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The quality of the *longissimus lumborum* muscle of Pietrain-cross fatteners in relation to electrical conductivity 48 hours *post mortem*

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The aim of the study was to analyse the relationship between the electrical conductivity of the *longissimus lumborum* muscle 48 hours *post mortem* and other selected quality characteristics of meat from 90 pigs – crosses with a 50% share of the Pietrain breed. Meat samples with conductivity (EC_u) in the range of 4.01-7.99 mS/cm were found to have significantly higher pH_u and significantly lower yellowness (*b) than samples with $EC_{48} \geq 8$ mS/cm. An increase in electrical conductivity considerably reduced the pH_u (r=−0.328**) and WHC of the meat (r=−0.338**), while increasing lightness (*L**) – r=0.211*, redness (*a**) – r=0.258* and yellowness (*b**) – r=0.442**. The results indicate that measurement of electrical conductivity 48 hours after slaughter is not sufficient in itself to evaluate meat quality, and should be combined with simultaneous determination of other characteristics, such as pH, WHC or lightness (*L**).**

KEY WORDS: fatteners / electrical conductivity / meat quality

The electrical conductivity (EC) of pork is one of the characteristics used to evaluate its quality [3, 4, 16, 17, 18]. An increase in the electrical conductivity of muscles is linked to an increase in the permeability of cell membranes post mortem and in ion concentration, which is particularly evident in exudative meat [3, 9, 13, 19]. Varying opinions can be found in the available literature on the usefulness of measurement of EC at different times post mortem in assessment of meat quality. EC is measured in both the initial hours (1-3) after slaughter and after 24 h [1, 13, 19], when the rate of transformations in the tissue has slowed down considerably and the quality of the pork has largely been determined. However, irrespective of when EC is measured, it generally has a statistically confirmed association with the rate of glycolysis up to 45 minutes post mortem [1]. This rate depends on both genetic and non-genetic factors and is linked to many other quality traits of pork in addition to electrical conductivity. The material being analysed is a significant factor. For example, correlation coefficients between EC and other quality traits of pork vary in different breeds, and their statistical significance is not always confirmed [1]. According to Łyczyński et al. [12], measurement of electrical conductivity in the meat of pigs of the 990 line 24 hours after slaughter may be used in practice to diagnose the quality of pork. Antosik et al. [1] report that the electrical conductivity of pork, irrespective of the time of measurement post mortem, is useful for assessing its quality, particularly in animals with genetic predispositions to produce PSE meat (the 890 line).

The objective of the study was to analyse the relationship between the electrical conductivity of the *longissimus lumborum* muscle determined 48 h post mortem and other selected quality characteristics of the meat of pig crossbreeds with a 50% share of the Pietrain breed.

Material and methods

The material for the study consisted of 90 samples of the *longissimus lumborum* muscle taken from 90 carcasses of pig crossbreeds obtained from crossbred sows (Deutsches Landschwein x Deutsches Edelschwein) and Pietrain boars, classified as class S (30 carcasses), E (30 carcasses) and U (30 carcasses).

After the carcasses had been chilled about 24 h, samples weighing about 1 kg (meat with bone) were taken (during dissection) from between the first and fourth lumbar vertebrae of the right half-carcass. They were packed in foil and transported to the laboratory in thermal insulated containers, where they were stored at 0-4^{o}C until the following day.

About 48 hours after slaughter, the electrical conductivity of the meat was measured in the laboratory (LF-Star conductometer, 1.2 kHz – R. Matthäus). The measurement was taken at the centre of the cross section of the muscle from the cranial side of the sample. Then the external fat and perimysium were removed from the samples and a physicochemical and chemical evaluation of the meat was performed. For this purpose the meat was minced twice, using a meat mincer with a plate with 4 mm holes.

The physicochemical evaluation of the meat included colour measurement ($L*$, $a*$ and $b*$), WHC and pH_u. Freshly minced meat was used for all determinations.

Colour measurements of the minced meat were performed using a MiniScan XE Plus 45/0, with a 31.8 mm port size. The instrument was calibrated against a white standard and a black standard. The coordinates of the white standard were X=78.5, Y=833 and Z=87.8 (for standard illuminant D65 and 10° standard observer). Colour parameters were determined for each sample on the CIELab scale [5] using a D65/10º illuminant/observer combination [7]. Prior to the colour measurements the meat was placed in measuring cells, the surface was carefully smoothed, and the cells were left for 20 minutes at 4ºC to allow oxidation of myoglobins in the surface layer of the meat.

