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EGG MORPHOMETRY AND EGGSHELL QUALITY IN RING-NECKED PHEASANTS KEPT IN CAGES*

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Abstract

The aim of the study was to evaluate the morphometry and shell quality of eggs laid by pheasants kept in cages, and also to analyse the dependence between egg shell colour parameters, its quality and morphometric characteristics. Four groups of 15 eggs (60 eggs), each classified according to their eggshell colours, i.e. blue, light brown, dark brown and olive, were examined. The eggs did not differ significantly between each other in their mean weight and olive-coloured eggs had a higher shape index (about 8.91 percentage points) than blue eggs. Blue and light brown coloured eggs had thinner shells than the dark brown eggs (by 33.57 and 27.97 µm, respectively). Blue eggs had the lightest shells (L* = 67.97) and the highest proportion of green colour in their shells since the a* parameter value for blue eggs was negative. A significant positive correlation was observed between the egg shape and the shell colour saturation (C*) and the proportion of yellow colour (b*) in it. In addition, a negative correlation was found between lightness in eggshell colour, its thickness and the egg shape (r = from –0.338* to –0.480). In comparison with the data obtained from the literature concerning the quality of eggs laid by pheasants kept in aviaries and eggs laid by birds kept in cages, the eggs were described as having similar weights and morphometries along with greater shell thicknesses. Furthermore, our study confirmed that pheasant eggs with blue and light brown colour have poorer shell quality, a fact which has been shown already in earlier research. However, this fact is related to the lightness of the shell pigment rather than its colour.**

Key words: ring-necked pheasant, egg, eggshell thickness, eggshell colour parameter, correlation

Under farming conditions, ring-necked pheasants are usually kept on the ground, in aviaries. However, it seems that the application of cages in the reproduction of this species could be an alternative to the aviary housing system, not only because

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of the better productive results (egg laying, egg fertilization), but also because of its contribution to reduced microbial egg contamination (Guidobono Cavalchini et al., 2005).

Nonetheless, good hatchability results in pheasants and the high quality of their chicks both depend on a number of factors. The literature includes several studies where the relationship between the physical, morphological and qualitative traits of the egg content (yolk and white) and hatchability characteristics and the parameters for the later performance of chicks was analysed (Bennett, 1992; Reijrink et al., 2008; Yang et al., 2009; Nowaczewski et al., 2010; Ulmer-Franco et al., 2010; Kontecka et al., 2011; Alabi et al., 2012). Ring-necked pheasant hens lay eggs with various shell colours, ranging from white, through blue and olive, up to dark brown. During one whole reproductive season, the female lays eggs of identical colour that gradually lose their intensities as the season elapses. On the other hand, there is a correlation between shell colour of pheasant eggs, egg quality, time course of the embryogenesis process and hatchability results (Kirikçi et al., 2005; Kożuszek et al., 2009 a, b). For example, according to previous studies, pheasant eggs with shells of a lighter shade had a lower weight and percentage of shell, that is, their shells were simply thinner (Kuźniacka et al., 2005 a). Blue eggs, which had even thinner shells with higher porosity and water vapour conductance, were characterized as having a lower shell quality compared to other different coloured eggs (Krystianiak et al., 2005). Moreover, research shows that eggs with blue shells can be related to lower fertilization and hatchability (Krystianiak et al., 2005; Kożuszek et al., 2009 b). These eggs also had the highest ergosterol content in their shells, which is an index for the presence/amount of microbial fungi and thus, it may indirectly reflect the microbial contamination of eggs (Nowaczewski et al., 2011). Similar experiments aimed at determining the influence of shell colour on hatchability indices were carried out on quails and turkeys (Mróz et al., 2008; Taha, 2011).

In most studies, eggs which were to be evaluated on the basis of shell colour were chosen visually. Thus, the choice was strongly subjective and the determination of dependence/correlation between shell colour and other individual qualitative characteristics in eggs was considerably difficult (Kirikçi et al., 2005; Kuźniacka et al., 2005 a; Mróz et al., 2008; Kożuszek et al., 2009 a; Taha, 2011). On the other hand, the literature does provide several studies about laying hens where selected parameters of the eggshell, i.e. lightness, proportion of green, red, blue and yellow colours, were analysed in relation to eggshell thickness, egg morphometry, egg quality, bird genotype and their respective housing systems (Caner, 2005; Zanon et al., 2006; Odabaşi et al., 2007; Ingram et al., 2008; Sekeroglu et al., 2010). The literature also provides a few results with detailed description of egg morphometry characteristics along with shell quality analysis in cage-kept pheasants (Kirikçi et al., 2003; Ozbey et al., 2011). Besides, there is no information about the distribution of individual colours or lightness in the eggshells of such birds. The investigation of the parameters of the eggshell colour combined with the analysis of its quality and egg morphometry will probably enable further interpretation of the reproductive results of the species, which are still very changeable and usually unsatisfying.

