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Product Quality and Safety

Relationships between pH values and some physico-chemical and colour traits of quail breast meat

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Abstract. *The aim of this study was to establish variation ranges of breast meat pH_{24}, water holding capacity (WHC), water absorption capacity (WAC), and colour (CIEL*a*b*) in domestic quails and to analyze the patterns of relationships between pH_{24} and muscle hydrophilic and colour characteristics in the studied dataset. The investigation summarizes the results of two research experiments performed on breast muscle (M. pectoralis) from 151 domestic quails. It was found that the studied dataset was relatively homogeneous (CV<30%). The least dispersion was shown for pH_{24} and L* traits (CV of 3.8% and 8.3%, respectively). The analysis of results demonstrated that hydrophilic properties (WHC, WAC) and colour characteristics (L*, a* and b*) of M. pectoralis depended on pH_{24} values. With the exception of the association between pH_{24} and WAC, which was positive, all other correlations were negative. According to the present study, the correlation between pH_{24} and WHC was weak, and only 6.6% of breast muscle WHC depended on change in pH_{24} values. The breast meat WAC and colour characteristics were largely dependent on pH_{24}, as more than 40% of their variation was determined by the tested factor.*

Keywords: domestic quails, breast muscle, correlations, pH, WHC, WAC, L*a*b*.

Introduction

Poultry meat is characterized by higher pH values compared to meat of mammals. Thus, meat pH at slaughter is close to neutral and afterwards, breast muscle (*M. pectoralis*) pH rapidly declines to average values of 5.74 (Omar et al., 2018) to 6.31 (Omidizadeh et al., 2021) as a result of active glycolysis. The quality of meat as a raw material for storage and processing is characterized by its hydrophilic properties: water holding capacity (WHC) and water absorption capacity (WAC). These properties are closely associated with meat pH values (Okuskhanova et al., 2017). In the specialized literature, WHC values of meat are more commonly reported. WHC of domestic quail breast muscle varies within a very large range: from 14.2-15.1 (Aksu Elmali et al., 2014) to 37.3-37.7% (Vargas-Sanchez et al., 2018).

The colour of meat is an important quality trait. In domestic quails, the meat is dark due to predominance of dark muscle fibres (95.1-96.7%) over light muscle fibres (3.7-4.9%) (Narinc et al., 2013). The appearance of the colour is a complex process, combining the lightness with pigment saturation. The average values of colour coordinates of domestic quail meat vary substantially in different research reports, but most commonly, lightness (L*) is reported within the range of 33.6-53.9; redness (a*) - within 4.7-14.5 and yellowness (b*) - from 2.2 to 12.4 (Zerehdaran et al., 2012; Aksu Elmali et al., 2014; Okuskhanova et al., 2017; Omidizadeh et al., 2021). In some studies, the values of the b* colour coordinates are even negative: from -0.7 to -3.7 (Zerehdaran et al., 2012).

Meat lightness (L*) depends on absorption and reflection of white light, but extents of light refraction and scattering are also important (Murashov et al., 2010). According to the authors, the saturation of pigments in the red spectrum is determined by myoglobin content of muscle fibres, but it is also influenced by the degree of iron oxidation in myoglobin and haemoglobin. In addition, some blood plasma and meat pigments (carotenoids, xanthophylls, and flavoproteins) may enhance or weaken the colour in the red spectrum and define pigmentation in the yellow-blue spectrum. For example, the colour of carotenoids can be yellow, orange or red with different shades, depending on double bond sequences. Oxidized flavoproteins have yellow colour, while in reduced form they are colourless. The first post-slaughter hours are not indicative for the real pigment saturation of poultry breast muscles. A more realistic picture could be obtained after the 24th *post mortem* hour (Petracci and Fletcher, 2002).

Often, research studies discuss the relationship between meat pH and its hydrophilic or colour characteristics, but specific data on the magnitude or the nature of these relationships are encountered relatively rarely. In most cases, the association of meat pH with its WHC has been reviewed with respect to problems with pale, soft, exudative (Lesiow and Kijowski, 2003; Kissel et al., 2009) and dark, firm, dry meat (Allen et al., 1997). Genchev (2014) has investigated the association of pH and WHC of breast meat in domestic quails and found out a weak inverse relationship with r = -0.218.

