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Usefulness of pork meat quality classes criteria in assessing of its culinary value

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The aim of the study was to determine the usefulness of criteria (pH, R_1 and EC) used to determine pork quality classes (RFN, PSE, DFD and AM) in assessing culinary value characteristics of pork. The study was carried out on 320 fatteners from the mass population in the spring-autumn season. Rearing conditions, pre-slaughter handling and carcass handling were the same for all animals. The fatteners were similar in terms of hot carcass weight (87.09 ±4.05 kg) and lean meat content (56.68 ±3.01%). The statistically significant correlations found confirmed that basic pork quality criteria are suitable for assessment of selected parameters of culinary value that are important to the consumer. To obtain more precise conclusions regarding the suitability of basic pork quality criteria (pH_1, pH_{24}, pH_{48}, R_1, EC_2 and EC_{24}) for estimation of characteristics of culinary value, canonical analysis should be used to determine the relationships between two sets of variables: independent (basic criteria of pork quality classes) and dependent (basic culinary values of pork).

KEY WORDS: pork / meat quality / culinary suitability / phenotypic correlations

Over the last quarter century, changes in the lifestyle of contemporary meat consumers in Poland and around the world have been associated with changes in the expectations of the market regarding the quality of meat and meat products. Adapting the quality of raw pork and pork products to consumer demands is very important in the development of marketing strategies by meat plants. Two aspects of pork quality should be analysed. The first concerns the quality of raw pork intended for culinary purposes, and the second is the quality and technological suitability of the raw meat for further processing [1, 2, 3, 39]. The quality of pork is currently highly varied, and quality deviations adversely affect its culinary and processing suitability [16, 19, 37]. The variability of pork quality traits is to a great extent determined by the intensity and scope of post-mortem glycolytic and energy transformations, expressed as muscle tissue acidification in the post-slaughter period and by the IMP/ATP ratio (R_1). The fundamental criteria for distinguishing the basic quality classes of pork, i.e. RFN (meat with the correct quality parameters, i.e. ‘normal’ meat), PSE (pale, soft and exudative), DFD (dark, firm and dry) and AM (‘acid meat’) include pH in the period from 35 min to 24-48 h post mortem, electrical conductivity (EC) at 2, 3 and 24 h after slaughter, and the IMP/ATP ratio – R_1 [4, 18, 19, 43].

The aim of the research was to determine the suitability of the criteria used to distinguish the basic quality classes of pork for estimating the basic features of its culinary suitability.

Material and methods

The research was carried out in the spring and autumn on 320 fattening pigs from the mass population (with an equal share of gilts and barrows). The housing, feeding (complete rations according to age) and pre-slaughter handling conditions were the same for all pigs. The pigs were slaughtered 2-4 h after transport (300 km) by electric stunning (INARCO system) and bleeding in a horizontal position, according to the technology in use at the meat plant. The hot carcass weight (HCW) was determined to the nearest 0.1 kg 35 minutes after slaughter on an electronic track scale. The meat content in the carcass was estimated using an ULTRA-FOM 300 ultrasound apparatus from the Danish company SFK Technology. The research material (320 carcasses) was similar in terms of HCW and the percentage content of meat in the carcass, i.e. 87.09 ± 4.05 kg with a coefficient of variation (V) of 4.65% and 56.68% ± 3.01% with a coefficient of variation (V) of 5.31%.

Meat quality characteristics were evaluated in the longissimus lumborum muscle (LL), based on the following parameters: muscle acidity (pH), IMP/ATP nucleotide ratio (R_1), electrical conductivity (EC), lightness of colour (L*), drip loss (DL), and water-holding capacity (WHC).

The pH was measured directly in the LL muscle tissue 45 min (pH_{45}), 24 h (pH_{24}) and 48 h (pH_{48}) post mortem, using a Dramiński MASTER pH meter with a spear tip electrode. The R_1 index (IMP/ATP) was determined 45 min post mortem by the laboratory method of Honikiel and Fischer [13]. Electrical conductivity was measured directly in the suspended carcass at 2 h (EC_2) and 24 h (EC_{24}) post mortem, using a Matthäus LF-Star conductometer. The lightness (L*) of the muscle tissue colour was determined 24 h after slaughter with a Minolta CR 310 apparatus. Drip loss was determined according to Prange et al. [32] at 48 h (DL_{48}), 96 h (DL_{96}) and 144 h (DL_{144}) after slaughter. The water holding capacity (WHC) was determined 24 h post mortem by the Grau and Hamm method [12], as modified by Pohji and Ninivaara [31]. The proximate composition was determined in samples taken from the LL muscle: water and dry matter content according to PN-ISO 1442:2000 [30], total protein by the Kjeldahl method according to PN-75/A-04018 [28], and intramuscular fat content (IMF) by the Soxhlet method, according to PN-ISO 1444:2000 [29].

