with the use the FoodScan camera from the FOSS company.

On a slice of raw meat weighing 120 g, visually determined: colour intensity according to 6-degree scale (PN-ISO 4121:1998): 1 pt. - very light meat, 6 - dark-red meat; the degree of marbling using Canadian and American models on a 10-degree scale (NPB, 2000): 1 - meat without overgrowth, 10 - very high marbling and tactile: firmness - hardness of meat on a 7-degree scale (PN-ISO 4121:1998): 1 - very hard, 7 - very soft.

The meat colour was also measured on a slice of raw meat, after 24, 48 and 72 h from the slaughter, using the Minolta CR 310 photocolorimeter (Konica Minolta, Japan) with a measurement port of 50 mm diameter. The standardization of the apparatus was conducted with the use of a white calibration plate CR310 with Y = 92.8, x = 0.3175 and y = 0.3333. The colour parameters were determined in the CIE $L^*a^*b^*$ system (L^* - lightness, a^* - participation of redness, b^* - participation of yellowness) (CIE, 1986), using the D65 illuminant and the standard observer 2°. The colour saturation (parameter C^*), and also the hue (h^o - hue angle) were calculated according to the formula given by Beattie et al. (1999) and Brewer et at. (2001):

$$C^* = \sqrt{(a^*)^2 + (b^*)^2},\ h^o = (\tan^{-1} \cdot b^*/a^*)$$

Calculated the changes (Δ) of colour parameters after 24 and 48 h of storage: ΔL^*, Δa^*, Δb^*, ΔC^* i Δh^o.

The obtained results were statistically calculated using the Statistica (2008) program. Calculated the arithmetic mean and standard deviation. The significance of the differences between the colours evaluated at 24, 48 and 72 h after the slaughter were verified by the F-Fisher test. Significance levels were determined: significant $P<0.05$ and high $P<0.01$. The following linear model was used:

$y_{ij} = \mu + \alpha_i + \varepsilon_{ij}$

where:

y_{ij} – value of dependent variable;

μ – total average;

αi – main effect of genotype: i = colour *L*, a*, b*, C** i h^o at 24, 48 and 72 h after slaughter;

εij – random error.

The Pearson's correlation coefficients were calculated between the parameters of colour *L*a*b**, saturation *C** and hue h^o in 24, 48 and 72 h after the slaughter, and other characteristics of meat quality. Correlation coefficients were estimated on the basis of the pairs of observations of the variables x and y. The computer program Statistica 8 PL (2008) was used for calculations.

Results and discussion

The results of the study showed that the assessed meat samples were characterized by good technological properties (Table 1), characteristic for meat of normal quality (Warriss et al., 2006; Kajak et al., 2007; Strzyżewski et al., 2008; Bocian et al., 2015). The low collagen content obtained in the study indicates that the meat was derived from young animals, which was confirmed by its good tenderness (Janicki and Buzała, 2013).

The results of meat colour were assessed with the uses of an apparatus and its change during 24 and 48 hours of storage are summarized in Table 2.

The lightness of colour *L** determines the total amount of light reflected from the surface of the slice of meat (Karamucki, 2008). It depends to a large extend on the structure of the meat tissue, its acidity (pH), water holding capacity and the depth of penetration of the light beam (Lindahl et al., 2001; Karamucki et al., 2013). A darker colour *L** was observed in the meat after 24 h rather than 72 h after slaughter; statistically significant changes into a lighter colour of meat were found during the storage.

The remaining colour parameters are: *a** - participation of red, *b** - the participation of yellow, its saturation *C** was calculated as the derivative of *a** and *b** and *h*° - hue angle (Beattie et al., 1999; Brewer et al., 2001; Bocian et al., 2015). The participation of red colour *a** increased during 24 h of storage (P<0.01), and also the *b** value determining the participation of yellow colour increased significantly at 24, 48 and 72 h after the slaughter (P<0.01). Similarly obtained values of saturation *C** and hue angle h^o showed and increasing tendency (P<0.01) in the direction of increasing the intensity during the storage of meat of to 72 h after the slaughter. Different result for the participation of red colour *a** were obtained in the Bocian et al. (2015) studies, where the participation of red colour *a** significantly decreased during 48 h of meat storage (P<0.01). The authors showed significant changes (Δ) of colour in the direction of increasing its intensity (P<0.01) in the case of yellow colour *b** and the hue angle h^o during 48 h of the meat storage. However, Karamucki et al. (2013) the highest colour changes found in the participation of red colour (Δ*a**) and hue angle (Δh^o) during the storage of quail muscle. In the studies of Kajak et al. (2007) and Turyk et al. (2013) no changes of colour parameters during the storage of meat were confirmed.

