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Association between drip loss and physicochemical properties of the *longissimus lumborum* muscle in fatteners

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The aim of the study was to assess the relationships between drip loss from *longissimus lumborum* (LL) muscle tissue and sets of physicochemical parameters of pork meat determined 1 and 24 h after slaughter. The study was conducted on the *longissimus lumborum* muscle of 250 porkers from four breed groups. The results obtained indicate substantial variability in drip loss from the LL muscle tissue of these animals. Drip loss and water-holding capacity at each time of measurement were found to be significantly correlated with the acidity level in the muscle tissue (pH_1 and pH_{24}), lactic acid and glycogen content, electrical conductivity (EC_{24}) and meat lightness. Canonical analysis showed that the meat quality parameters investigated determine the variability in drip loss from the LL muscle tissue only to a small extent (31-36%). This suggests the need for further research on the biochemical mechanisms of drip loss.

KEY WORDS: pork meat / drip loss / physicochemical properties / correlations

The share of fresh meat in the total sales of meat and meat products has increased in recent years (depending on the market and season) to about 30-35% [14, 21]. The increase in sales of fresh meat and in consumer demand have led the meat industry to undertake work on the introduction of meat quality indicators to carcass classification systems, while at the same time establishing and monitoring sources of variability modifying this quality. A significant problem for the modern meat industry is the high incidence of pork carcasses with meat characterized by high drip loss, which is determined by a number of factors [3, 11, 19]. Recognition of the determinants of excessive drip loss from muscle

tissue is a necessary condition for reducing financial losses resulting from the decrease in muscle mass due to the loss of meat juices [6, 9, 13].

The purpose of the study was to estimate to what extent sets of physicochemical parameters of pork meat, determined 1 h and 24 h post-slaughter, are associated with the amount of drip loss from the *longissimus lumborum* muscle.

Material and methods

The study was conducted on 250 fattening pigs of four breeds: 990 line x Pietrain (L--990xP) – 50 pigs; (Landrace x Yorkshire) x Duroc ((LxY) xD) – two groups of 50 differentiated by the origin of the paternal component; (Landrace x Yorkshire) x Hampshire ((LxY) xH) – 50 pigs; and (Landrace x Yorkshire) x (Duroc x Pietrain) ((LxY) x (DxP)) – 50 pigs. All breed groups had equal proportions of barrows and gilts (1:1). During the fattening period all animals were provided with the same complete feed and, except for the L-990xP group, were kept at the same piggery. The animals were slaughtered in the autumn/winter season at a meat plant in east-central Poland, in accordance with the technology in use at the plant. All animals were slaughtered 2-4 h after transport (a distance of 280 km) in accordance with animal welfare principles. The animals were stunned by an electric current (250V) and bled in a horizontal position. The bleeding was initiated immediately after the application of the electric current (Inarco slaughtering chain from the Dutch company STORK).

The study material included class E and U carcasses (meat content 55.1-60% and 50.1-55%, respectively) with a hot carcass weight of about 85 kg (± 3 kg). The subject of the quality assessment of the meat was longissimus lumborum (LL) muscle tissue. Muscle samples were taken 35 min after slaughter from the right half-carcasses, behind the last rib, for tests performed 45 minutes post mortem (R_1, lactic acid content and glycogen content).

From 38 minutes after slaughter, the carcasses were cooled in a three-phase cooling tunnel (–10ºC for 15 min, –15ºC for 25 min and –5ºC for 40 min, air velocity 3 m/s), and then refrigerated until 24 h post-slaughter at 4ºC. At 24 hours post-slaughter samples were taken from the longissimus lumborum muscle of the chilled right half-carcasses to test the following physicochemical properties of the meat:

– Drip loss (WN) was determined according to Prange et al. [16] at 48 h (WN_{48}), 96 h (WN_{96}) and 144 h (WN_{144}) post-slaughter.

– The pH of the muscle tissue was measured at 35 min (pH_1) and 24 h (pH_{24}) post mortem directly in the LD muscle tissue, in the suspended carcass, using a Dramiński Master pH-meter with a spear tip electrode.

– The energy conversion index R_1 (IMP/ATP) was determined according to a method described by Honikel and Fischer [10].

