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THE RELATIONSHIP BETWEEN COLOUR AND PH IN COLD-STORED QUAIL BREAST MUSCLE*

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Abstract

The purpose of this study was to analyse the colour of the breast muscles of Japanese Pharaoh quail on the first day after slaughter and again after further six days of cold storage, in relation to their muscle pH. The material for the study consisted of 40 breast muscles taken from the carcasses of six-week-old Japanese Pharaoh quail. Based on pH results, the muscles were divided into three groups: I (pH = 5.51–5.70), II (pH = 5.71–5.90) and III (pH = 5.91–6.10). After this the muscles were stored for a further 6 days at 4°C. It was found that the pH of freshly dissected quail breast muscle is a good indicator of the colour stability of muscles cold-stored at 4°C for six days. The lowest degree of colour stability was observed in the pH range 5.51–5.70. In the sensory evaluation muscles displaying this degree of colour instability were considered unacceptable or barely acceptable. In contrast, muscles in the pH ranges 5.71–5.90 and 5.91–6.10 displayed a high degree of colour stability and were considered acceptable in the sensory evaluation. The colour changes that occurred during storage of the muscles were due to changes in the values of all of the colour parameters (*L, *a**, *b**, *C** and *h°*); however, the greatest changes were found in the case of redness (*a**) and the hue angle (*h°*). The changes were caused both by alterations in the amount of pigment reached by light, and by changes in the relative amounts of the chemical forms of myoglobin.**

Key words: colour, muscle, pH, quail

Colour is perceived to be one of the most important determinants of meat quality (Risvik, 1994; Brewer and Mc Keith, 1999). In the case of raw meat sold in transparent packaging, it is the most readily available characteristic open to examination by consumers, other than water holding capacity and fat content (Andersen, 2000). For the consumer, meat colour is not only a determinant of general quality but also demonstrates the freshness of the meat. As such, it is crucial in making the decision whether or not to purchase the meat.

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Little is known about the formation of meat colour in species that are rarely used as a source of meat for humans. One such species is the Japanese quail, whose meat has a low fat content (Gardzielewska et al., 2010) and whose muscle fibres are of small diameter, which makes its meat tender and attractive to consumers (Tarasewicz et al., 2007). It is considered to be an interesting alternative to other types of meat. Quails' breast muscles make up about 30% of their body mass and have a significantly darker colour (Gardzielewska et al., 2010) than the breast muscles of broiler chickens. Gardzielewska et al. (2004) showed that the quail's muscles vary in their pH range, colour and water holding capacity. This indicates that quail muscles will probably also vary in terms of colour stability. There is no research available into the correlation between the formation of the quail's breast muscle colour and the pH of the muscles.

As is well known, pH is one of the most important factors affecting the colour of meat. The degree of tissue acidification affects the redox processes (Bekhit and Faustman, 2005; Mancini and Hunt, 2005), as well as the formation of the structure of the meat postmortem. The range of postmortem pH decline also affects the myofilament lattice spacing, and consequently its degree of transparency. This in turn determines how deeply light penetrates the surface layer of the meat (Hamm, 1996). This factor is important in the formation of the colour of the raw meat, because it determines both the amount of pigment that can be reached by the light and also the relative proportions of oxymyoglobin, metmyoglobin and deoxymyoglobin (Krzywicki, 1979). Tissue pH is also an important factor in the colour stability of raw meat (Mikkelsen et al., 1999), which decreases with decreases in pH values.

The purpose of this study was to analyse the colour in the breast muscles of Japanese Pharaoh quail on the first day after slaughter and again after further six days of cold storage, in relation to their muscle pH.

