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Estimation of the external quality characteristics of goose eggs of known breadth and length

*Osman Karabulut**

Department of Biometrics, Faculty of Veterinary Medicine, Aksaray University, Aksaray, Turkey

**Corresponding author: okarabulut02@gmail.com*

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Abstract: In this study, we investigated whether the mathematical formulas, which generally reveal the external quality characteristics of living organisms, yield the correct results in goose eggs. For this purpose, three genotypes and 555 eggs were studied that were grouped into Native (n = 356), Chinese (n = 163) and Linda (n = 36), which were raised in Aksaray province. The averages in the Native, Chinese and Linda geese were 5.43, 5.38 and 5.7 cm, respectively, in breadth; were 8.12, 8.03 and 8.67 cm in length, respectively; the shape index was 66.9, 67.2 and 66.7 cm, respectively; the egg volume was 142.8, 138.8 and 172.5 cm^3, respectively; the egg surface area was 136.9, 134.3 and 155.4 cm^2, respectively; the egg weight was 159.1, 154.5 and 192.3 g, respectively; the specific gravity of the eggs was 1.11, 1.11 and 1.12 g/cm^3, respectively; the shell thickness was 0.510, 0.504 and 0.555 mm, respectively; the shell weight was 14.79, 14.32 and 18.26 g, respectively; the shell volume was 70.06, 67.82 and 86.41 cm^3, respectively; the shell specific gravity was 2.111 3, 2.111 0 and 2.113 5 g/cm^3, respectively; and the shell ratio was 9.29, 9.26 and 9.49 g, respectively. The number of pores is calculated as 14 828, 14 502 and 17 152, respectively. Although the formulas used give compatible results, there is a need for formulas that calculate closer to the truth rather than formulas that calculate the egg weight and egg shell weight.

Keywords: egg measurements; equations; geese; shape index

Although the shape of the egg is generally known as being oval, when examined closely, it can be seen that it has different shapes than being oval. Considering that this difference in the shape of the egg cannot be accidental, the eggs have been classified according to their shapes with attempts to interpret them (Nishiyama 2012).

The eggs of birds living in places where there is a danger of breaking by rolling away from the nest are generally pear-shaped. Birds that nest in flat places such as ostriches have elliptical eggs, and species such as tortoises that bury their eggs in the sand are round (Nishiyama 2012)

Since oval eggs are resistant to external impacts, they are preferred in commercial flocks and the production of eggs for poultry hatching (Bain 1992). The utilisation of this ovoid form has also spread to architectural designs (Petrovic et al. 2011) The most commonly used measurements in defining the different shapes in egg geometry are the width and length (Mulder and Wollan 1974).

By knowing these two measurements, it has become possible to make predictions about the egg morphology, components and many other parameters.

Onk and Kirmizibayrak (2019), in their study on classifying Kars region geese according to their feather colours and their age, found that both measurements differ significantly in these groups. The same differences were found in the shape index and egg weights using these two measurements. In other words, by looking at the shape of the egg, one can have an idea about which race and age it belongs to. Based on these two measurements,

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researchers have developed formulas that estimate the parameters related to the egg shell quality, and Alasahan et al. (2019) calculated almost all of the parameters with these formulas.

The average length of goose eggs varies between (approximately) 8 cm to 10 cm (Paganelli et al. 1974; Rabsztyn et al. 2010; Nedomova and Buchar 2014; Kumbar et al. 2016; Ahmad et al. 2017; Sreten et al. 2018; Onk and Kirmizibayrak 2019), the width averages vary between 5 cm to 6 cm (Rabsztyn et al. 2010; Nedomova and Buchar 2014; Kumbar et al. 2016; Ahmad et al. 2017; Sreten et al. 2018; Onk and Kirmizibayrak 2019), and the shape index averages vary between 65 cm and 69 cm (Saatci et al. 2002; Saatci et al. 2005; Rabsztyn et al. 2010; Nedomova and Buchar 2014; Kumbar et al. 2016; Sreten et al. 2018; Onk and Kirmizibayrak 2019).

