Repeatability estimates of egg weight and egg-shell weight under various production periods for Bovan Nera Black laying chicken

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ABSTRACT

The present research was designed to examine the repeatability estimates of egg weight and egg shell weight of exotic layers at 25, 51, 72 weeks and overall ages of the bird. For this purpose, thirty birds were selected from the flock of layers in the Babcock University Teaching and Research Farm. A total of thirty (30) eggs were collected daily from the birds continuously for five (5) days of egg production, at each age 25, 51 and 72 weeks. The total number of eggs collected at each age was 150 and 450 for the total of three age periods. Data were collected on egg production traits for egg weight and egg shell weight. The mean values of the egg quality traits revealed an apparent increase for egg weight 55.02–63.29 g and egg shell weight 6.36–7.81 g with a corresponding mean combined data of bird of 60.17 g for egg weight and 7.26 g for egg shell weight. A significant positive genetic correlation was obtained among traits with linear regression equations at different age groups. General linear model procedure of statistical analytical system was used to obtain the variance components for the estimation of repeatability. High repeatability estimates were obtained when the age variance was included in the computation and low to moderate estimates were registered when the age variance was excluded from the computation. Since repeatability estimates from various production periods of egg weight and egg shell weight were low to moderate, these traits can be improved by mass selection there culminating in egg production with optimal quality.

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1. Introduction

Poultry farming is one of the steadfastly growing section of the livestock production segment of the Agricultural sector in Nigeria. It contributes immensely to the three major economy sectors (Petroleum, mining and agriculture) and has evolved from subsistence farming to an extremely business oriented enterprise. This transformation could be attributed to the widespread of the necessity of animal protein intake per day of an average Nigerian and estimating genetic parameters especially heritability estimates of internal and external egg quality traits of exotic and local chickens thereby improving quality and overall growth rate considering the economic need to increase egg size and improve the post low value of the chickens to march the protein requirement of the teeming population and overall growth rate considering the economic need to increase egg size and improve the post low value of the chickens to march the protein requirement of the teeming population especially heritability estimates of internal and external egg quality traits of exotic and local chickens thereby improving quality and overall growth rate considering the economic need to increase egg size and improve the post low value of the chickens to march the protein requirement of the teeming population.

2. Materials and methods

2.1. Location of study

The experimental site, Ilara, is located at the Teaching and Research Farm of Animal Science Department, Babcock University. Ilara is situated between Latitude 6.867°N and Longitude 3.717°E with an altitude of 235.2 meters above sea level in Tropical rainforest belt of Nigeria. It has an annual rainfall of 1200 mm, 65% mean relative humidity and 21.4 °C mean temperature. The research lasted for 54 weeks (John-Jaja et al., 2016b).

2.2. Experimental birds and management

Day old chicks were randomly selected and purchased from the base population of Nera Black chickens, and kept on little till 18 weeks before they are moved to the battery cage. The chicks were protected from cold during the first four weeks of developmental processes. During lay, the birds were fed twice daily and water was administered accordingly with compounded ration containing 16% crude protein, other constituents of their feed includes vitamins, minerals and amino acid. Water was provided. At inception, birds were quarantined separately for 7 days and dewormed. The chickens were randomly selected based on their health conditions after being quarantined separately for 7 days and were dewormed appropriately. The birds were routinely vaccinated at various stages of development against diseases such as Newcastle, Gumboro and Coccidiosis. Thirty (30) eggs were collected daily in the morning at 8am, afternoon at 2 pm and then the final collection was made in the evening at 6.00 pm for five (5) days of egg production at 25, 51 and 72 weeks of age. One hundred and fifty (150) eggs were collected for three age groups (25, 51 and 72 weeks) and 450 for the overall ages of the birds for egg yolk weight and albumen weight.