Statistical analysis of the results was performed using the Statistica 7.1 PL statistics package (StatSoft). The characteristics of the research material are presented as arithmetic means ($\bar{x}$), standard deviations (SD) and coefficients of variation (V). The usefulness of meat quality class criteria in assessing the basic features of culinary suitability was estimated by regression (b was determined in a linear regression model $y = a + bx$) and by simple linear correlation (r).

Results and discussion

The research material was of good quality in terms of the basic criteria used to distinguish meat quality classes (except for pH_{48}). The average values for pH_{45}, pH_{24}, R_1 and EC_2 and EC_{24} were within the range of values typical for normal meat. Variation in these features expressed by the coefficient of variation was low, from 2.13% for pH_{45} to 5.43% for R_1. The exception was electrical conductivity. The variability expressed by the coefficient of variation for EC_2 and EC_{24} of the LL muscle was about 40% (Table 1).

It is particularly worth noting the pH_{48} of the LL muscle in the present study, which was 5.46 ± 0.12, with a low coefficient of variation of 2.20% (Table 1). This pH_{48} of the LL muscle is typical for acid meat, which has a low final pH (below 5.5) [18, 19, 23, 43]. Acid meat is found in pigs of the Hampshire breed and its crossbreds with the RN^- gene [26, 33, 34].

Table 2 presents features of culinary suitability. The muscle tissue analysed was of high nutritional value, expressed as high total protein content of 22.67%, with a low coefficient of variation of 3.30%. The lightness L* of the LL muscle, which was 54.01 (V = 3.30%), can be considered acceptable to the consumer. According to Koćwin-Podsiadła et al. [18], the colour of meat considered normal (pink-red) should have an L* value from 52 to 55.

Table 1

Basic meat quality criteria

Trait	$\bar{x}$	SD	V (%)
pH_{45} LL	6.55	0.18	2.75
pH_{24} LL	5.62	0.12	2.13
pH_{48} LL	5.46	0.12	2.20
R_1	0.92	0.05	5.43
EC_2 LL (mS/cm)	2.94	1.16	39.46
EC_{24} LL (mS/cm)	3.86	1.54	39.90

$\bar{x}$ – mean
SD – standard deviation
V – coefficient of variation

The colour of meat is one of the significant determinants of its culinary suitability. It is one of the fundamental criteria for the selection and acceptability of meat by consumers [14, 24, 25, 38, 40]. Its intensity is influenced in part by the acidity of the muscle tissue and its intramuscular fat content, causing marbling [11]. Optimal intramuscular fat content (2-3%) increases the consumer and culinary acceptability of meat by improving its tenderness, juiciness and palatability [42].

Table 2
Selected characteristics of culinary suitability of pork

Characteristic	$\bar{x}$	SD	V (%)
Water content (%)	74.47	0.96	1.29
Dry matter content (%)	24.82	1.50	6.04
Protein content (%)	22.67	0.75	3.30
Intramuscular fat content (%)	1.69	0.66	39.05
Colour lightness (L*)	54.01	3.02	5.49
Drip loss 48 h (%)	5.73	2.66	46.42
Drip loss 96 h (%)	8.97	2.99	33.33
Drip loss 144 h (%)	11.40	3.02	26.49
WHC (cm^2)	5.48	1.62	29.56

$\bar{x}$ – mean
SD – standard deviation
V – coefficient of variation

In the experiment, the mean intramuscular fat (IMF) content was about 1.7% (Table 2), which is below the average value (2-3%) considered by Wood et al. [42] to be optimal in terms of suitability for consumers. The variability of IMF of about 40% indicates that the pig population analysed includes a significant group of carcasses with meat of optimal intramuscular fat content (above 2%). The experimental material most likely includes crossbred pigs with a share of Duroc on the paternal side. A positive effect on IMF is noted in crossbreds with a 25% or 50% contribution of the Duroc breed [17, 37, 42].