The egg volume and egg surface area are important criteria in calculating the parameters that determine the external quality of the egg, and when the width and length are known, it is possible to calculate close to reality (Paganelli et al. 1974; Narushin 2005).

Paganelli et al. (1974) calculated the egg shell surface area as 146.15 ± 7.08 cm^2 depending on the egg weight of Embden geese. The average volume of goose eggs varies between approximately 125 cm^3 to 175 cm^3 (Paganelli et al. 1974; Saatci et al. 2002; Nedomova and Buchar 2014; Kumbar et al. 2016) and the average surface area varies between approximately 135 cm^2 to 150 cm^2 (Paganelli et al. 1974; Rabsztyn et al. 2010; Nedomova and Buchar 2014; Kumbar et al. 2016). Paganelli et al. (1974) calculated the volume of Embden geese as 158.74 ± 10.95 based on the egg weight.

When the egg surface area is known, the weight of the egg can be estimated (Paganelli et al. 1974). Copur-Akpinar et al. (2017) calculated almost all of the parameters related to the egg's inner and outer quality based on the egg weight.

The average weight of goose eggs varies between 143 g and 185 g (Paganelli et al. 1974; Saatci et al. 2005; Rabsztyn et al. 2010; Nedomova and Buchar 2014; Kumbar et al. 2016; Ahmad et al. 2017). Arroyo (1990) used African, Chinese, Toulouse and Embden breed goose eggs in his study and reported that the egg weight was 170, 173, 168, and 183 g, respectively. Tilki and Inal (2004a) found that the average egg weight in French White geese was 154.9 ± 0.80 g and increased significantly after two years of age.

After the egg volume and weight are known, the specific gravity can be calculated. Saatci et al. (2002) found the specific weight of eggs as 1.113 ± 0.004 g/cm^3 in his study on Native goose eggs in the Kars region. In his study, Arroyo (1990) used the eggs of African, Chinese, Toulouse and Embden breeds and reported the specific weight of the eggs as 1.079, 1.08, 1.08 and 1.079 g/cm^3, respectively.

In determining the shell quality, protecting the shell against external factors and ensuring air intake from the outside and minimising water loss are important criteria, which have an important relationship with the shell thickness (Erensayin 2000; Yamak et al. 2016; Veldsman et al. 2020). When the egg weight is known, the shell thickness and weight can be estimated. Studies investigating the effects of the shell quality also focused on the shell thickness and the average shell thickness in geese was found to be around 0.44–0.55 mm (Carey et al. 1990; Tilki and Inal 2004a; Ahmad et al. 2017). Tilki and Inal (2004a) found, in their study on French White geese, that the shell thickness decreased significantly after the age of one and the shell weight was 19.0 ± 0.10 g, and there was a significant increase after the age of two.

When calculating the shell density, Rahn and Paganelli (1989) proportioned the shell weight to the shell volume, not by proportioning the shell weight to the shell surface area, as other scientists did, and recommended the use of this method. In his study, he found that the shell density of the eggs of 27 kinds of animals varied between 1.85 and 2.39 g/cm^3 and was 2.10 g/cm^3 in Anseriformes. He reported that the shell rate in Francolinus birds is around 20–28%. Tilki and Inal (2004a) reported, in their study on French White geese, that the shell rate was 12.6 ± 0.55 and it decreased significantly as the age progressed.

There are formulas that can calculate the number of pores based on the shell thickness. As a result of the studies, it has been observed that there is an inverse proportion between the shell thickness and the number or pores (Carey 1980; Balkan and Biricik 2006; Portugal et al. 2014). As a matter of fact, the thickness of the egg shell is not the same in all parts of the egg, and it thickens from the blunt end to the pointy end. The pores densify in the thin part (Balkan and Biricik 2006).

The aim of this study is to predict the external quality characteristics of goose eggs with formulas found by researchers considering only the width and the length.

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MATERIAL AND METHODS

In this study, eggs belonging to three goose genotypes, which were Gray Chinese, Linda and Aksaray region Native geese collected from the public, were evaluated. The Chinese and Linda races have been found to be pure, although most of the Native geese of Aksaray region consist of grey and pied geese, very few of them have blood transfusions from Chinese and other races.