2.3. Experimental design

Two experimental designs were adopted in the course of this study viz: completely randomized design (CRD) and visual appraisal. CRD was used to select healthy layers after quarantine and vaccination while visual appraisal was employed to select a total of thirty (30) layers capable of laying 5–6 eggs weekly; and rest for 1–2 days after monitoring their laying cycle and patterns between 21 and 24 weeks. Randomization was performed using a random number table computer program (i.e. number of treatments and replicates is only limited by the available number of experimental units) (John-Jaja et al., 2016a, 2016b).

2.4. Measurement of external egg quality traits

The external egg quality traits such as egg weight and egg shell weight were measured using a 0.09 sensitive digital scale. This was done by gently placing the egg on the flat surface of the scale ensuring that the scale was set to 0.0 g before measuring the egg weight. In order to determine the egg shell weight, the content of the eggs were emptied, the shell was thoroughly washed in running water, dried for two hours at 105 °C with the shell membrane intact, and weighed on an analytical scale to the nearest two decimal place (0.0 g).

2.5. Statistical model and data analysis

2.5.1. Effects of age on egg quality traits

The least squares means with the corresponding overall mean and their respective standard error were estimated for egg weight and egg shell weight using Statistical Analytical System program.

2.5.2. Models for repeatability estimates

The variance components that were used for the estimation of repeatability were evaluated using the method of paternal...
half-sib correlation analysis adopted to multiparous species, given by Becker (1984). For the pooled data each trait was analyzed using two models. Model 1 considers only the bird variance and model 2 included both the bird and the age variances as shown below. The age variances estimated were removed from the computation of repeatability in model 2 (John-Jaja et al., 2016a, 2016b).

Model 1: \( Y_{ij} = \mu + \alpha_i + e_{ij} \)  

Model 2: \( Y_{ijk} = \mu + \alpha_i + \beta_j + e_{ijk} \)  

\( Y_{ij} \) = The mean performance of ith bird  
\( Y_{ijk} \) = The mean performance of ith bird and jth age variance  
\( \mu \) = Overall mean  
\( \alpha_i \) = Random direct genetic effect of hen i  
\( \beta_j \) = Effect of age variance j (25, 51 and 72 weeks of age)  
\( e_{ij} \) and \( e_{ijk} \) = Random residual error

The components of variance were estimated by PROC VARCOMP (Procedure Variance Components) of (SAS, 1999) using Restricted Maximum Likelihood (REML) method. Repeatability coefficient was estimated using the following formulae (Becker, 1984).

\[ R = \frac{\hat{\sigma}_B^2}{\hat{\sigma}_B^2 + \hat{\sigma}_E^2} \]  

\( R \) = Repeatability using paternal half-sib correlation  
\( \hat{\sigma}_B^2 \) = Variance component of the Bird  
\( \hat{\sigma}_E^2 \) = Variance component (error)

The standard error (S.E.) of the estimation in this study is given by Becker (1984) as follows:

\[ S.E.(R) = \sqrt{\frac{2(1-R)^2[1+(K-1)R]}{k(k-1)(N-1)}} \]  

\( t = \frac{\hat{\sigma}_B}{\hat{\sigma}_{ab} + \hat{\sigma}_E} \)  

\( t \) = inraclass correlation  
\( \hat{\sigma}_{ab} \) = variance component (error)  
\( K \) = number of record per bird

### 3. Results and discussion

#### 3.1. Phenotypic least square means

The evaluated phenotypic least square means with standard error and coefficient of variation of egg weight and egg shell weight are presented in Table 1. The least square means of egg shell weight at 25, 51 and 72 weeks of age are significantly different at (P < 0.05) whereas egg weight was significantly the same with different magnitude. The least square means of egg shell weight at 72 weeks registered the highest value of 7.81 ± 0.07 which is significantly lower than 7.62 ± 0.06 recorded at 51 weeks and 6.36 ± 0.04 obtained at 25 weeks of age. This suggests that the environmental effects were large and marked observable genetic variation on the egg shell weight except for egg weight. Similar reports were recorded in literature. Paleja et al. (2008) observed that egg weight at 32, 40 and 56 weeks of age were significantly the same with the different values of 50.37, 51.65 and 52.43 respectively for white leghorn, Tadesse et al. (2015) recorded different values of least square mean of egg weight for intensive and village production systems for Isa Brown and Boran Brown having the same significant attributes. However, Khalil et al. (2013) observed varying values of both heart square means of egg weight and egg shell weight with an observable significant difference at (P < 0.05) for golden Montazah and white Leghorn breeds. This variation could be due to influence of environmental variance on the traits.