Drip loss from the LL muscle tissue during storage requires detailed analysis. Excessive drip loss from the muscle reduces its potential to be sold as fresh meat. The loss of meat weight due to the loss of juices during storage and in retail sale is directly reflected in financial losses incurred by meat producers, distributors and consumers [8, 10, 15, 20, 21]. In the material analysed in our study, high variation was observed in drip loss at each measurement time and in the water-holding capacity (WHC): 46.62% with an average of 5.73% for DL_{48}, 33.33% with an average of 8.97% for DL_{96}, 26.49% with an average of 11.40% for DL_{144}, and about 30% with an average of 5.48 cm^2 for WHC (Table 2). The average obtained for drip loss at 48 h post mortem is characteristic for meat considered to be dripping meat – over 4.0% according to Bertram et al. [5].

In the Danish pig population, Bertram et al. [5] and Schäfer et al. [35] reported the presence of carcasses with dripping meat (above 4.0%), accounting for 90% and about 60%, respectively. Krzęcio et al. [22], in a study conducted on pigs from the mass population in Poland, found high variability in drip loss from the LL muscle at 48 h after slaughter (from 2% to 16%).

The usefulness of commonly used criteria for distinguishing the basic meat quality classes of meat in the assessment of features characterizing its culinary suitability was estimated on the basis of coefficients of simple phenotypic correlation (r) and regression (b) – Table 3.

The meat quality criteria concerning pH (pH_1, pH_{24} and pH_{48}) were negatively significantly correlated (at $p \leq 0.01$ and $p \leq 0.05$) with the drip loss throughout the storage period from 24 to 144 hours post mortem, i.e. when it reaches shop shelves. The IMP/ATP ratio (R_1) was positively significantly correlated only with the drip loss at 48 h post mortem (r = 0.18*). The highest correlations between these parameters were found for acidity of the muscle tissue at 48 h after slaughter. The simple phenotypic correlation coefficients between the pH_{48} of the LL muscle and the drip loss during the storage period were r = −0.40** for DL_{48}; r = −0.49** for DL_{96}; and r = −0.44** for DL_{144}. The pH_{24} and pH_{48} of the LL muscle were negatively highly correlated with its lightness (r = −0.39). In the case of the pH_{48} of the LL muscle, there was also a negative high correlation with WHC (r = −0.26**). These statistically confirmed coefficients of simple phenotypic correlation and regression, shown in Table 3, indicate that the drop in pH at the final stage of ageing, i.e. at 24 and 48 h after slaughter, significantly contributed to an increase in drip loss from the LL muscle tissue throughout the storage period (up to 144 h), as well as to lightening of the meat colour. Muscle acidity (from 24 to 48 h post mortem) is one of the basic parameters for diagnosing acidic meat, which is characterized by increased drip loss, a higher WHC value and a lighter colour. The present study also found statistically (at $p \leq 0.01$, $p \leq 0.05$) confirmed relationships between the pH_{45} of the LL muscle and the drip loss throughout the storage period (24-144 h) and water-holding capacity (WHC). As in the case of final pH, the increase in acidity in the initial period after slaughter (up to 1 hour) contributes significantly to the wateriness of the meat. The pH value up to 1 h post mortem is an effective criterion in diagnosing PSE (pale, soft and exudative) meat.

The relationships between muscle acidification and drip loss during meat storage after slaughter have been the subject of many studies. For example, in a study by Krzęcio [21], the negative correlations between the pH value of the LL muscle tissue and the drip loss at 48 h after slaughter were significant for pH measurements from 45 min to 48 h post mortem. Pliquett et al. [27], Czarniecka-Skubina et al. [9] and Sieczkowska et al. [36] sta-

Table 3

Coefficients of simple phenotypic correlation (r) and regression (b) between pork quality criteria and culinary suitability characteristics