The distance between the two extreme points of the long axis of the egg was taken as the length (L) and the distance at the widest part of the short axis was taken as the breadth (B). Measurements were made with digital callipers capable of measuring a 200 mm distance with a precision of 0.01 mm.

The estimated parameters

I.
Shape index: Generally, the

$$SI = \frac{B}{L} 100 \qquad (1)$$

where:
SI – shape index;
B – breadth (width);
L – length.

formula is used (Schonwetter 1960).

II.
Volume (V), shell surface area (S): Nedomova and Buchar (2014) reported that the following formulas were useful for the poultry industry using imaging techniques in egg grading. Narushin's (2005) formula:

$$V = (0.605\,7 - 0.001\,8B)LB^2 \text{ cm}^3 \quad (r^2 = 0.985) \qquad (2)$$

$$S = (3.155 - 0.013\,6L + 0.011\,5B)LB \text{ cm}^2 \quad (r^2 = 0.961) \qquad (3)$$

where:
V – volume;
B – breadth (width);
L – length;
S – shell surface area;
r^2 – correlation coefficient.

III.
Egg weight (W): If the egg surface area is known, the egg weight can be calculated (Mohsenin 1970; Erensayin 2000):

$$S \text{ (cm}^2) = 4.67 W^{2/3} \text{ g} \qquad (4)$$

$$\text{thus; } W = \left(\frac{S}{4.67}\right)^{3/2} \text{ g} \qquad (5)$$

where:
S – shell surface area;
W – egg weight.

IV.
Specific gravity (SG): It can be calculated after the egg volume and weight are known:

$$SG = \frac{W}{V} \text{ g/cm}^3 \qquad (6)$$

where:
SG – specific gravity;
W – egg weight;
V – volume.

V.
Shell thickness (ST), shell weight (SW), shell volume (SV), shell specific gravity (SSG) and shell ratio (SR): Rahn and Paganelli (1989) formulas that calculate the correlation highly can be listed as:

$$ST \text{ (mm)} = 0.054\,6\ W^{0.441} \quad (r^2 = 0.89) \qquad (7)$$

$$SW \text{ (g)} = 0.052\,4\ W^{1.113} \quad (r^2 = 0.98) \qquad (8)$$

$$SV \text{ (cm}^3) = ST \times S \qquad (9)$$

$$SSG = SW/SV \qquad (10)$$

$$SR = SW/W \qquad (11)$$

where:
ST – shell thickness;
W – egg weight;
r^2 – correlation coefficient;
SW – shell weight;
SV – shell volume;
S – shell surface area;
SSG – shell specific gravity;
SR – shell ratio.

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VI.

Pore number (*PN*): The egg pore number formula reported by Rahn and Paganelli (1989) is:

$$PN = 304W^{0.767} \quad (12)$$

where:

PN – pore number;

W – egg weight.

Comparisons of the genotypes for each trait was made by a one-way analysis of variance (ANOVA) and the differences between the genotypes used Duncan's test. The analyses were made using the SPSS package program, v22 (IBM, USA, 2013).

RESULTS

The differences between the characteristics of the genotypes related to the shape and specific gravity of the egg are given in Table 1. Except for shape index and specific gravity ($P > 0.05$), the difference between the genotypes in all traits was very

Table 1. Analysis of variance results for the overall external quality characteristics of the eggs

