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External egg characteristics in eight species of the Phasianinae subfamily: a morphometric and colourimetric study

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Abstract. Basic external morphometric characteristics, along with a detailed colorimetric analysis, were studied in the eggs of eight Phasianidae species reared as ornamental birds in Bulgaria: Temminck's tragopan (*Tragopan temminckii* Gray, 1831), Satyr tragopan (*Tragopan satyra* Linnaeus, 1758), Golden pheasant (*Chrysolophus pictus* Linnaeus, 1758), Lady Amherst's pheasant (*Chrysolophus amherstiae* Leadbeater, 1829). Silver pheasant (*Lophura nycthemera* Linnaeus, 1758), Reeves's pheasant (*Syrmaticus reevesii* Gray, 1829), Grey peacock-pheasant (*Polyplectron bicalcaratum* Linnaeus, 1758), and Common pheasant (*Phasianus colchicus* Linnaeus, 1758).

Key words: egg weight, egg shape index, colourimetry.

Introduction

The Phasianinae are a subfamily within the pheasant family, Phasianidae, in the order Galliformes. They comprise true pheasants, tragopans, grouse, turkeys, and related landfowl (Winkler *et al.* 2020). The pheasant subfamily includes 67 species across 20 genera (Madge & McGowan 2002). Due to their ornamental appeal, many are well known in captivity but remain poorly studied in the wild (Madge & McGowan 2002). Of all pheasants, two species are classified as Critically Endangered: Edwards's pheasant (*Lophura edwardsi* Oustalet, 1896) and the Vietnamese Crested Argus (*Rheinardia ocellata* Elliot, 1871), while the Malay Peacock-pheasant (*Polyplectron malacense* Scopoli, 1786), Bornean peacock-pheasant (*Polyplectron schleiermacheri* Brüggemann, 1877) and Hainan peacock-pheasant (*Polyplectron katsumatae* Rothschild, 1906) are classified as Endangered. An additional 13 species are classified as Vulnerable (IUCN 2025). The primary threats to pheasant survival include habitat loss and degradation, hunting, human disturbance, and hybridisation with released stock (Fuller & Garson 2000).

The striking diversity in avian egg colouration and patterning has been the subject of various hypotheses. Proposed functions include crypsis, mimicry by brood parasites and host rejection, protection from solar radiation, and aposematism (Kilner 2006). More recent research suggests that egg coloration may also be constrained by three key factors: birds' ability to perceive ultraviolet light under specific nest lighting conditions, the potential for blue-green pigmentation to act as a sexual signal indicating female genetic quality, and the structural role of pigments in reinforcing shell strength (Cherry & Gosler 2010). Eggshell colouration in birds is primarily determined by two pigments-biliverdin (IXα) and protoporphyrin (IX) (Verdes *et al.* 2015). In addition, other pigments such as bilirubin,

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uroerythrin, and coproporphyrin-III have also been identified in certain bird species (Hamchand *et al.* 2020; Stoddard 2022).

This study aimed to examine the fundamental external morphometric traits and conduct a comprehensive colourimetric analysis of the eggs from eight species within the Pasianidae family.

Material and Methods

For this study, fresh eggs from the following species were collected from pheasant breeders, the Stara Zagora Zoo, and a commercial common pheasant farm in Bulgaria: *Tragopan temminckii* (n = 8), *Tragopan satyra* (n = 10), *Chrysolophus pictus* (n = 32), *Chrysolophus amherstiae* (n = 31), *Lophura nycthemera* (n = 28), *Syrmaticus reevesii* (n = 24), *Polyplectron bicalcaratum* (n = 16), and *Phasianus colchicus* (n = 90). 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 = (d/D) × 100 %) and shell surface area (SSA = 4.835×Egg Weight$^{2/3}$, cm^2) were subsequently calculated. Eggshell colour was analysed using a portable colourimeter (PCE-CSM 2) in the CIE L*a*b* colour space, with measurements taken at three points per egg (equator, pointed pole, blunt pole). Average L*, a*, and b* values were calculated per zone and egg. Chroma (C) and Shell Colour Index (SCI**) were also calculated, with a correction factor of −1 applied to account for biliverdin pigmentation in the eggs of the Common pheasant: SCI** = (L-C)*(-1) (Lukanov *et al.* 2018).

Results and Discussion

Significant differences in average egg weight were observed among the various pheasant species studied, reaching up to 38.46%, ranging from 25.33 ± 2.36 g in the Golden Pheasant to 41.16 ± 1.36 g in Temminck's Tragopan. A similar pattern was logically evident in egg dimensions and eggshell surface area (Table 1). In contrast, species within the same genus, such as *T. temminckii* and *T. satyra*, as well as *C. pictus* and *C. amherstiae*, showed no significant differences in egg weight and size. In general, when comparing the egg weight and dimensions from the present study with the average body weight of the species examined, as reported by Madge & McGowan (2002), a direct proportional relationship can be observed. Deviations from this trend were noted in *P. bicalcaratum* and *P. colchicus*, which represent one of the lightest and one of the heaviest species studied, respectively.

