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Characteristics of Crested Tinamou (*Eudromia elegans* Saint-Hilaire, 1832) (Aves: Tinamidae) eggs

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Abstract. The main characteristics of Crested Tinamou eggs, including shell colour characteristics in two age groups (young and old birds) were studied. The average value of the egg shape index was 73.23±0.51 with the average egg size of 50.13±0.47 mm/36.67±0.18 mm. The average egg weight of all eggs was 35.58±0.64 g, lighter in the young birds (P<0.001). The share of albumen: yolk: shell with shell membranes was 58.4%:32.2%:9.4%. Crested Tinamou eggshell is characterized by average values in the CIE L*a*b* colour system as follows: 51.62±0.51 (L*), -11.57±0.21 (a*), and 36.62±0.54 (b*) with an average shell color index (SCI**) of -13.19±0.4.

Key words: eggshell, colorimetry, egg quality.

Introduction

The Crested Tinamou (*Eudromia elegans* Saint-Hilaire 1832) was first described in the first half of the 19th century and has not changed its original name since then (Saint-Hilaire 1832). Its habitat is shrub steppes, savannahs, grasslands and farmland. The tinamou is distributed in Argentina, Chile and Bolivia over a total area of about 2,140,000 km^2 (BirdLife International 2023). This species is a sedentary ratite. The live weight of the birds is 400-800 g and the length is 37-41 cm (del Hoyo & Collar 2014). In captivity, the Crested Tinamou is kept by many hobby breeders and in a number of zoos around the world. Under such conditions, the female usually lays 30-40 apple-green eggs per year, with a shiny, spotless shell (Gomes *et al.* 2024). Some authors point out that the birds' productivity potential is significantly higher and can reach up to 200 eggs/annually (Bruslund & Magnus 2011).

The eggshell of Tinamidae has an attractive monochromatic color that varies by species, with a characteristic sheen (Cabot *et al.* 1992). The color of the eggshell depends on the presence or absence of certain pigments, such as biliverdin and protoporphyrin IX (Kennedy & Vevers 1976). In addition to these pigments, a recent study by Hamchand *et al.* (2020) points out two other pigments that are associated with the expression of a specific shell color in representatives of the Tinamidae family and are known as porphyrin catabolites. One of these is tetrapyrrolic bilirubin, which gives the crested tinamou eggs a yellow-brown shell color, and the other is tripyrrolic uroerythrin, which is responsible for the red-orange shell color of the eggs of the Spotted Nothura (*Nothura maculosa* Temminck 1815). In the literature available to us, we did not find specific information on the colorimetric characteristics of the shell of this species determined by the direct method. Indirectly, through a colorimetric analysis of a photograph of eggs of 32 species from the family Tinamidae, Schläpfer (2017) provides generalized data on their color in the CIE L*a*b* and RGB system. Li & Wang (2021) use these data to create ecological models.

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The aim of the study was to determine the main characteristics of Crested Tinamou eggs, including shell colour characteristics, depending on age.

Material and Methods

The eggs of young (one-year-old) and adult (two- and three-year-old) birds were examined. The number of eggs examined in each group was 20. The eggs were kindly provided by an amateur poultry breeder from Northern Bulgaria, stored for up to 3 days after laying at a temperature of 12°C (delivered for analysis in three consecutive weeks). The most important qualitative characteristics of the eggs were determined using generally accepted analytical methods used in industrial poultry farming (Lukanov & Pavlova 2022).
The shell color was determined using a PCE-CSM 2 spectrophotometer in the CIE L*a*b* system (illuminant D-65). Based on the results obtained, the Shell color index (SCI**) was calculated by using the formula: SCI** = (L-C)*(-1) (Lukanov *et al.* 2018).

The results obtained were statistically processed using the IBM® SPSS® Statistics (V26) package. Statistical comparisons were performed using the T-test, and differences were considered significant at $P<0.05$.

Results and Discussion

Table 1 shows that the average weight of the eggs of the Crested Tinamou was 35.58±0.64 g, with a range of 23.95 to 40.4 g. The eggs of the young birds were 11.7% lighter ($P<0.001$).

In terms of the traits characterizing the internal egg quality, no significant age differences were observed. However, there was a tendency for thicker and denser eggshell of adult birds eggs. It is interesting that the eggs of the Crested Tinamou had quite clearly defined large and small yolk diameters, and the difference in diameters was 11.6%.

The share of egg components albumen: yolk: shell with shell membranes was 58.4%:32.2%:9.4%. Regardless of the fact that statistically significant differences in the composition of eggs were not observed between young and adult birds ($P>0.05$), we found that the proportion of yolk and shell tended to be higher in the eggs of the young birds.

Table 1. Morphological characteristics of the Crested Tinamou eggs.