Characteristics	Genotypes	n	$\bar{x}$	SD	Min.	Max.	%V	P
B (cm)	Native	356	5.43[b]	0.182	4.94	5.93	3.35	**
	Chinese	163	5.38[b]	0.132	4.95	5.74	2.46	
	Linda	36	5.78[a]	0.214	5.32	6.13	3.71	
	total	555	5.43	0.194	4.94	6.13	3.57	
L (cm)	Native	356	8.12[b]	0.408	5.56	9.46	5.02	**
	Chinese	163	8.03[b]	0.419	7.00	9.58	5.22	
	Linda	36	8.67[a]	0.343	7.89	9.73	3.96	
	total	555	8.13	0.433	5.56	9.73	5.32	
SI (cm)	Native	356	66.9	3.401	57.6	98.5	5.08	NS
	Chinese	163	67.2	3.020	56.3	74.3	4.50	
	Linda	36	66.7	2.859	54.7	71.0	4.29	
	total	555	67.0	3.257	54.7	98.5	4.86	
V (cm^3)	Native	356	142.8[b]	14.34	99.1	198.0	10.05	**
	Chinese	163	138.8[b]	11.92	107.7	177.0	8.59	
	Linda	36	172.5[a]	16.03	140.8	201.8	9.29	
	total	555	143.5	15.85	99.1	201.8	11.04	
S (cm^2)	Native	356	136.9[b]	9.669	95.5	173.6	7.06	**
	Chinese	163	134.3[b]	8.793	111.9	161.1	6.55	
	Linda	36	155.4[a]	9.474	136.1	171.7	6.10	
	total	555	137.4	10.59	95.5	173.6	7.71	
W (g)	Native	356	159.1[b]	16.94	92.5	226.7	10.65	**
	Chinese	163	154.5[b]	15.23	117.3	202.5	9.86	
	Linda	36	192.3[a]	17.45	157.3	223.0	9.08	
	total	555	159.9	18.66	92.5	226.7	11.67	
SG (g/cm^3)	Native	356	1.11	0.024	0.93	1.19	2.17	NS
	Chinese	163	1.11	0.023	1.06	1.20	2.06	
	Linda	36	1.12	0.023	1.08	1.22	2.06	
	total	555	1.11	0.024	0.93	1.22	2.13	

[a,b]Differences between genotypes; $^{**}P < 0.001$

%V = percent variance; $\bar{x}$ = mean; B = breadth (width); L = length; max. = maximum; min. = minimum; n = number of eggs; NS = non-significant; S = shell surface area; SD = standard deviation; SG = specific gravity; SI = shape index; V = volume; W = egg weight

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significant ($P < 0.001$), and the averages of the genotypes Linda, Native and Chinese occurred from large to small.

The difference was due to the averages of the Linda goose eggs being much larger than the other genotypes. It is normal to find differences in the parameters other than the shape index and the egg specific gravity, and it can be said that the formulas used in the calculations give balanced results. The differences are due to the fact that the Linda eggs are larger than the others, and the size of the egg varies depending on the genetic (such as race, age) and environmental (such as care-feeding, climate) effects.

The fact that the shape index and egg specific gravity are similar between the genotypes can be considered as an indicator of the accuracy of the formulas used. Because these parameters are not related to the size of the egg.

The differences between the genotypes of the eggshell characteristics are given in Table 2.

When the differences between the genotypes were analysed in the examined characteristics, it was observed that the Native and Chinese were similar ($P > 0.05$) and Linda had extremely significantly higher ($P < 0.001$) averages from both genotypes.

The shell thickness, shell weight, and shell volume are features affected by the environment, and these differences are normal. The very low variation in the shell specific gravity made even a small difference in the average significant.

Table 2. Analysis of variance statistics of the egg shell characteristics

Characteristics	Genotypes	n	$\bar{x}$	SD	Min.	Max.	%V	P
ST (mm)	Native	356	0.510[b]	0.02	0.40	0.60	4.32	**
	Chinese	163	0.504[b]	0.022	0.45	0.57	4.05	
	Linda	36	0.555[a]	0.022	0.51	0.59	5.08	
	total	555	0.511	0.026	0.40	0.60	11.88	
SW (g)	Native	356	14.79[b]	1.757	8.08	21.93	10.99	**
	Chinese	163	14.32[b]	1.573	10.53	19.34	10.08	
	Linda	36	18.26[a]	1.840	14.60	21.53	13.03	
	total	555	14.88	1.938	8.08	21.93	11.82	
SV (cm^3)	Native	356	70.06[b]	8.280	38.40	103.65	10.93	**
	Chinese	163	67.82[b]	7.415	49.97	91.48	10.03	
	Linda	36	86.41[a]	8.666	69.13	101.77	12.96	
	total	555	70.46	9.134	38.40	103.65	0.06	
SSG (g/cm^3)	Native	356	2.111 3[b]	0.001 2	2.105	2.115	0.06	**
	Chinese	163	2.111 0[b]	0.001 1	2.108	2.114	0.05	
	Linda	36	2.113 5[a]	0.001 1	2.111	2.115	0.05	
	total	555	2.111 4	0.001 3	2.105	2.115	0.06	
SR (g)	Native	356	9.287[b]	0.111	8.74	9.67	1.10	**
	Chinese	163	9.257[b]	0.102	8.98	9.55	1.05	
	Linda	36	9.489[a]	0.099	9.28	9.65	1.29	
	total	555	9.291	0.120	8.74	9.67	8.13	
PN	Native	356	14 828[b]	1 206	9 793	19 477	7.54	**
	Chinese	163	14 502[b]	1 093	1 175	17 862	7.00	
	Linda	36	17 152[a]	1 200	1 471	19 232	8.89	
	total	555	14 883	1 324	9 793	19 477	4.32	

