Effects of selection on allometric relationships between egg components and egg weight in Japanese quails of different lines

Einfluss der Selektion nach allometrischen Beziehungen zwischen Eibestandteilen und dem Eigewicht bei verschiedenen Linien japanischer Wachteln

S. Alkan¹, M. Mendes², K. Karabag³ and T. Karsli¹


Introduction

Intraspecific egg composition may vary depending upon the size of the egg (Ricklefs, 1984; Alisauskas, 1986; Hepp et al., 1987; Hill, 1988; Arnold et al., 1991). Statistical techniques derived from allometry are used to examine the relationships between egg size and egg composition (Reiss, 1989). Typically, the log of egg component mass, such as wet albumen, is regressed on the log of egg mass (log[y] = log[a] + b log[x]). The slopes of these functions depict the rate at which the egg component varies with egg size. When the slope of a log-log function is equal to 1.0 (isometry), the percentage of egg component remains constant across different sizes of eggs. Slopes greater than 1.0 (positive allometry) indicate that the component mass increases disproportionately by rising egg mass. Accordingly, large eggs proportionately contain more component mass than small ones. Contrary, slopes less than 1.0 (negative allometry) demonstrate that components increase proportionately less than egg mass, so that large eggs consist of relatively small amounts of the egg component.

Egg, a major poultry product, is mainly composed of albumen, yolk and egg shell (Abanikannda and Leigh, 2007). The yolk contains all the fat and most of the vitamins in the egg. The eggs as cheap and readily available sources of protein in developing countries can not be overemphasized and the contribution of major constituents of egg i.e. albumen and yolk to dietary intakes of humans have been well documented (Orji et al., 1998; Kürşhid et al., 2005).

Intraspecific variation in egg composition and its allometric relationship with egg weight as a result of differences in sizes of eggs has been well studied (Dzialowski and Sotherland, 2004; Hill, 1995; Arnold et al., 1991). Intraspecific variation in egg has been attributed to several factors such as heritability, size and nutritional status of hen, feed availability, laying sequence and some combination of these factors (Alisauskas, 1986; Quinney, 1983). Allometric relationships between egg components and egg mass were studied altricial-precocial birds, earlier (Abanikannda and Leigh, 2007).

Materials and Methods

Japanese quails used in this research have been taken from a selection experiment running for 11 generations at Akdeniz, University Faculty of Agriculture in Turkey. The experiment comprises two selection lines on high (HL) or low (LL) 5-weeks body weight, a random bred control line (C) and a layer line (L) selected for 120 d egg production. The lines were established by applying individual selection with 10% and 40% selection intensity for males and females, respectively. Mating was random to minimize inbreeding.

Birds were housed in individual cages in a quail house with windows at both sides, exposed to 16 hours of light and 8 hours of darkness. During the experiment, quails were fed with a diet with 11.7 MJ/kg metabolizable energy (ME) and 210 g crude protein/kg. Feed and water was provided ad libitum during the experiment. A total of 60 eggs per line were examined for egg weight (g), egg length (mm), egg width (mm), yolk width (mm), yolk height (mm), albumen width (mm), albumen length (mm), albumen height (mm). Egg weights were measured by digital balance to the nearest 0.01 g. Egg width, egg length; yolk width, albumen length, and albumen width were measured by digital compass to the nearest 0.01 mm. Also, yolk height and albumen height were measured by micrometer to the nearest 0.01 mm.

Since, the relationship between egg component and egg weight shows no linear trend, there was a need for logarithmic transformation of raw data to obtain the allometric equation (Abanikannda and Leigh, 2007). Egg weight had a statistically significant effect on egg components (P < 0.01), while no significant effect was obtained for the other traits (P > 0.05). Therefore, the allometric relationships between egg component dimensions and egg weight were only investigated in this research. Furthermore, a simple allometric function was used to describe the relationships between...
Egg components and egg weight. Allometric growth equation (Huxley, 1932; Mendes, 2008) was described as follows:

\[ Y = ax^b \text{ or } \log(Y) = \log(a) + b \log(X) \]

where

- \( Y \): value dependent variables
- \( X \): value of independent variable
- \( a \): allometric constant or intercept
- \( b \): allometric growth coefficient or slope. The coefficient \( b \) is defined as the allometric coefficient. If \( b > 1 \), then \( Y \) is growing at a faster rate than \( X \) and vice versa (allometric growth). If \( b = 1 \), then growth of both components are similar or the same (isometric growth).

Coefficient of determination \( (R^2) \) and residual mean square error \( (\text{RMSE}) \) were used as goodness-of-fit criteria. One-way analysis of variance was used to test effect of lines (groups) with respect to allometric growth coefficient \( (b) \). NCSS statistical package program was used in the present statistical analyses (Hintze, 2001).

