Egg Geometry Calculation Using the Measurements of Length and Breadth

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ABSTRACT

Egg geometrical calculations that include estimations of volume and surface areas are important for the poultry industry and in biological studies, as they can be used in research on population and ecological morphology, and to predict chick weight, egg hatchability, shell quality characteristics, and egg interior parameters. The research reported here is directed at the prediction of egg volume and surface area, and develops a formula that could be both accurate and suitable for calculations. The objective of this research was to improve the accuracy of the calculations of egg volume and surface area based on the measurements of the egg length and breadth. The experiment was carried out with 90 fresh eggs from a flock of Hy-Line Brown chicks at the age of 65 wk. The resulting formula for egg volume, \( V \), was \( V = (0.6057 - 0.0018B)LB^2 \) in which \( L \) is the egg length in millimeters, and \( B \) is the egg maximum breadth in millimeters. Egg surface area, \( S \), was calculated as \( S = (3.155 - 0.0136L + 0.0115B)LB \), in which both \( L \) and \( B \) are taken in millimeters.

(Key words: egg geometry, egg volume, egg surface area)

INTRODUCTION

Egg geometrical calculations that include estimations of volume (\( V \)) and surface area (\( S \)) are important for the poultry industry and in biological studies, as they can be used in research on population and ecological morphology (Mánd, 1988), and to predict chick weight, egg hatchability (Narushin and Romanov, 2002a), shell quality characteristics (Narushin, 2001b), and egg interior parameters (Narushin and Romanov, 2002b). Although recently reported models (Narushin, 1997a, 1993, 2001a) for calculation are accurate, some of the complicated measurements should be carefully undertaken to minimize a calculative error. As practice shows, the \( V \) and \( S \) calculations are still based on the measurements of the egg length, \( L \), and the maximum breadth, \( B \). These 2 variables are suitable for measuring with a simple instrument, such as a vernier caliper, and that is, probably, the principal objective that determines their popularity in research with avian eggs.

The basic formula for calculating egg volume from the measurements of \( L \) and \( B \) was taken from the geometry of ovoids:

\[
V = k_VLB^2, \tag{1}
\]

in which \( k_V \) is a coefficient for volume calculation. The coefficient values, which were in use before 1949, were reported by Romanoff and Romanoff (1949). Later data gave \( k_V = 0.523 \) (Ayupov, 1976), and \( k_V = 0.496 \) (Narushin, 1997a); and a number of values of \( k_V \) were proposed by Hoyt (1979) for eggs of various species of wild birds. However, the variability of the proposed coefficients means that such calculations are imperfect. Similar to equation [1] and taking into account the changes of the dimensionalities, a formula for calculating \( S \) can be written as follows:

\[
S = k_SLB, \tag{2}
\]

in which \( k_S \) is a coefficient for calculating surface area.

The objective of the research reported herein was to improve the accuracy of the calculation of egg volume and surface area based on the measurements of egg length and breadth. Narushin (2001a) showed that egg volume can be estimated by means of a theoretically deduced formula:

\[
V = \frac{2\pi L^3}{3(3n + 1)} \tag{3}
\]

in which \( n = 1.057 \left(\frac{L}{B}\right)^{0.372} \tag{4}\)

The obtained equations [3] and [4] can be transformed into the form of equation [1] by approximation of the data of Table 1 from Narushin (2001a) by a function \( f(L/B) \). The result of approximation gave the best-fit solution as
The correlations between in combination, were calculated according to Sokal and

\[
V = \left(0.452 + 0.069 \frac{L}{B}\right)LB^2
\]  

Comparing equations [6] and [1] it is possible to suggest that the value of \(k_V\) depends on the measurements of the egg length and breadth. Equation [6] is of a theoretical nature; therefore, a calculative error may occur when used in practice. To make it a better fit for practical needs, the following experimental procedure was carried out.

**MATERIALS AND METHODS**

A sample of 90 fresh eggs was collected from hens of the Hy-Line Brown strain at 65 wk of age. The volume \(V\) of every egg was calculated as a difference between the measurements of egg weight in air and water. The balance system, produced by Technical Services & Supplies Ltd.,\(^2\) was used. The length \(L\) of egg longitudinal axis and maximum breadth \(B\) were measured with a vernier caliper.\(^3\) As no direct accurate method could be used to measure the egg surface area (Narushin 1997b), their values were measured under the formula of Narushin (2001a) using the measurements of \(L, B,\) and \(V\). The measured data were used for calculating of the coefficients \(k_V\) and \(k_S\) from equations [1] and [2]:

\[
k_V = \frac{V}{LB^2}
\]  

and

\[
k_S = \frac{S}{LB}
\]

The correlations between \(k_V, k_S,\) and \(L, B\), taken alone and in combination, were calculated according to Sokal and Rohlf (1969), and different formulae between the above variables were estimated using the computer software package, Statistica.\(^4\)

**RESULTS AND DISCUSSION**

The results of the measurements and calculations are shown in Table 1. The most variable egg parameters were volume (CV = 6.68%) and surface area (CV = 4.48%). Both coefficients \(k_V\) and \(k_S\) showed less variability, CV = 1.41 and 1.27%, respectively. The average means of the coefficients can be used for calculating \(V\) and \(S\). This results in an average value of \(k_V = 0.525\), which is very close to the one reported by Ayupov (1976), \(k_V = 0.523\). Thus, equations [1] and [2] can be rewritten in a first approximation as

\[
V = 0.525LB^2
\]  

\[
V = 2.854LB
\]