#### 3.2. Descriptive statistics of egg production traits

The mean egg weight and egg shell weight varied from one age group to another as shown in Table 1. This could be attributed to the genetic potential, and the prevailing environment factor influencing each trait studied and the age of the layers as age is a major factor that determines to a great extent the growth and physiological development of the traits. The mean egg weight recorded 55.02 g at 25 weeks, 62.20 g at 51 weeks and 63.29 g at 72 weeks with a corresponding mean value of 60.17 g for the overall ages of the hen indicating an increasing trend. These results are similar to 57.78 g recorded by Rath et al. (2015) for egg weight at 50 weeks of age for white lehorns; 48.1–63.9 g registered for single comb, while leghorn at 25–65 weeks of age reported by Chen et al. (1993); 50.01–53.89 g obtained for three pure lines and one control lines of white leghorns at 40 weeks by Sreenivas et al. (2013); 60.3–62.4 g recorded for white egg lines of Lohmann Tierzucht Gmbh at 67–70 weeks and Brown egg line of Lohmann Tierzucht Gmbh at 35–64 weeks by Sreenivas et al. (2013); 45.67–51.33 g reported for white leghorn (IWN line) at 25–56 weeks of age by Paleja et al. (2008); 60.6 g, 60.3 g and 61.1 g registered for ATAK-S commercial layers hybrids at 52 weeks of age employing incandescent bulb, mini fluorescent and light-emitting diodes by Kamanli et al. (2015); 58.0–62.1 g reported for white leghorn at 35–65 weeks of age by Ledur et al. (2002);

<table>
<thead>
<tr>
<th>Age of bird</th>
<th>N</th>
<th>Egg weight (M ± SE (g))</th>
<th>Egg shell weight (M ± SE (g))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall mean</td>
<td>450</td>
<td>60.17 ± 0.31</td>
<td>10.81</td>
</tr>
<tr>
<td>25</td>
<td>150</td>
<td>55.02 ± 0.40</td>
<td>8.83</td>
</tr>
<tr>
<td>51</td>
<td>150</td>
<td>62.20 ± 0.45</td>
<td>9.17</td>
</tr>
<tr>
<td>72</td>
<td>150</td>
<td>63.29 ± 0.47</td>
<td>8.77</td>
</tr>
</tbody>
</table>

\( a, b, c \) means in the same column with different superscript are significantly different \( P < 0.05 \) and \( N \), the number of observation.  
\( M \pm SE \) represents the mean and standard error, CV indicates coefficient of variation.
62.0–67.3 g observed for commercial layers at 28–73 weeks of age by Minelli et al. (2007); 58.75 g, 60.27 g and 48.8 g obtained for Isa Brown, Bovan Brown and Potchelstrum Koekoek breeds at 32 weeks of age by Tadesse et al. (2013); 51.09–61.04 g observed for Vanavojia male line (PDI) at 32–60 weeks of age by Padhi et al. (2015); 63.9 g–65.2 g for commercial layers at 60–80 weeks of age by Molnar et al. (2016); 64.78 g, 63.46 g and 47.79 recorded for Isa Brown, Novan Brown, Koekoek respectively under intensive production system and 58.92 g, 59.32 g and 47.53 g reported for Isa Brown, Bovan Brown and Koekoek respectively under village production system by Tadesse et al. (2015); 51.9–55.6 g for Isa Brown under graded dosage levels of Ovabolin (0 ug, 10 ug, 20 ug and 30 ug) at 69 weeks of age by Akitola et al. (2011); 61.58 g for white leghorn group and 60.72 g for Rhode Island Red at 38 weeks of age by Lukano et al. (2015); 56.6 g for young (22–29 weeks) and 68.6 g for old (83.99 weeks) of Lohmann Brown laying hens, 66.4 g for young (36–73 weeks) and 7.1.6 g for old (64–71 weeks) of Cobb 500 broiler breeders by Tumova and Goust (2012); 53.30 g and 56.72 g for Block Olympia and H and N Brown Nick breeds respectively between 36–46 weeks of age by (Ewa et al., 2005).