Culinary suitability characteristics		Meat quality criteria					
		pH_1	pH_{24}	pH_{48}	R_1	EC_2	EC_{24}
Water content	r	0.06 NS	–0.17*	–0.09NS	0.12*	0.27**	0.19*
	b	–	–1.39	–	2.24	0.23	0.12
Dry matter content	r	0.01 NS	0.29**	0.08 NS	–0.01 NS	–0.33**	–0.08 NS
	b	–	3.50	–	–	–0.40	–
Protein content	r	0.07 NS	0.05 NS	0.08 NS	0.02 NS	–0.06 NS	–0.08 NS
	b	–	–	–	–	–	–
Intramuscular fat content	r	0.08 NS	0.24**	0.26**	–0.15*	–0.21**	0.10 NS
	b	–	1.32	1.46	–1.88	–0.21	–
Colour lightness (L*)	r	–0.01 NS	–0.39**	–0.39**	0.09 NS	0.04 NS	0.10 NS
	b	–	–9.68	–10.17	–	–	–
Drip loss 48 h	r	–0.20**	–0.49**	–0.40**	0.18*	0.26**	0,26**
	b	–2.91	–10.69	–9.09	9.07	0.60	0,45
Drip loss 96 h	r	–0.17*	–0.53**	–0.49**	0.06 NS	0.22**	0,24**
	b	–2.71	–13.07	–12.29	–	0.55	0,46
Drip loss 144 h	r	–0.17*	–0.50**	–0.44**	0.02 NS	0.17*	0,18*
	b	–2.83	–12.57	–11.41	–	0.45	0,37
Water-holding capacity	r	–0.14*	–0.09 NS	–0.26**	0.17*	0.06 NS	0,15 NS
	b	–1.17	–	–3.68	5.24	–	–

NS – not significant
**Significant at $p \leq 0.01$
*Significant at $p \leq 0.05$

tistically demonstrated a simple phenotypic correlation between drip loss and pH measured in the early post mortem period (up to 1 h). Van Wijk et al. [41] statistically demonstrated a genetic correlation ($r = -0.92$) between the final pH of meat and drip loss during storage. Krzęcio-Nieczyporuk et al. [23] also noted – as in the present study – a statistically confirmed relationship between the value of the IMP/ATP ratio (R_1) and the drip loss at 48 h after slaughter.

In our study, the drip loss from LL muscle tissue during the entire storage period (up to 144 h after slaughter) was positively significantly (at $p \leq 0.01$, $p \leq 0.05$) correlated with electrical conductivity measured 2 and 24 h post mortem (Table 3). Electrical conductivity is a parameter easily measurable in meat plants on the slaughter line [4, 36]. It is a very important determinant in the diagnosis of PSE meat, acid meat and dripping meat (DL_{48} above 4%). Many scientists suggest the use of electrical conductivity together with pH as a criterion for initial assessment of meat quality [6, 7, 16, 36].

An important parameter in assessing the culinary suitability of pork is the content of intramuscular fat in the muscle tissue. As mentioned above, optimal intramuscular fat content (about 2-3%) in muscle tissue improves the tenderness, juiciness and palatability of pork.

Of the six criteria for diagnosing pork quality analysed in this study, four, i.e. pH_{24}, pH_{48}, the IMP/ATP ratio (R_1) and EC_2, showed a statistically confirmed relationship with intramuscular fat content (Table 3). The pH_{24} and pH_{48} values were highly (at $p \leq .01$) positively correlated with the intramuscular fat content; r = 0.24** and r = 0.26**, respectively. The IMP/ATP ratio (R_1) and electrical conductivity 2 h after slaughter were statistically negatively correlated with intramuscular fat content; r = −0.15* and r = −0.21**, respectively (Table 3). As in the present experiment, a statistically confirmed simple phenotypic correlation for R_1 and intramuscular fat was also reported by Krzęcio-Nieczyporuk et al. [23]. Sieczkowska et al. [36] found no statistical correlations for R_1 and intramuscular fat, but they statistically proved a simple phenotypic correlation for EC_2 and intramuscular fat (r = 0.47**).

To sum up, the statistically demonstrated significant relationships between the basic criteria for assessing pork quality with selected (important to the consumer) features of culinary suitability confirm their usefulness in assessing the basic features of culinary value. More accurate and more precise conclusions regarding the suitability of the basic quality criteria for pork (pH_1, pH_{24}, pH_{48}, R_1, EC_2 and EC_{24}) for assessment of basic features of culinary suitability would require statistical computations using canonical analysis, which would make it possible to determine the relationships between two sets of variables: variables explained (characterizing culinary suitability) and explanatory variables (the basic meat quality criteria).

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