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ANALYSIS OF SELECTED PARAMETERS INFLUENCING TECHNOLOGICAL AND SENSORY QUALITY OF PORK

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ABSTRACT

The aim of the study was to analyze selected parameters influencing the technological and sensory quality of pork. The material for the study was pork from the ham muscle and the ribeye muscles. The raw material came from a meat processing plant located in north-eastern Poland. The research was carried out on 80 porkers from various farms and farms. The tests included pH in 45 minutes and 24 hours from slaughter, meat color, water holding capacity, and the chemical composition of meat. It was found that half of the porkers had a lean content of more than 50%, and the best distinction between meat of normal quality and other quality classes results from the use of two or three different evaluation methods. The measurements of color and pH are most useful in assessing the quality of meat, but for the classification to be precise, some of them must be carried out immediately on the slaughter and as soon as the carcasses have cooled down. The brightness of the meat and the final pH values enable distinguishing between DFD meat and PSE meat. The color of normal meat is very similar to that of meat with the RSE defect. Significant ($P \leq 0.01$) relationships were found between the protein content and the pH of the meat measured 45 minutes and 24 hours after slaughter. Significant relationships ($P \leq 0.01$) also occurred between the values of the parameter a* and b* (trichromaticity coordinates).

Key words: pork, meat quality, meat defects, pH

INTRODUCTION

Pig farming represents the largest sector of the animal production in Poland. Przybylski et al. [2012] report that pork constitutes more than a half of the total meat consumed in Poland. However, in terms of quality, pork may not always be fully acceptable by consumers. When purchasing meat, the consumer pays attention to its color, tenderness, smell, juiciness and sensory values. Recently, an improvement in the carcass lean content in pigs has been observed; this, however, has been at the expense of generally deteriortated quality of the product [Pospiech and Lisiak 2012].

The main technological quality defects of meat include those resulting from improper course of the glycolysis process [Sionek and Przybylski 2015]. Due to an insufficient amount of glycogen in the muscles during slaughter, its pH does not drop and DFD meat is an outcome. It is characterized by an unnaturally dark red color and a hard and dry structure [Przybylski et al. 2012]. On the other hand, a sharp decrease in meat pH within 45 minutes post-slaughter produces PSE meat, of a brighter, unnaturally pale color, with very low water absorption, including own meat juices, which causes a high drip and a cross-section surface is wet and non-cohesive, inelastic and softened structure [Strzelecki 2006, Chmiel et al. 2011]. On the other hand, ASE meat is characterized by a very low pH (below 5.4), which persists for 3 hours after slaughter. Sour meat has a light color and shows high water drip. The main reason of this defect is a very high glycolytic potential, mainly a high glycogen content in the muscles, already present in the live animal [Zybert 2016]. Changes of this type occur in muscle tissue as a result of improper handling of the animals, both before and after slaughter [Jurczak 2005, Pisula and Florowski 2006]. The various stressors and the way they affect the body during period preceeding the slaughter have been the subject of many studies [Bertol et al. 2006, Correa

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et al. 2010, Probst et al. 2012]. They are the main factors stimulating the neurohormonal system of the body, which results in the loss of physiological balance and acceleration of metabolic changes. An improperly conducted ante-mortem handling elevates the rate of PSE or DFD.

Too many or too few pigs per unit area cause a decrease in pH of the meat, as measured 30 minutes after slaughter [Vermeulen et al. 2015]. As shown by Guàrdia et al. [2004] shorter transport time combined with too low density of animals increased the risk of the PSE defect.

An important element influencing the quality of meat is also the method of stunning and bleeding. According to Koćwin-Podsiadła and Krzęcio [2005], stunning with carbon dioxide instead of electric current generates less stress in pigs, and bleeding in the lying position instead of hanging reduces the incidence of defective meat.