Material and methods

The material for this research consisted of 40 breast muscles obtained from the carcasses (weighing 102–110 g) of Japanese Pharaoh quail bred at the University premises. Whilst being reared, the quails were kept in the cages with dimensions 100 × 60 × 20 cm. At room temperature and under light conditions tailored to the age of the quails (Rutkowski, 2000). In the first three weeks of rearing, the birds were given feed with the energy value of 12.1 MJ/kg, 24.2% protein and 3.5% crude fibre. Then, until the end of rearing, their feed had the energy value of 11.6 MJ/kg, 20.5% protein and 4.0% crude fibre. Throughout the rearing period (6 weeks), the birds had constant access to feed and water. On the 42nd day of their life, the quails were slaughtered by decapitation. After postmortem treatment, the carcasses were kept in a cold store at about 4°C for a period of 24 hours (for pH stabilization), after which the breast muscles were separated from the carcasses. The muscles were cold-stored at 4ºC for 1 hour for myoglobin oxygenation, and then were subjected to a sensory evaluation, after which pH and colour measurements were taken. After taking these measurements, the muscles were packed in foil which was gas- but not water-permeable and kept at a temperature of 4°C for six further days. After this period the

muscles were unpacked and the sensory evaluation and colour measurements were performed again.

Sensory evaluation of colour

The sensory evaluation of the muscles was carried out using a 5-point scale (1 point – colour too bright, not acceptable; 2 points – bright colour, barely acceptable; 3 points – moderately acceptable colour; 4 points – correct colour, acceptable; 5 points – correct colour, highly desirable – excellent). The evaluation was carried out by a five-person team with proven sensory sensitivity skills, according to PN-ISO 8586-1 (1996) and PN-SO 8586-2 (1996).

Measurement of pH

The measurements of the muscle pH were taken directly from the breast muscles one day after slaughter, using ESAgP.302W electrodes and the CyberScan 10 pH meter (manufactured by EUTECH Cybernetics Ltd., Singapore). Based on the results of these measurements, the muscles were divided into three groups. In the first group of muscles (I) the pH was in the range 5.51–5.70, in the second group (II) the pH was 5.71–5.90, and in the third group (III) the pH was 5.91–6.10.

Colour measurements and determination of the relative amounts of the chemical forms of myoglobin

Colour measurements were taken from the inner surface of the breast muscle (*Musculus pectoralis superficialis*) using a Mini Scan XE Plus 45/0 camera, with the port hole diameter measuring 31.8 mm. Standardisation of the equipment was carried out with reference to black colour and white colour standard references with the following coordinates: X = 78.5, Y = 83.3 and Z = 87.8 (for D65 illuminant and 10° standard observer). The colour parameters were as specified in the CIELAB and CIELCh scales (CIE, 1976), using standard illuminant D65 and a 10° standard observer. Reflectance measurements were taken at 10 nm intervals between 400 and 700 nm.

The relative contents of Mb, MbO_2 and MetMb were calculated from the reflectance curve according to Krzywicki (1979), using 700 nm (the highest wavelength on the instrument) instead of 730 nm. The reflectance values at wavelengths not given by the instrument (473, 525 and 572 nm) were calculated using linear interpolation. The reflectance values were converted into absorbance values according to the formula $A = 2–\log 10R$, where A denotes absorbance and R reflectance.

The colour measurements using the CIELAB and CIELCh scales and the reflectance measurements were taken using duplicate standards. This allowed the values of all the colour parameters of a given sample and its reflectance values to be obtained from a single measurement.

After 6 days cold storage, the same measurements were taken again using the aforementioned colour scales, illuminant D65 and 10° standard observer. Then the values of the total and chromatic absorbance at the wavelength 525 nm (A_{525} and A_{525p}), absorbance at the wavelength 700 nm (A_{700}) and the relative content of the various forms of chemical myoglobin in the surface layer of the meat penetrated by light were all determined.

On the basis of the colour measurements obtained on the day of muscle dissection (1 day after slaughter) and then after 6 days of cold storage (7 days after slaughter), the differences in the colour parameters according to the CIELAB and CIELCh scales (ΔL^*, Δa^*, Δb^*, ΔC^*, $\Delta h°$) were calculated, as were the differences in the total and chromatic absorbance at the wavelength 525 nm (ΔA_{525}, ΔA_{525p}), absorbance at the wavelength 700 nm (ΔA_{700}) and the relative content of MbO_2, MetMb and Mb (ΔMbO_2, ΔMetMb and ΔMb).