In view of the aforementioned facts, the authors carried out an experiment in order to evaluate the morphometry of eggs and eggshell quality in cage-kept pheasants. In addition, the authors also attempted to determine the dependence between the morphometric traits of the egg, the eggshell colour and the eggshell quality. The correlation between the traits under analysis and the selected parameters characterizing eggshell colour was also analysed.

Material and methods

The material used in this research consisted mainly of eggs laid by ring-necked pheasants, usually one year of age, that were bred on a commercial farm. Breeder stock accounted for more than 10,000 pheasants. During the reproductive season birds were outdoors in cages. One cage with an area of 2.25 m^2 and height of 0.5 m could contain up to 10 birds (1 cockerel and 9 hens). A lighting programme was applied in order to provide at least 16–17 hours of light per day to pheasants during their reproduction period (the natural day light in the 12th week of reproduction lasted from 12 to 13 hours). The feed, which was only complete diet (in pelleted form), contained the following components in 1 kg: 11.72 MJ metabolizable energy (ME); 18.0% crude protein; 5.0% crude fibre; 3.05% Ca and 0.42% P. It was provided *ad libitum*. The method of feeding and watering the birds was fully automated.

The hatching eggs used for investigation were selected from all the eggs collected on the day they were laid (total number of eggs – 6252) during the 12th week of reproduction when the egg laying rate was about 60%. Sixty eggs were selected at random and divided into four groups of 15 with each group consisting of eggs sharing the same eggshell colour, i.e. blue, light brown, dark brown and olive (the percentage of blue, light brown, dark brown and olive eggs, in the total number of laid eggs, was 10–15, 15–20, 25–30 and 45–50%, respectively). After one day of storage, the following morphological egg traits and eggshell characteristics were evaluated: egg weight (g) (with 0.01 g accuracy), egg shape index (%) – by measuring the egg length and width (with 0.01 mm accuracy, electronic caliper), eggshell weight (g) after drying at 105ºC (with 0.01 g accuracy) and lastly, eggshell thickness (μm) and shell membrane measurements at the equator and at the blunt and sharp ends of the egg (with 0.01 μm accuracy) (Mitutoyo electronic micrometer). Eggs and eggshells were weighed on a RADWAG WPS 360C type balance. Eggshell surface colour parameters (L*, a* and b*), on the other hand, were determined with the CR 400 Chroma-Meter (Minolta, Japan). The device recorded colour values in the CIE system (L * a * b) with radiation being reflected from the egg's surface. Each measurement was performed in 3 different locations on the egg. The diameter of the measuring device was 8 mm. Lightness was represented by the value L*, where 0 corresponds to black and 100 to white. A positive value for the parameter a*, represents the level of redness (max = 120) in the eggshell colour whereas a negative value for this parameter indicates the proportion of greenness (max = –120). Similarly, positive or negative values of the b* parameter mean that the eggshell colour is dominated by yellow (max = 120) or blue (max = –120), respectively. The saturation (C*) and hue (H^0) of each eggshell colour were calculated as $(a^{*}2 + b^{*}2)^{1/2}$ and $\tan^{-1} (b^{*}/a^{*})$, respectively (Zarubica et al., 2005).

The results obtained were analysed statistically with the SAS v. 9.2 statistical package. The arithmetic mean values and standard error of means (SEM) were calculated for the egg morphological traits, eggshell characteristics and eggshell colour parameters. Since eggshell colour parameters were different for each group of shell-coloured eggs, presenting the overall values of these traits would be insignificant. In view of some colour parameters (a* and b*) symbolizing traits that did not exhibit a normal distribution, the analysis of variance (ANOVA) was preceded by data transformation: x = log 10y, where y was the value of the trait. The significance of differences between eggshell colours related to the traits being analysed was verified by one-way ANOVA. The statistical differences were established at the level of $P \leq 0.05$ (Fisher test). Furthermore, the value of Spearman rank correlation coefficient was also determined for the aforementioned traits. As a consequence of C* and H^0 being used to describe every eggshell colour individually, the comparison of such parameters among the selected eggshell colours would be invalid. Therefore, C* and H^0 were only taken into account when the relationship between eggshell colour, egg morphological traits and eggshell characteristics was being evaluated.