However, lower value 42.87 g was obtained for Iranian fowl at 30 weeks by Begli et al. (2010); 34.84 g for Onagadori breed and 41.01 g for white leghorn at 20–34 g for both breed, by Goto et al. (2015); 46.80 g and 39.83 g for Cobb 500 of Broller and Fayoumi breeds at 48 weeks of age by Islam and Dutta (2010); 44.0 g and 45.7 g for Golden Montazali and white leghorn respectively at 120 weeks by Khalil et al. (2013); whereas, Petek et al. (2008) reported higher values of 74.11 g, 73.20 g and 69.70 g for commercial brown egg laying hens under effects of non-feed removal molting methods (non-molting control, Barley and Alfalfa respectively). The variation could be attributed to the breed differences, the age of the layers and environmental temperature as recommended by Kitalyi, 1998.

There was a consistent increase in the standard error of egg weight at different age groups except at 72 weeks of age. At 25 weeks of age, 0.40 g was registered, 0.47 g at 51 weeks, 0.45 g at 72 weeks and 0.31 g at overall ages of the hen. These value, are similar with the report in literature. Begli et al. (2010) recorded 0.17 g; Khalil et al. (2013) registered 0.10–0.14 g for golden montazali and white leghorn breeds; 0.73–0.74 at 60 and 80 weeks of age by Molnar et al. (2016); 0.10–0.16 g between 32–60 weeks of age reported by Padhi et al. (2015); 0.26 g at 50 weeks for white leghorn by Rath et al. (2015); 0.42–0.48 g for three strains of white leghorn recorded by Sreenivas et al. (2013).

At 25 weeks of age the birds recorded the least coefficient of variation of egg weight value of 8.83% while at 51 weeks, the birds recorded the maximum value of 9.17% with a corresponding value of 10.81% for total age of the hen. These values are similar to the range of 8.9–9.98% reported by Mube et al. (2014), and 11.75% obtained by Begli et al. (2010); and 8.34% registered by Zhang et al., 2010.

The bird egg shell weight follows a successive increase as the age of the hen increases. At 25 weeks of age, egg shell weight recorded 6.36 g, 7.62 g and 8.81 g at 25, 51 and 72 weeks of age with a corresponding value of 7.26 g for the overall ages of the birds. These values are in agreement with 6.00 g at 28–32 weeks, 6.16 g at 47–50 weeks and 6.29 g at 70–73 weeks of age reported by Minelli et al. (2007); 6.00 g at 50 weeks reported by Rath et al. (2015); 6.91–7.81 g at 28–60 weeks of age in New Black breed; and 6.50–6.91 g for litter raised Hisex Brown at 60 weeks recorded by Tumova et al. (2011). However, lower values 5.05 g for Black Olympia breed and 5.34 g for H & N Brown Nick breed at 36–46 weeks of age obtained by Ewa et al. (2005); 4.45 g at 30 weeks of age for Iranian fowl by Begli et al. (2010); 4.75 g for Onagadori breed and 5.60 g for white leghorn at 20–34 weeks of age registered for both breeds by Goto et al. (2015); 4.32–5.12 g for four genetic groups in white leghorn breed at 40 weeks recorded by Sreenivas et al. (2013); and 5.5 g for both golden Montazali and white leghorn obtained by Khalil et al. (2013). These discrepancies could be attributed to the breed differences, the ages of the layers and environmental temperatures as recommended by FAO (1998).