[a,b]Differences between genotypes; **$P < 0.001$

%V = percent variance; $\bar{x}$ = mean; max. = maximum; min. = minimum; n = number of eggs; *PN* = pore number; SD = standard deviation; *SR* = shell ratio; *SSG* = shell specific gravity; *ST* = shell thickness; *SV* = shell volume; *SW* = shell weight

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DISCUSSION

When looking at the width, length and the shape index obtained from proportioning these two measurements (underlying the study), the average width of the Native, Chinese and Linda geese was 5.43 ± 0.18, 5.385 ± 0.13 and 5.78 ± 0.214 cm, respectively; the length was 8.18 ± 0.41, 8.03 ± 0.42 and 8.67 ± 0.34 cm, respectively; the shape index was found as 66.9 ± 3.40, 67.2 ± 3.02 and 66.7 ± 2.86 cm, respectively, and the average of the Native geese was lower in terms of the width and the length when compared with the average of the width, length and shape index (5.70 ± 0.486, 8.67 ± 0.486 and 65.78 ± 3.89 cm, respectively) of the Native geese reported by Onk and Kirmizibayrak (2019), while the shape index was higher.

In the study conducted by Tilki and Inal (2004b) on Native geese originating from three different regions (Armutlu, Tatlicak and Baskuyu) in the Isparta and Konya provinces, the average of the shape index was 67.1 ± 2.75, 70.3 ± 2.75 and 66.7 ± 2.75 cm, respectively, and Saatci et al. (2002), in his study on Native geese in the Kars province, was 66.63 ± 3.040 cm, while the average of the Native geese in our study is lower than the average of the Tatlicak-origin geese, but similar to the other averages. While the width and length were close to the values of the width, length and shape index (5.89 ± 0.94, 8.57 ± 1.43 and 68.82 ± 0.13 cm, respectively) identified by Rabsztyn et al. (2010) in Linda geese, the shape index was low. Likewise, it is lower than the shape index value (66.34 ± 4.648 cm) reported by Sari et al. (2019).

With the formulas developed by Narushin (2005) using the width and length, the egg volume and surface area were calculated for the Native geese, which were 142.8 ± 14.34 cm^3 and 136.9 ± 9.67 cm^2, respectively, and the volume was greater than the average 126.47 ± 14.11 cm^3 found in the study conducted by Saatci et al. (2002) on the Native geese in Kars.

In terms of the surface area, it was smaller than the average calculated by Rabsztyn et al. (2010) (140.60 ± 9.93 cm^2) and larger than the average calculated by Sari et al. (2019) (117.94 ± 0.84 cm^2). The egg weights were calculated as 159.1 ± 16.94, 154.5 ± 15.23 and 192.3 ± 17.45 g, respectively, in the Native, Chinese and Linda geese with the formulas reported by Mohsenin (1970) and Erensayin (2000).