Table 1. Characteristics of technological suitability of pork meat

Trait	Statistical measure	
	Average	Standard deviation
pH_{45}	6.34	0.05
pH_{48h}	5.44	0.07
Visual colour intensity, 1-6 scale	3.5	0.47
Marbling, 1-10 scale	2.4	0.72
Firmness, 1-7 scale	4.3	0.56
Muscle pigments (micrograms of hematin per 1 g of meat)	30.74	7.62
Water holding capacity (% of free wate)r	19.67	2.8
Free juice drip (%)	4.03	1.61
Thermal drip (%)	20.17	2.94
Meat tenderness (N)	41.93	10.21
Chemical composition of meat		
Water content (%)	73.19	0.52
Total protein content (%)	23.46	0.56
Intramuscular fat content (%)	2.35	0.75
Collagen content (%)	0.89	0.13

The obtained relationships between the colour parameters *L**, *a**, *b**, *C** and h^o measured 24, 48 and 72 h after the slaughter, and characteristics of the technological assessment are presented in Table 3.

Demonstrated both positive and negative statistically significant correlations, which indicates that together with the increase of parameter values of colours *L*a*b*,* saturation *C** and hue angle h^o increased the free juice drip, the thermal drip, and the tenderness of meat decreased ($P<0.01$; $P<0.05$). Different from these values of correlation coefficients between the colour parameters *L*, b** and the saturation *C**, and pH_{45} and pH_{24h} were found in the studies of Strzyżewski et al. (2008). The authors found that the change in the acidity of meat was caused by the change in the *L** colour, towards lighter colour, the yellowness *b** and saturation *C** without

changes in the participation of red colour *a**. The obtained results in the study are consistent with those of other researchers (Brewer et al., 2001; Van Laack et al., 2001; Kajak et al., 2007; Strzyżewski et al., 2008; Bocian et al., 2015).

The relationships between the colour of meat measured at 24, 48 and 72 h after the slaughter, and the characteristics of the sensory assessment and the muscle pigments are summarized in Table 4.

The sensory intensity of the colour, as well as the content of the muscle pigments was changing towards lighter colours evaluated 24, 48 and 72 h after slaughter ($P<0.01$; $P<0.05$). There was a significant positive correlation between *L** colour lightness measured 48 and 72 h after the slaughter and the marbling ($P<0.05$). In the studies by Bocian et al. (2015) showed similar relationships between the parameters of colour *L*a*b** and tone h^o 48 and 96 h after the slaughter, and the colour intensity and the muscle pigments. The authors did not confirm the significant correlations between the saturation *C**, and the sensory intensity of colour, and the content muscle pigments.

Table 2. Colour parameters measured at 24, 48 and 72 h after slaughter and their changes

Trait	Time after slaughter (h)			Changes (Δ) of colour during storage (h)	
	24	48	72	24	48
*L**	53.95^{A} ±2.4	54.6 ±2.22	55.3^{B} ±2.13	+0.65	+1.35
*a**	14.95^{A} ±0.99	15.67^{B} ±1.01	15.31 ±1.1	+0.72	+0.36
*b**	2.79^{A} ±0.73	3.49^{B} ±1.53	6.61^{C} ±0.71	+0.7	+3.82
*C**	15.23^{A} ±1.01	16.12^{B} ±1.09	16.69^{C} ±1.09	+0.89	+1.46
h°	10.57^{A} ±2.63	12.49^{B} ±5.16	23.38^{C} ±2.52	+1.92	+12.81

Explanations: *L**- lightness, *a**- participation of redness, *b**- participation of yellowness, *C** - saturation, *h*°- hue angle. Significance of differences: $^{A, B, C}$ $P<0.01$.

Table 3. Simple correlation coefficients between meat colour characteristics measured 24, 48 and 72 h after slaughter and some of technological quality traits

Colour	Time after slaughter	pH_{45}	pH_{48h}	Free juice drip	Thermal drip	Meat tenderness	Intramuscular fat
*L**	24	-0.066	-0.243	0.458**	0.24	-0.29*	-0.069
	48	0.11	-0.065	0.289*	0.225	-0.157	0.032
	72	0.001	-0.152	0.409**	0.274*	-0.309*	0.123
*a**	24	-0.119	-0.084	-0.078	-0.172	0.031	-0.075
	48	0.152	0.276*	-0.273	-0.362*	0.194	0.009
	72	-0.075	-0.116	-0.101	-0.326*	0.237	-0.238
*b**	24	-0.019	-0.154	0.13	0.178	-0.098	0.136
	48	0.308*	0.164	0.052	-0.009	0.004	0.047
	72	-0.154	-0.309*	0.393**	0.106	0.023	-0.23
*C**	24	-0.113	-0.097	-0.062	-0.144	0.015	-0.053
	48	0.251	0.302*	-0.234	-0.366**	0.176	0.019
	72	-0.106	-0.187	0.011	-0.28*	0.227	-0.281*
h^o	24	0.008	-0.138	0.167	0.238	-0.109	0.164
	48	0.281*	0.123	0.104	0.034	-0.019	0.048
	72	-0.01	-0.222	0.424**	0.288*	-0.119	-0.066

Explanations: *L**- lightness, *a**- participation of redness, *b**- participation of yellowness, *C** - saturation, *h*°- hue angle. *Significance at P<0.05. **Significance at P<0.01.

