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Effects of age variance on repeatability estimates of egg dimensions of Bovan Nera Black laying chickens

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Abstract   The present research was designed to examine the effects of age variance on repeatability estimates of egg length, egg breadth and egg shape index of Bovan Nera Black laying chickens at 25, 51, 72 weeks and combined ages of the bird. For this purpose thirty birds were selected from the flock of layers in the Babcock University Teaching and Research Farm. They were individually housed in labeled separate battery cage. A total of thirty (30) eggs were collected daily from the birds continuously for five (5) days of egg production, at each age of 25, 51 and 72 weeks. The total number of eggs collected at each age were 150 and 450 for the total of three age periods. Data were collected on egg production traits for egg length, egg breadth and egg shape index. These data were subjected to statistical analysis using Completely Randomized Design. General linear model procedure of statistical analytical system (SAS) was used to obtain the variance components for the estimation of repeatability. Moderate repeatability estimates were obtained when the age variance was included in the computation and low estimates were registered when the age variance was excluded from the computation. The repeatability estimates from different egg quality traits were low to high. Since most of the traits recorded low repeatability values, these traits can be improve by mass selection thereby culminating into egg production with optimal quality.

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Contents

1. Introduction

Poultry in one form or the other is kept in most areas of the world. There are fewer religious or social taboos associated with them than there are with livestock, thus products produced from poultry provide an acceptable form of animal protein to most people throughout the world except strict vegetarians and vegans. The contribution that poultry makes to the supply of animal protein varies from area to area and the consumption per head of population is greater in developed countries than in developing countries. Poultry production has the greatest potentials of bridging the protein deficiency gap existing in developing countries particularly Nigeria. The population of Nigeria is over 140 million people and with an estimated growth rate of 3.2% per annum NPC [1], the population is projected to reach about 184.8 million people in year 2016.

Improvement in body size and overall growth of exotic chicken is important from economic considerations bothering on the need to increase egg size and to improve the post-lay value of the chickens, since spent layers are generally in high demand. This can be achieved through estimation of genetic parameters [2–4].

The characters of economic importance in animals which are of concern to a breeder normally show continuous variation. Such characters are controlled by a large number of genes, each having a small, similar and supplementary effect on the character. The cumulative effects of such genes, coupled with environmental effects produce continuous variation in the phenotypic values of individuals.

If all the variation is attributable to environment, selection of phenotypically superior individuals does not result in any alteration in the next generation [5–7]. In making breeding plans, it is, therefore, necessary to know the relative importance of the heritable and environmental variation of the characters. Only the phenotypic values of individuals can be directly measured, but it is, the breeding value that determines their influence on the next generation. Therefore, if the breeder or experimenter chooses individuals to be parents according to their phenotypic values, his success in changing the characteristics of the population can be predicted only from knowledge of the degree of correspondence between phenotypic values and breeding values. This degree of correspondence is measured by one of the very important genetic parameters, heritability Falconer [6].

Also, sometimes basic information needed is that when selection is made for one particular character, how much genetic improvement is expected in the other character not selected for. This depends upon the degree of association between the two characters due to the pleiotropic effects of genes governing them, a measure of which is provided by the second parameter genetic correlation. Also, when the character under improvement is repeatable over time such as egg weight, egg length, egg breadth, egg shape index, egg yolk weight, egg albumen weight and albumen height to mention but a few in livestock, yet another basic information one must have is how much reliance can be placed on an individual's early record as an indication of its later performance, because in the event of high reliability, inferior individuals can be disposed of on the basis of their early performance [4,8–10]. The existence of reliability obviously depends upon the degree of association among the repeated records of the character on the same individual – a measure of which is provided by the third genetic parameter-the repeatability co-efficient.

The repeatability is thus the correlation between the repeated measurements of the same individual and represents the proportion of the variance of single measurement which is due to permanent or non-localized differences between individuals, both genetic as well as environmental Jain [5].

Repeatability estimates for the number of eggs laid in Bovan Nera, Harco black and Brown Lohman layers ranged from moderate to high which suggests great reliability on selection or culling of monogastric animal.

Toye et al. [9] reported repeatability estimates of egg number 0.22 for black harco layer, 0.20 for brown Lohman layer, and 0.21 for black harco and brown Lohman Layer. The estimates of egg weight was 0.41 for black harco layer 0.47 for brown Lohman layer and 0.43 for black harco and brown Lohman layers. Estimates of egg length was 0.26 for black harco layer, 0.31 for brown Lohman, black harco and brown
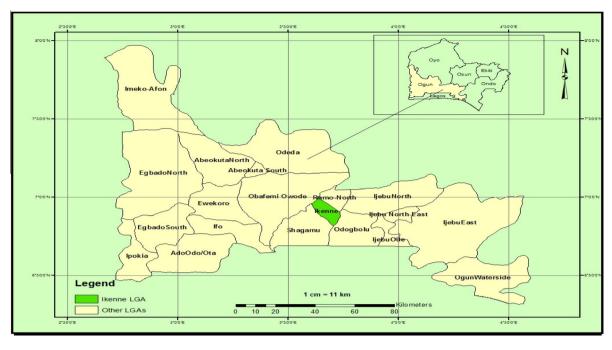
Figure 1 Map of Ogun State showing Ikenne Local Government Area.

Lohman were 0.29. The egg mass estimates were 0.16 for black harco layer, 0.05 for brown Lohman, and 0.12 for black harco and brown Lohman layers. Superior repeatability of traits in brown Lohman layer relative to black harco birds may reflect biological inefficiency of the latter. Low repeatability estimates recorded for most traits suggest that use of multiple records and elimination of non-genetic factors influencing egg production and quality will improve the precision with which inherent ability is determined, and thereby increase speed and efficiency of selection for improved egg production and quality.

