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Characteristic of meat colour of different duck populations

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Abstract

Out of 6 conservative flocks (Khaki Campbell – Kh1, Orpington – O1, Miniducks – K2, Polish Pekin – P33, Pekin originated from Danish – P8 and cross-breeds in Pekin type – SB) 60 female ducks were used for comparison (10 ducks in each group). Birds were slaughtered at 7 week of age.

The investigation of breast muscles covers: determination of the colour parameters L* (lightness), a* (redness), b* (yellowness), C (saturation), h° (hue) and ΔE (colour difference), total haem pigments' content (THP) including myoglobin (Mb), oxymyoglobin (MbO_2) and metmyoglobin (MMb) content. Sensory evaluation of raw muscles' colour intensity in 10 point scale and Principal Component Analysis (PCA) of all measured parameters were also performed.

Low THP and MbO_2 were shown by Kh1 and P33 (THP: 3.79 and 3.74 mg/g, MbO_2: 2.32 and 2.46 mg/g respectively). They were also characterized by the highest L* value of the all flocks (45.27 and 44.25 respectively) ($P \leq 0.01$, $P \leq 0.05$).

The Kh1 was evaluated by the sensory panel as the lightest (5.01 conventional units [CU]) ($P \leq 0.01$). However P8 and K2 were assessed as darker than Kh1 and P33 (6.12 and 6.22 CU vs. 5.01 and 5.71 CU) ($P \leq 0.01$, $P \leq 0.05$) and also had significantly higher pigments content (4.48 and 4.57 mg/g respectively) ($P \leq 0.01$). Additionally K2 was characterized by the highest MMb content (0.48 mg/g) ($P \leq 0.01$), but this value is below the level that makes the colour undesirable. The ΔE values between flocks were in the 1.02-2.86 range. With just few exceptions, flocks with ΔE value higher than 2, differed significantly in pigments content, L* parameter, and sensory panel scores. As regards the obtained results Kh1 and P33 appeared significantly lighter than P8 and K2. Kh1 and P33 had lower pigments content, higher L* value and were assessed by a sensory panel as having lower colour intensity than P8 and K2. PCA analysis confirmed ANOVA results and also indicated large total colour variation of the samples within breeds except of O1 muscles.

Keywords: duck, genetic reserve flocks, meat quality, meat colour

Zusammenfassung

Merkmale der Fleischfarbe verschiedener Entenpopulationen

Für die Untersuchung der Fleischfarbe wurden je 10 Enten von 6 verschiedenen bodenständigen Entenpopulationen und Genreserven im Alter von 7 Wochen geschlachtet. Einbezogen waren die Tierpopulationen Khaki Campbell (Kh1), Orpington (O1),

Miniducks (K2), Polish Pekin (P33), Peking 1978 aus Dänemark importiert (P33) und Kreuzungstiere im Pekingtyp (SB) als Nachfahren von 1977 aus England importierten Tieren. Es erfolgte die Erfassung zahlreicher Farbmerkmale am Brustmuskel der Tiere. Geringe Gesamthaempigment-(THP) und Oxymyoglobinwerte (MbO_2) wurden bei Kh1 und P33 beobachtet, die auch im Vergleich mit allen anderen Populationen die höchsten Farbwerte (L*) erreichten. Die P8 und K2 Population wiesen dunkleres Fleisch sowie signifikant höhere THP Werte auf. K2 war auch durch den höchsten Metmyoglobingehalt (MMb) gekennzeichnet jedoch lag dieser Wert unterhalb der erwünschten Farbwerte. Die ΔE Werte der Farbdifferenz zwischen den Populationen lagen bei den Rängen 1,02 bis 2,86. Mit nur wenigen Ausnahmen unterschieden sich Populationen mit ΔE Werten größer als 2.0 im THP Gehalt, den L*- und den Sensorikwerten. Die erhaltenen Kh1 und P33 Populationen schienen offensichtlich hellere Probenwerte als P8 und K2 zu erreichen. Sie wiesen geringere Pigmentgehalte sowie höhere L*-Werte und eine geringere Farbintensität auf als P8 und K2. Die Auswertungen ergaben mit Ausnahme der O1 eine große Variation der Farbwerte innerhalb der einzelnen Populationen.