Table 4. Simple correlation coefficients between meat colour traits measured 24, 48 and 72 h after slaughter and characteristics of sensory evaluation, and muscle pigments meat

Colour	Time after slaughter	Visual colour intensity	Firmness	Marbling	Muscle pigments meat
*L**	24	-0.714**	0.128	0.219	-0.555**
	48	-0.52**	0.169	0.316*	-0.444**
	72	-0.711**	0.169	0.274*	-0.529**
*a**	24	0.224	0.061	-0.028	0.251
	48	0.55**	0.012	-0.104	0.502**
	72	0.387	-0.024	-0.178	0.209
*b**	24	-0.459**	0.114	0.171	-0.316*
	48	0.066	0.191	0.184	-0.024
	72	-0.347*	0.048	-0.11	-0.288*
*C**	24	0.157	0.073	-0.005	0.205
	48	0.486**	0.075	-0.026	0.456**
	72	0.267	-0.011	-0.198	0.122
h^o	24	-0.526**	0.106	0.178	-0.389**
	48	-0.154	0.196	0.199	-0.094
	72	-0.554**	0.049	0.002	-0.39**

Explanations: *L**- lightness, *a**- participation of redness, *b**- participation of yellowness, *C** - saturation, *h*°- hue angle. *Significance at P<0.05. **Significance at P<0.01.

Conclusion

In the study it has been shown that the evaluated pork meat was characterized by the correct technological properties and that it was tender with a low content of collagen. In the value of the *L** colour changed statistically toward a lighter colour, while the participation of red colour *a**, yellow *b** and the saturation *C** and its hue *h*° showed an increasing tendency during the storage of meat at 24, 48 and 72 h from the slaughter (P<0.01). Found a significant coefficients of correlation between the parameters *L**, *a**, *b**, and the saturation C* and the hue h^o, and the technological

characteristics of quality, and the sensory intensity, and the muscle pigment content in 24, 48 and 72 h after the slaughter (P<0.01; P<0.05).

References

Balogh, P., Békési, D., Gorton, M., Popp, J., Lengyel, P. (2016) Consumer willingness to pay for traditional food products. Food Policy, 61, 176-184. DOI: https://dx.doi.org/10.1016/j.foodpol.2016.03.005

Beattie, V. E., Weatherup, R. N., Moss, B. W., Walker, N. (1999) The effect of increasing carcass weight of finishing boars and gilts on joint composition and meat quality. Meat Science, 52, 205-211. DOI: https://dx.doi.org/10.1016/S0309-1740(98)00169-7

Bocian, M., Jankowiak, H., Kapelański, W. (2015) Changes of meat colour during storage. Nauka Przyroda Technologie, 9, 4, 57. DOI: https://dx.doi.org/10.17306/J.NPT.2015.4.57

Bogucka, J., Kapelański, W. (2016) Microstructure of *longissimus lumborum* muscle and meat quality of native Polish pig breeds: Złotnicka Spotted and Puławska. Annals of Animal Science, 16, 4, 1199-1210. DOI: https://dx.doi.org/10.1515/aoas-2016-0029

Brewer, M. S., Zhu, L. G., Bidner, B., Meisinger, D. J., McKeith, F. K. (2001) Measuring pork color: effects of bloom time, muscle, pH and relationship to instrumental parameters. Meat Science, 57, 2, 169-176.

CIE (1986) Colorimetry. Publication CIE 15.2. Vienna: Central Bureau of CIE.

Czarniecka-Skubina, E., Przybylski, W., Jaworska, D., Wachowicz, I., Urbańska, I., Niemyjski, S. (2007) Quality profile of pork meat with varying contents of intramuscular fat. Żywność. Nauka. Technologia. Jakość, 55, 6, 285-294.

Grau, R., Hamm, R. (1952) Eine einfache Methode zur Bestimmung der Wasserbindung in Fleisch. Fleischwirtschaft, 4, 295-297.

Honikel, K. O. (1987) The water binding of meat. Fleischwirtschaft, 67, 9, 1098-1102.