Assessment of colour stability

The assessment of the colour stability of the meat was carried out using the Kortz method (1966), as modified by Karamucki (2008), using the following formula:

$$CS = 2 - \left(\frac{A_{580}}{A_{630}} - \frac{A'_{580}}{A'_{630}} \right)$$

where:

CS – colour stability,

A_{580}, A_{630} – absorbance values at the wavelengths 580 and 630 nm 1 day after slaughter,

A'_{580}, A'_{630} – absorbance values at the wavelengths 580 and 630 nm 6 days after slaughter.

The colour stability was expressed as a percentage of the change of colour (Różyczka and Michalski, 1978).

$$\%CC = 50 \cdot (2 - CS)$$

where

CC – % colour change.

Statistical methods

The measurements were analysed using the data analysis software system STATISTICA version 9 (StatSoft, Inc. 2009). An analysis of the differences between the two sets of measurements was carried out according to the non-orthogonal system, and the significance of these differences was estimated at the levels of probability $P \leq 0.05$ and $P \leq 0.01$. The simple and partial correlation coefficients and the coefficients of determination were also calculated, as was their significance at the levels of probability $P \leq 0.01$ and $P \leq 0.001$.

Results

Table 1 presents the results of the sensory evaluation of the colour of the dissected breast muscles before and after 6 days of cold storage. In the freshly dissected muscles, the colour was acceptable in all the pH groups, although the muscles in group I received an average grading (3.20 points) significantly lower than the muscles in groups II (4.11 points) and III (4.55 points).

Table 1. Means and standard deviations (SD) of sensory assessment of muscle colour before and after a 6-day cold storage and *%CC* in three groups of muscles

Group	pH range	n	pH	Sensory evaluation of colour (points)		*%CC*
				before cold storage	after 6-day cold storage	
I.	5.51–5.70	10	5.64±0.03 A	3.20±0.42 A	1.40±0.52 A	51.44±20.45 A
II.	5.71–5.90	19	5.80±0.06 B	4,11±0.66 B	3.79±0.71 B	25.19±13.65 Ba
III.	5.91–6.10	11	6.00±0.05 C	4.55±0.52 B	4.18±0.40 B	10.50±8.90 Bb

Means ± SD denoted with different cases differ significantly: at P≤0.05 (lowercase); P≤0.01 (uppercase).

Table 2. Means and standard deviations (SD) of pH and muscle colour parameters before and after a 6-day cold storage

Group	pH range	n	pH	*L**	*a**	*b**	*C**	*h*°
				Before cold storage				
I.	5.51–5.70	10	5.64±0.03 A	42.27±2.27 A	14.26±0.98 A	14.42±2.17 A	20.32±1.99 A	45.07±3.76 A
II.	5.71–5.90	19	5.80±0.06 B	37.20±2.35 B	13.59±0.81 B	11.15±1.51 B	17.60±1.46 B	39.20±2.89 B
III.	5.91–6.10	11	6.00±0.05 C	36.71±1.59 B	13.22±0.89 B	10.24±1.27 B	16.73±1.36 B	37.67±2.50 B
				After 6-day cold storage				
I.	5.51–5.70	10	5.64±0.03 A	43.00±3.68 A	11.94±1.50 A	15.70±1.43 A	19.80±0.84	52.70±5.50 A
II.	5.71–5.90	19	5.80±0.06 B	37.84±2.61 B	13.69±1.11 B	13.06±1.50 B	18.94±1.64	43.58±2.68 B
III.	5.91–6.10	11	6.00±0.05 C	37.34±2.77 B	12.11±1.40 B	12.11±1.40 B	18.61±1.47	40.52±2.47 B

Means ± SD denoted with different cases differ significantly at P≤0.01.

Table 3. Means and standard deviations (SD) of differences in the values of colour parameters of muscles

Group	pH range	n	pH	Δ*L**	Δ*a**	Δ*b**	Δ*C**	Δ*h*°
I.	5.51–5.70	10	5.64±0.03 A	0.73±1.83	–2.32±1.88 A	1.28±0.89	–0.52±1.65 A	7.63±2.64 A
II.	5.71–5.90	19	5.80±0.06 B	0.64±1.99	0.10±1.32 B	1.91±1.04	1.34±1.55 B	4.38±1.93 B
III.	5.91–6.10	11	6.00±0.05 C	0.63±1.49	0.89±0.81 B	1.87±0.90	1.88±1.09 B	2.85±1.48 B

Means ± SD denoted with different cases differ significantly at P≤0.01.
The sign "–" denotes a decrease in the parameter during storage.