– Muscle glycogen content was determined by the enzymatic method according to Dalrymple and Hamm [5].

– Lactic acid content in the muscle tissue was determined according to Bergmeyer [2].

– Electrical conductivity (EC) was measured directly in the suspended carcass in the longissimus lumborum muscle, behind the last rib, at 24 h post mortem (EC_{24}), with a Matthaüs LF-Star conductometer.

– Muscle tissue colour was determined at 24 h post-slaughter using a Minolta CR-310 apparatus in the CIE L*a*b* system; the measurement was made on the cranial surface of the longissimus lumborum muscle (cut behind the last rib, transversely to the muscle fibres); the colour was expressed by three parameters: lightness (L*), red saturation (a*) and yellow saturation (b*).

– Water-holding capacity (WHC) was determined at 24 h post-slaughter according to the Grau-Hamm method [8] as modified by Pohja and Ninivaara [15].

Statistical analysis of the results was performed using the STATISTICA 7.1 PL statistics package (StatSoft, Tulsa, OK, USA). The relationships between the meat quality characteristics and the amount of drip loss from the longissimus lumborum muscle tissue of the pigs and the water-holding capacity were presented as linear phenotypic correlation coefficients (Pearson's r) and canonical correlations.

Canonical analysis was performed according to the following model:

$$U = A^T X;\ V = B^T Y$$

where:

U, V – canonical variables

X, Y – matrices in which each column corresponds to one of the input variables from set X and set Y

A, B – coefficient vectors

For the canonical analysis, four sets were included in the group of explanatory features (Y): Y_1 – containing the amount of drip loss at 48 h (WN_{48}) and WHC; Y_2 – containing WN_{48} and WN_{96}; Y_3 – containing WN_{96} and WN_{144}; and Y_4 – containing WN_{48}, WN_{96} and WN_{144}. Different sets of features showing (based on the linear phenotypic correlation coefficients) a significant correlation with drip loss or water-holding capacity were adopted for the sets of explanatory features (X_1-X_4): X_1 – containing pH_1, R_1, lactic acid content and glycogen content; X_2 – containing pH_1, lactic acid content and glycogen content; X_3 – containing pH_{24}, EC_{24}, L* and a*; and X_4 – containing pH_{24}, EC_{24} and L*.

Results and discussion

The results of the study indicate substantial variation in the drip loss from the longissimus lumborum muscle of the group of crossbred fatteners at all measurement times, i.e. 48,