Increasing trend was observed for the standard error of egg shell weight at different ages of the birds. At 25 weeks of age, 0.04 g was registered, 0.06 at 51 weeks, 0.07 g at 72 weeks and 0.05 g for the overall ages of the birds. These values are comparable to the report in literature. Khalil et al. (2013) reported 0.01 g and 0.02 g for golden montazah and white leghorn respectively; Sreenivas et al. (2013) recorded 0.05 g white leghorn, Goto et al. (2015) obtained 0.10 g and 0.13 g for onagadori and white leghorn respectively, Begli et al. (2010) registered 0.01 g for Iranian fowl at 30 weeks; and 0.03 g for white leghorn at 50 weeks.

There was a progressive increase in the coefficient of variation of egg shell weight at different ages of the birds that is, 8.39% at 25 weeks, 10.05% at 51 weeks, 10.18% at 72 weeks and 13.18% at overall ages of the hen. This is similar with 12.1% reported by Mube et al. (2014); 10.6% recorded by Begli et al. (2010); 10.90% obtained by Zhang et al. (2010).

### 3.3 Genetic correlation

Pearson correlation coefficient between egg quality traits at 25, 51 and 72 weeks of age are presented in Table 2. A significant positive and same high magnitude correlations were recorded between egg weight (0.998) and egg shell weight (0.998) at different age groups. This could be attributed to similar variances in the additive variance and the permanent environment variance on the egg weight and egg shell weight as a proportion of phenotypic variance at different age groups as age is a major determinant in the growth and development of egg quality traits. Additionally, the significant and positive high correlation between egg weight and egg shell weight as a proportion of phenotypic variance at different age groups as age is a major determinant in the growth and development of egg quality traits.

<table>
<thead>
<tr>
<th>Traits</th>
<th>EW</th>
<th>EAW</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 weeks</td>
<td>EW 0.998*</td>
<td>EAW 1</td>
</tr>
<tr>
<td>EW 1</td>
<td>EAW 0.998*</td>
<td></td>
</tr>
<tr>
<td>51 weeks</td>
<td>EW 1</td>
<td>EAW 0.998*</td>
</tr>
<tr>
<td>EW 1</td>
<td>EAW 0.998*</td>
<td></td>
</tr>
<tr>
<td>72 weeks</td>
<td>EW 1</td>
<td>EAW 0.998*</td>
</tr>
</tbody>
</table>

* Correlation is significant at the 0.01 level.

EW = Egg weight, EAW = Egg albumen weight, EYW = Egg yolk weight.
egg shell weight indicates that egg weight can be used to predict egg shell weight with a reasonable level of accuracy and precision in Bovan Neva Black laying chickens. Similar high positive significant correlation of egg weight with egg shell weight in Bovan Neva Black laying chickens at 25, 51 and 72 weeks of age recorded in this study have been previously reported in white leghorn and other commercial breeds in literature (Jayalaxmi et al., 2002; Molnar et al., 2016; Sharma et al., 2002; Sreenivas et al., 2013).

3.4. Repeatability estimates

Empirical model 1 was used to evaluate the repeatability estimates of overall ages of egg weight and egg shell weight at 25, 51 and 72 weeks when the age of the bird was excluded from the computation and model 2 was employed when the age of the bird was included as presented in Table 3.

High repeatability estimates of 0.45 and 0.55 for egg weight and egg shell weight respectively using data from overall ages for egg quality traits when the age of the bird were included indicating higher role of additive genetic variance in phenotypic expression of the traits and the low standard error for different age groups and overall mean age group indicates greater precision. These high estimates generally agreed with the report in literature. Goto et al. (2015) recorded values at 0.47 and 0.42 for egg weight employing Onagadori and white leghorn breeds, 0.50 for egg shell weight employing Onagadori breed at 20–34 weeks of age using half-sib correlation analysis adopted to multifarious species and evaluated using one-way analysis of variance with start view for windows software of statistical analytical system at P < 0.05. Blanco et al. (2014) obtained 0.75 and 0.71 for egg weight employing white eggs of Lohmann selected leghorn and brown eggs of Lohmann Brown respectively at 67–70 weeks of age using half-sib correlation analysis adopted to multifarious species and estimated using mixed procedure from the statistical analytic system. Udeh (2010) reported 0.44 for egg weight employing Black Olympia (Stain 2) at 40 weeks of age using one-way analysis of variance described by Becker (1984) for multifarious species and half-sib correlation.