Six days of cold storage resulted in adverse colour changes in group I (pH 5.51–5.70). The colour of these muscles was barely acceptable or not acceptable in the sensory evaluation (average grading 1.40 points). The colour of the muscles in groups II and III altered less, being acceptable in the sensory evaluation (average grading 3.79 points for group II and 4.18 points for group III). In the group I muscles the colour of the meat displayed the lowest stability, demonstrated by having the highest percentage (51.44%) of colour change (%CC) – as compared with 25.19% for group II and 10.50% for group III.

Table 2 shows the changes in colour between the freshly dissected breast muscles and those cold-stored for 6 days in the three pH groups. Freshly dissected muscles in group I exhibited significantly higher lightness (L^*), yellowness (b^*), chroma (C^*) and hue angle ($h°$) than the muscles in both groups II and III, and significantly higher redness (a^*) than the muscles in group III. The freshly dissected muscles in groups II and III exhibited similar values for their individual colour parameters. After six days of cold storage at 4°C, the group I muscles exhibited significantly higher lightness (L^*), yellowness (b^*) and hue angle ($h°$), and significantly lower redness (a^*) than the muscles in groups II and III – that is, the colour of the group I muscles was the worst.

The differences in the muscle colour parameters as shown in Table 3 indicate that during storage, the muscles in group I decreased in redness (Δa^*) and colour saturation (ΔC^*), while at the same time displaying an increase in the hue angle ($\Delta h°$). In contrast, in groups II and III there was an increase in redness (Δa^*) and chroma (ΔC^*), as well as in the hue angle ($\Delta h°$).

To sum up, the hue angle ($h°$) of the muscles deteriorated during storage in every group, with the greatest deterioration being found in group I. This was due both to a decrease in redness (Δa^*) and an increase in yellowness (Δb^*) in this group of muscles, and also to a greater increase in yellowness (Δb^*) than redness (Δa^*) in groups II and III.

Table 4 shows the total and chromatic absorbance at the wavelength 525 nm (A_{525} and A_{525p}), the absorbance at the wavelength 700 nm (A_{700}) and the relative amounts of MbO_2, MetMb and Mb in both the freshly dissected muscles and cold-stored for 6 days. Table 5 shows the differences in the absorbance values and in the relative amounts of the chemical forms of myoglobin between the freshly dissected and cold-stored muscles.

The freshly dissected muscles in group I exhibited significantly lower absorbance at the wavelengths 525 nm and 700 nm (A_{525} and A_{700}), a significantly lower relative amount of Mb and a significantly higher relative amount of MbO_2 than those in both groups II and III, as well as significantly lower chromatic absorbance at the wavelength 525 nm (A_{525p}) than the muscles in group II. The cold-stored muscles in this group exhibited significantly lower total and chromatic absorbance at the wavelength 525 nm (A_{525} and A_{525p}), absorbance at 700 nm and a significantly higher relative amount of MetMb than those in groups II and III. In addition, the cold-stored muscles in groups I and II had significantly lower relative amounts of Mb and MbO_2 than those in group III (see Table 4).

Table 4. Means and standard deviations (SD) of pH, A_{525p}, A_{525}, A_{700} and the relative amounts of the chemical forms of myoglobin in the muscles before and after a 6-day storage