Among the studies conducted on Native geese, while it is higher than the averages in the study conducted by Tilki and Inal (2004b) on Native geese originating from 3 different regions (Armutlu, Tatlicak and Baskuyu) in the Isparta and Konya provinces (145.1 ± 11.85, 148.5 ± 11.85 and 147.2 ± 11.85 g, respectively) and the averages detected by Saatci et al. (2002) and Saatci et al. (2005) (144.51 ± 17.67 and 148.43 ± 16.96 g, respectively), it is lower than the averages reported by Onk and Kirmizibayrak (2019) (163.74 ± 4.86 g) which occurred between the averages of the first and second spawning season (154.99 ± 13.27 and 161.94 ± 13.42 g, respectively).

In the study conducted on Chinese geese, it is lower than that (173 g) reported by Arroyo (1990). Apart from being higher than the weight of Linda geese 150–170 g (Decoratex 2016) and the average reported by Rabsztyn et al. (2010) (164.97 ± 17.93 g), it is close to the weight of Koluda® White geese in the second and third seasons (194 and 191 g, respectively) reported by Biesiada-Drzazga (2016). All in all, it has been seen that the results of the formulas used in the calculations are higher than the real values.

The egg specific weights of the genotypes were calculated and the averages were almost the same (1.11–1.12 g/cm^3). The averages are similar to the specific gravity (1.113 ± 0.004 g/cm^3) that Saatci et al. (2002) found in his study on Native geese eggs in the Kars region, and they are higher than the specific gravity of African, Chinese, Toulouse and Embden eggs that Arroyo (1990) used in his study (1.079, 1.08, 1.08 and 1.079 g/cm^3, respectively). If the egg weight had been calculated closer to the truth, it would have been closer to the results of Arroyo (1990).

The shell thickness, shell weight, shell volume, shell density and shell ratio were calculated with the highly correlated formulas of Rahn and Paganelli (1989) and the Linda egg values were higher than the other genotypes in all the parameters.

The average shell thickness was calculated as 0.510 ± 0.024, 0.504 ± 0.022 and 0.555 ± 0.022 mm in the Native, Chinese and Linda geese, respectively, and the average of the Native geese was smaller than the 0.72 ± 86 mm found by Saatci et al. (2002). The average of the Linda geese was greater than what Sari et al. (2019) found (0.48 ± 0.095 mm). The averages of the genotypes are closer to the average (0.52 ± 0.02 mm) in the study conducted by Tilki and Inal (2004a) on French White geese. The shell thickness was calculated based on the egg weight,

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and if the egg weight was calculated lower, the results would be similar to the results of Tilki and Inal (2004a) or lower.

The averages of the shell weight were calculated as 14.79 ± 1.76, 14.32 ± 1.57 and 18.26 ± 1.84 mm in the Native, Chinese and Linda geese, respectively, while Tilki and Inal (2004a) found Linda close to the average (19.0 ± 1.75 g) than that they had identified in their study on French White geese, the other genotypes were calculated to be lower. The values calculated for the Native and Chinese geese were close to the value (14.46 ± 0.19 g) found by Sari et al. (2019) in Linda geese. The shell weight was calculated based on the egg weight and it would have been even lower if the egg weight was calculated as lower.

The averages of the shell specific gravity were calculated as 2.111 3 ± 0.001 2, 2.111 0 ± 0.001 1 and 2.113 5 ± 0.001 1 g/cm^3 in the Native, Chinese and Linda geese, respectively, and the shell specific gravity of Rahn and Paganelli (1989) was in the range between (1.85–2.39 g/cm^3) and it was found to be similar to Anseriformes (2.10 g/cm^3).

The mean shell ratios were found to be 9.287 ± 0.111, 9.257 ± 0.102, and 9.489 ± 0.099 in the Native, Chinese and Linda geese, respectively, than those found by Tilki and Inal (2004a) and Sari et al. (2019) (12.6 ± 0.55 and 11.84 ± 0.95, respectively). This is because the formulas calculated the egg weight high and the egg shell weight low.

It can be said that the formulas used in the study give compatible results. However, instead of formulas that calculate the egg weight and egg shell weight, formulas that calculate closer to the truth are needed. The importance of the width and length in obtaining information about the egg without damaging the structure of the egg has once again been revealed in the current study.

With a computer program to be created, it may be possible to obtain all this information about the egg's external quality by looking only at these two parameters.

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Conflict of interest

The author declares no conflict of interest.

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