



### Original Contribution

## EXTERNAL CHARACTERISTICS OF EGGS FROM THREE SUBSPECIES OF THE COMMON PHEASANT (*PHASIANUS COLCHICUS* LINNAEUS, 1758) REARED IN CAPTIVITY IN BULGARIA

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### ABSTRACT

Basic external morphometric characteristics, including a detailed colorimetric analysis, were studied in eggs from three subspecies of the Common Pheasant (*Phasianus colchicus* Linnaeus, 1758), reared for restocking purposes in Bulgaria. A total of 120 fresh eggs from each of three Common Pheasant subspecies bred in captivity on pheasant farms in Bulgaria were collected to evaluate external egg characteristics. Morphometric traits, such as weight, major and minor axes were measured to calculate the egg shape index and shell surface area. Eggshell colour was assessed using the CIE L\*a\*b\* colour space, and additional parameters, such as chroma and shell colour index were also calculated. Significant differences were observed among the subspecies in terms of egg weight, minor axis length, and shell surface area ( $p < 0.001$ ). The colorimetric analysis revealed statistically significant differences in all examined shell colour traits between *Phasianus colchicus karpowi* Buturlin (1904) and the other two subspecies - *Phasianus colchicus mongolicus* Brandt (1844) and *Phasianus colchicus colchicus* Linnaeus (1758) ( $p < 0.05$ ). The study revealed significant inter-subspecific variation in egg morphometric and shell colour traits, with *P. c. karpowi* differing markedly from *P. c. mongolicus* and *P. c. colchicus*.

**Keywords:** egg weight, egg shape index, CIE L\*a\*b\*, colorimetry.

### INTRODUCTION

The Common Pheasant (*Phasianus colchicus*) is the most widespread species in the Phasianidae family, native to temperate Asia and southeastern Europe, and introduced widely across Europe, North America, and other regions. Its broad distribution has led to considerable intraspecific variation, with around 30 recognized subspecies, typically grouped into five major forms based on phenotypic traits (1). Recent genetic studies, however, suggest deeper evolutionary divergence, potentially supporting a reclassification into three separate species (2).

The native subspecies in Bulgaria, *P. c. colchicus*, became extinct in the wild about 50 years ago due to extensive releases of

years ago due to extensive releases of introduced subspecies and resulting hybridization (3). Three main subspecies have been introduced over time: *P. c. torquatus*, *P. c. mongolicus*, and *P. c. karpowi* (4). Today, most breeding facilities focus on producing 'hunting pheasants' that resemble *P. c. mongolicus*, while a few rear birds resembling the native *P. c. colchicus* for restocking purposes (4, 5). A population of *P. c. karpowi*, introduced from North Korea in the latter half of the 20th century, is still maintained in Bulgaria (6). The subspecies differ in the presence and expression of the cervical white ring, which is well developed in *P. c. karpowi* and *P. c. mongolicus* and absent in *P. c. colchicus*.

The Common Pheasant is widely studied for its role in game management, ecosystem research, and meat quality, yet detailed colorimetric data in this trait among subspecies remain limited despite numerous morphological studies.

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The aim of this study was to evaluate basic external morphometric characteristics and conduct a detailed colorimetric analysis of eggs from three subspecies of the Common Pheasant (*Phasianus colchicus* Linnaeus, 1758) reared for restocking purposes in Bulgaria.

## MATERIAL AND METHODS

In this study, a total of 360 fresh eggs were sampled from two pheasant farms in Bulgaria, comprising 120 eggs from each subspecies of the Common Pheasant (*Phasianus colchicus*): *P. c. colchicus* (Colchian Pheasant), *P. c. mongolicus* (Mongolian Pheasant), and *P. c. karpowi* (Korean Ring-necked Pheasant). The parent flocks were of similar age ( $12 \pm 1$  months). The eggs used in the study were obtained at the end of April. Fresh eggs were randomly sampled on a single day and subsequently stored at  $+16^{\circ}\text{C}$  until analysis. Prior to colorimetric assessment, the eggs were equilibrated at room temperature ( $+23^{\circ}\text{C}$ ) for three hours to ensure thermal consistency. All analyses were conducted at the Egg Quality Laboratory, Poultry Science Unit, Faculty of Agriculture, Trakia University, Stara Zagora, Bulgaria.