Some research studies reported data on the relationships of meat pH and its colour characteristics. The phenotype correlation of pH with breast muscle colour is weak and negative (Oğuz et al., 2004; Narinc et al., 2013). According to cited authors, respective correlation coefficients were $r_{pH/L*}$= -0.26, $r_{pH/a*}$= -0.15; $r_{pH/b*}$= -0.12 and $r_{pH/L*}$= -0.14, $r_{pH/a*}$= -0.22, and $r_{pH/b*}$= -0.09.

The scarce information on these relationships has set the aim of the present study: to investigate the range of variation of breast muscle pH, WHC, WAC and colour in domestic quails and to analyze the relationship patterns between pH_{24} and muscle hydrophilic and colour characteristics.

Material and methods

The study summarizes data from two research experiments on breast muscle (*M. pectoralis*) in 151 domestic quails. In the first experiment, muscle pH, WHC, WAC, and colour have been studied, whereas in the second one - pH, WHC and colour. All analyses were performed on the 24th hour *post mortem*. The values of pH were measured with a portable pH-meter Milwaukee MW 102 (Milwaukee Instruments, Inc.). The instrument, equipped with a glass electrode, was calibrated using standard solutions of pH 4.0 and pH 7.0. Results were recorded after the pH-meter's glass electrode was inserted 1 cm deep into the pectoral muscle tissue.

The colour characteristics were determined by means of PCE-CSM 2 spectrophotometer (PCE Instruments), calibrated immediately before the analysis. Colour coordinates in the CIEL*a*b* system were determined in CIE illuminant D-65. The measurements of *M. pectoralis* were carried out on the proximal third of lateral muscle surface.

For WHC determination, approximately 2 g samples were collected from the pectoral muscle. The weight of muscle samples was determined with precision of 0.001 g on analytical balance Kern EMB 200-3 (KERN & SOHN GmbH) and carefully placed between two filter paper sheets. The water holding capacity (WHC) of muscles was determined on *post mortem* hour 24 by the classical method of Grau and Hamm, described by Zahariev and Pinkas (1979) with modification of Petrov (1982). All samples were run in duplicate for better precision. The analysis was performed by compression of muscle specimens between two glass plates with a 5 kg weight for 5 minutes. Then, compressed samples were weighed once again with the same precision. The WHC of samples was based on calculation of the amount of water released following the compression by the formula: WHC% = [(muscle sample weight before compression – muscle sample weight after compression) / muscle sample weight before compression] × 100; higher values corresponding to lower muscle tissue WHC.

WAC of meat was determined in physiological saline. To this end, samples of approximate size 2.0×1.0×0.5 cm were collected from pectoral muscle. The weight of samples was determined with precision of 0.001 g and placed in tubes containing 15 ml physiological saline for 24 h at 2-4°C. After the exposure, meat samples were carefully dried with filter paper to remove free water and weighed once again on the same balance. The WAC of meat was calculated using the formula:

WAC, % = $\frac{b \quad a}{a}.100$, where:

a – weight of meat sample before the analysis, g;

b – weight of meat sample after 24-hour stay in physiological saline, g.

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The results were statistically analyzed using IBM® SPSS® Statistics (V26) software. The relationship patterns between the criterion trait pH and resultant traits WHC, WAC and colour of meat were determined by models described in detail by Merkurieva (1970). For this purpose, the range of variation of criterion and resultant traits was divided into six classes. For each class, we identified where pH_{24} intersected with the other traits on the coordinate system. We calculated the average values of the resultant traits for each pH_{24} class to plot the correlation line, then determined its strength and nature.