Schlüsselwörter: Enten, Genreserve, Fleischqualität, Fleischfarbe

Introduction

Poland and other countries membership the United Nations signed the Convention on Biological Diversity at the World Summit in Rio de Janeiro in 1992. Some breeds of ducks were included in the national genetic resources programme, but not only because of the formal obligations but also for maintaining the reproducibility of old, local animal species and breeds for future generations. Conservative flocks are kept in Poland by *»in situ«* method since the 1970s. National Research Institute of Animal Production worked out the programme for the maintenance of genetic resources and determined diversity of reproduction and fleshiness traits between flocks.

There were a lot of research conducted to know better the individual traits of ducks populations among others determining of biochemical compounds of blood, eggs and meat, genetic parameters of ducks and changes of production value in the next generations maintained without selection (KSIĄŻKIEWICZ 2002). However data about functional traits of meat of the specific ducks are scarce and that is why the investigation on the technological quality of the ducks muscles is needed.

Among many quality traits of meat, colour has always been considered a very important feature. Colour is regarded as an indicator of meat freshness by many consumers, therefore can be the main element which influences purchasing behaviour. The impression of colour is caused by diffusion and absorption of light falling on the surface. However the shade of colour depends on kind and concentration of pigments. The relative proportions of myoglobin forms such as purple deoxymyoglobin (Mb), red oxymyoglobin (MbO_2) and brown metmyoglobin (MMb) determine the colour of fresh meat. All factors affecting meat colour, in fact influence directly or indirectly on concentration and chemical state of myoglobin as well as physical structure of meat (MILLAR *et al.* 1996, RENERRE 1999, MANCINI and HUNT 2005). Colour depends on breed, age, sex of animal (KISIEL and KSIĄŻKIEWICZ 2004, WOŁOSZYN *et al.* 1997, WAWRO *et al.*

2004), type of muscle (SKRABKA-BŁOTNICKA *et al.* 2002a), feeding, pre-slaughter treatment and stress (ROMBOLI 1995, FLETCHER *et al.* 1992), method of slaughter (BIANCHI *et al.* 2006), electrical stimulation (UIJTTENBOOGAART 1993), storage conditions (SKRABKA-BŁOTNICKA *et al.* 2002b). Colour can be shaped by combination of these and many other factors (RENERRE 1999). The aim of this paper was to characterize and compare the colour of ducks' muscles from different genotypes by determining, L*, a*, b*, C*, h° parameters, colour difference ΔE between individual flocks, pigments' contents and performing sensory evaluation of meat colour intensity.

Material and methods

The study was conducted on breast muscles of 7 week – old female ducks from 6 flocks: Khaki Campbell (Kh1), Orpington (O1), Miniduck (K2), Pekin originated from Danish (P8), Pekin (P33) as well as crossbreeds of ducks of English origin in Pekin type (SB) (n=10 head for each flock) (Table 1). These unique on international scale populations of birds are kept by in situ method at the Waterfowl Genetic Resources Station of the National Research Institute of Animal Production in Dworzyska. The birds are characterized by very good health, resistance to variable, often adverse climatic conditions of region of their origin and good conversion of farm-produced feeds. Geese and ducks from conservative flocks provide unique material for studies of DNA polymorphism, blood serum proteins, embryo karyotypes and quality traits of eggs and meat. The fat of this birds is considered to be healthier than pork fat as it contains more unsaturated fatty acids and the meat is fine fibred. Another important characteristic of the waterfowl from conservative flocks is very good quality of down and feathers, which are used for the manufacture of sheeting fabrics (KSIĄŻKIEWICZ 2007).

Ducks were raised in controlled conditions in a poultry house until the 4th week of age and next on range of limited and sheltered area with straw bedding. Birds were fed *ad libitum* on the same compound feeds (Table 2). The diet until 3rd week of age contained 20 % crude protein and 12.13 MJ metabolizable energy (ME) and from 4th to 7th week 16.5 % crude protein and 12.34 MJ ME per 1 kg of feed.

Slaughter of birds and excising of breast muscles were made in a local slaughterhouse. The analysis of muscles was made 24 h after slaughter.