An external morphometric assessment was performed for the following traits: weight (g), major axis (D, mm), and minor axis (d, mm) of the egg. Based on these measurements, the shape index (SI, %) and shell surface area ( $\text{cm}^2$ ) were subsequently calculated. Shape index (%) was determined by measuring the major and minor egg axes using a Vernier caliper, and calculated using the formula:

$$\text{SI} (\%) = (d/D) \times 100 \quad (1),$$

where SI is the egg shape index, d is the minor axis of the egg (mm), and D is the major egg axis (mm) (7).

Shell surface area (SSA,  $\text{cm}^2$ ) was calculated using the formula:

$$\text{SSA} = 4.835 \times W^{0.662} \quad (2),$$

where W is the egg weight in grams (8).

Colorimetric analysis was performed using a portable colorimeter (PCE-CSM 2, PCE Instruments SE), equipped with a Silicon-photodiode sensor, an LED light source (illuminant D65), and an 8 mm diameter measuring aperture. Measurements were conducted in the CIE  $L^*a^*b^*$  colour space. Each egg was assessed at three locations: the

equator, the pointed pole, and the blunt pole. For each of these zones,  $L^*$ ,  $a^*$ , and  $b^*$  values were recorded, and mean values were calculated. To provide a comprehensive representation of eggshell coloration, the average of the three measurement points was used to obtain a single set of  $L^*$ ,  $a^*$ , and  $b^*$  values for each egg. Based on measurements in the CIE  $L^*a^*b^*$  colour space, chroma ( $C^*$ ) and the shell colour index ( $\text{SCI}^{**}$ ) were calculated. Chroma was determined using the formula:

$$C^* = \sqrt{(a^2 + b^2)} \quad (3),$$

where a is the  $a^*$  axis measures the colour balance between green and red; b is the  $b^*$  axis that measures the colour deviation between blue and yellow (9). For eggs with biliverdin pigmentation, a correction factor was applied in the shell colour index ( $\text{SCI}^{**}$ ) calculation:

$$\text{SCI}^{**} = (L^* - C^*) \times (-1) \quad (4),$$

where  $C^*$  represents chroma or colour saturation and  $L^*$  represents the lightness of a colour, ranging from black (0) to white (100) (10,11).

Statistical analysis was performed using IBM® SPSS® Statistics (v.26), applying a One-Way ANOVA. Descriptive statistics included the mean ( $\bar{x}$ ), standard deviation (SD), and the Coefficient of Variation (CV, %), with results expressed as mean  $\pm$  SD. Intergroup differences were considered statistically significant at  $p < 0.05$ , based on the LSD Post Hoc Test, provided the data were normally distributed and the ANOVA indicated significance ( $p < 0.05$ , F-test). Microsoft Excel 16.0 (2018, Windows) was used to create graphical representations.

## RESULTS AND DISCUSSION

**Table 1** presents the main external morphometric characteristics of eggs from the three studied subspecies of the Common Pheasant. The highest egg weight was recorded in *P. c. mongolicus* ( $32.81 \pm 2.69$  g), the largest of the three subspecies, while the lowest was observed in the native *P. c. colchicus* ( $26.99 \pm 2.77$  g) ( $p < 0.001$ ). Although the Korean Ring-necked Pheasant (*P. c. karpowi*) is the smallest in body size among the three, its eggs exhibited an intermediate weight ( $29.63 \pm 2.26$  g). The lowest individual egg weight was recorded in the *P. c. colchicus* group (22.32 g), and the highest in *P. c. mongolicus* (36.32 g). Similar variation in individual egg weight within the species has also been reported by Ashraf et al. (12). The results obtained in the present study,

particularly for *P. c. colchicus* and *P. c. karpowi*, indicate lower egg weights compared to some previous reports on the Common Pheasant, including various subspecies (13, 14). Differences in egg weight may be influenced not only by the age of the birds but also by their diet (15) live weight (16), as well as by other external factors (17). In this study, both farms used feed formulations that were similar in both composition and nutritional content.