The WHC of the meat was determined according to Grau and Hamm [6] with a modification by Pohja and Niinivaara [14] and expressed as the percentage share of bound water in the total water.

The pH_u of the meat was measured using an ESAgP.302W combination electrode and a CyberScan 10 pH meter in an aqueous extract of the meat, with a 1:1 proportion of water and meat, after one hour of extraction.

Chemical evaluation was carried out in minced meat kept in frozen storage for 1 to 2 months. Samples wrapped in a double layer of foil were frozen at –18ºC. The samples were thawed at 0-4ºC, in plastic containers to avoid the loss of juices, and before testing each sample was thoroughly mixed. The evaluation involved determination of the percentage content of basic chemical components: total water, crude protein and fat [2].

Means and standard deviations were calculated for the meat quality characteristics for the entire material and for electrical conductivity (EC) groups: ≤4.00; 4.01-7.99 and ≥8 mS/cm. Statistical analysis was performed to compare the meat quality characteristics in relation to their electrical conductivity (EC), using the least squares method according to the GLM procedure (Statistica 10), with the following linear model:

$$Y_{ij} = \mu + a_i + e_{ij}$$

where:

Y_{ij} – characteristic tested
μ – grand mean
a_i – effect of conductivity (i = ≤4.00; 4.01-7.99; ≥8 mS/cm)
e_{ij} – random error

Significance of differences between pairs of means was estimated using Duncan's range test, at probability levels of $P \leq 0.05$ and $P \leq 0.01$.

In addition, phenotypic correlation coefficients (Pearson's r) between characteristics (for the entire material) were calculated and their significance was estimated at probability levels of $P \leq 0.05$ and $P \leq 0.01$.

All calculations were made using Statistica 10 software.

Results and discussion

Table 1 presents the means and standard deviations for the quality characteristics tested for all samples as a whole and in relation to electrical conductivity: ≤4.00, 4.01-7.99 and ≥8 mS/cm. These values are representative of DFD, RFN and PSE meat, respectively [15]. Meat with conductivity (EC_{48}) of 4.01-7.99 mS/cm, in comparison with meat with EC_{48}≥8 mS/cm, had significantly higher pH_u and at the same time significantly lower yellowness (b^*). No statistically significant differences between groups were noted for the remaining quality characteristics, which suggests that electrical

Table 1
Mean and standard deviation (SD) for meat quality traits for all samples combined and depending on electrical conductivity

Trait	$\bar{x}$ (n=90)	SD	Range of electrical conductivity (mS/cm)					
			≤4.00		4.01-7.99		≥8.00	
			$\bar{x}$ (n=3)	SD	$\bar{x}$ (n=27)	SD	$\bar{x}$ (n=60)	SD
Electrical conductivity – EC (mS/cm)	8.52	1.89	3.23^{A}	0.59	6.85^{B}	1.04	9.54^{C}	1.07
pH_u	5.47	0.07	5.48^{AB}	0.03	5.55^{A}	0.06	5.46^{B}	0.07
Total water (%)	72.02	0.77	73.27	0.87	73.90	0.81	74.11	0.72
Total protein (%)	22.73	0.49	23.38	0.49	22.63	0.50	22.74	0.47
Fat (%)	2.15	0.80	2.20	1.13	2.37	0.86	2.05	0.75
Lightness (L^*)	54.88	2.27	54.84	1.95	54.45	2.18	55.08	2.33
Redness (a^*)	8.60	1.03	8.49	0.52	8.21	0.76	8.79	1.11
Yellowness (b^*)	16.23	0.89	15.83^{AB}	0.71	15.72^{A}	0.64	16.47^{B}	0.90
Water holding capacity –WHC (%)	73.85	4.12	76.07	1.13	75.22	2.46	73.12	4.60

Means with different superscript letters differ significantly at $P \leq 0.01$

conductivity measured 48 hours after slaughter is a characteristic with little association with other meat quality characteristics. This is confirmed by the correlation coefficients presented in Table 2. Electrical conductivity measured 48 h after slaughter was significantly correlated with pH_u, colour parameters (*L**, *a** and *b**), and the percentage of bound water in total water.

As EC_{48} increased, the pH_u of the meat significantly decreased (Tab. 2), but the correlation coefficient was low (r=−0.328**), which is consistent with the results of studies by other authors. Łyczyński et al. [12], for example, obtained a low and insignificant value for the correlation coefficient between EC and pH at 24 hours post mortem (r=−0.210), while the correlation coefficient between EC and pH_{45} in that study was high and statistically significant (r=−0.756).