Group	pH range	n	pH	A_{525}	A_{525p}	A_{700}	MbO_2	MetMb	Mb
Before cold storage									
I.	5.51–5.70	10	5.64±0.03 A	0.978±0.054 A	0.597±0.025 a	0.381±0.039 A	0.449±0.110 A	0.321±0.039	0.230±0.125 A
II.	5.71–5.90	19	5.80±0.06 B	1.102±0.061 B	0.625±0.031 b	0.477±0.040 B	0.319±0.069 B	0.320±0.013	0.361±0.071 B
III.	5.91–6.10	11	6.00±0.05 C	1.110±0.043 B	0.618±0.030	0.493±0.031 B	0.290±0.078 B	0.326±0.028	0.384±0.073 B
After 6-day cold storage									
I.	5.51–5.70	10	5.64±0.03 A	0.969±0.089 A	0.577±0.051 A	0.392±0.041 A	0.511±0.047 a	0.476±0.045 A	0.013±0.041 A
II.	5.71–5.90	19	5.80±0.06 B	1.094±0.066 B	0.636±0.034 B	0.458±0.039 B	0.519±0.049 a	0.416±0.039 B	0.065±0.062 A
III.	5.91–6.10	11	6.00±0.05 C	1.108±0.070 B	0.638±0.048 B	0.470±0.041 B	0.452±0.087 b	0.391± 0.038 B	0.157±0.092 B

Means ± SD denoted with different cases differ significantly: at P≤0.05 (lowercase); P≤0.01 (uppercase).

Table 5. Means and standard deviations (SD) of difference in absorbance (ΔA525p, ΔA525 and ΔA700) and in the relative amounts of the chemical forms of myoglobin in the muscles

Group	pH range	n	pH	ΔA_{525}	$\Delta A_{525}p$	ΔA_{700}	ΔMbO_2	ΔMetMb	ΔMb
I.	5.51–5.70	10	5.64±0.03 A	–0.009±0.044	–0.020±0.040 a	0.011±0.021 A	0.062±0.120 Aa	0.156±0.067 A	–0.217±0.111 a
II.	5.71–5.90	19	5.80±0.06 B	–0.008±0.054	0.011±0.036 b	–0.019±0.025 B	0.200±0.070 B	0.096±0.046 B	–0.296±0.078 b
III.	5.91–6.10	11	6.00±0.05 C	–0.002±0.040	0.020±0.028 b	–0.022±0.017 B	0.162±0.103 b	0.065±0.041 B	–0.227±0.085

Means ± SD denoted with different cases differ significantly: at P≤0.05 (lowercase); P≤0.01 (uppercase).
The sign "–" denotes a decrease in the parameter during storage.

Table 6. Simple correlation coefficients (r) between pH, colour parameters, the absorbance and the relative amounts of the chemical forms of myoglobin in the muscles before cold storage (**bold font**) and after 6 days of storage (normal font) – (n = 40)

Trait	pH 5.81 (5.6–6.08)	*L**	*a**	*b**	*C**	*h°*	A_{525}	A_{525p}	A_{700}	MbO_2	MetMb	Mb
*L**	**–0.654****	**1**										
	–0.596**	1										
*a**	**–0.437****	**0.301**	**1**									
	0.472**	–0.551**	1									
*b**	**–0.681****	**0.786****	**0.693****	**1**								
	–0.672**	0.792**	–0.297	1								
*C**	**–0.649****	**0.684****	**0.842****	**0.972****	**1**							
	–0.349*	0.446**	0.322*	0.364*	1							
h°	**–0.666****	**0.846****	**0.450****	**0.951****	**0.855****	**1**						
	–0.728**	0.857**	–0.707**	0.575**	0.437**	1						
A_{525}	**0.622****	**–0.995****	**–0.244**	**–0.738****	**–0.065**	**–0.809****	**1**					
	0.596**	–0.994**	0.578**	–0.754**	–0.390*	–0.843**	1					
A_{525p}	**0.245**	**–0.705****	**0.371***	**–0.250**	**–0.630****	**–0.460****	**0.753****	*1*				
	0.467**	–0.888**	0.681**	–0.560**	–0.138	–0.749**	0.920**	1				
A_{700}	**0.702****	**–0.955****	**–0.527****	**–0.835****	**–0.810****	**–0.837****	**0.935****	**0.471****	**1**			
	0.630**	–0.943**	0.386*	–0.827**	–0.578**	–0.804**	0.923**	0.698**	1			
MbO_2	**–0.533****	**0.522****	**0.619****	**0.739****	**0.762****	**0.622****	**–0.495****	**–0.121**	**–0.598****	**1**		
	–0.383*	0.033	0.133	0.347*	0.403**	0.194	–0.047	0.056	–0.142	1		
MetMb	**–0.013**	**–0.005**	**–0.286***	**–0.035**	**–0.120**	**0.093**	**0.030**	**0.145**	**0.103**	**0.013**	**1**	
	–0.594**	0.534**	–0.733**	0.564**	–0.099	0.772**	–0.511**	–0.427**	–0.514**	0.029	1	
Mb	**0.520****	**–0.504****	**–0.532****	**–0.739****	**–0.710****	**–0.625****	**0.472***	**–0.116**	**0.555****	**–0.972****	**–0.249**	*1*
	0.656**	–0.347*	0.337*	–0.610**	–0.375*	–0.616**	0.344*	0.213	0.420**	–0.800**	–0.623**	1