Egg dimensions logically follow the trends observed in egg weight, with eggs from *P. c. mongolicus* exhibiting the largest overall size compared to the other two studied subspecies. An interesting observation is that no statistically significant differences were found in the mean values of the major axis among the subspecies, ranging from  $44.07 \pm 2.02$  mm in *P. c. colchicus* to  $45.38 \pm 2.04$  mm in *P. c. mongolicus* ( $p > 0.05$ ). More pronounced and statistically significant differences were observed in the minor axis ( $p < 0.001$ ), which is directly associated with the inter-subspecific variation in egg shape index and shell surface area. The egg shape index represents the form of the egg,

indicating how round or elongated it is (7). Higher values of the shape index correspond to more rounded eggs, whereas lower values indicate a more elongated egg shape. For domestic chickens, standard values of the shape index are considered to range between 72 and 76 (18). In the present study, differences in egg shape were observed among the three tested Common Pheasant subspecies, with *P. c. mongolicus* exhibiting the most rounded eggs ( $80.24 \pm 2.9\%$ ), and *P. c. colchicus* producing eggs closest to the ideal egg shape ( $76.42 \pm 3.1\%$ ) ( $p < 0.01$ ). Our results confirm the conclusion of Galic et al. (14) that, based on shape index values, eggs of the Common Pheasant can be characterized as relatively rounded. However, the values we recorded for *P. c. colchicus* were lower compared to those reported in many studies on this trait in the Common Pheasant (14, 19-22). Among the eggs included in the study, the shape index varied by approximately 20% between individual eggs, with minimum and maximum values ranging from 72.19% (*P. c. colchicus*) to 86.84% (*P. c. karpowi*).

**Table 1.** Main external morphometric traits of eggs from the three Common Pheasant subspecies studied.

<i>P. colchicus</i> subspecies		Parameter				
		Egg weight, g	D, mm	d, mm	Shape Index, %	Egg surface area, cm <sup>2</sup>
<i>P. c. colchicus</i>	Mean±SD	26.99±2.77 <sup>a</sup>	44.07±2.02	33.64±1.22 <sup>a</sup>	76.42±3.1 <sup>a</sup>	43.15±3.03 <sup>a</sup>
	CV, %	10.26	4.58	3.63	4.06	7.03
<i>P. c. karpowi</i>	Mean±SD	29.63±2.26 <sup>b</sup>	44.34±1.78	34.95±1.08 <sup>b</sup>	78.93±3.64 <sup>b</sup>	45.45±2.93 <sup>b</sup>
	CV, %	7.64	4.02	3.09	4.61	5.36
<i>P. c. mongolicus</i>	Mean±SD	32.81±2.69 <sup>c</sup>	45.38±2.04	36.36±0.99 <sup>c</sup>	80.24±2.9 <sup>b</sup>	48.61±2.93 <sup>c</sup>
	CV, %	8.21	4.50	2.73	3.62	6.03
LSD post hoc test <i>p</i> -value		<0.001	NS	<0.001	<0.01	<0.001

Note: D - major egg axis; d - minor egg axis; NS - not significant. Means within a column with different superscript letters (a-c) differ significantly according to the LSD post hoc test.

The summarized colorimetric analysis of the eggshell is presented in **Table 2**. The results indicate that two of the three tested subspecies exhibit similar eggshell colour characteristics, while the Korean Ring-necked Pheasant (*P. c. karpowi*) differs significantly from them ( $p < 0.05$ ). It should be noted that, unlike many other bird species, Common Pheasant eggs exhibit considerable variation in eggshell coloration, ranging from very light to very dark (23). The two primary pigments responsible for eggshell

coloration in birds are biliverdin (biliverdin IX $\alpha$ ) and protoporphyrin (protoporphyrin IX), corresponding to blue-green and brown hues, respectively (24). In the Common Pheasant, eggshell colour likely results from a combination of these two pigments, with varying degrees of deposition during shell formation. This contributes to the wide spectrum of eggshell colours observed, ranging from bluish-green to olive and dark brown (23, 25). The highest within-group variation across

all four evaluated colorimetric traits was observed in *P. c. mongolicus*, which may be associated with reduced genetic purity and hybridization, possibly involving the previously

introduced subspecies *P. c. torquatus* (5). In contrast, the other two subspecies exhibited significantly lower variability in the studied colorimetric parameters.