The correlation coefficients presented in Table 2 show that as EC_{48} increased there was a significant increase in lightness (*L**) – r=0.211*, redness (*a**) – r=0.258* and yellowness (*b**) – r=0.442**. This is consistent with results obtained by other authors, who found that lighter meat (*L**) often has greater electrical conductivity, although Antosik et al. [1] noted significant correlation coefficients between EC and colour lightness (*L**) only in the case of certain groups of pigs.

A significant increase in redness (*a**) and yellowness (*b**) accompanying the increase in EC_{48}, together with an increase in lightness (*L**), was probably linked to an increase in the relative quantity of oxymyoglobin, which increases in the surface layer of fresh meat as its pH decreases [8, 11]. Somewhat higher correlation coefficients than in the case of redness (*a**) were noted between EC_{48} and yellowness (*b**) – r=0.442**. According to Lindahl et al. [11] and Karamucki et al. [8], variation in the *b** parameter in pork depends almost exclusively on the relative content of chemical forms of myoglobin, with the most yellowness (*b**) associated with oxymyoglobin, less for metmyoglobin, and the least for deoxymyoglobin. The presence of oxymyoglobins in the surface layer of the meat samples is also indicated by other correlation coefficients (Tab. 2); the *b** parameter increased with lightness (*L**– r=0.605**) and redness (*a** – r=0.553**). As mentioned above, the relative content of forms of myoglobin depends significantly on the pH_u of the meat, which affects the intensity of redox processes. Lower pH_u is conducive to oxygenation and oxidation of muscle pigments. Therefore when oxygen is available oxymyoglobin dominates on the surface of fresh meat, leading to an increase in redness (*a**) and yellowness (*b**). At the same time, the content of this form of myoglobin increases as pH_u decreases and as lightness (*L**) increases.

As EC_{48} increased, the WHC, i.e. the proportion of bound water in the total water of the meat, significantly decreased (r=−0.338**). This is consistent with results obtained by Łyczyński et al. [12], who noted a significant correlation between EC and the percentage content of free water (r=0.331). Antosik et al. [1] also found that drip loss and WHC were significantly correlated with EC measured 2 h and 24 h post mortem, with higher correlation coefficients noted in the case of EC measured 2 hours after slaughter,

Table 2
Simple correlation coefficients between meat quality traits (n=90)

Trait	pH_u	Total water (%)	Total protein (%)	Fat (%)	Lightness (*L**)	Redness (*a**)	Yellowness (*b**)	WHC (%)
Electrical conductivity – EC (mS/cm)	–0.328**	0.098	–0.023	–0.072	0.211*	0.258*	0.442**	–0.338**
pH_u	–	0.124	–0.321**	0.117	–0.523*	–0.194	–0.567**	0.652**
Total water (%)		–	–0.273**	–0.765**	–0.202	–0.012	–0.018	–0.168
Total protein (%)			–	–0.389**	–0.087	0.046	–0.052	–0.146
Fat (%)				–	0.255*	–0.041	0.048	0.292**
Lightness (*L**)					–	–0.124	0.605**	–0.376**
Redness (*a**)						–	0.553**	–0.284**
Yellowness (*b**)							–	–0.459**

*Significant at P≤0.05
**Significant at P≤0.01

especially in the group of animals with genetic predispositions to produce PSE meat (890 line). Thus according to Antosik et al. [1], measurement of EC in the second hour post mortem is most useful in predicting drip loss. In contrast, the results of a study by Lee et al. [10] indicate that measurement of EC 24 hours after slaughter is more useful for this purpose.

In the material analysed in the present study no significant correlation coefficients were found between electrical conductivity and the percentage content of total water, crude protein and fat in the meat, which indicates that the content of basic chemical components of the meat did not significantly influence its electrical conductivity (Tab. 2). This was most likely due to the low variation in the percentage content of crude protein in the meat and its low (2.15% ±0.80) fat content (Tab. 1).

Analysis of the correlation coefficients presented in Table 2 reveals that the total water content in the meat decreased significantly as the content of crude protein and fat increased. No significant correlation coefficients were found between total water content and the remaining quality characteristics of the meat. The highest correlation coefficients were noted between pH_u and WHC, as well as lightness (L^*) and yellowness (b^*), which indicates that pH_u, lightness (L^*) and WHC had a markedly greater influence on meat quality than EC.

To sum up, although measurement of the EC of pork 48 hours after slaughter is significantly correlated with other quality characteristics, it is not by itself sufficient for an objective assessment of meat quality. EC measurement in such an evaluation should be used in combination with determination of other quality characteristics, such as pH_u, WHC and lightness of colour (L^*), which have a greater influence than EC on the quality of pork.

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