Haem pigments were extracted according to the procedure described by PIKUL (1993). The muscles were frozen at −18°C for 24 h and subsequently (without thawing) cut in thin flakes after that were mixed. About 10 g of sample were homogenised with 50 cm^3 of phosphate buffer (pH 6.8) at 4-6°C for 1 min at 3 000 rpm. The homogenate was stored at 4-6°C for 1h. After the period the homogenate was centrifuged at 4 000× g for 10 min. The supernatant was decanted and the remainder was extracted once more with 42.5 cm^3 of the above mentioned buffer and centrifuged (in the same conditions as previously). The both supernatants were mixed and the volume was measured. The extract was centrifuged at 30 000× g for 1 h and filtered with the Whatman 1 paper filters. The absorbance was measured at 525, 545, 565 and 572 nm using the Hewlett Packard's Diode Array UV/VIS Spectrophotometer. The concentration of total haem pigments (THP) and relative concentration of: Mb, MbO_2 and MMb were calculated with the equations given by KRZYWICKI (1982).

Table 1
Characteristics of experimental material
Beschreibung der Versuchspopulationen

Flock	Duck's origin	Characteristics
Kh1	Khaki Campbell: originating from a parent stock imported from France in 1978 (conservative).	Their feathers are brown in colour. Males' legs are orange coloured and females grey coloured. They are characterized by rather low weight compared with Pekin ducks (adult males – 1 800 g, females – 1 700 g). They are representing an egg type although they possess meat traits too. The number of laid eggs are high (156-144 eggs/laying period). Eggs have very high biological value, that's why the ducks have outstanding breeding performance. (KSIĄŻKIEWICZ 2002, 2003)
O1	Orpington fauve (yellow variety): progeny of a breeding stock bought in France in 1971 (conservative).	Plumage is light brown with black and brown neck for males. Legs are light grey coloured. Beak is brown and olive green. Body weight of an adult male is 2 050 g and female 1 900 g. Laying is 143-126 eggs/laying period, eggshells are cream coloured. It is representing a multipurpose type. They were used many times for mating with Mullards, Pekins, Wild ducks and Khaki Campbell. Their meat is characterized by high fibres fineness (KSIĄŻKIEWICZ 2002, 2003).
K2	Miniduck: crossbred of wild white mallards (*Anas platyrhynchos L.*) and light Pekin type ducks (conservative).	WOŁOSZYN *et al.* (2006), WORLD WATCH LIST (2000)
P33	Polish Pekin: the native and old indigenous breeding strain (conservative).	WOŁOSZYN *et al.* (2006), WORLD WATCH LIST (2000)
P8	Pekins of Danish origin: progeny of Pekin parents imported from Denmark in 1978 (conservative).	They are characterized by white plumage. Legs and beak are yellow and orange. Weight of adult birds range from 3 200 to 3 400 g. Laying is 153 eggs in first and 135 in second performance period. These ducks are characterized by outstanding reproduction and meatiness traits (KSIĄŻKIEWICZ and KIEŁCZEWSKI 1999, KSIĄŻKIEWICZ 2002).
SB	Crossbreeds of ducks from three conservative groups A1, A2 and A3, which were progeny of Pekin ducks imported from England in 1977	Feathers of these ducks are white, legs are orange and yellow, and beak is yellow or pale pink. Adult birds weigh from 2 900 g to 3 100 g. The birds are characterized by good health, high number of laid eggs (137 to 151 eggs/lying period), and very good musculature (KSIĄŻKIEWICZ 2002).

Table 2
Diet composition used in the trial
Futterzusammensetzung während der Versuchsdauer

Ingredients	1-21days	22-49 days
Wheat meal, %	72.8	57.6
Soybean meal, %	17.0	10
Barley meal, %	17.4	–
Rapeseed oil, %	1.0	1.6
Calcium carbonate, %	0.8	6.0
Dicalcium phosphate, %	2.0	2.0
Premix KB (vitamin-mineral premix), %	1.0	1.4
Fish meal, %	5.4	4.0

The colour parameters of the surface of muscles i.e. lightness (L*), redness (a*) and yellowness (b*) were determined by the Minolta CR–310 ChromaMeter; hue (h^o) and chroma (C*) were calculated using the following equations:

$$h^o = tg^{-1}\left(\frac{b^*}{a^*}\right) \qquad \textit{and} \qquad C^* = (a^{*2} + b^{*2})^{\frac{1}{2}} \tag{1}$$

while colour difference (ΔE) was calculated from formula:

$$\Delta E = \left[(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2\right]^{\frac{1}{2}} \tag{2}$$

The ΔL*, Δa* and Δb* were differences between mean L*, a* and b* values for individual flocks.