**Results and Discussion**

Average egg weights were determined as 14.2 ± 0.23 g, 9.27 ± 0.09 g, 10.5 ± 0.11 g and 11.6 ± 0.26 g in HL, LL, L and C lines, respectively. Significant differences \((P < 0.01)\) were observed among the lines with respect to egg weights. Also, there were found significant differences \((P < 0.01)\) among the lines in terms of \( b \)-parameters for egg traits. Allometric constant \((a)\), allometric growth coefficient \((b)\), coefficient of determination \((R^2)\) of egg traits on egg weight are presented in Tables 1 to 3.

Table 1 shows significant differences for \( b \)-parameter \((P < 0.01)\). There was found a positive allometry in LL, L and C lines. Approximately isometry \((1.056)\) was only observed in HL line for \( b \)-parameter. The coefficients of determination \((R^2)\) were ranging from 0.155 to 0.771. The lowest \( R^2 \) was determined as 0.155 for C line, while the highest \( R^2 \) was obtained as 0.771 for HL line. The \( R^2 \) of egg width on egg weight was relatively high and this implies that egg weight was a good estimator of egg width for HL line. Also, there was positive allometry observed between egg length and egg weight for HL, L and C lines, and approximately isometry \((1.055)\) was observed only in LL line in terms of \( b \)-parameter. The differences among the lines for \( b \)-parameter were found to be significant \((P < 0.01)\). The coefficients of determination \((R^2)\) were ranging from 0.199 to 0.532. While the highest \( R^2 \) was found as 0.532 for HL line, the lowest \( R^2 \) was obtained as 0.199 for C line. The \( R^2 \) of egg length on egg weight was medium high and this emphasizes that egg weight was a moderate estimator of egg length for HL line. In general, egg width and egg length increased faster than egg weight in all lines for \( b \)-parameter.

As shown in Table 2, positive allometry \((1.094)\) was only determined for C line while a negative allometry was found between yolk height and egg weight for HL, L, and LL lines for \( b \)-parameter. Significant differences among

<table>
<thead>
<tr>
<th>Lines</th>
<th>Egg width = Y</th>
<th>Egg weight = X</th>
<th>Egg length = Y</th>
<th>Egg weight = X</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a</td>
<td>b</td>
<td>( R^2 )</td>
<td>MSE</td>
</tr>
<tr>
<td>HL</td>
<td>0.239</td>
<td>1.056 D</td>
<td>0.771</td>
<td>6.3E-05</td>
</tr>
<tr>
<td>LL</td>
<td>0.244</td>
<td>1.136 B</td>
<td>0.501</td>
<td>3.7E-05</td>
</tr>
<tr>
<td>L</td>
<td>0.204</td>
<td>1.188 A</td>
<td>0.275</td>
<td>1.2E-04</td>
</tr>
<tr>
<td>C</td>
<td>0.016</td>
<td>1.104 C</td>
<td>0.155</td>
<td>1.4E-04</td>
</tr>
</tbody>
</table>

A, B, C, D Means with different superscript within the same column are significant \((P < 0.01)\)

HL: High body weight line, LL: Low body weight line, L: Layer line, C: Control line

\( a \): Allometric constant, \( b \): Allometric coefficient, \( R^2 \): Coefficient of determination, MSE: Mean square error

Table 2 shows significant differences for \( b \)-parameter \((P < 0.01)\). There was found a positive allometry in LL, L and C lines. Approximately isometry \((1.056)\) was only observed in HL line for \( b \)-parameter. The coefficients of determination \((R^2)\) were ranging from 0.155 to 0.771. The lowest \( R^2 \) was determined as 0.155 for C line, while the highest \( R^2 \) was obtained as 0.771 for HL line. The \( R^2 \) of egg width on egg weight was relatively high and this implies that egg weight was a good estimator of egg width for HL line. Also, there was positive allometry observed between egg length and egg weight for HL, L and C lines, and approximately isometry \((1.055)\) was observed only in LL line in terms of \( b \)-parameter. The differences among the lines for \( b \)-parameter were found to be significant \((P < 0.01)\). The coefficients of determination \((R^2)\) were ranging from 0.199 to 0.532. While the highest \( R^2 \) was found as 0.532 for HL line, the lowest \( R^2 \) was obtained as 0.199 for C line. The \( R^2 \) of egg length on egg weight was medium high and this emphasizes that egg weight was a moderate estimator of egg length for HL line. In general, egg width and egg length increased faster than egg weight in all lines for \( b \)-parameter.

