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ON THE EVALUATION OF CHICKEN EGG SHAPE VARIABILITY

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Abstract

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Although recently reported models for determining egg shape are highly accurate, certain complicated measurements or computations are to be performed. Thus relatively simple and attainable analysis methods of chicken egg shape variability were chosen and used for the purpose of presented research. Sample of 250 eggs of ISA BROWN strain was examined. Geometrical parameters were measured and calculated with following expression of their coefficient of variation – namely egg length 3.56 %, egg maximum width 2.84 %, shape index 3.80 %, surface area 5.08 %, and egg volume 7.23 %. The second method consisted in shape quantitative measuring by the score of the principal components of elliptic Fourier descriptors (EFDs). The first four principles components which could explain over 99 % of the egg shape variations were found to be very good measures of the monitored phenomenon. It was found that 87.41 % of the total shape variation can be accounted to length to width ratio. Usefulness and relevance of the shape index usage was confirmed.

chicken egg, shape variability, elliptic Fourier analysis

Description of chicken egg shape is important for numerous applications and studies. Generally, when talking about avian eggs (both domestic and wild species), the knowledge of their geometric parameters is relevant to a number of studies, such as population and ecological morphology (Mänd, 1998), predicting chick weight (Narushin et al., 2002), egg hatchability (Narushin and Romanov, 2002), shell quality (Altuntaş and Şekeroğlu, 2008), egg interior parameters, avian biology, taxonomy, classification, reproduction, poultry selection, genetics, and processing.

There is a natural variability in egg shape. High variability of egg shapes creates difficulties in their description. Egg shape evaluation can be performed by two ways: (a) by mathematical equations, and (b) by different indices, which show the deviation of a true shape from some model object. Characterization of egg's shape by use of two indices: (a) egg length to a maximum width ratio (shape index) and (b) the ratio of long and short sections of the longitudinal axis of the egg after division by the axis of maximum diameter, was proposed by Schonwetter (1960). Other indices were used by Kostin, 1977 (index of displacement of the axis of maximum diameter from the middle point of egg length, index of pear-shapedness, index of conicity); Myand, 1988 (index of sphericity, oviformity, pear-shapedness, plumpness); Klimov, 1993 (index of equality, index of zone differences, index of roundness; Narushin, 2001 (index of ellipticity and conicity), and others.

Usage of the indices, which reflect all possible variations in egg shape, leads to a contradiction: on one hand, it is necessary to use as many indices as possible for better description of the egg shape, and on the other hand, a large number of indices leads to an unjustified variability of the investigated sample of eggs, making it increasingly difficult to choose either typical characteristics for the given species, or the tendency of their variability (Narushin, 2001).

The aim of presented research is to perform and combine two simple but satisfactory methods of chicken egg shape variability evaluation, namely (i) variability of SI, completed for calculated variability of egg volume and area (based on formulas of Narushin, 2001, 2005), and (ii) shape variability determined by analytical software Shape 1.3 (based on elliptic Fourier descriptors and developed by Iwata and Ukai, 2002).

The second method was recently applied with success for description of numerous biological shapes

(Toayohara et al., 2000; Iwata et al., 2002b; Yoshioka et al., 2004; Yoshioka et al., 2006 and other). The method describes the entire shape mathematically through transforming coordinate information concerning its contour into Fourier coefficients.

MATERIALS AND METHODS

For the purpose of experiment, a sample of 250 fresh eggs was collected. The eggs were laid in 52[nd] week of age by the hens of ISA BROWN strain.

Egg geometry calculated from length (L) and width (W)

The lenght L of egg longitudinal axis and maximum width W were measured by digital micrometer SOMET (Germany). With regard to measurement accuracy and relevance, two decimal numbers were considered. Accurate direct measuring of egg surface represents rather difficult problem (Narushin, 1997b). Thus different formulas using different coefficients and values were proposed. Generally, a formula for egg surface S calculating can be expressed as

$$S = k_s LB,$$

where k_s is a calculating coefficient. The correlation analysis (Narushin, 2005) indicated that egg surface calculation may be improved by approximation of k_s by a function f(W/L). The results of the approximation were:

$$k_s = 0.9658 \frac{W}{L} + 2.1378,$$

where W and L values are in mm. Obtained equation can be used for rewriting original equation which yields in:

$$S = \left(0.9658 \frac{W}{L} + 2.1378\right) LW.$$

The same approach was used for calculation o egg volume. General formula is expressed as

$$V = k_v LW^2,$$

where k_v is a coefficient for volume calculation. Similar method as in the case of egg surface calculation led to expression of k_v as:

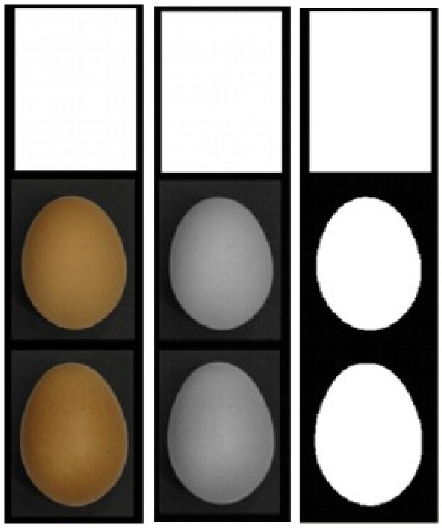
$$k_v = 0.6057 - 0.0018W$$

with rewritten form of V calculation

$$V = (0.6057 - 0.0018)LW^2.$$

Evaluation of variation of egg shape based on image analyses using elliptic Fourier analyses

The digital images with resolution of 180 dpi were acquired using a digital camera Olympus SP-560UZ (Olympus, Japan). The raw images were converted to full color (24-bit) bitmap format. This procedure was followed by converting the images to grey scale. The grey scale images were converted to binary images in which the objects and background are represented as 1 (white) and 0 (black), respectively. Example of image processing is given in Fig. 1.



1: *Raw images, grey scale images, and binary images. The white rectangle situated in the top of the picture represents a measure scale*

The image analysis software Shape (Iwata and Ukai, 2002) was used to perform all following steps. The closed contours of the eggs were obtained through binary images with appropriate tresholds, and were described by a chain-code (Freeman, 1974). Namely, each contour was represented as a sequence of x and y coordinates of ordered points that were measured counter-clockwise from an arbitrary starting point. Assuming that the contour between the (i – 1)-th and i-th chaincoded points is linearly interpolated, and that the length of the contour from the starting point to the p-th point and the perimeter of the contour are denoted by the t_p and T, respectively, then

$$t_p = \sum_{i=1}^{p} \Delta t_i$$

and $T = t_K$, where Δti and K are the distance between (i – 1)-th and i-th points and the total number of chain-coded point of the contour, respectively. Notice that the K-th point is equivalent to the starting point. The x and y coordinates p-th point are

$$x_p = \sum_{i=1}^{p} \Delta x_i$$

and

$$y_p = \sum_{i=1}^{p} \Delta y_i,$$

where Δx_i and Δy_i are the distances along x and y axes between $(i-1)$-th and i-th point. Thus, the elliptic Fourier expansions of the coordinates on the contour are

$$x_p = A_0 + \sum_{n=1}^{\infty}\left(a_n \cos\frac{2n\pi t_p}{T} + b_n \sin\frac{2n\pi t_p}{T}\right)$$

and

$$y_p = C_0 + \sum_{n=1}^{\infty}\left(c_n \cos\frac{2n\pi t_p}{T} + d_n \sin\frac{2n\pi t_p}{T}\right)$$

The elliptic Fourier coefficients of the n-th harmonic (a_n, b_n, c_n, d_n) are given as

$$a_n = \frac{T}{2n^2\pi^2}\sum_{p=1}^{K}\frac{\Delta x_p}{\Delta t_p}\left(\cos\frac{2n\pi t_p}{T} - \cos\frac{2n\pi t_{p-1}}{T}\right),$$

$$b_n = \frac{T}{2n^2\pi^2}\sum_{p=1}^{K}\frac{\Delta x_p}{\Delta t_p}\left(\sin\frac{2n\pi t_p}{T} - \sin\frac{2n\pi t_{p-1}}{T}\right),$$

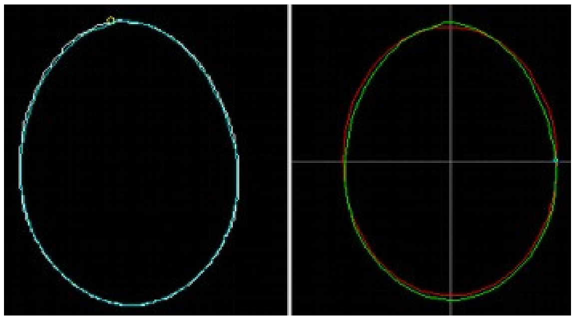
$$c_n = \frac{T}{2n^2\pi^2}\sum_{p=1}^{K}\frac{\Delta y_p}{\Delta t_p}\left(\cos\frac{2n\pi t_p}{T} - \cos\frac{2n\pi t_{p-1}}{T}\right)$$

and

$$d_n = \frac{T}{2n^2\pi^2}\sum_{p=1}^{K}\frac{\Delta y_p}{\Delta t_p}\left(\sin\frac{2n\pi t_p}{T} - \sin\frac{2n\pi t_{p-1}}{T}\right).$$