* Significant at P≤0.05; ** significant at P≤0.01.

In the case of the muscles in group I, six days of cold storage led to decreases in the total and chromatic absorbance at the wavelength 525 nm (ΔA_{525} and ΔA_{525p}) and in the relative amount of Mb (ΔMb), and increases in absorbance at the wavelength 700 nm (ΔA_{700}) and in the relative amounts of MetMb and MbO_2 (ΔMetMb and ΔMbO_2). In groups II and III there were decreases in total absorbance at the wavelengths 525 and 700 nm (ΔA_{525} and ΔA_{700}) and in the relative amount of Mb (ΔMb), and increases in chromatic absorbance at 525 nm (ΔA_{525p}) and in the relative amount of MetMb and MbO_2 (ΔMetMb and ΔMbO_2). Changes in chromatic absorbance at 525 nm (ΔA_{525p}) and in the relative amount of MetMb (ΔMetMb) were significantly higher in group I than in both groups II and III. Changes in absorbance at 700 nm (ΔA_{700}) and in the relative amount of MbO_2 (ΔMbO_2) were significantly lower in group I than in both groups II and III. In addition, changes in the relative amount of Mb (ΔMb) were significantly lower in group I than in group II (Table 5).

Table 6 presents the simple correlation coefficients between the pH values of the 1-day-old muscles, their colour parameters, total and chromatic absorbance at the wavelength 525 nm (A_{525} and A_{525p}), total absorbance at the wavelength 700 nm (A_{700}), and the relative amount of the chemical forms of myoglobin. Increases in pH led to significant decreases in lightness (L^*), in the chromatic colour parameters and in the relative amount of MbO_2, and in the case of cold storage of the meat at 4°C for six days also in the relative amount of MetMb. At the same time, there were significant increases in total absorbance at the wavelengths 525 nm (A_{525}) and 700 nm (A_{700}) and in the relative amount of Mb.

Increases in lightness (L^*) were accompanied by significant increases in yellowness (a^*) and chroma (C^*), and in the hue angle ($h°$); this increase in ($h°$) was due to a greater increase in yellowness (b^*) than in redness (a^*). In addition, such increases led to significant decreases in total and chromatic absorbance at the wavelength 525 nm (A_{525} and A_{525p}), absorbance at the wavelength 700 nm (A_{700}) and in the relative amount of Mb. There was also an increase in the relative amount of MbO_2.

Table 7. The coefficients of determination R^2 (adjusted) between differences in colour parameters and (i) differences in absorbance (ΔA_{525p}, ΔA_{525} and ΔA_{700}) and (ii) in the relative amounts of the chemical forms of myoglobin (n = 40)

Trait	ΔL^*	Δa^*	Δb^*	ΔC^*	Δh^o
ΔA_{525}	0.9438**	0.1734**	0.2332**	0.2241**	0.0000
ΔA_{525p}	0.6050**	0.6016**	0.4488**	0.6140**	0.1833**
ΔA_{700}	0.3913**	0.0921*	0.0000	0.0397	0.1453**
ΔMbO_2	0.0323	0.3771**	0.2664**	0.3666**	0.1426**
ΔMetMb	0.1219*	0.6708**	0.0753*	0.4529**	0.7057**
ΔMb	0.0000	0.0102	0.1447**	0.0481	0.0000
ΔMbO_2+ΔMetMb+ΔMb	0.1022	0.7322**	0.2507**	0.5510**	0.6977**
ΔA_{525p}+ ΔMbO_2+ΔMetMb+ΔMb	0.5938**	0.8516**	0.5461**	0.7461**	0.6903**

* Significant at P≤0.05; ** significant at P≤0.01.