Sensory evaluation of the raw muscles' colour and its intensity was conducted by the sensory panel using the Analsens NT programme with 10 point scale (1 – very light colour; 10 – very dark colour) (BARYŁKO 2000). Sensory panel had 7 trained testers. The intensity was expressed in conventional units (CU).

Statistical analysis was based on arithmetic means and standard deviation (SD). The effects of flock were analysed by one way analysis of variance (ANOVA) in a non-orthogonal scheme. Significant differences between the average values were determined by Duncan's multiple range test. Principal component analysis (PCA) was applied to all analysed parameters of colour. The statistical analysis was conducted with the Software System Statistica, version 7.1 (STATSOFT INC. 2006).

Results

The investigation established differences in examined parameters. Physicochemical properties of meat and results of sensory evaluation of raw muscles' colour are shown in Table 3.

Table 3
Haem pigments content, colour parameters and sensory evaluation of colour duck‹s breast muscles
Hämpigmentgehalt, Farbmerkmale und Sensorikwerte des Brustmuskels

Parameter	Flock											
	Kh1, n=10		O1, n=10		K2, n=10		P8, n=10		P33, n=10		SB, n=10	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
L*	45.27^{A}	1.06	42.69^{Bb}	1.24	42.56^{BD}	1.30	42.82^{Bb}	1.50	44.25^{Ca}	0.94	42.72^{Bb}	1.55
a*	16.69	1.15	17.22	0.59	16.99	0.67	17.65^{b}	1.67	16.35^{a}	0.66	16.56	1.15
b*	3.97^{Bb}	1.17	3.57^{c}	1.15	4.56^{BDd}	1.12	3.59^{c}	0.65	2.83^{Ca}	0.61	2.67^{A}	1.16
C	17.17	1.08	17.59	0.79	17.61	0.79	18.02^{b}	1.44	16.60	0.73	16.81^{a}	0.99
h^o	13.26^{b}	1.60	11.74^{c}	0.91	14.98^{Bd}	1.04	11.44^{c}	0.90	9.82^{Aa}	1.39	9.21^{Aa}	1.46
Mb,mg/g	1.36^{Ec}	0.04	1.34^{Ca}	0.05	1.52^{BDd}	0.11	1.58^{BDF}	0.06	1.24^{Ad}	0.05	1.48^{Bb}	0.05
MbO_2, mg/g	2.32^{A}	0.08	2.53	0.09	2.57	0.15	2.76^{Bb}	0.10	2.46^{a}	0.07	2.80^{Bb}	0.14
MMb, mg/g	0.11^{B}	0.02	0.11^{B}	0.03	0.48^{A}	0.14	0.14^{B}	0.03	0.04^{B}	0.01	0.05^{B}	0.008
THP, mg/g	3.79^{A}	0.13	3.98^{Ca}	0.12	4.57^{BD}	0.37	4.48^{BD}	0.32	3.74^{A}	0.12	4.33^{Bb}	0.19
Pink-red colour intensity, CU	5.01^{A}	0.75	6.07^{B}	0.63	6.22^{Bb}	0.61	6.12^{Bb}	0.54	5.71^{Ba}	0.49	6.07^{B}	0.51

Mean carrying different superscripts in the same row differ significantly: $^{a\text{-}d}P \leq 0.05$, $^{A\text{-}F}P \leq 0.01$, Mb myoglobin, MbO_2 oxymyoglobin, Mb metmyoglobin, THP total haem pigments, SD standard deviation, CU conventional unit

Table 4
Colour differences (ΔE) between individual flocks
Farbunterschiede zwischen den Populationen

	Kh1	O1	K2	P8	P33	SB
Kh1		2.66	2.78	2.65	1.56	2.86
O1	2.66		1.02	0.44	1.93	1.11
K2	2.78	1.02		1.20	2.50	1.94
P8	2.65	0.44	1.20		2.07	1.42
P33	1.56	1.93	2.50	2.07		1.55
SB	2.86	1.11	1.94	1.42	1.55	

The data in Table 3 show that the Kh1 and P33 muscles were significantly higher in L* ($P \leq 0.01$, $P \leq 0.05$) than the rest of the flocks. The P33 ($P \leq 0.05$) was characterized by higher a* value than P8 ($P \leq 0.05$), however K2 breast muscles showed higher b* than SB and P33 ($P \leq 0.01$, $P \leq 0.05$). The C* values ranged from 16.60 (for P33) to 18.02 (for P8) and alike in the case of a*, difference between these two values was statistically significant at $P \leq 0.05$. The h° parameter varied from 14.98 to 9.21 and the differences were significant similarly to the differences in b*.