The opinions on the impact of the housing system on the quality of meat raise many controversies. In general, no significant effect of the level of nutrition has been found in relation to most of the essential characteristics of the technological and organoleptic quality of pork. Massive, large-scale production and intensive fattening, using excessives dose of carbohydrates, are believed to increase the rates of watery structure of meat [Rosenvold et al. 2001]. According to Łyczyński et al. [2003], ad libitum feeding of pigs did not significantly reduce the post-slaughter meatiness of their carcasses and had a positive effect on the quality of the meat. With a restrictive feeding system, on the other hand, the highest share of defective meat of the PSE and ASE type was recorded.

The season and the related weather are some of the most important factors determining the quality of meat. The meat of porkers slaughtered in the spring and summer and in early autumn is characterized by higher acidification and greater water drip. Meat with PSE defect is most common in spring and summer, while DFD in autumn and winter [Čbanović et al. 2016].

The research by Koćwin-Podsiadła et al. [2001] shows that of all the factors influencing meat quality, environmental effects account for about 70% on average, and the rest may be attributed to genetic factors, of which the genotype of the animal is usually decisive. The incidence of PSE and DFD meat defects largely depends on the susceptibility to stress of different breeds of pigs. The sensitivity of pigs to stress is conditioned by the recessive gene, the locus of which was named HAL. The recessive allele responsible for the occurrence of pig stress syndrome has the symbol HAL^n [Stepanow et al. 2019].

Duroc is considered to be a stress-sensitive breed. A very low percentage of stress-sensitive pigs are found in Yorkshire, Large White and Hampshire breeds. The highest incidence of PSE meat are found in the groups of top conformation and extremely burdened with the gene HAL^n, i.e. Pietrain [Stepanow et al. 2019]. Various methods are used in the pork industry to assess the quality of meat and detect its defects. According to Pospiech [2000], Strzelecki [2006] and Warris et al. [2006], these include laboratory methods (e.g., determination of enzyme activity in blood plasma, concentration of metabolites, such as lactate, inosine), sensory methods (e.g. determination of color and brittleness), and methods that can be used in the slaughter line (e.g. pH measurement 45 minutes after slaughter, measurement of electrical properties, such as conductivity, active resistance, or optical properties, like color components.

One of the methods of assessing carcasses currently used is computer image analysis (CIA). This method consists in taking a digital photograph and determining the meat quality parameters using a software package. Du and Sun [2004] and Faucitano et al. [2005] used this method to evaluate the marbling and tenderness of pork. In turn, Lu et al. [2000], as well as Wu and Sun [2013] used CIA to measure the color of pork. Chmiel et al. [2000] found that the CIA method allows detecting PSE and DFD defects in pork.

The aim of the study was to analyze selected parameters of technological quality and sensory properties of pork.

MATERIAL AND METHODS

The material was pork samples from the muscles of the ham and the ribeye muscles. The raw material was obtained from a meat-processing plant located in north-eastern Poland. The research was carried out on 80 fatteners (interracial hybrids) from farms of various sizes, arriving at the plant at the same time. The pigs were slaughtered after 24 hours of rest (from the moment they were delivered to the meat processing plant). The animals rested in clean and air-conditioned rooms. Immediately after slaughter, suspended split-carcasses were cooled with the air system at a temperature of +4°C. After 24-hour cooling, the carcasses were dissected into basic cuts, of which the ribeye muscle (*Longissimus dorsi*, *LD*) and the ham muscle (*Semimembranosus*, *SM*) were examined. The analyses included: pH in 45 minutes and 24 hours post-slaughter, meat color, water-holding capacity, and chemical composition of meat. Evaluation of lean content was estimated with the use of the ULTRA-FOM apparatus (SKF-Technology).

Water content was determined in accordance with PN-73/A-82110 [Polska Norma 1973a]. For this purpose the drying technique was used, which consists in determining the test substance before and after drying in the oven. Drying and weighing are carried out until constant weight is obtained. The water content is determined by the mass loss during drying [Polska Norma 1973b].