Results and discussion

The study demonstrated that on the 24th *post mortem* hour, breast meat pH_{24} in domestic quails varied between 5.21 and 6.20, with mean value for both experiments of 5.84±0.018 (Table 1). Our results are similar to previously published data (Narinc et al., 2013; Güler, 2022). However, pH_{24} values beyond these limits have been also published – 4.3 (Nasirifar et al., 2016) and 7.4 (Zerehdaran et al., 2012). Most probably, these extremely low and high values could be attributed to erroneous analysis or erroneous calibration of the pH meter. The coefficient of variation of pH_{24} in both experiments was low – CV 2-4% (3.8% after summing up the results), evidencing that the dataset was homogeneous. The used dataset was almost homogeneous also with respect to resultant traits, as the dispersion of WAC and colour coordinates a* and b*. In a study on the extent of variation of the same traits, Nasirifar et al. (2016) reported data from a heterogeneous dataset with CV of WAC of almost 44%, and CV of a* - 31%. Contrasting to our data, the variation of the colour coordinate b* in the studies of Narinc et al. (2013) and Nasirifar et al. (2016) was about 19%. WHC in the present results varied from 15.1 and 30.8%, in line with data of Awan et al. (2017) – 18.3-30%. Among all resultant traits presented in Table 1, the least variation was observed for meat lightness (CV 8.3%), and L* values ranged within 41.2 - 58.5.

Table 1. Average values and degree of variation of the studied parameters characterizing the quality of quail's breast meat

Parameter	pH_{24}	WHC	WAC	L*	a*	b*
First experiment						
n	69	69	69	69	69	69
x	5.72	20.88	22.53	48.89	11.42	11.65
Sx	0.032	0.373	0.685	0.649	0.281	0.279
SD	0.268	3.078	5.650	5.355	2.317	2.303
CV, %	4.7	14.7	25.1	11.0	20.3	19.8
min	5.21	15.09	11.27	41.19	8.48	6.98
max	6.16	30.36	33.52	58.46	16.92	15.72
Second experiment						
n	82	48		82	82	82
x	5.92	23.65		49.19	9.63	8.21
Sx	0.013	0.452		0.298	0.155	0.127
SD	0.118	3.099		2.72	1.41	1.16
CV, %	2.0	13.1		5.5	14.7	14.1
min	5.69	16.04		43.65	6.69	5.9
max	6.20	30.79		55.41	13.13	11.13
Total						
n	151	117	69	151	151	151
x	5.84	22.02	22.53	48.97	10.36	9.68
Sx	0.018	0.312	0.685	0.332	0.160	0.192
SD	0.220	3.365	5.650	4.068	1.955	2.352
CV, %	3.8	15.3	25.1	8.3	18.9	24.3
min	5.21	15.09	11.27	41.19	6.69	5.90
max	6.20	30.79	33.52	58.46	16.25	15.72

The investigation of the association between pH_{24} and the two resultant traits (WHC and WAC) characterizing meat hydrophilic properties showed divergent relationships (Figure 1).