The ΔE values indicate that Kh1 muscles' colour differed much from other flocks' colour, except for P33. The ΔE value between Kh1 and P33 was 1.56 and between Kh1 and other flocks from 2.86 to 2.65 (Table 4).

As regards the total haem pigments' content (THP), breast muscles can be divided in two groups. The P33, Kh1 and O1 belong to a group with lower THP (3.74, 3.79 and 3.98 mg/g respectively); however SB, P8 and K2 had higher THP (4.57, 4.48 and 4.33 mg/g respectively). Differences between these two groups are statistically significant at $P \leq 0.01$ and $P \leq 0.05$.

Myoglobin content (Mb) in breast muscles ranged from 1.24 mg/g (for P33) to 1.58 mg/g (for P8). The P33 and O1 showed significantly higher Mb content than SB, K2 and P8 (1.24 and 1.34 mg/g vs. 1.48, 1.52 and 1.58 mg/g respectively). Oxymyoglobin content (MbO_2) varied from 2.32 mg/g to 2.80 mg/g. The Kh1 and P33 had significantly higher MbO_2 content than P8 and SB (2.32 and 2.46 mg/g vs. 2.76 and 2.80 mg/g respectively) ($P \leq 0.01$, $P \leq 0.05$). Metmyoglobin content (MMb) amounted from 0.04 mg/g to 0.48 mg/g. The highest MMb content was showed by K2 ($P \leq 0.01$) but this value didn't exceed content that makes the colour undesirable. Taking into consideration the obtained results oxymyoglobin was predominant in the duck muscles.

As regards the sensory evaluation – colour of the meat was recognised as pink – red and the surface' colour intensity scores given for breast muscles ranged from 5.01 to 6.22 CU. The Kh1 was assessed as the lightest (5.01 CU) ($P \leq 0.01$). The notes for P8 and K2 (6.12 CU and 6.22 CU respectively) were significantly higher than for P33 (5.71 CU) at $P \leq 0.05$.

The principal component analysis (PCA) was performed on the all measured parameters of duck meat colour. Table 5 contains the loadings for the first three principal components (PC) with their variances. The two first PCs accounted for 56.2% of the total variance. The PC1 explained for 35,09% of the variance and has high positive loadings for THP, Mb and MbO_2 content, a* and C parameter as well as negative loadings for L*. The PC2 accounts for 21.09% of the total variance and is associated with b* and h° value (Figure 1).

Table 5.
Loadings for the first three PCs
Analysenwerte für die ersten drei Hauptkomponenten

	PC1	PC2	PC3
L*	−0.56	−0.34	0.42
a*	0.67	−0.12	−0.62
b*	0.38	−0.86	0.16
C	0.70	−0.30	−0.54
h°	0.29	−0.84	0.31
Mb	0.79	0.27	0.26
MbO_2	0.59	0.43	0.41
MMb	0.37	−0.28	0.17
THP	0.84	0.26	0.44
CI	0.46	0.18	−0.01