Results

Table 1 summarizes the egg morphometry results. Eggs which had their eggshell colour analysed did not differ significantly from each other in their mean weight values. As far as the egg shape index is concerned, only blue and olive coloured eggs proved to be different from the other eggs ($P \leq 0.05$). In olive eggs, a higher value of this trait was observed which could have been due to egg length since the length of olive eggs was significantly smaller than that of blue eggs (by 0.34 cm).

Table 1. Egg morphometry characteristics in ring-necked pheasant (mean ± SEM)

Traits	Eggshell colour				Overall (n = 60)
	blue (n = 15)	light brown (n = 15)	olive (n = 15)	dark brown (n = 15)	
Egg weight (g)	32.46±0.94	31.35±0.92	31.98±0.99	32.34±1.00	32.03±0.33
Egg length (cm)	4.56±0.06 a	4.42±0.07 ab	4.22±0.19 b	4.42±0.07 ab	4.41±0.04
Egg width (cm)	3.58±0.03	3.72±0.12	3.62±0.03	3.72±0.10	3.66±0.03
Egg shape index (%)	78.72±1.18 b	84.21±2.8 ab	87.63±4.43 a	84.19±2.32 ab	83.69±1.02

a, b – values in rows with different letters differ significantly ($P \leq 0.05$).

As for the mean eggshell thickness, blue and light brown eggs were characterized by a lower value of the trait (33.57 and 27.97 µm, respectively) than dark brown eggs. Most importantly, this resulted from the differences in the thickness of those eggs on the equator and at the sharp end.

During the analysis of eggshell colour parameters, light brown and olive eggs were the ones that were identified as having similar lightness (L*). The highest value of this trait, that is, shells with the highest lightness in colour, was observed in the blue eggs. Blue-coloured eggs were also shown to have the highest proportion of green colour and this was confirmed by the negative value of parameter a*. Simultaneously, in comparison with the other eggs, the blue ones were characterized as having the lowest proportion of yellow colour in their shells (Table 2).

Table 2. Eggshell characteristics and its colour parameters in ring-necked pheasant (mean ± SEM)

Traits	Eggshell colour				Overall (n = 60)
	blue (n = 15)	light brown (n = 15)	olive (n = 15)	dark brown (n = 15)	
Eggshell weight (g)	2.97±0.15	2.89±0.14	2.96±0.12	3.16±0.14	3.00±0.05
Eggshell thickness – blunt end (µm)	266.80±12.34	274.33±15.34	296.10±7.98	298.20±9.39	283.86±3.96
Eggshell thickness – equator (µm)	273.80±5.35 b	274.55±9.89 b	288.00±8.35 ab	304.40±8.48 a	285.19±3.18
Eggshell thickness – sharp end (µm)	304.50±2.76 c	313.00±9.87 bc	332.50±0.13 ab	343.20±12.72 a	323.30±4.08
Eggshell thickness (µm)	281.70±4.68 c	287.30±9.93 bc	305.53±7.54 ab	315.27±9.69 a	297.45±3.18
L*	67.97±0.68 a	61.67±0.56 b	59.86±0.88 b	53.12±0.58 c	
a*	–8.85±0.81 c	4.60±0.48 a	–1.33±0.33 b	5.51±0.56 a	
b*	6.10±0.76 b	22.03±0.6 a	18.19±0.43 a	21.50±0.56 a	

a, b – values in rows with different letters differ significantly (P≤0.05).

Table 3. Coefficients of correlation (Spearman rank) between morphometric traits and eggshell characteristics in ring-necked pheasant

Traits	Eggshell weight	Eggshell thickness			
		blunt end	equator	sharp end	overall
Egg weight	0.753***	0.190	0.174	0.036	0.147
Egg length	0.480***	0.332*	0.013	0.235	0.290
Egg width	0.612***	0.073	0.183	–0.020	0.084
Egg shape index	–0.038	–0.209	0.143	–0.166	–0.152

* Significant at P≤0.05.
** Significant at P≤0.01.
*** Significant at P≤0.001.

Table 4. Coefficients of correlation (Spearman rank) between egg morphometric traits, eggshell characteristics and its colour parameters in ring-necked pheasant

Traits	Egg weight	Egg length	Egg width	Egg shape index	Eggshell weight	Eggshell thickness			
						blunt end	equator	sharp end	overall
L*	–0.085	1.167	–0.258	–0.338*	–0.264	–0.408***	–0.399**	–0.467***	–0.480***
a*	–0.072	–0.172	0.124	0.303	0.102	0.211	0.121	0.225	0.208
b*	–0.070	–0.240	0.139	0.373**	0.056	0.179	0.041	0.193	0.150
C*	–0.081	–0.243	0.139	0.375**	0.087	0.176	0.097	0.216	0.169
H°	–0.094	–0.189	0.049	0.287	0.127	-0.053	0.078	0.034	-0.032

* Significant at $P \leq 0.05$.
** Significant at $P \leq 0.01$.
*** Significant at $P \leq 0.001$.