The egg shape index reflects the overall form of the egg, indicating how spherical or elongated it is (Romanoff & Romanoff 1949). Higher shape index values denote more spherical eggs, while lower values are characteristic of more elongated shapes. Substantial differences in average shape index values were observed among the studied species, ranging from 70.33 ± 0.5% in Temminck's Tragopan to 79.55 ± 2.00% in the Silver Pheasant. The lowest and highest individual values were recorded in *T. satyra* (66.97%) and *P. colchicus* (86.68%), respectively. Overall, the shape index in most of the species examined falls within or close to the range considered optimal for domestic chicken eggs - 72 to 76% (Genchev & Lukanov 2025).

Table 1. Comparative analysis of external morphometric characteristics of eggs from eight Phasianidae species.

Pheasant species	Parameter (x ± SD)				
	Egg weight, g	D, mm	d, mm	SI, %	SSA, cm^2
Tragopan temminckii	41.16±1.36	57.13±1.16	40.18±0.53	70.33±0.5	57.64±1.96
Tragopan satyra	40.41±1.97	55.57±2.28	39.53±0.91	71.21±2.45	56.94±3.12

Chrysolophus pictus	25.33±2.36	43.76±2.53	32.62±1.14	74.73±4.19	41.7±2.96
Chrysolophus amherstiae	27.17±2.09	45.22±2.95	33.82±0.88	75.02±3.88	43.7±3.18
Lophura nycthemera	37.06±1.59	47.28±2.97	37.29±2.79	79.55±2.00	53.74±2.45
Syrmaticus reevesii	30.38±1.41	44.79±1.21	34.73±0.92	77.59±2.56	47.07±1.75
Polyplectron bicalcaratum	31.8±1.14	48.24±1.58	35.39±0.54	73.43±2.55	46.5±1.93
Phasianus colchicus	29.65±3.48	44.59±2.03	34.88±1.55	78.31±3.49	46.32±3.48

The eggshell colour of the studied pheasant species varies markedly, ranging from pale buff to olive, and from uniformly coloured to speckled (Ogilvie-Grant 1896; Madge & McGowan 2002; Winkler *et al*. 2020). Among the examined eggs, distinct speckling of the eggshell was observed only in representatives of the genus *Tragopan*, while the Common pheasant exhibited pronounced biliverdin-based (green) pigmentation. The a* value shows the balance between red and green: positive values indicate red colour, while negative values point to green (CIE 2018). In Reeves's Pheasant, a faint bluish-green tint was noted, likely due to weak biliverdin deposition in the shell, which was not instrumentally confirmed except in two eggs showing slightly negative a* axis values. Interestingly, despite the visibly green colouration of the Common pheasant eggshells, they exhibited low positive mean a* values (Table 2), placing them within the red spectrum. The presented data and visual analysis of eggshell colour support the conclusion that, in all examined pheasant eggs, the a* values are primarily influenced by protoporphyrin deposition, including cases where both pigments are deposited.

L* represents the lightness component of colour, with lower values indicating darker eggshell pigmentation and higher values corresponding to lighter shells (Aygun 2013). The darkest eggshells were observed in *T. satyra*, where the low mean L* value (62.19 ± 8.22) is most likely influenced by heavy speckling. Another species with dark eggshells is *P. colchicus*, where the combination of protoporphyrin and biliverdin, along with more intense deposition of the brown pigment, contributes to the recorded low L* values (63.71 ± 6.07). The eggs of Lady Amherst's pheasant exhibited the highest lightness values (85.18 ± 2.59). The b* axis represents colour variation along the blue–yellow spectrum, where positive values indicate yellow hues and negative values indicate blue. All analysed eggs fall within the yellow range, with individual values spanning from 5.73 (*C. amherstiae*) to 27.61 (*T. satyra*). The highest mean SCI** was observed in *P. bicalcaratum* (69.75 ± 1.69), and the lowest in *P. colchicus* (-45.08 ± 8.74). On an individual level, the highest value was recorded in a *C. amherstiae* egg (82.11), and the lowest in *P. colchicus* (-27.11).

The conducted colourimetric analysis enables the transformation of a purely visual trait, such as eggshell colour, into a numerical expression, allowing for an objective comparison of pigmentation-related traits among different pheasant species and subspecies. This study provides a foundation for further, more extensive research on the colourimetric characteristics of eggshells in various pheasant species.

Table 2. CIE L*a*b* colourimetric characteristic of eggs from the eight Phasianidae species.

Pheasant species	Parameter (x ± SD)				
	L*	a*	b*	C*	SCI**
Tragopan temminckii	75.73±1.88	7.14±1.64	22.64±0.89	23.75±1.16	51.98±2.78
Tragopan satyra	62.19±8.22	12.17±2.36	22.51±2.19	25.67±2.36	36.51±9.66

Chrysolophus pictus	81.86±2.11	6.01±2.29	16.11±4.15	17.22±4.64	64.64±5.91
Chrysolophus amherstiae	85.18±2.59	4.33±1.73	15.48±4.22	16.12±4.37	69.06±6.55
Lophura nycthemera	74.92±3.19	11.60±1.95	21.79±1.92	24.71±2.46	50.21±5.18
Syrmaticus reevesii	76.92±1.53	2.16±0.95	15.3±1.41	15.47±1.46	60.75±2.73
Polyplectron bicalcaratum	83.79±0.86	7.19±0.93	12.05±1.19	14.04±1.37	69.75±1.69
Phasianus colchicus	63.71±6.07	3.77±3.85	17.89±3.25	18.63±3.52	-45.08±8.74

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