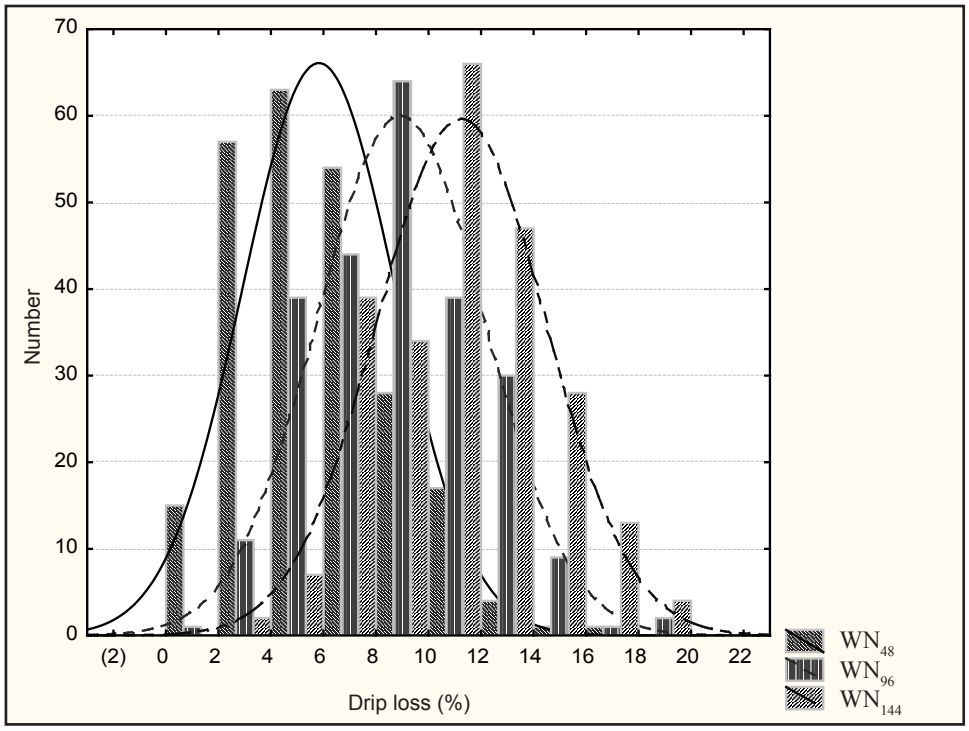

Fig. The distribution of drip loss from *longissimus lumborum* muscle tissue of porkers, determined at 48, 96 and 144 h *post mortem*

96 and 144 h post mortem (Fig.). Drip loss ranged from 0.09% to 16.47% at 48 h (WN_{48}), 1.52% to 18.61% at 96 h (WN_{96}), and 3.03% to 19.94% at 144 h (WN_{144}) post-slaughter.

The variability in the drip loss from the LL muscle tissue in this study should be considered high (Figure). Barbin et al. [1], in a group of 75 fattening pigs, reported variation in drip loss 48 h after slaughter in a range of 0.50% to 9.54%. Mörlein et al. [12] and Ryu and Kim [17] found similar variation in WN_{48} as in our study, from 2.52% to 16.08% and from 0.23% to 16.68%, respectively.

Only six carcasses (2.4%) with PSE meat (five in group L-990xP and one in group (LxY) x (DxP)) were found among the pigs, and no other typical meat defects were identified.

The high variation in drip loss at all measurement times and the variability of the meat quality characteristics (Fig., Tab. 1) justified the calculation of linear phenotypic correla-

Table 1

Descriptive statistics and correlation coefficients between drip loss (WN) and WHC of *longissimus lumborum* muscle tissue and quality parameters of the pork meat

Trait	Mean ±SD V (%)	WN_{48} (%)	WN_{96} (%)	WN_{144} (%)	WHC (cm^2)
		5.78 ±2.89 50.00	8.88 ±3.19 35.93	11.17 ±3.20 28.64	5.88 ±1.43 24.32
pH_1	6.52 ±0.21 3.22	r=–0.27**	r=–0.24**	r=–0.20**	r=–0.26**
R_1	0.93 ±0.08 8.60	r=0.20**	r=0.11^{NS}	r=0.12^{NS}	r=0.15*
Lactic acid content (µmol/g)	48.13 ±12.95 26.91	r=0.32**	r=0.24**	r=0.23**	r=0.30**
Glycogen content (µmol/g)	48.73 ±19.70 40.42	r=0.21**	r=0.38**	r=0.40**	r=0.34**
pH_{24}	5.67 ±0.11 1.94	r=–0.41**	r=–0.54**	r=0.59**	r=–0.35**
EC_{24} (mS/cm)	4.24 ±1.76 40.55	r=0.26**	r=0.20**	r=0.19**	r=0.27**
L*	55.14 ±3.51 6.36	r=0.22**	r=0.25**	r=0.25**	r=0.28**
a*	14.56 ±1.31 8.99	r=0.03^{NS}	r=–0.01^{NS}	r=–0.08^{NS}	r=–0.16*
b*	5.03 ±1.25 24.85	r=0.09^{NS}	r=–0.07^{NS}	r=0.03^{NS}	r=0.05^{NS}

SD – standard deviation, V – coefficient of variation, r – coefficient of simple phenotypic correlation
**Significant at p≤0.01
*Significant at p≤0.05
NS – not statistically significant

tions between them. Coefficients of correlation were calculated between the characteristics adopted as determinants of drip loss (pH_1, R_1, lactic acid content, glycogen content, pH_{24}, EC_{24}, L*, a* and b*) and drip loss (WN_{48}, WN_{96} and WN_{144}) and between determinants of drip loss and water-holding capacity (WHC).

Drip loss at individual measurement times and water-holding capacity were found to be significantly correlated with acidification of muscle tissue (pH_1 and pH_{24}), lactic acid and glycogen content, electrical conductivity (EC_{24}) and meat lightness (Table 1).