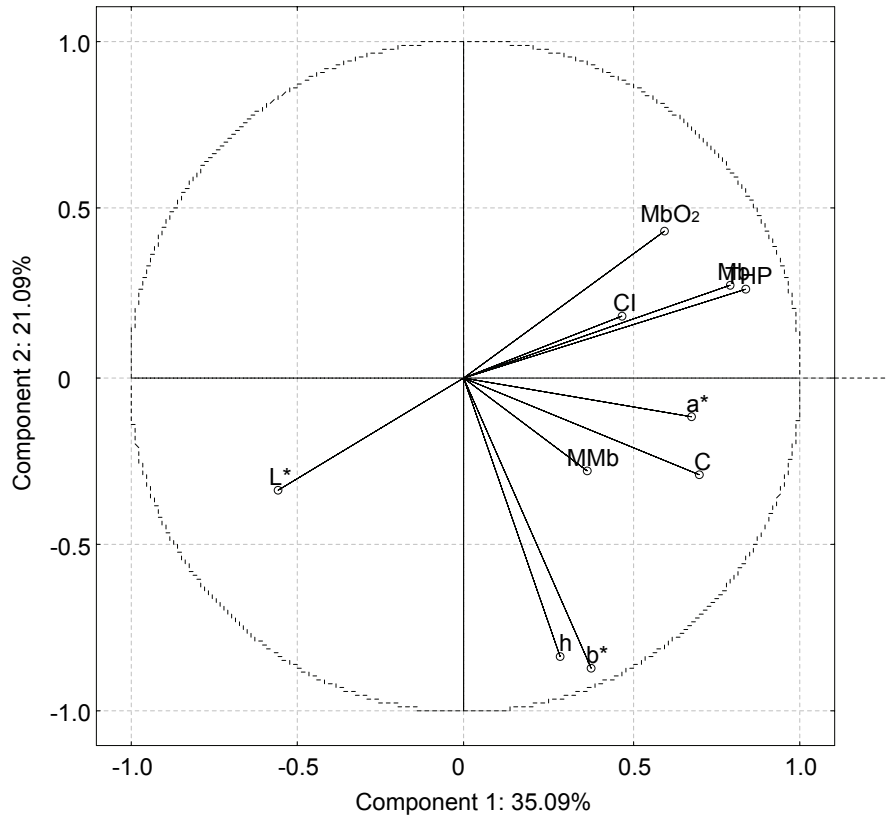

Figure 1
Loadings for the two first PCs (PCA of all analysed duck meat colour parameters)
Analysenwerte der ersten zwei Hauptkomponenten aller Farbparameter

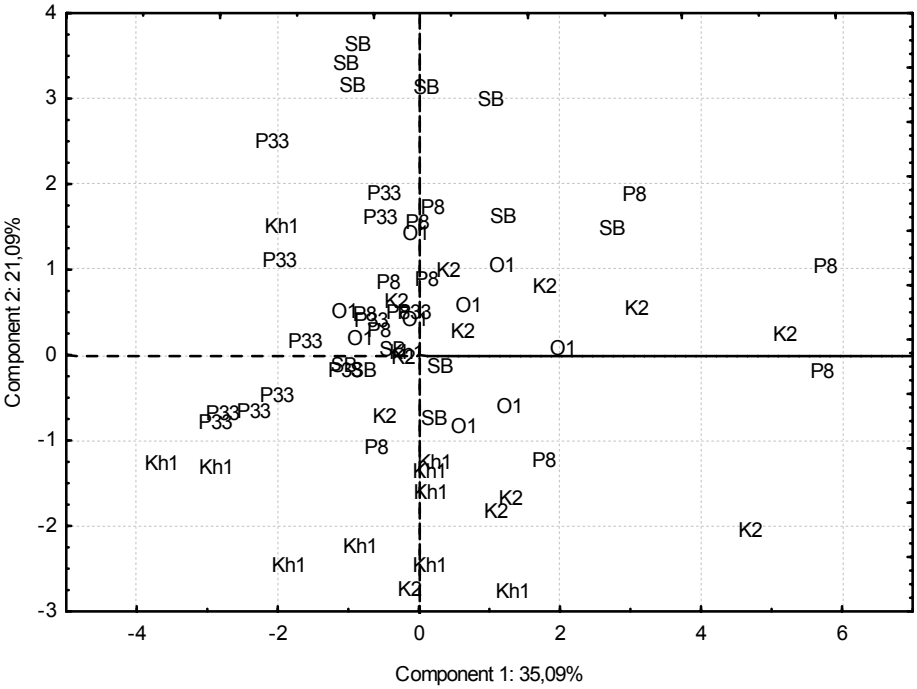

Figure 2
Scores for the two first PCs
Wertediagramm für die ersten zwei Hauptkomponenten

The score plot (Figure 2) shows the location of the samples in the multivariate space of two first PCs. It can be seen that samples were not homogeneous in colour also within the genotypes. There is no clear separation between these breeds. The parts of the samples overlap each other, so it means that they are similar. However it can be noted that some samples gathered in different places of a score plot, so they were different what resulted in statistically significant differences in colour between breeds. The Kh1 and P33 muscles differ much from K2 and P8. Samples to the right in the score plot have a large value for response variables to the right in the loading plot (NAES *et al.* 1996). According to this rule K2 and P8 samples, situated on the right, are characterized by high pigments content, low L* and high a* and C parameter. Kh1 and P33 situated opposite had low pigments concentration, high L* value and relatively low a* and C values. Considerable part of SB samples is concentrated at the top of the scores plot. It is caused by low b* and h° parameters values. It seems that O1 muscles had the most moderate traits and were the most homogenous in colour.