Parameters	Young females[1]		Old females[1]		Average	
	x±SEM	CV, %	x±SEM	CV, %	x±SEM	CV, %
External egg parameters						
Egg weight, g	33.38±0.61[a]	5.5	37.79±0.53[a]	4.17	35.58±0.64	7.9
Large egg diameter, mm	48.73±0.66[a]	4.1	51.52±0.24[a]	1.40	50.13±0.47	4.1
Small egg diameter, mm	36.06±0.12[a]	1.0	37.28±0.2[a]	1.62	36.67±0.18	2.2
Shape index, %	74.1±0.92	3.7	72.36±0.32	1.33	73.23±0.51	3.0
Shell area, cm^2	50.73±0.65[a]	3.9	55.16±0.51[a]	2.78	52.95±0.65	5.4
Internal egg parameters						
Haugh units	77.09±1.93	7.5	74.82±2.12	8.5	75.95±1.38	7.9
Albumen index	0.08±0.01	20.0	0.08±0.01	20.0	0.08±0.00	19.4
Yolk index	0.36±0.01	6.6	0.36±0.01	6.6	0.36±0.01	6.5
Shell thickness, µm	247.2±6.86	8.3	254.5±4.44	5.2	250.8±3.96	6.9
Shell density, mg/cm^2	62.29±1.61	7.7	63.19±1.41	6.7	62.74±1.02	7.1
Egg components share						
Albumen, %	57.81	0.8	59.01	0.7	58.41±0.52	3.9
Yolk, %	32.72	0.6	31.77	0.7	32.24±0.45	6.1
Shell, %	9.48	0.3	9.22	0.2	9.35±0.15	6.8

Values marked with the same letters are statistically significant: [c-c] $P<0.05$; [b-b] $P<0.01$; [a-a] $P<0.001$.
[1] "Young females" refers to one-year old; "Old females" refers to 2-3 years old.

No significant differences were found between the groups in the egg shell color characteristics examined (P>0.05) (Table 2). However, a tendency towards lower mean values was observed in young birds compared to adult birds. The largest variation in both groups (CV>7%) was considered in the green spectrum (-a*). With regard to the yellow spectrum (b*), a deviation of more than 7% was only observed in eggs of young birds.

Table 2. Color characteristics of the Crested Tinamou eggshell.

Parameters	Young females[1]		Old females[1]		Average	
	x±SEM	CV, %	x±SEM	CV, %	x±SEM	CV, %
L*	50.73±0.82	4.84	52.51±0.56	3.19	51.62±0.51	4.34
a*	-11.57±0.3	-7.86	-11.58±0.32	-8.31	-11.57±0.21	-7.87
b*	35.83±0.88	7.41	37.41±0.61	4.88	36.62±0.54	6.44
C*	37.68±0.85	6.79	39.18±0.56	4.31	38.43±0.52	5.84
SCI**	-13.05±0.44	-10.19	-13.33±0.72	-16.19	-13.19±0.4	-13.27

Values marked with the same letters are statistically significant: $^{c\text{-}c}$ P<0.05; $^{b\text{-}b}$ P<0.01; $^{a\text{-}a}$ P<0.001.
*"Young females" refers to one-year old; "Old females" refers to 2-3 years old.

Our results are at the lower limit of the egg weights of wild and captive birds found by Bohl (1970) - 32-52 g. A similar age dependence was observed in relation to other external characteristics - large and small diameter of the egg and eggshell area (P<0.001). The Crested Tinamou eggs do not show very pronounced polar differences, and their shape is rather roundish. The average value of the egg shape index was 73.23±0.51, which is within the optimal limits of 72-76 (Altuntas & Sekeroglu 2007) and close to the ideal value of chicken eggs - 74 (Romanoff & Romanoff 1949).

Comparing the proportion of egg components with those typical of chicken species, it is found that the proportion of yolk in the Crested Tinamou egg is higher, the proportion of albumen is lower, while the proportion of eggshell is comparable to that of chicken eggs (Okubo *et al.* 1997).

Summarizing the results of the study, it can be concluded that there are age differences in the ratio of external features that characterize the quality of Crested Tinamous (*Eudromia elegans*) eggs. The shape index approaches the ideal parameters characteristic of chicken eggs, but unlike these, there are no clearly defined blunt and sharp poles of the egg. A characteristic feature of the eggs of the Crested Tinamou is the clearly defined ovality of the yolk.

The results presented by Schläpfer (2017) show values of 68 (L*) and 66 (C*) for the shell color of the Crested Tinamou. The same author's results in the RGB system were 156, 176 and 43, respectively. After conversion to CIE L*a*b*, they correspond to 68.2 (L*), -23.9 (a*) and 61.07 (b*), respectively, characterizing the eggshell color as light yellow-green. Comparing our results with the above, we found that indirect color analysis based on the use of photographs leads to quite large differences for all coordinates. These differences may be due to individual color characteristics of the eggs, inaccuracies in the previous processing of the photographs or errors in the software used.

The analysis of the results obtained shows that the lightness (L*) was higher (lighter) at the poles of the egg than in the equatorial zone (53.88 at the blunt end, 48.71 in the equatorial zone and 52.27 at the sharp end). When analysing the results of the b* coordinate, we note that the highest values were considered in the equatorial zone (40.27) compared to the blunt (35.01) and sharp (34.59) ends. The smallest zonal differences were recorded in the green spectrum of coordinate a*, where a slight increase in values from the blunt to the sharp end was taken into account (-12.15>-11.61>-10.95). Visually, the color of

the Crested Tinamou eggshell corresponds to the descriptions of Bohl (1970), who defines it as homogeneous, shiny, green (the color of moss).

We can conclude that the eggs of the Crested Tinamou do not show significant age differences in shell color. They are characterized by average values in the CIE L*a*b* system, respectively: 51.62±0.51 (L*), -11.57±0.21 (a*) and 36.62±0.54 (b*) with an average shell color index (SCI**) of -13.19±0.4. On this basis, the color can be characterized as glossy green (moss color).

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