The value of the energy conversion ratio was significantly correlated only with the drip loss determined at 48 h post mortem (r = 0.20**), while there was no significant relationship between drip loss and red or yellow colour saturation (a* and b*) – Table 1. Such relationships were previously reported by Barbin et al. [1], who noted a significantly high correlation coefficient between drip loss and meat colour components (r = 0.80** for L*, r = 0.55** for α* and r = 0.77** for b*). Our results confirm earlier observations by Gardner et al. [7], who reported that in non-PSE meat the correlation between drip loss from muscle tissue and pH was higher for acidification of muscle tissue in a later (than one hour) period after slaughter. The degree of acidification of muscle tissue (pH) is one of the most common criteria for assessing meat quality, as it provides information on the rate of post-slaughter glycolysis and is the main cause of differences in meat quality [18].

Canonical analysis was used to determine which features are jointly associated with drip loss from the LL muscle during the entire period from 24 to 144 h post mortem and the water-holding capacity of the meat. The canonical correlation coefficient (C_R) indicates the strength of the connection between two sets of attributes, while the coefficient of determination (R_C^2) expresses the degree to which one set of variables is determined by the other [20].

As mentioned in the 'Material and methods' section, we distinguished four sets of explanatory features (Y_1-Y_4) containing the drip loss determined at different times post

Table 2
Canonical correlation coefficients (C_R) and composite determination coefficients (R_C^2)

Variables explained	Explanatory variables			
	pH_1, R_1, lactic acid, glycogen (X_1)	pH_1, lactic acid, glycogen (X_2)	pH_{24}, EC_{24}, L*, a* (X_3)	pH_{24}, EC_{24}, L* (X_4)
WN_{48}, WHC (Y_1)	C_R=0.523** R_C^2=0.273	C_R=0.582** R_C^2=0.338	C_R=0.540** R_C^2=0.291	C_R=0.552** R_C^2=0.304
WN_{48}, WN_{96} (Y_2)	C_R=0.487** R_C^2=0.237	C_R=0.520** R_C^2=0.270	C_R=0.551** R_C^2=0.303	C_R=0.560* R_C^2=0.313
WN_{96}, WN_{144} (Y_3)	C_R=0.495** R_C^2=0.245	C_R=0.513** R_C^2=0.263	C_R=0.584** R_C^2=0.341	C_R=0.594** R_C^2=0.352
WN_{48}, WN_{96}, WN_{144} (Y_4)	C_R=0.495** R_C^2=0.245	C_R=0.525** R_C^2=0.275	C_R=0.584** R_C^2=0.341	C_R=0.599** R_C^2=0.359

WN – drip loss
**Significant at p≤0.01

mortem and WHC (Table 2). Various sets of features showing (based on linear phenotypic correlation coefficients) a significant relationship with drip loss or water-holding capacity were adopted for the sets of explanatory features (X_1-X_4) (Table 2).

Among the meat quality characteristics shown to be correlated with drip loss or water--holding capacity, the most favourable results were found for set X_4, containing physicochemical parameters of muscle tissue determined at 24 h post mortem ($pH_{24,}$ EC_{24} and L*) – Table 2. These parameters together explain 31.3% to 35.9% of the variability in drip loss determined at various times post mortem (R_C^2=0.313, R_C^2=0.352 and R_C^2=0.359, respectively). On the other hand, the Y_1 set of explanatory features, including drip loss and water-holding capacity at 24 h post mortem, was determined to the greatest degree by the X_2 set of explanatory variables, including pH_1, lactic acid content and glycogen content (R_C^2=0.338) (Table 2).

Czarniecka-Skubina et al. [4], using canonical analysis, showed that changes in the pH of longissimus lumborum muscle tissue at various times after slaughter (determinant set including pH_1, pH_3, pH_{24}, pH_{48} and pH_{120}) determine drip loss from this muscle at 48 h post mortem (C_R=0.72**, R_C^2=0.5) at a level of about 52%.

To summarize the results of our research, the physicochemical parameters of the meat explain only 31-36% of the variation in drip loss from the longissimus lumborum muscle tissue. The fact that the variation in drip loss from the LL muscle tissue is nearly 70% dependent on factors other than those analysed in this study indicates the need for further research to explain the biochemical mechanisms of this phenomenon.

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