After six days of cold storage of the muscles at 4°C, the increase in lightness (L^*) was accompanied by an increase in all the chromatic colour parameters except redness, which decreased (a^*); this reduction in redness (a^*) was accompanied by a significant increase in the hue angle (h^o), which shifted towards shorter waves and as a result deteriorated. Additionally, the increase in lightness (L^*) was accompanied by significant decreases in total and chromatic absorbance at 525 nm (A_{525} and A_{525p}), absorbance at 700 nm (A_{700}) and in the relative amount of Mb, and by an increase in the relative amount of MetMb.

The determination coefficients (R^2) presented in Table 7 show that the changes in redness (Δa^*) and chroma (ΔC^*) after six days of cold storage depended most heavily on changes in the relative amount of MetMb (ΔMetMb) and changes in chromatic absorbance at the wavelength 525 nm (ΔA_{525p}) and thus in the amount of pigment affecting the colour. The changes in hue angle (Δh^o) were caused primarily by changes in the relative amount of MetMb (ΔMetMb).

Discussion

It is known that changes in the lightness of meat colour (L^*) are dependent both on changes in the amount of light absorbed by the tissue achromatically and on changes in the amount of pigment in the layer of meat that is penetrated by light (Krzywicki, 1979). In the present study, there was a slight increase in the lightness (ΔL^*) of the muscles in group I as a result of the decrease in pigment absorbance at the wavelength of 525 nm (ΔA_{525p}), while in groups II and III there was a similar increase resulting from the decrease in absorbance at the wavelength of 700 nm (ΔA_{700}), which was mainly accounted for by achromatic absorbance. The decrease in absorbance at 700 nm slightly exceeded the increase in pigment absorbance at 525 nm (ΔA_{525p}) (Tables 4 and 5).

As is well known, redness (a^*) depends, among other things, on the amount of pigment and on the relative content of the forms of myoglobin in the surface layer of meat that is penetrated by light. The highest redness is observed in the case of MbO_2, and the lowest with MetMb (Brewer, 2004). The results shown in Tables 3 and 5 show that the reduction in redness (Δa^*) in group I was due mainly to an increase in the relative amount of MetMb (ΔMetMb) and a decrease in the relative amount of Mb (ΔMb), as well as to a smaller amount of pigment being reached by light, as indicated by the decrease in chromatic absorbance at the wavelength 525 nm (ΔA_{525p}). The increase in yellowness (Δb^*) resulted from an increase in MbO_2 and MetMb (ΔMbO_2 and ΔMetMb), which is consistent with the results obtained by Feldhusen and Reinhard (1994). The smallest increase in yellowness was in group I, in the case of which cold storage resulted primarily in an increase in the relative amount of MetMb. As is already known, an increase in the yellowness (b^*) of muscles is more dependent on the oxygenated form of myoglobin (MbO_2) than on the oxidized form (MetMb) (Karamucki, 2008).

In groups II and III, decreases in redness (a^*) – induced by an increase in the relative amount of MetMb (ΔMetMb) and in the relative amount of Mb (ΔMb) – were

offset by increases in MbO_2 (ΔMbO_2) and in the amount of pigment reached by light (ΔA_{525p}) (Table 5). As a result, in these groups the cold storage of the muscles at 4°C increased redness (a^*), particularly in group III (Table 4).