Discussion

Values of L*, a* and b* reported by KISIEL and KSIĄŻKIEWICZ (2004) for K2 and P33 were somewhat different than results obtained by the authors of this paper, but the revealed differences are the same – P33 had significantly higher L*, a* and b* colour parameters values than K2.

SKRABKA-BŁOTNICKA *et al.* (2003) reported similar values of L^*_{24h} for K2 and P33 drakes (42.2 and 43.6 respectively) but higher in a* and b* value (19.4 and 6.7 for K2; 19.4 and 5.7 for P33 respectively). Lower L* (41.14) and a* (11.72) and much higher b* (12.61) in breast muscles of Mullards were found by BAEZA *et al.* (1999). SKRABKA-BŁOTNICKA *et al.* (2002a) obtained for Muscovy ducks' breasts somewhat lower L* (42.27) but higher a* (20.99) and b* (4.83) compared to the examined muscles. ROMBOLI *et al.* (1997) tested breast muscles of heat stressed Muscovy ducks and found higher h^o (17.89) and b* (5.71) as well as lower L* (40.43) than all examined duck muscles. Obtained by these authors C (18.37) and a* (17.44) values were similar to P8. WOŁOSZYN (2002) carried out research on breasts of force fattened Mullards and the results were higher in a* (21.47) and b* (6.86) than present findings but L* were much the same to Kh1 (45.18). In the same publication can be found somewhat lower THP (3.20 mg/g) and Mb content (1.25 mg/g) as well as much lower MbO_2 (1.13 mg/g) and MMb content (0.78 mg/g). SKRABKA-BŁOTNICKA *et al.* (2002a) investigated among other things haem pigments content in breasts of Mullards and gained higher THP (4.63 mg/g), Mb (1.82 mg/g) and MMb (0.97 mg/g) but lower MbO_2 (1.65 mg/g) than values obtained in this paper for each individual flock.

PIKUL *et al.* (1982, 1987) and NIEWIAROWICZ *et al.* (1986) founded THP values in similar range of THP in Pekin breasts (from 3.68 to 4.54 mg/g). Sightly lower pigments content in Muscovy muscles was stated by PIKUL *et al.* (1987) (3.68 mg/g). ALEXIEVA *et al.* (1998) found also lower haem pigments in 8 weeks old White Pekin and Muscovy ducks (2.75 mg/g and 3.26 mg/g respectively).

Some relation can be noticed comparing the significant differences in colour parameters and pigments content with the ΔE values. If the ΔE equalled more than 2, there is a real chance of occurring significant difference between these groups within traits analysed in the paper. Only few exceptions to the rule can be found.

A similar situation occurs when comparing ΔE values with sensory evaluation of colour intensity results – flocks which had ΔE more than 2, were evaluated as different in colour.

This rule didn't work only in the case of ΔE for Kh1 and P33 ($\Delta E_{Kh1,P33}$=1.56). These groups didn't differ as regards pigments content and L* parameter but despite the fact, sensory panel observed the difference in colour.

These results can be explained by a fact that, measurement of sensory traits by human senses and instrumentally (L*, a*, b* parameters) cannot be substituted. The reason for it is that, the results of instrumental methods are related to physical stimuli creating sensations, while sensory evaluation informs about sensations caused by the stimuli. Therefore both methods of measurement sensory characteristics of foods are complementary but cannot be substituted (BARYŁKO-PIKIELNA 1998).

On the basis of gained results can be concluded that muscles of Kh1 and P33 are significantly lighter than P8 and K2. Kh1 and P33 muscles had less pigments, high L* value and were sensory evaluated as lighter than other muscles. The K2 and P8 showed high pigments content, low L* and sensory panel assessed them as darker than Kh1 and P33. Additionally it is confirmed by the ΔE values for these flocks which are in the 2.1-2.7 range. Furthermore K2 muscles were more yellow than others due to high h^o value. The results of PCA analysis were in accordance with the obtained ANOVA results. High

heterogeneity in colour of the analysed muscles was stated. The O1 showed the least variation in total colour.

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