Total protein content measurements were carried out in accordance with PN-75/A-04018 [Polska Norma 1975], using the Kjeldahl method. Fat content was determined using the technical method (Gerbera) according to PN-73/A-82111 [Polska Norma 1973b]. Measurements of pH was carried out according to PN-77/A-82058 [Polska Norma 1977]. For this purpose, a CP-315M pH-meter with a glass-calomel composite electrode was used. The pH was determined by inserting the electrode into the ribeye muscle (*LD*) between the last thoracic and first lumbar vertebrae, and into the ham muscle (*SM*). The measurements were carried out on 80 carcasses.

Color brightness was measured by the reflection method using the Minolta CR-200 spectrometer. Meat samples 1 cm thick were transferred to petri dishes with a diameter of 5 cm. In the samples prepared in this way, color measurements were made at three different points. The results obtained in this way were averaged. Three color components were measured: a*, b*, L*. The a* and b* values are trichromaticity coordinates and indicated with plus and minus. Value +a* corresponds to red, –a* to green, +b* to yellow, –b* to blue. The size L* indicates the brightness of the color and its values vary from 100 for perfect white to 0 for black.

Determination of water holding capacity

Native water holding capacity was analysed using filter paper to absorb the meat juice released (separated) from a meat sample when exposed to force. About 1 gram of comminuted meat was weighed onto polyethylene film and transferred to a paper disc (conditioned for 24 hours over an aqueous solution of KCl). The water-holding capacity of the meat was calculated from the difference in the area. The result was related to 1 gram of meat (cm/g).

Statistical analysis

Arithmetic means, standard deviations and coefficients of variation were calculated for each of the examined traits. Phenotypic correlations were also estimated for the following traits: meatiness, pH, meat color, content of protein, water and fat in it. The calculations were made using the specialized statistical package STATISTICA [Statsoft 2009].

RESULTS AND DISCUSSION

In the studied pig population, the mean meat content was 50.1%. The mean pH^{45} *LD* value was 6.21, while the pH^{24} *LD* was 5.75. The average value for the brightness of the L color in the assessed material is 47.32 (Table 1).

According to Prasow et al. [2018] the nutritional value of meat is determined by its chemical composition, energy value and nutritional quality indicators. Chemical analysis of the tested meat raw material showed that the average water content was almost 73% (Table 1) and was similar to the results obtained by Prasow et al. [2018]. A similar value of this parameter was noted by Chmiel et al. [2012]. The fat content in the tested material was on average 2.82% and was higher than in the pigs tested by Prasow et al. [2018], but lower compared to the research by Chmiel et al. [2012]. The fat content of meat is an important indicator of its quality. Research by numerous authors [Grajewska and Bocian 2005, Czarniecka-Skubina et al. 2007, Szulc and Skrzypczak 2015, Tyra and Mitka 2015, Prasow et al. 2018] indicate an unfavorably low content of intramuscular fat in pig meat. According to Gerbens [2004], the selection of pigs for the lean meat content in the carcass resulted in its reduction below the recommended optimum. Too little or too high its level adversely affects the color of the meat [Karamucki et al. 2005].

As reported by Czarniecka-Skubina et al. [2007], meat with a high intramuscular fat content was not uniform in color. Moreover, Wajda et al. [2004] showed that carcasses with a high fat content are characterized by a significantly lower level of protein in the muscle tissue. Grześkowiak et al. [2009] and Tyra [2013] showed that the intramuscular fat content at the level of 2.5–3% is a necessary condition for maintaining the optimal taste and aroma of meat. On this basis, it can be concluded that the results of measuring fat in meat obtained in the tests are good. As for the protein content in the analyzed raw material, it should be noted that its value – 20.08% was similar to the results obtained by Pomianowski and Sobotka [2018], while it differed from the results obtained by Chmiel et al. [2012] and Prasow et al. [2018]. In the latter studies, the percentage of protein in pork ranged between 21.8–24.54%, while in Chmiel et al. [2012] was more even and averaged 22%. Also Blicharski et al. [2013] believe that relatively high protein content in meat is desirable, if only due to the fact that protein has the ability to maintain water in meat. Water absorption is the basic parameter of meat quality, determining its technological suitability. Immediately after slaughter, it exhibits maximum water-binding capacity, which is due to its low acidity. The water-binding capacity decreases significantly with maturation. The raw material, which is characterized by low water absorption, is of worse quality and shows limited suitability for processing [Szulc and Skrzypczak 2015]. The worst ability to maintain own water is characterized by meat with a PSE defect [Chmiel et al. 2012].