However, low estimates of 0.032 and 0.001 were recorded for egg weight and egg shell weight respectively when the age variance was excluded from the computation. This variation could be attributed to the removal of age variance which determines its developmental processes hence robust the non-additive gene actions thereby culminating into low and more accurate estimates of repeatability of the traits compared to the report recorded in literature (Blanco et al., 2014; Goto et al., 2015; Udeh, 2010).

Theoretically, repeatability estimates should decline in magnitude when the age variance was excluded from the computation due to decrease in additive genetic variance. Practically, this trend was observed in this study suggesting moderate influence of non-genetic and permanent environmental variance on repeatability estimates of the traits at 25, 51 and 72 weeks of age hence lower to the estimates of egg weight and egg shell weight obtained by several researchers (Blanco et al., 2014; Goto et al., 2015; Udeh, 2010).

From the results, it could be noted that egg weight is more repeatable compared to egg shell weight as it recorded moderate estimates at 25, 51 and 72 weeks of age whereas egg shell weight reported low estimates of repeatability at 25, 51 and 72 weeks of age when the age variance were excluded from the computation in order to obtain a more realistic estimate hence identify traits that are more repeatable under the influence of age variance.

4. Conclusion

From the finding, it was observed that as the age of the laying bird increases, the magnitude of the egg weight and egg shell weight increases, with a significant difference for egg shell weight due to genetic variance whereas there is no significant difference recorded for egg weight indicating the minimal influence of genetic variance. The Pearson correlation coefficient recorded a significant positive and the same high correlation between egg weight and egg shell weight at different age groups. The influence of age variance on repeatability estimates of egg weight and egg shell weight is appreciable as considerable changes in repeatability values would result by excluding the effects of age variance thereby obtaining more realistic estimates of repeatability. However, since egg shell weight registered low estimates at different age groups and egg weight report moderate estimates at different age groups, these traits can be improved by mass selection. Improvement in the production environment and non-genetic factors influencing egg production will improve the accuracy of estimating the inherent transmitting ability of the layers in the low and moderate repeatable traits for egg shell weight and egg weight respectively at 25, 51 and 72 weeks under the influence of age variance.

References


Table 3 – Age variance, K-value and repeatability estimates ± standard error for egg weight and egg shell weight for overall ages of bird, at 25, 51 and 72 weeks of age for model 1 analysis (age of bird excluded), overall ages of bird for model 2 analysis (age of bird excluded).

<table>
<thead>
<tr>
<th>Age variance</th>
<th>K-value</th>
<th>Egg weight R ± SE</th>
<th>Shell weight R ± SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall (age included)</td>
<td>15</td>
<td>0.45 ± 0.0260</td>
<td>0.550 ± 0.0025</td>
</tr>
<tr>
<td>Overall (age excluded)</td>
<td>15</td>
<td>0.032 ± 0.0091</td>
<td>0.001 ± 0.0065</td>
</tr>
<tr>
<td>Age groups (age excluded)</td>
<td>25</td>
<td>0.190 ± 0.0275</td>
<td>0.090 ± 0.0453</td>
</tr>
<tr>
<td></td>
<td>51</td>
<td>0.210 ± 0.0533</td>
<td>0.020 ± 0.0388</td>
</tr>
<tr>
<td></td>
<td>72</td>
<td>0.190 ± 0.0275</td>
<td>0.080 ± 0.0427</td>
</tr>
</tbody>
</table>

1 R ± SE represents Repeatability ± standard error and K-value is the number of bird per record.


Tumova E, Goust RM. Interaction of hen production type, age, and temperature on laying pattern and egg quality. Poult Sci 2012;91:1269–75.