Hornsey, H. C. (1956) The colour of cooked cured pork. I. Estimation of the nitric oxide-haem pigments. Journal of the Science of Food and Agriculture, 7, 534-540.

Janicki, B., Buzała, M. (2013) Effect of collagen on technological quality of meat. Żywność. Nauka. Technologia. Jakość, 87, 2, 19-29.

Kajak, K, Przybylski, W., Jaworska, D, Rosiak, E. (2007) Characteristics of technological quality, sensorial and shelf-life of pork with different pH. Żywność. Nauka. Technologia. Jakość, 1, 50, 26-34.

Karamucki, T. (2008) Studies on the formation of colour of the porcine *longissimus lumborum* muscle and the usefulness of selected methods of its measurement for pork quality assessment. Rozprawy 249, AR w Szczecinie.

Karamucki, T., Gardzielewska, J., Jakubowska, M., Rybak, K., Garczewska, J. (2013) The relationship between colour and pH in cold-stored quail breast muscle. Annals of Animal Science, 13, 2, 401-413. DOI: https://dx.doi.org/10.2478/aoas-2013-0019

Kortz, J. (1970) Colour durability as a general indicator of meat quality. Zeszyty Problemowe Postępów Nauk Rolniczych, 103, 99-104.

Lindahl, G., Lundström, K., Tornberg, E. (2001) Contribution of pigment content, mioglobin forms and internal reflectance to the colour of pork loin and ham from pure breed pigs. Meat Science, 59, 141-151.

Novotni-Danko, G., Balogh, P., Huzsvai, L., Győri, Zs. (2015) Effect of feeding liquid milk supplement on litter performances and on sow back-fat thickness change during the suckling period. Archives of Animal Breeding, 58, 229-235. DOI: https://dx.doi.org/10.5194/aab-58-229-2015

National Pork Board (2000) Pork composition and quality assessment procedures. Des Moines, IA: EP Berg - National Pork Board.

Pisula, A. (2011) Mięso zwierząt rzeźnych, budowa histologiczna i skład chemiczny. Barwa i barwniki mięsa. (In Polish) In: A. Pisula, E. Pospiech, eds. (2011) Mięso – Podstawy nauki i technologii. Warszawa: Wyd. SGGW, 160-166.

PN-A-82109:2010 (2010) Mięso i przetwory mięsne – oznaczenie zawartości tłuszczu, białka i wody. Metoda spektrometrii transmisyjnej w bliskiej podczerwieni (NIT) z wykorzystaniem kalibracji na sztucznych sieciach neuronowych (ANN). Warszawa: PKN. In Polish.

PN-ISO 4121:1998 (1998) Analiza sensoryczna. Ocena produktów spożywczych przy użyciu metod skalowania. Warszawa: PKN.

Pohja, M. S., Niinivaara, F. P. (1957) Die Bestimmung der Wasserbindung des Fleisches mittels der Konstantdruckmethode. Fleischwirtschaft, 9, 193-195.

Pospiech, E. (2016) Jakość mięsa i tłuszczu a image mięsa. In Polish. In: W. Kiernożycki, E. Herbut, E. and W. Olech, eds. (2016) 9 Szkoła Zimowa „Od hodowli świń do przetwórstwa – wczoraj i dziś". Ustroń, 16-19 lutego 2016, Szczecin: Wyd. ZUT., 54-64.

StatSoft, Inc. (2008) Statistica, version 8. Kraków: StatSoft Inc.

Strzyżewski, T., Bilska, A., Krysztofiak, K. (2008) Correlation between pH value of meat and its colour. In Polish, summary in English. Nauka Przyroda Technologie, 2, 2, 12.

Szalata, M., Pospiech, E., Łyczyński, A., Urbaniak, M., Frankiewicz, A., Mikołajczak, B., Medyński, A., Rzosińska, E., Bartkowiak, Z., Danyluk, B. (1999) Tenderness of meat from pigs of various quality. Roczniki Instytutu Przemysłu Mięsnego i Tłuszczowego, 36, 61-76.

Van Laack, R. L. J. M., Kauffman, R. G., Greaser, M. L. (2001) Determinants of ultimate pH of meat. Proceedings 47th International congress of meat science and technology, Kraków 2001, 22-26.

Walczak, Z. (1959) A laboratory method for the determination of jelly content in canned meat. Roczniki Nauk Rolniczych, 74, 4, 619-621.

Warriss, P. D., Brown, S. N., Paściak, P. (2006) The colour of the adductor muscle as a predictor of pork quality in the loin. Meat Science, 73, 4, 565-569.

Turyk, Z., Osek, M., Milczarek, A. (2013) Effect of herbal preparation on the change in colour and acidity of pork during storage. Roczniki Naukowe Polskiego Towarzystwa Zootechnicznego, 9, 4, 53-61.