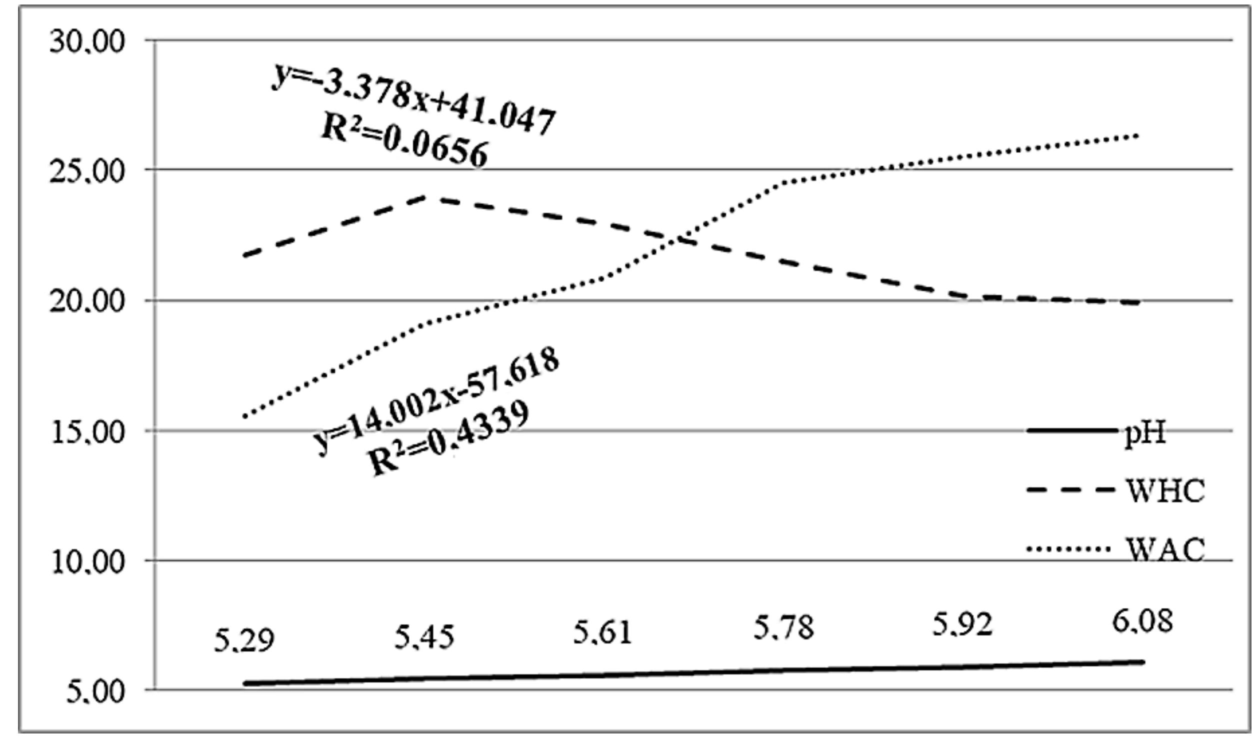

Figure 1. The relationship between pH_{24}, WHC, and WAC of breast meat from domestic quails

The relationship between pH_{24} and WHC was negative, with more visible decrease in WHC (16.9%) at pH_{24} values over 5.45. The analysis demonstrated that this association in the studied dataset was close to the linear model. The performed regression analysis showed a weak negative association between pH_{24} and WHC (r=-0.256±0.086; p<0.001), with linear regression equation y=-3.378x+41.047. In the studied dataset, 6.6% of the variation of WHC may be explained by changes of pH_{24} (R^2=0.0656). A similar weak negative relationship between both traits was reported by Güler (2022). Moderate negative correlation between pH_{24} and WHC in broiler chickens (-0.41; p<0.001) was found out by Berri et al. (2007).

The relationship between pH_{24} and WAC in the studied dataset was linear, with very clear WAC increase proportional to pH_{24} increase (69.3%). The calculations showed that the relationship between these traits was close to linear, and that more than 40% of variation in resultant traits depended on changes in pH_{24} values (R^2=0.4339). The correlation between these traits was strong (r=0.659±0.068; p<0.001), and was described by the linear regression equation y=14.002x-57.618.

Figure 2 illustrates the inverse associations between pH_{24} and the color coordinates of quail breast meat. The analysis demonstrated that all they were inverse.

The association of pH_{24} and L* for the studied dataset was negative, close to linear, with more significant decline in meat lightness (18.3%) for pH_{24} values over 5.48. The linear relationship between the two traits suggested that the correlation coefficient provided sufficient information for its strength. The correlation was strong, negative (r=-0.639±0.048; p<0.001), with linear regression equation y=-11.844x+118.124. The proportion of meat lightness variation in the studied dataset that may be explained by changes in pH_{24} values was 45% (R^2=0.4516).