In the examined material, meat content over 50.0% was achieved by half of the slaughtered porkers (50%), of which 22.5% were animals with meat content over 60.0%. It should be noted that in the group of animals with the lowest meat content, ie below 42.0%, about 9.0% of the total slaughtered porkers were found. The meat content in the range from 42.0% to 50.0% was achieved

Table 1. Statistical description of pork quality characteristics in the analyzed meat processing plant

Tabela 1. Charakterystyka statystyczna cech jakościowych mięsa wieprzowego w analizowanym zakładzie mięsnym

Trait Badana cecha		Basic trait description – Charakterystyka podstawowych cech			
		Number, n Liczebność, n	Arithmetic mean Średnia arytmetyczna	Standard deviation, s Odchylenie standardowe, s	Coefficient of variability, % Współczynnik zmienności, %
Lean content, % – Mięsność, %		80	50.09	7.153	14.3
pH_{24} *LD*		80	5.75	0.246	4.3
pH_{24} *SM*		80	5.77	0.250	4.3
pH_{45} *LD*		80	6.21	0.210	3.4
Meat color characteristics Cechy barwy mięsa	L*	80	47.32	2.742	5.8
	a*	80	18.34	1.511	8.2
	b*	80	10.04	1.726	17.2
Protein content – Zawartość białka		80	20.08	2.450	12.2
Water content – Zawartość wody		80	72.98	1.840	2.5
Fat content – Zawartość tłuszczu		80	2.82	1.250	44.3

LD – *Longissimus dorsi*, *SM* – *Semimembranosus*, L* – color brightness, a*, b* – trichromaticity coordinates.
LD – *Longissimus dorsi*, *SM* – *Semimembranosus*, L* – jasność barwy, a*, b* – współrzędne trójchromtyczności.

Table 2. Percentage distribution of pH_{45} and pH_{24} values

Tabela 2. Procentowy rozkład wartości pH_{45} i pH_{24}

pH_{45}	Percent of animals – Procent zwierząt	pH_{24}	Percent of animals – Procent zwierząt
< 5.59	6	< 5.0	1
5.95–6.05	21	5.0–5.2	3
6.05–6.15	19	5.2–5.4	6
6.15–6.25	9	5.4–5.6	10
6.25–6.35	16	5.6–5.8	24
6.35–6.45	13	5.8–6.0	52
6.45–6.55	10	6.0–6.2	3
≥ 6.55	6	≥ 6.2	1
	100		100

Table 3. Percentage distribution of color in the tested material

Tabela 3. Procentowy rozkład barwy w badanym materiale

Color brightness distribution of L Rozkład jasności barwy L		Color trichromaticity distribution a* Rozkład trójchromatyczności barwy a*		Color trichromaticity distribution b* Rozkład trójchromatyczności barwy b*	
value of color L wartość barwy L	percent of animals procent zwierząt	trichromaticity value of color a* wartość trójchromatyczności barwy a*	percent of animals procent zwierząt	trichromaticity value of color b* wartość trójchromatyczności barwy b*	percent of animals procent zwierząt
< 43	4	< 15	2	< 6	4
43–44.5	13	15–16	2	6–7	0
44.5–46.0	16	16–17	13	7–8	4
46.0–47.5	20	17–18	31	8–9	11
47.5–49.0	28	18–19	18	9–10	26
49.0–50.5	5	19–20	20	10–11	28
50.5–52.0	7	20–21	7	11–12	16
≥ 52.0	7	≥ 21	7	≥ 12	11

by 41.25% of slaughtered animals (Fig. 1). In the studies by Przybylski et al. [2012] the studied fattening pigs were characterized by meat content above 50%. Prasow et al. [2018] obtained diversified meat content of fatteners (within 44.69–59.2%), which depended on the breed of pigs.