Table 3 represents results concerning the correlation between the shells and the morphometry characteristics of eggs that were investigated. A positive value ($P \leq 0.05$) of the correlation between shell thickness at the blunt end and egg length is worth noting. Moreover, a positive relationship ($P \leq 0.001$) was also found between eggshell weight and egg weight, egg length as well as egg width. Finally, Table 4 summarizes the correlation coefficients between eggshell colour parameters and characteristics of the eggs under investigation. The authors found a statistically negative correlation between the lightness in eggshell colour and the egg shape index (–0.338*) and the overall shell thickness measured at three different places (r = from –0.399** to –0.480***). On the other hand, a positive value of the correlation coefficient was calculated for the egg shape index, colour saturation (0.375**) and for the proportion of yellow colour in the shell (0.373**).

Discussion

The average weight (31.3 g) of the eggs laid by the pheasants used in our investigation was similar to that obtained by Kuźniacka et al. (2005 b), who also reported a lower index of the pheasant egg shape ($\bar{x}$ = 78.0%). On the other hand, Esen et al. (2010) observed a similar egg shape index ($\bar{x}$ = 84.14%) for the eggs of one-year--old pheasants kept in a semi-open system on the ground, where the weight of the eggs was lower (28.74 g) than in our investigations (for shape index of all eggs). In comparison to our results, Ozbey et al. (2011) measured slightly lower weight for eggs of pheasants kept in cages. Birds, over the 12 weeks of reproduction, laid eggs which weighed 30.86 g on average.

Although blue, light, dark brown and olive eggs did not differ in their mean weight, there were significant differences observed in their shapes. Olive eggs were the roundest whereas blue eggs were the most elongated amongst all the eggs. Kożuszek et al. (2009 a) studied eggs laid by pheasants kept in aviaries that had similar egg shell colours to the ones we investigated and they were unable to find any differences in their weights as well ($\bar{x}$ = 32.7 g). As far as egg shape is concerned, they obtained the lowest index value for light brown eggs ($\bar{x}$ = 77.7%). Kirikçi et al. (2005), on the other hand, did not find any differences between the shape indices ($\bar{x}$ = 80.9%) during their analysis of characteristic morphometries of pheasant eggs (blue, brown and olive) and they also determined that blue pheasant eggs had the lowest weight. Krystianiak et al. (2005) in turn observed that blue-coloured pheasant eggs had the lowest weight ($\bar{x}$ = 29.9 g). In our study, no significant correlations between egg weight, mean shell thickness and thickness measured at individual parts of the egg were made. Different results in pheasants were obtained by Kirikçi et al. (2003), who found a positive ($P \leq 0.01$) coefficient for the correlation between mean shell thickness and egg weight.

Our analysis of eggshell weight showed no existing differences among the coloured eggs while eggshell thickness of blue and light brown eggs was shown to be lower in comparison with the other eggs. Kożuszek et al. (2009 a) obtained similar results in pheasants kept in aviaries. The authors also proved that the shell was the thinnest in blue and light brown eggs ($\bar{x}$ = 259 µm) without there being any differences in the shell weight between the eggs. However, in comparison with our studies, the mean shell thickness value of the eggs under analysis was lower by about 25.2 µm. Kirikçi et al. (2005) also reported similar results as they obtained a mean shell thickness value of 216 µm for pheasant eggs, which was a lower than that obtained in our study. The differences between these results could have been due to the different types of housing systems used. Besides, the eggshell thickness is known to be affected by age, environmental temperature and composition of the diet (calcium, phosphorus and magnesium content). However, the results of investigations carried out on different bird species presented in the literature are not unequivocal. The results obtained by Ozbey et al. (2011) are similar to ours. In caged pheasants, they found that the mean shell thickness of eggs laid after the 12th week was 308 µm. On the other hand, Ozbey and Esen (2007) proved that eggs from rock partridges (*Alectoris graeca*) kept in cages during the reproductive season had similar eggshell thickness to eggs obtained by birds kept on the ground. Wang et al. (2009) carried out an experiment on hens which laid blue-shelled eggs where they analysed the shell thickness in the 34th and 42nd weeks of bird age. They found a higher value for this trait when the birds were kept in cages in comparison with those kept outdoors. In an experiment with pheasants kept in aviaries, Krystianiak et al. (2005) observed that blue eggs had the lowest shell thickness ($\bar{x}$ = 222.8 µm). This provided further confirmation of the earlier similar finding of Hulet et al. (1985).