**Table 2.** CIE L\*a\*b\* colorimetric characteristic of eggs from the three Common Pheasant subspecies studied.

<i>P. colchicus</i> subspecies		L*	CIE L*a*b* parameter		C*
			a*	b*	
<i>P. c. colchicus</i>	Mean±SD	66.93±3.99 <sup>a</sup>	2.45±1.88 <sup>a</sup>	17.18±2.28 <sup>a</sup>	17.43±2.47 <sup>a</sup>
	CV, %	5.96	76.65	13.29	14.17
<i>P. c. karpowi</i>	Mean±SD	59.81±3.86 <sup>b</sup>	6.99±2.14 <sup>b</sup>	19.95±2.12 <sup>b</sup>	21.21±2.44 <sup>b</sup>
	CV, %	6.45	30.57	10.61	11.49
<i>P. c. mongolicus</i>	Mean±SD	64.54±7.17 <sup>a</sup>	1.67±4.33 <sup>a</sup>	16.34±3.77 <sup>a</sup>	16.99±3.71 <sup>a</sup>
	CV, %	11.11	259.56	23.07	21.82

Note: Different superscript letters (a, b) within a column indicate statistically significant differences between groups according to the LSD post hoc test ( $p < 0.05$ ).

L\* denotes the lightness component of colour; in eggshells, lower L\* values indicate darker pigmentation, whereas higher values reflect lighter shell coloration (26). The highest mean values for L\* were observed in the eggshells of *P. c. colchicus* ( $66.93 \pm 3.99$ ), while the lowest were recorded in *P. c. karpowi* ( $59.81 \pm 3.86$ ) ( $p < 0.001$ ). Individual minimum and maximum variations in the L parameter ranged from 50.77 to 78.32, with these extreme values noted in *P. c. mongolicus*.

Positive a\* values indicate a shift toward the red spectrum, while negative values correspond to a greenish spectrum (9). The mean values of the a\* axis are low and positive for all three subspecies, placing them within the red spectrum. The highest mean a values were recorded for the *P. c. karpowi* group ( $6.99 \pm 2.14$ ), while the lowest were observed in *P. c. mongolicus* ( $1.67 \pm 4.33$ ) ( $p < 0.001$ ). Unlike the Korean Ring-necked Pheasant (*P. c. karpowi*), eggs with negative a\* values were recorded in the other two subspecies, reaching as low as -8.81 in *P. c. mongolicus* and -1.01 in *P. c. colchicus*. This indicates a greater influence of protoporphyrin deposition on the colour characteristics in *P. c. karpowi* compared to the other two subspecies, even though visually almost all eggshells can be described as different variations of green. The a\* coordinate of the CIEL\*a\*b\* colour space exhibited markedly higher coefficients of variation compared to the other colour axes, ranging from 30.57 in *P. c. karpowi* to 259.56 in *P. c.*

*mongolicus*. This high variability reflects the low mean values and frequent sign changes of the a\* parameter, indicating an unstable red-green chromatic component in Common pheasant eggshell coloration.