As shown in Table 2, positive allometry \((1.094)\) was only determined for C line while a negative allometry was found between yolk height and egg weight for HL, L, and LL lines for \( b \)-parameter. Significant differences among

<table>
<thead>
<tr>
<th>Lines</th>
<th>Yolk height = Y</th>
<th>Yolk width = X</th>
<th>Egg weight = X</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a</td>
<td>b</td>
<td>( R^2 )</td>
</tr>
<tr>
<td>HL</td>
<td>0.354</td>
<td>0.675 C</td>
<td>0.358</td>
</tr>
<tr>
<td>LL</td>
<td>0.371</td>
<td>0.663 C</td>
<td>0.196</td>
</tr>
<tr>
<td>L</td>
<td>0.236</td>
<td>0.788 B</td>
<td>0.181</td>
</tr>
<tr>
<td>C</td>
<td>-0.021</td>
<td>1.094 A</td>
<td>0.244</td>
</tr>
</tbody>
</table>

A, B, C, D Means with different superscript within the same column are significant \((P < 0.01)\)

HL: High body weight line, LL: Low body weight line, L: Layer line, C: Control line

\( a \): Allometric constant, \( b \): Allometric coefficient, \( R^2 \): Coefficient of determination, MSE: Mean square error
The differences among the lines for b-parameter were significant (P < 0.01). The coefficients of determination showed a moderate level and ranged from 0.162 to 0.404. The R² of albumen width on egg weight was relatively low and this implies that especially egg weight was a very weak estimator of albumen width for C line. But, there was found a positive allometry between albumen length and egg weight in HL, LL and C lines. Isometry (1.045) was only observed for L line. The differences among the lines in terms of b-parameter were significant (P < 0.01). The coefficients of determination were quite low and ranged from 0.176 to 0.301. The R² of albumen length on egg weight was relatively low and this implies that egg weight was no good estimator of albumen length for HL and C lines. While only albumen height showed higher growth than egg weight in HL line, lower growth was exhibited in LL, L and C lines. Albumen width exhibited higher growth than egg weight in LL, L and C lines, and lower growth was only obtained in HL line in term of b-parameter. But, except for LL line, albumen length showed higher growth than egg weight in HL, L and C lines in respect to b-parameter. Dzialowski and Sotherland (2004), Hill (1995) and Alisauskas (1986) reported positive allometry of albumen weight on egg weight in altricial birds, but negative allometry of albumen weight in precocial birds. Also, Ricklefs (1984) found for altricial European Starling that albumen content varied isometrically with egg weight, whereas yolk and lipid weight displayed negative allometry. Hence, the percentage of albumen remained more or less constant in eggs of different sizes, but the percentage of yolk and lipid decreased with increasing egg size. In contrast, Anney (1980) demonstrated for precocial Lesser Snow Goose that both albumen and yolk varied isometrically with egg size. Large eggs contained proportionately greater amounts of dry yolk and lipid in Mute swans (Birkhead, 1984), Mallards (Birkhead, 1985), American Coops (Alisauskas, 1986), and Blue-wing Teal (Rohwer, 1986), implying that chicks from these eggs could have larger yolk reserves. Large Ruddy Duck eggs produced heavier ducklings with proportionately greater yolk reserves, and this may partly explain why wild Ruddy Duck ducklings hatching from large eggs had better body condition (Pelayo, 2001).

Generally, negative allometry was found between yolk height and egg weight in terms of b-parameter in HL, LL and L lines, except C line. Negative allometry was only determined for yolk width and egg weight in respect to b-parameter in HL line. Also, only positive allometry was found between albumen height and egg weight in HL line, but negative allometry was only determined in HL line.

Table 3. Allometric constant (a), allometric growth coefficient (b), coefficient of determined (R²) of albumen height, albumen width and albumen length on egg weight

<table>
<thead>
<tr>
<th>Lines</th>
<th>Albumen height = Y</th>
<th>Egg weight = X</th>
<th>Albumen width = Y</th>
<th>Egg weight = X</th>
<th>Albumen length = Y</th>
<th>Egg weight = X</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a</td>
<td>b</td>
<td>R²</td>
<td>MSE</td>
<td>a</td>
<td>b</td>
</tr>
<tr>
<td>HL</td>
<td>-0.493</td>
<td>1.201</td>
<td>A</td>
<td>0.285</td>
<td>8.1E-02</td>
<td>0.877</td>
</tr>
<tr>
<td>LL</td>
<td>0.149</td>
<td>0.443</td>
<td>D</td>
<td>0.287</td>
<td>2.9E-03</td>
<td>0.354</td>
</tr>
<tr>
<td>L</td>
<td>-0.333</td>
<td>0.581</td>
<td>C</td>
<td>0.265</td>
<td>5.1E-05</td>
<td>0.354</td>
</tr>
<tr>
<td>C</td>
<td>-0.028</td>
<td>0.678</td>
<td>B</td>
<td>0.222</td>
<td>3.04E-04</td>
<td>0.013</td>
</tr>
</tbody>
</table>