In both the freshly dissected and cold-stored muscles (for 6 days), the increase in yellowness (b^*) significantly contributed to an increase in chroma (C^*) and to a deterioration in the hue angle (h^o). This effect of yellowness (b^*) on chroma (C^*) and the hue angle ($h°$) was greater in the freshly dissected muscles. In these muscles, the increase in yellowness (b^*) was significant and was caused primarily by an increase in the relative amount of MbO_2 and a decrease in the relative amount of Mb, while in the cold-stored muscles a similar significant increase was caused by an increase in the relative amount of MetMb and a decrease in the relative amount of Mb. The increase in chroma (C^*) was accompanied by a significant increase in the hue angle ($h°$), which shifted towards shorter waves and was less red, and simultaneously in the freshly dissected muscles the chromatic absorbance significantly decreased at the wavelength 525 nm (A_{525p}) – and therefore light reached less of their pigment. In both freshly dissected and cold-stored muscles, chroma (C^*) significantly increased as the relative amount of Mb decreased and the relative amount of MbO_2 increased – MbO_2 being the form of myoglobin which contributes most to an increase in chroma (Lindahl et al., 2001).

The hue angle ($h°$) increased significantly as the amount of pigment in the layer of meat penetrated by light decreased (A_{525p}), the relative amount of Mb increased and the relative amounts of MbO_2 (in the case of the freshly dissected muscles) and MetMb (in the case of muscles cold-stored for 6 days) increased. At the same time, the relative amounts of MbO_2 and MetMb increased significantly, at the expense of the relative amount of Mb.

In summary, the pH of the freshly dissected quail breast muscles is a good indicator of the colour stability of muscles cold-stored at 4°C for six days, in that it was observed that colour stability increases as pH increases. The lowest level of colour stability was observed in muscles with a pH of 5.51–5.70, with adverse changes occurring over the six days of cold storage. After storage the colour of these muscles was unacceptable or barely acceptable in a sensory evaluation. Muscle colour stability at pH 5.71–5.90 and pH 5.91–6.10 proved to be satisfactory after six days of storage at 4°C. The highest grading in the sensory evaluation of colour after six days of cold storage was given to muscles with a pH of 5.91–6.10.

Storage of the breast muscles of Japanese quail at 4°C for six days was accompanied by changes in all the colour parameters, both achromatic (L^*) and chromatic (a^*, b^*, C^* and h^o). These changes were caused both by changes in the structure of the meat, which affected the degree of light absorbance, and by changes in the relative amounts of the chemical forms of myoglobin in the surface layer of meat that was penetrated by light. The greatest changes, in redness (a^*) and hue angle ($h°$), were due primarily to a decrease in chromatic absorbance at the wavelength 525 nm, i.e. a reduction in the amount of pigment reached by light accompanied by an increase in the relative amount of metmyoglobin.

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Zależność między barwą a pH w mięśniach piersiowych przepiórek przechowywanych w warunkach chłodniczych

STRESZCZENIE

Celem pracy była analiza kształtowania się barwy mięśni piersiowych przepiórek japońskich rasy faraon w pierwszym dniu po uboju oraz po 6 dniach przechowywania w warunkach chłodniczych w zależności od wartości pH. Materiał do badań stanowiło 40 mięśni piersiowych wypreparowanych z tuszek 6-tygodniowych przepiórek japońskich rasy faraon. Na podstawie wartości pH mięśnie podzielono na trzy grupy: I (pH = 5,51–5,70), II (pH = 5,71–5,90) i III (pH = 5,91–6,10). Stwierdzono, że wartość pH mięśni piersiowych przepiórek w pierwszym dniu po uboju jest dobrym wskaźnikiem trwałości barwy tych mięśni przechowywanych w warunkach chłodniczych w temperaturze 4ºC przez okres 6 dni. Najmniejszą trwałością barwy charakteryzowały się mięśnie o pH 5,51–5,70, których barwa ulega w tym czasie niekorzystnym zmianom, a po okresie przechowywania była nieakceptowana lub słabo akceptowana w ocenie sensorycznej. Barwa mięśni o pH 5,71–5,90 i 5,91–6,10 cechowała się natomiast dobrą trwałością i była akceptowana w ocenie sensorycznej. Zmiany barwy zachodzące w czasie przechowywania mięśni polegały na zmianie wartości wszystkich parametrów barwy (L^*, a^*, b^*, C^* i h^o), przy czym największe zmiany stwierdzono w przypadku czerwoności (a^*) i tonu barwy (h^o). Były one wywołane zarówno zmianami w ilości barwników, do których dotarło światło, jak i we względnej ilości form chemicznych mioglobiny.