The same method was used for petal shape variation analysis (Yoshioka et al., 2004). The coefficients of elliptic Fourier descriptors that were normalized to avoid variations related to the size, rotation, and starting point of the contour traces, were then calculated from the chain-code through the procedure based on the ellipse of the first harmonic (Kuhl and Giardina, 1982). By this procedure, the egg shape was approximated by the first 20 harmonics, which correspond to the 77 coefficients of normalized elliptic Fourier descriptors. Example of egg countour visualization is given in Fig. 2.

To summarize the information contained in the coefficients of the Fourier descriptors, the principal components analysis based on a variance-covariance matrix of the coefficients was performed. The scores of the components were used in subsequent analysis as egg shape characteristic. The variation in shape accounted for by each component was visualised using inverse Fourier transformation (Rohlf and Archie, 1984; Furuta et al., 1995).



2: *Selected egg's contour visualization*

RESULTS AND DISCUSSION

Table I lists the basic statistics of performed measurements and calculations. The least variable egg parameter was egg width W with coefficient of variation of 2.84 %, followed by egg length L with coefficient of variation equal to 3.56 %. Egg surface area S and volume V exhibited higher values of variation coefficients, 5.08 and 7.23 %, respectively. Generally, V and S can be calculated with use of average values of coefficients k_v and k_s. Average value of $k_v = 0.524$ corresponds to the values mentioned in literature $k_v = 0.523$ (Ayupov, 1976) and $k_v = 0.525$ (Narushin, 2005). Other values of k_v were proposed by Narushin, 1997b and Hoyt, 1979.

I: *Measurements and calculated egg geometrical parameters*

Parameter	Minimum value	Maximum value	Average	Standard deviation (±)	Coefficient of variation (%)
Egg length L [mm]	53.12	66.51	58.82	2.10	3.56
Egg maximum width W [mm]	41.31	47.89	44.81	1.27	2.84
Shape index (W to L ratio)	0.69	0.84	0.76	0.03	3.80
Coefficient k_s	2.795	2.944	2.864	0.028	0.98
Calculated surface area S [cm^2]	66.96	86.68	75.52	3.83	5.08
Coefficient k_v	0.519	0.531	0.526	0.002	0.44
Calculated egg volume V [cm^3]	52.15	75.07	62.10	4.49	7.23

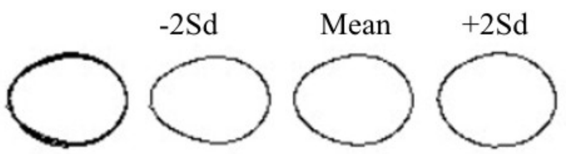
One of the instruments often used for description of egg shape is shape index. Eggs are characterized by the SI as sharp, normal (standard) and round if they have an SI value of <0.72, between 0.72 and 0.76, and >0.76, respectively (Sarica and Erensayin, 2004). SI index of the standard egg of the ovoid shape is 0.75. The ideal value of SI index for industrial processing and packaging lies in the range 0.7–0.8 (Nedomová, 2007). Dependence of SI index on hen strain was confirmed (Monira et al., 2003). Monitored sample of 250 eggs included 7.2 % of sharp eggs, 49.6 % of normal eggs, and 43.2 % of round eggs. Calculation of standard deviation led to the value of 0.03. Coefficient of variation was quantified as 3.80 %. This value essentially describing the variation of egg shape is in accordance with other findings mentioned in literature such as 3.00 % (Clerici et al., 2006), 3.47 % (Narushin, 2005), and 4.09 % (Zhang et al., 2005).

Comparative analyses of eggs' shape variability was performed by image analysis, employing principal components analysis of elliptic Fourier descriptors. The mean egg shape was drawn using the mean values of the standardized Fourier coefficients. The first five principal components provide a good summary of the data, accounting for 100 % of the total variance (Table II).