The lightness of the eggshell colour, which was negatively correlated with its thickness along with egg shape, was similar in both light brown and olive eggs. On the other hand, blue eggs proved to be the lightest. Olive and blue eggs were characterized by the proportion of green colour they had in their shells (the negative value of the a* parameter). However, the shells of the latter had the lowest proportion of yellow colour and this correlated positively with the egg shape index. Thus, the results obtained in this study indicate that it is the lightness of the pheasant eggshell colour rather than the colour (pigment) itself that is related with eggshell thickness. Apart from that, it seems that as far as 'blue' pheasant eggs are concerned, it would be more appropriate to refer to them as green eggs instead since no blue colour was found in their shells. As the literature does not provide relevant information on this subject about pheasants, we cannot fully analyse and interpret the results of our investigation. However, there were certain experiments on other poultry species where eggshell colour parameters were evaluated. For example, similarly to our studies, Ingram et al. (2008) proved that there was a negative dependence between the lightness of the eggshell of broiler breeders and its thickness ($r = -0.140$; $P \leq 0.01$). The researchers suggest that such a dependence could be due to a possible relation between the pigment deposition process in the shell and the eggshell calcification process. Simultaneously, the authors observed a statistically significant, positive correlation between the eggshell thickness and the a* and b* parameters. In our study, similar (positive) index values showing such a correlation between the aforementioned traits were obtained but those values were statistically insignificant. Although Sekeroglu et al. (2010) did not find a significant correlation between eggshell lightness and eggshell thickness or strength, they did observe that eggs obtained from laying hens with a significantly higher shape index, were darker in colour (lower value of the L* parameter). Our study seems to confirm this fact especially because of the significantly negative value of the correlation coefficient between those traits. Yang et al. (2009), however, obtained different results. They observed that hens' eggs with a higher proportion of white colour in their shells (lighter) could also be characterized by a higher value of the shape index. Nonetheless, the positive correlation observed by the authors for those traits, remained statistically unconfirmed.

To sum up, our investigations proved that, in view of literature reports, eggs obtained from pheasants kept in cages during the reproductive season did not differ in weight and/or morphometry from those laid by birds kept in aviaries. Simultaneously, our investigations also confirmed that blue and light brown coloured pheasant eggs have poorer quality of the shell. Yet, this fact remains related to the lightness of the shell pigment rather than its colour.

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Budowa jaja i jakość skorupy u bażantów obrożnych utrzymywanych w klatkach

STRESZCZENIE

Celem badań była ocena budowy jaj i jakości skorupy u bażantów utrzymywanych w klatkach oraz analiza zależności między barwą skorupy (parametrami koloru) a jej jakością oraz cechami morfometrycznymi jaja. Łącznie oceniono 60 jaj, po 15 jaj o niebieskiej, jasno- i ciemnobrązowej oraz oliwkowej barwie skorupy. Badane jaja nie różniły się istotnie między sobą pod względem średniej masy. Większym indeksem kształtu niż jaja niebieskie (o 8,91 jednostek procentowych) cechowały się te o oliwkowej barwie skorupy. Jaja niebieskie i jasnobrązowe miały mniejszą grubość skorupy niż ciemnobrązowe (odpowiednio o 33,57 i 27,97 µm). Największą jasnością skorupy (L* = 67,97) charakteryzowały się jaja niebieskie, które miały również największy udział barwy zielonej w skorupie (ujemna wartość parametru a*). Istotne dodatnie korelacje stwierdzono między kształtem jaja a nasyceniem koloru skorupy (0,375**) oraz udziałem w niej barwy żółtej (0,373**). Statystycznie ujemną zależność stwierdzono natomiast między jasnością koloru skorupy a jej grubością i kształtem jaja (r = od –0,338 do –0,480). Badania wykazały, iż w porównaniu z danymi literaturowymi dotyczącymi jakości jaj bażantów utrzymywanych w wolierach, jaja z chowu klatkowego tych ptaków cechuje zbliżona masa i budowa, przy jednocześnie większej grubości skorupy. Potwierdzono również wcześniej już stwierdzoną gorszą jakość skorup jaj niebieskich i jasnobrązowych, przy czym było to raczej związane nie tyle z kolorem skorupy, a raczej jej jasnością.