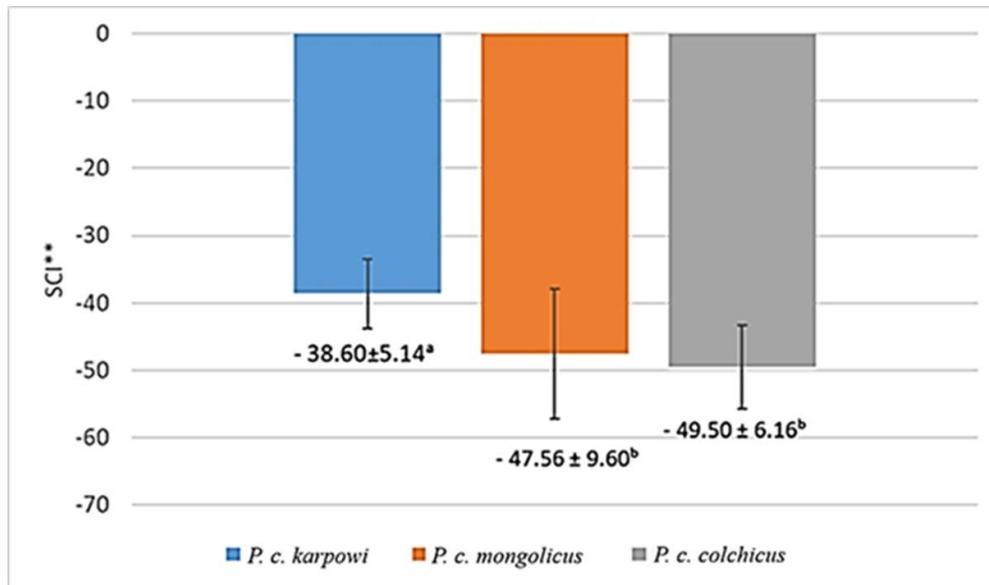
The b\* axis measures colour deviation along the blue–yellow spectrum, with positive values indicating yellow tones and negative values indicating blue. All tested eggs show a clear position within the yellow spectrum, with individual variations ranging from 6.91 (*P. c. mongolicus*) to 23.23 (*P. c. karpowi*). Significantly highest mean values were recorded for *P. c. karpowi* ( $21.21 \pm 2.44$ ), and the lowest for *P. c. mongolicus* ( $16.34 \pm 3.77$ ) ( $p < 0.001$ ).

In the CIE L\*a\*b\* colour space, Chroma (C\*) indicates colour saturation, with low values reflecting dull colours and high values representing vivid, intense ones (9). In Common Pheasant eggs, mean C\* values are closely aligned with b\* values, due to the stronger influence of the b\* axis in the Chroma calculation.

**Figure 1** presents the results of the modified shell colour index (SCI\*\*) within the CIE L\*a\*b\* colour space, originally introduced by Lukanov et al. (11) for assessing meat colour and later adapted by Genchev et al. (27) as a more objective method for evaluating eggshell colour. Due to the presence of visibly green pigmentation, a correction factor (-1) was

applied to differentiate the index values of eggs with greenish shells from those with brown pigmentation (28). Significantly highest mean SCI\*\* values were recorded for *P. c. karpowi*, and the lowest for *P. c. colchicus*, with values

of  $-38.6 \pm 5.14$  and  $-49.5 \pm 6.16$ , respectively ( $p < 0.001$ ). On an individual basis, the highest value was observed in an egg from *P. c. karpowi* (-27.11), while the lowest was recorded in *P. c. mongolicus* (-66.1).



**Figure 1.** Shell Colour Index (SCI\*\*) of eggs from the three studied subspecies of the Common pheasant. Bars represent mean values  $\pm$  SD. Different superscript letters indicate statistically significant differences between subspecies ( $p < 0.001$ ).

### CONCLUSIONS

The study revealed significant differences in egg weight and dimensions among the three Common Pheasant subspecies, with *P. c. mongolicus* producing the heaviest and largest eggs, and *P. c. colchicus* the lightest. Egg shape also varied significantly, with *P. c. mongolicus* laying the most rounded eggs, while *P. c. colchicus* eggs were closest to the ideal shape index.

The findings show that two of the three tested subspecies share similar eggshell colour traits, while the Korean Ring-necked Pheasant (*P. c. karpowi*) differs significantly ( $p < 0.05$ ). Variation in eggshell colour within the Common Pheasant is broad, likely due to differing proportions of biliverdin and protoporphyrin pigments. Notably, *P. c. mongolicus* exhibited the greatest colorimetric variability, possibly linked to hybridization, whereas the other subspecies showed more consistent eggshell coloration. Eggshell colour parameters varied significantly among the three subspecies, with *P. c. colchicus* exhibiting the lightest shells (highest  $L^*$  values) and *P. c. karpowi* the darkest (lowest  $L^*$  values). While all subspecies' eggshells fall within the red ( $a^*$ ) and yellow ( $b^*$ ) spectra, *P. c. karpowi* showed a

stronger protoporphyrin influence, reflected in higher  $a^*$  and  $b^*$  mean values compared to the others. Despite these differences, visually, almost all eggs appear as shades of green due to the combined pigment effects. The results reveal distinct differences in shell colour characteristics across the studied Common Pheasant subspecies.

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