When assessing the pH of the meat of the tested porkers according to the Pospiech criteria [2000], the presence of pH^{45} was found, corresponding to PSE meat in 5 carcasses (6.25%), partially PSE in 52 carcasses (65%) and normal meat in 23 carcasses (28.75%). Comparing the obtained results with the values of pH^{45} (≤ 5.8) and pH^{24} (>5.8) determined for PSE meat by Chmiel et al. [2012], 20% of the studied population showed meat with PSE defect (Table 2).

The use of pH measurements in ham enables detecting other defects in the muscle tissue, e.g. meat of the DFD type. Again, there is disagreement over the determination of the pH24 limit for DFD meat. According to Pospiech [2000], DFD meat has a pH24 value > 6.3, and according to Pospiech et al. [2011] The pH of 24 for this meat is 6.0. Taking into account the above criteria, the share of DFD meat in the tested material was small, 1–3% (Table 2). The obtained low prevalence of DFD meat may indicate that in the case of the analyzed material the animal welfare requirements were met.

Color brightness measurement is also used to assess the quality of meat. Many authors [Brewer et al. 2006, Warris et al. 2006, Strzyżewski et al. 2008, Chmiel et al. 2011, 2012] showed the existing dependencies between the pH and the brightness of meat color. The results of the conducted research indicate that 60% of the animals obtained the value of the L parameter, corresponding to normal meat (Table 3).

The estimated correlations show an insignificant, but unfavorable (negative) relationship between the brightness of the meat and the protein content (r = –0.107), (Table 4) and pH^{45} (r = 0.049) and pH^{24} (r = –0.135) (Table 5). Lower and also negative correlations between the value of the L parameter and the values of pH^{45} and pH^{24} were shown in their studies by Strzyżewski et al. [2008].

Table 4. Phenotypic correlation coefficients between meat content, pH, color and the content of protein, water and fat

Tabela 4. Współczynniki korelacji fenotypowej pomiędzy mięsnością, pH, barwą a zawartością białka, wody i tłuszczu

Studied trait Badana cecha	Number, n Liczebność, n	Protein content Zawartość białka	Water content Zawartość wody	Fat content Zawartość tłuszczu
Lean cointent – Mięsność	80	0.363	0.012	–0.228
pH_{45} *LD*	80	–0.434*	–0.122	–0.284
pH_{24} *LD*	80	–0.569**	0.494	0.019
pH_{24} *SM*	80	–0.594**	0.515**	0.063
L	80	–0.107	0.174	0.298
a*	80	–0.085	0.212	0.377
b*	80	–0.081	0.207	0.301
Protein content – Zawartość białka	80	1	–0.450	0.141
Water content – Zawartość wody	80	–	1	–0.388
Fat content – Zawartość tłuszczu	80	–	–	1

*significant correlation coefficient ($P \leq 0.05$), **highly significant correlation coefficient ($P \leq 0.01$).
*istotny współczynnik korelacji ($P \leq 0{,}05$), **wysoce istotny współczynnik korelacji ($P \leq 0{,}01$).

Table 5. Phenotypic correlation coefficients between fleshiness, pH and color

Tabela 5. Współczynniki korelacji fenotypowej pomiędzy mięsnością, pH a barwą

Studied trait Badana cecha	Number, n Liczebność, n	Cechy barwy mięsa		
		L	a*	b*
Mięsność	80	–0.058	0.200	0.175
pH_{45} *LD*	80	–0.049	0.013	0.002
pH_{24} *LD*	80	–0.135	0.053	0.029
pH_{24} *SM*	80	–0.101	0.061	0.081
L	80	1	–0.029	0.116
a*	80	–	1	0.802**
b*	80	–	–	1