The next component of the study was to make equations [9] and [10] more representative. For this, a correlation between \(k_V, k_S,\) and egg geometrical variables was determined. The results of single and multiple correlations are shown in Table 2. The maximum single correlation for the egg volume coefficient was between \(k_V\) and \(B\) \((R = -0.27)\). The multiple correlation with \(L\) and \(B\) taken together resulted in comparable \(R\) values. When calculating the surface area, the values of \(k_S\) were highly correlated with the \(B\) to \(L\) ratio \((R = -0.70)\), and when \(L\) and \(B\) were taken together, the multiple correlation was slightly higher \((R = 0.71)\). This corresponded with the theoretical approach, as concluded by Narushin (1997a). The correlation analysis showed that egg geometry calculation can be improved by an approximation of \(k_V\) by

**TABLE 1. The data of the measurements of egg geometrical parameters and the coefficients calculated by equations [7] and [8]**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Minimum value</th>
<th>Maximum value</th>
<th>Average</th>
<th>Standard deviation (±)</th>
<th>Coefficient of variation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg length (L), mm</td>
<td>54.8</td>
<td>63.4</td>
<td>58.75</td>
<td>2.00</td>
<td>3.41</td>
</tr>
<tr>
<td>Egg maximum breadth (B), mm</td>
<td>41.5</td>
<td>47.1</td>
<td>44.13</td>
<td>1.09</td>
<td>2.47</td>
</tr>
<tr>
<td>(B) to (L) ratio</td>
<td>0.697</td>
<td>0.801</td>
<td>0.752</td>
<td>0.026</td>
<td>3.47</td>
</tr>
<tr>
<td>Egg volume (V), cm(^3)</td>
<td>52.0</td>
<td>70.4</td>
<td>60.19</td>
<td>4.02</td>
<td>6.68</td>
</tr>
<tr>
<td>Surface area (S), cm(^2)</td>
<td>67.49</td>
<td>82.52</td>
<td>74.26</td>
<td>3.33</td>
<td>4.48</td>
</tr>
</tbody>
</table>

**TABLE 2. Single and multiple correlations between egg geometrical parameters and the coefficients calculated by equations [7] and [8]**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>(k_V)</th>
<th>(k_S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg length (L)</td>
<td>-0.09</td>
<td>-0.64</td>
</tr>
<tr>
<td>Egg maximum breadth (B)</td>
<td>-0.27</td>
<td>0.10</td>
</tr>
<tr>
<td>(B) to (L) ratio</td>
<td>-0.09</td>
<td>0.70</td>
</tr>
<tr>
<td>Multiple correlation with: (L) and (B)</td>
<td>0.27</td>
<td>0.71</td>
</tr>
</tbody>
</table>

\(^2\)Technical Services & Supplies Ltd., York, United Kingdom.

\(^3\)Harkov Instrument Plant, Harkov, Ukraine.

TABLE 3. The coefficients of determination and final loss function derived from the egg volume and surface area calculations by different equations

<table>
<thead>
<tr>
<th>Egg volume calculation</th>
<th>Egg surface area calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R^2$</td>
<td>0.955</td>
</tr>
<tr>
<td>Final loss</td>
<td>489.75</td>
</tr>
<tr>
<td></td>
<td>0.954</td>
</tr>
<tr>
<td></td>
<td>77.87</td>
</tr>
</tbody>
</table>

a function $f(B)$, and $k_S$ by a function $f(B/L)$ or $f(L, B)$. The results of the approximation were as follows:

$$k_V = 0.6057 - 0.0018B$$  \[11\]

$$k_S = 0.9658 \frac{B}{L} + 2.1378$$  \[12\]

$$k_S = 3.155 - 0.0136L + 0.0115B$$  \[13\]

in which $B$ and $L$ are taken in millimeters. Considering the obtained equations [11] to [13], equations [1] and [2] can be rewritten as

$$V = (0.6057 - 0.0018B)LB^2$$  \[14\]

$$S = \left(0.9658 \frac{B}{L} + 2.1378\right)L$$  \[15\]

$$S = (3.155 - 0.0136L + 0.0115B)LB$$  \[16\]

The measured values of $B$ and $L$ were substituted in equations [6], [9], [14] to [16], and the calculated means of egg volume and surface area were compared with those derived from our measurements. Fitting criteria were estimated as coefficients of determination $R^2$ and goodness-of-fit, determined as a final loss $L_f$ of a loss function: sum of observed minus predicted data in the second power. The results of the calculations are shown in Table 3.

Results of the approximation showed that all evaluated formulae for $V$ and $S$ calculations fit the experimental data well. The values of all the coefficients of determination were rather high and identical to each other. Therefore, the final loss function becomes a more appropriate index for comparing the results of the calculations. The less $L_f$, the more accurate the obtained result appears to be. The most accurate calculations were observed using equation [14] for the volume ($L_f = 61.35$) and equation [16] for the surface area ($L_f = 38.73$) estimations. That stipulates the reasonability of their usage in practice. Equations [9] and [10] are accurate too: $L_f = 67.24$ for $V$ and $77.87$ for $S$ calculations. However, it is not permissible to use these formulae in practice, because the constant coefficients were averaged according to the data of the given investigated sample. The theoretically deduced equation [6] gave the highest meaning of $L_f$ 489.75, but has merit in expressing all possible variations of all kinds of avian eggs that can be observed in nature.

REFERENCES