II: *Eigenvalues and contributions of principal components*

Component	Eigenvalue	Proportion (%)	Cumulative (%)	Indicator
1	1.67 . 10-4	87.41	87.41	length to width ratio
2	1.12 . 10-5	5.85	93.26	position of the center of gravity
3	7.67 . 10-6	4.01	97.27	curvature
4	3.74 . 10-6	1.96	99.23	degree of roundness
Total variance	1.91 . 10-4			

Fig. 3 shows the visualization of the effect of first principal component on egg shape. The coefficients of the elliptic Fourier descriptors were re-calculated inversely. An eigen-vector matrix was used, letting the score on a particular principal component be equal to the mean ± 2 s.d. (standard deviation). For the purpose of clearness, three randomly selected eggs were included. Reconstructed shapes indicated that the first principal component (which represents length to width ratio) is very good measure of the the total shape variation. It represents 87.41 % of the total shape variation.



3: *Example of effect of principal component on egg shape. The left-hand element shows the overlaid drawings of all three samples (see text for explanation). Following drawings represent the case where the score takes –2 s.d. (standard deviation), mean, or +2 s.d. as labeled.*

There are two major advantages of using elliptic Fourier descriptors and principal component analysis. Firstly, this approach can accurately detect small shape variations. The contributions of the second, third and fourth principal components to the total variance were 5.85 % (position of the center of gravity), 4.01 % (curvature), and 1.96 % (degree of roundness), respectively (Table 2). Detection of rather small variations are difficult for humans, but the analyses based on the component scores can clearly detect significant variations among individual eggs. Secondly, the analyses can evaluate the shapes of objects independently of size. This independence is a great advantage because human visual judgment of shape is often deceived and misled by size factors.

Dominant importance and relevance of shape index as a determining parameter of egg shape was thus quantitatively confirmed. Although there is a number of other shape or contour analyses methods based on different mathematical techniques (Baker, 2002; Bartoň and Křivánek, 2001; Chen and Nelson, 2004; Todd, 1985), the above mentioned method represents relatively simple but powerful interpretation tool which suits perfectly for evaluating of biological shapes.

SUMMARY

There is a natural variability in avian egg shapes (both domestic and wild species). Highly accurate methods for description of egg shape are available but complicated measurements must be performed in order to achieve satisfying results. Presented paper is aimed on evaluation of chicken egg shape using simple, accessible approaches. Sufficiently large group of eggs (250 pieces) laid by Isa

Brown strain in 52nd week of age has been collected and examined. Basic geometrical parameters have been measured and calculated, namely egg length, maximum width, shape index, surface area, and egg volume. Average values, values of standard deviation and values of coefficient of variation have been calculated. Concerning surface calculation, the correlation analysis (Narushin, 2005) proven the possibility of approximation of ks (calculating coefficient) by a function f(W/L). The results of the approximation were: $k_s = 0.9658\,\frac{W}{L} + 2.1378$ and $S = \left(0.9658\,\frac{W}{L} + 2.1378\right) LW$. Similar procedure was applied for volume calculation with satisfying result of $k_v = 0.6057 - 0.0018W$ and $V = (0.6057 - 0.0018)LW^2$. The second method was based on quantitative measuring of shape by means of elliptic Fourier descriptors (EFDs). It was found that more than 99 % of the egg shape variations can be explained by first four principles components and over 87 % of the total shape variation can be accounted to length to width ratio. It was verified by both approaches that simple but satisfactory description of egg shape is possible.

SOUHRN

Hodnocení variability tvarů slepičích vajec

Pro popis tvaru slepičích vajec byly vytvořeny velice přesné modely. Jejich použití je ovšem podmíněno komplikovaným měřením a výpočty. V předkládané práci jsou hodnoceny dvě relativně jednoduché metody, jejichž pomocí je možno hodnotit variabilitu tvarů vajec. Zkoumáno bylo celkem 250 kusů vajec plemene Isa Brown. Byly změřeny a vypočteny základní geometrické parametry. Korelační analýza potvrdila možnost aproximace výpočtových koeficientů ks s možností uspokojivých výsledků při výpočtu plochy povrchu a objemu vajec. Dále byly vyjádřeny variační koeficienty měřených a vypočtených hodnot, které měly následující hodnoty: délka vajec 3,56 %, maximální šířka vajec 2,84 %, index tvaru 3,80 %, plocha povrchu 5,08 % a objem 7,23 %. Druhá metoda spočívala v kvantitativním hodnocení tvaru vajec pomocí vyjádření hlavních komponent eliptické Fourierovy analýzy. Pro získání vstupních dat byly použity digitální fotografie vajec. První čtyři Fourierovy deskriptory zahrnují více než 99 % variability tvaru vajec a jsou tak vynikajícím nástrojem pro popis a hodnocení sledovaného fenoménu. Bylo zjištěno, že více než 87 % celkové variability tvaru je možno vysvětlit pomocí poměru délky a šířky.

slepičí vejce, variabilita tvarů, eliptická Fourierova analýza

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