A, B, C, D Means with different supercript within the same column are significant (P < 0.01)

HL: High body weight line, LL: Low body weight line, L: Layer line, C: Control line

a: Allometric constant, b: Allometric coefficient, R²: Coefficient of determination, MSE: Mean square error
between albumen width and egg weight. The highest coefficient of determination was found between egg width and egg weight (0.771). Obviously, selection affected lines in different ways in terms of allometric relationships between egg components and egg weight. The $R^2$ of albumen height on egg weight was relatively low in all lines and this implies that egg weight was no good estimator for albumen height.

Consequently, if large eggs are proportionally similar to small eggs, then they will contain higher absolute amounts of essential nutrients than small eggs. Moreover, large eggs might have even greater advantages if they proportionally contain more nutrients than small eggs, as variation in egg composition within species can affect developmental characteristics of chicks (Hill, 1993; SOTHERLAND et al., 1990). It is suggested that researchers investigate further the potential impact of these allometric patterns for selected quails in different developmental conditions.

Acknowledgement

This study was financially supported by the Scientific Research Projects Unit of Akdeniz University under the project number of 2005.01.0104.007.

Summary

The purpose of this study was to determine allometric relationships between egg components and egg weight in 11 generations of selected Japanese quails from different lines. The birds were obtained from four genetic lines selected for 11 generations for either high (HL) or low body weight (L) at five weeks of age, a randomly bred control line (C) and a layer line (L) selected for egg production over 120 days.

Significant differences were observed among lines for egg width, egg length, yolk width, yolk height, albumen width, albumen height and albumen length with respect to b-parameter. Positive allometry was determined for egg width, egg length and albumen length for all lines. After all, negative allometry was found for yolk weight in HL, LL, L lines, for yolk width in HL line, for albumen height in LL, L, C lines, and for albumen width in HL line. The highest coefficient of determination was determined as 0.771 between egg width and egg weight in HL line.

Key words

Quails, egg components, egg weight, allometry

Zusammenfassung

Einfluss der Selektion nach allometrischen Beziehungen zwischen Eibestandteilen und dem Eigewicht bei verschiedenen Linien japanischer Wachteln


Stichworte

Wachtel, Eibestandteile, Eigewicht, Allometrie

References


Alkan et al.: Effects of selection on allometric relationships in Japanese Quails of different lines 125


PÉLAYO, J.T., 2001: Correlates and consequences of egg size variation in wild Ruddy Ducks (oxysura jamaicensis). M.Sc. thesis, University of Saskatchewan, Saskatoon, SK.


Correspondence: Assist. Prof. Dr. Sezai Alkan, Akdeniz University, Faculty of Agriculture, Department of Animal Science, 07059 Antalya, Turkey. E-mail: sezaialkan@akdeniz.edu.tr

Impressum

74. Jahrgang

Redaktion: Prof. Dr. M. Grashorn (V. i. S. d. P.), Institut 470, FG Nutztierelektologie und Kleintierzucht, Universität Hohenheim, D-70593 Stuttgart, Germany, E-Mail: grashorn@uni-hohenheim.de
Verlag: Eugen Ulmer KG, Postfach 70 05 61, 70574 Stuttgart, Telefon (07 11) 45 07-0, Telefax (07 11) 45 07-120 Hausanschrift: Wollgrasweg 41, 70599 Stuttgart (Hohenheim), E-Mail: info@ulmer.de, UST-ID: DE147639185
Herstellung: Petra Klein
Vertriebsleitung: Detlef Noffz
Abo-Service: Gitta Bieber, Sylvia Brauner, Tel. (0711) 4507-121

Druck: Druckhaus „Thomas Müntzer“ GmbH, Neustädter Str. 1-4, 99947 Bad Langensalza.


Pressespiegel: Für die Übernahme von Artikeln in interne elektronische Pressespiegel erhalten Sie die erforderlichen Rechte unter www.presse-monitor.de oder telefonisch unter 030/284330, Presse-Monitor Deutschland GmbH & Co. KG

Diese Zeitchrift wird von Current Contents (Series Agriculture, Biology & Environmental Sciences), SciSearch und vom Science Citation Index (SCI) erfasst. This journal is covered by Current Contents (Series Agriculture, Biology & Environmental Sciences), SciSearch and is included in the Science Citation Index (SCI).