**Highly significant correlation coefficient ($P \leq 0.01$).
**Wysoce istotny współczynnik korelacji ($P \leq 0{,}01$).

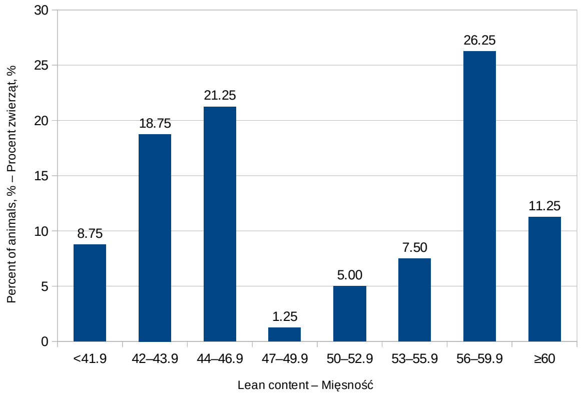

Fig. 1. The percentage distribution of meatiness in the analyzed meat processing plant

Rys. 1. Procentowy rozkład mięsności w analizowanym zakładzie mięsnym

Significant relationships were found between the protein content and meat pH measured, respectively in 45 minutes (r = –0.43) and in 24 hours after slaughter (r = –0.59 and r = –0.57) (Table 4). For the remaining features, the correlation values were clearly lower. Significant (r = 0.802) relationships were also obtained between the parameter value a* and b* (the value of trichromaticity coordinates).

CONCLUSIONS

1. The average meat content in the studied pig population was 50.1%; the average value of the pH^{45} *LD* was 6.21, while the pH^{24} *LD* – 5.75, while the average value for the lightness of the color L in the assessed material was 47.32.
2. By using the final pH value measurements in conjunction with the color brightness measurement, DFD meat can be distinguished from PSE. The color of normal meat is very similar to that of meat with RSE defect.
3. It has been found that the best distinction between meat of normal quality and the other quality grades is the use of two or three different evaluation methods.
4. Measurements of its color, electrical conductivity and the obtained pH values are particularly useful in assessing the quality of meat.
5. Statistically significant relationships were found between the protein content and the pH of meat measured 45 minutes and 24 hours after slaughter. The phenotypic correlation between the value of the parameter a* and b* (values of trichromaticity coordinates) in the tested material also turned out to be statistically high.

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ANALIZA WYBRANYCH PARAMETRÓW WPŁYWAJĄCYCH NA JAKOŚĆ TECHNOLOGICZNĄ I SENSORYCZNĄ MIĘSA WIEPRZOWEGO

STRESZCZENIE

Celem pracy była analiza wybranych parametrów wpływających na jakość technologiczną i sensoryczną mięsa wieprzowego. Materiał do badań stanowiło mięso wieprzowe z mięśnia szynki i mięśnia najdłuższego grzbietu. Surowiec pochodził z zakładów mięsnych znajdujących się w północno-wschodniej Polsce. Badania przeprowadzono na 80 tucznikach pochodzących z różnych ferm i gospodarstw rolnych. Badania obejmowały: pomiar pH dokonywany w 45 minut i 24 godziny od momentu uboju; pomiar barwy mięsa; oznaczenie zdolności utrzymania wody własnej; oznaczenie składu chemicznego mięsa. Stwierdzono, że mięsnością powyżej 50% charakteryzowała się połowa ubijanych tuczników; najlepsze rozróżnienie między mięsem normalnej jakości a pozostałymi klasami jakościowymi daje zastosowanie dwóch lub trzech różnych metod oceny. Najbardziej przydatne w ocenie jakości mięsa są pomiary barwy oraz pH, przy czym, aby klasyfikacja była precyzyjna, wymagane jest przeprowadzenie niektórych pomiarów bezpośrednio po uboju i po wychłodzeniu tusz. Stosując pomiary jasności mięsa i wartości pH końcowego, można odróżnić mięso DFD od PSE. Barwa mięsa normalnego jest bardzo zbliżona do barwy mięsa z wadą RSE. Stwierdzono istotne ($P \leq 0{,}01$) zależności pomiędzy zawartością białka a odczynem mięsa mierzonym w 45 minut i w 24 godziny po uboju. Istotne zależności ($P \leq 0{,}01$) wystąpiły także pomiędzy wartościami parametrów a* i b* (wartościami współrzędnych trójchromatyczności).

Słowa kluczowe: wieprzowina, jakość mięsa, wady mięsa, pH

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