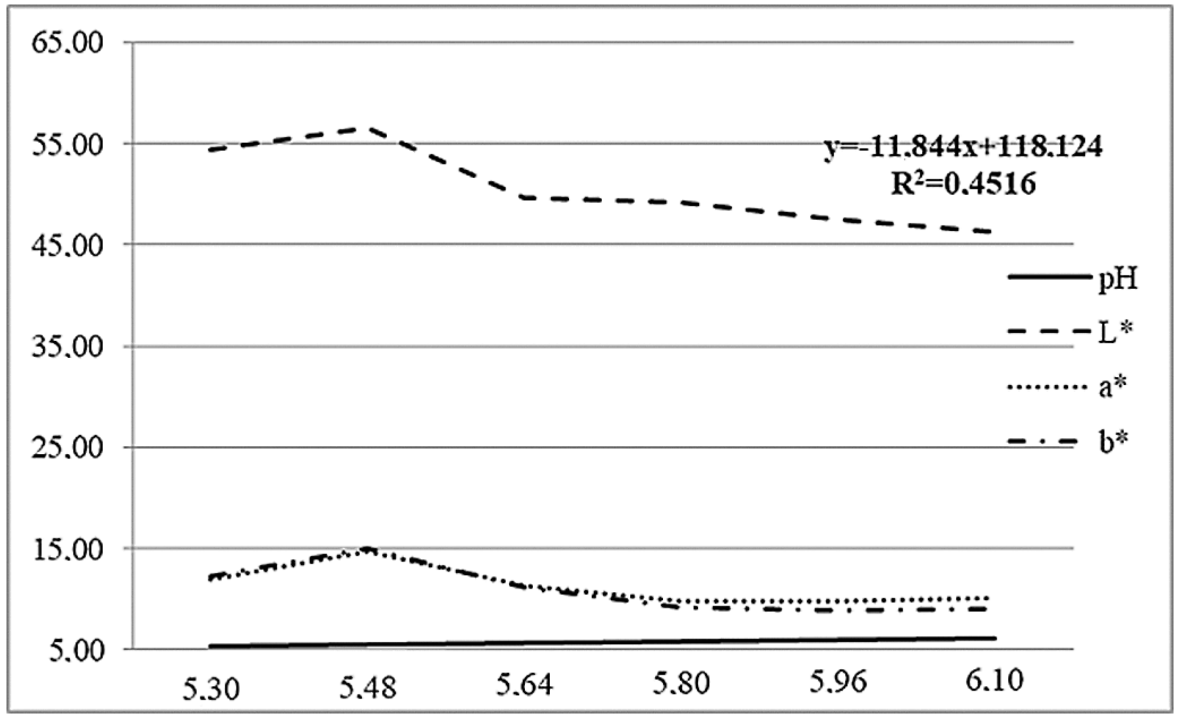

Figure 2. The relationship between pH_{24} and colour characteristics of domestic quail breast meat

In their investigations on correlations between lightness (L*) of quail breast meat and pH_{24}, some research teams reported weak (Narinc et al., 2013; Güler, 2022) to moderate (Oğuz et al., 2004) negative associations. In line with our results, Berri et al. (2007) and Le Bihan-Duval et al. (2008) showed a strong negative relationship between the two traits (-0.61; p<0.001 and -0.65; p<0.01) in meat-type broiler chickens. Data about very strong negative correlation between both breast meat traits (-0.901; p<0.0001) in broiler chickens were also reported (Qiao et al., 2002).

For the other two colour coordinates (a* and b*), overlapping of the lines describing their dependence on the pH_{24} criterion trait was observed. Both breast meat redness and yellowness decreased as meat pH_{24} increased. The reduction was more obvious at pH values exceeding 5.48 (31.2% for a* and 40.4% for b*). The analysis of published results showed that the relationship between the criterion and resultant traits had a marked curvilinear pattern with curvilinearity coefficient L=0.235±0.069 (p<0.001) between pH_{24} and breast meat redness and L=0.196±0.065 (p<0.01) between pH_{24} and breast meat yellowness (Merkurieva, 1970). The curvilinear character of the relationship demonstrated that the correlation coefficient (r) could not define the strength of association in this specific dataset. The calculations made clear that the correlations between pH_{24} and both colour coordinates in the dataset were strong (η=0.635±0.049; p<0.001 for pH/a* and η=0.668±0.045; p<0.001 for pH/b*). More than 40% of pigmentation of breast meat was dependent on changes in pH_{24} (η^2_{a*}=0.403 and η^2_{b*}=0.4458).

Conclusion

According to the results obtained, the studied dataset was relatively homogeneous (CV<30%). The least dispersion was shown for pH_{24} and L*. The analysis of results demonstrated that hydrophilic properties (WHC, WAC) and colour characteristics (L*, a*, b*) of quail *M. pectoralis* depended on pH_{24} values. With the exception of the positive association between pH_{24} and WAC, all other correlations were negative. According to the present study, the correlation between pH_{24} and WHC was weak, and only 6.6% of breast muscle WHC can be attributed to pH_{24} variations. The breast meat WAC and colour characteristics strongly correlated with pH_{24}, as more than 40% of their variation was determined by the tested criterion.

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