Ibe [11] obtained an estimate of 0.76 for egg weight in white Leghorn Chickens. Korolev [12] obtained an estimate of 0.46–0.71 for egg weight in different lines of white leghorns. Olowofeso and Adeleke [13] obtained repeatability estimates of eggs laid by Bovan Nera layer strain of 0.50 and 0.37 for Harco Black layer strain. Ayorinde and Sado [14] also reported repeatability estimates of 0.58–0.60 for egg weight from reports of individual egg weight, taken over a 56 day period from Hubbard layers. These estimates are also corresponding to the estimates of more researchers [12,14–17,9]. The aim of this study was to determine the effects of age variance on repeatability estimates of egg dimensions of Bovan Nera Black laying chickens which was achievable from the use of sensitive digital scale, vernier caliper sensitive to 0.00 cm and Panda [18] formula for measuring performance in each of the traits examined.

2. Materials and methods

2.1. Location of study

This study was conducted at Babcock University Teaching and Research Farms Ilara, Ogun State Nigeria. This study was conducted in Ilara farm of Babcock University in Ikenne Local Government Area (LGA) of Ogun State, which has its Headquarter at Ikenne Remo. The Local Government Area is bounded 4 km to the East by Odogbolu Local Government

Area (LGA), 5 km to the South by Ayepe, 10 km to the North East by Irolu, 4 km to the North by Ilara, 2 km to the East by Ilishan and 7 km to the West by Sagamu. The Local Government is located along the transitional forest zone of Southern Nigeria and Guinea Savannah. It is situated 235.2 m above sea level, has an annual rainfall of 1200 mm, 65% mean relative humidity and 21.4° mean temperature. Fig. 1 shows the map of Ikenne Local Government Area in Ogun State, Nigeria.

2.2. Experimental birds and management

Thirty Bovan Nera Black laying birds from the flock of layers in the University Teaching and Research farm were randomly selected based on visual appraisal starting from 23 weeks of age. They were individually housed in labeled separate battery cage. The hen was caged individually in a 0.45×0.35 m battery cage, and fed commercial diet formulated based on laying birds' requirements NRC [19]. Each bird was fed on average of 131 g per head per day with water supplied ad libitum for the period of 50 weeks of experimentation and data collection.

2.3. Experimental design

Completely Randomized Design (CRD) was used for selecting and analyzing the laying birds from the flocks of Bovan Nera Black layers. 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).

2.4. Data collection

Thirty laying birds were randomly selected and housed in labeled separate battery cage. Each egg collected was identified and labeled by the appropriate identification numbers on the egg trays. A total of thirty (30) eggs were collected daily from

each bird continuously for five (5) days of egg production, at each ages 25, 51 and 72 weeks. The total number of eggs collected at each age was 150 for three age periods (25, 51 and 72 weeks).

2.5. Measurement of egg quality traits

The external egg quality traits such as egg length and breadth were measured with a manual venire caliper sensitive to two decimal (0.00 cm). The Shape Index was estimated using [18] formula thus:

Shape index = [egg breadth/egg length] × 100

2.6. Statistical model and data analysis

2.6.1. Effect of age on egg quality traits

The influence of age on the various egg quality traits was determined by general linear model of analysis of variance of SAS [20]. The age of the bird was independent variable while the various egg quality traits were considered as the dependent variables. The analytical model is as follows:

$$Y_{ij} = \mu + \alpha_i + e_{ij}$$

Y_{ij} = Observation on the jth egg quality traits of ith birds.
μ = Overall population mean.
α_i = Random effect of the ith age of birds.
e_{ij} = The uncontrolled environmental and genetic variation attributable to individual egg quality traits of birds.

2.6.2. Variance components for the determination of repeatability estimates

The variance components that were used for the estimation of repeatability were evaluated using the method of paternal half-sib correlation analysis adapted to multiparous species, given by [21]. 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.

Model 1: $Y_{ij} = \mu + \alpha_i + e_{ij}$
Model 2: $Y_{ij_k} = \mu + \alpha_i + \beta_j + e_{ij_k}$
Y_{ij} = Observation on the jth egg quality traits of the ith birds
μ = Overall population
α_i = Random effect of the ith birds

Table 1 Descriptive statistics of egg length.

Egg length (cm)	N	Mean	Standard deviation	Standard error	Coefficient of variation
Combine	450	4.38	0.46	0.02	10.51
Age of bird					
25	150	4.05	0.52	0.04	12.75
51	150	4.44	0.40	0.03	9.05
72	150	4.65	0.15	0.01	3.26

Table 2 Descriptive Statistics of Egg Breadth.

Egg breadth (cm)	N	Mean	Standard deviation	Standard error	Coefficient of variation
Combine	450	2.56	0.28	0.01	10.78
Age of bird					
25	150	2.47	0.02	0.00	6.00
51	150	2.54	0.25	0.02	9.64
72	150	2.66	0.39	0.03	14.56

e_{ij} and e_{ij_k} = Random error associated with dependent variable

The components of variance were estimated by PROC VARCOMP (Procedure Variance Components) of [20] using Restricted Maximum Likelihood (REML) method. Repeatability coefficient was estimated using the following formulae [21].

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

$$\hat{\sigma}_E^2 = MS_E$$

$$\hat{\sigma}_B^2 = \frac{MS_B - MS_E}{K}$$

R = Repeatability
MS_B = Mean square within individuals
MS_E = Mean square between individuals
K = Number of record per bird
$\hat{\sigma}_B^2$ = Variance component of the bird = estimates all the genetic variance and the portion of the environmental variance peculiar to the individual bird
$\hat{\sigma}_E^2$ = Variance component (error) = the differences among measurements within the individual bird.

The standard error (S.E.) of the estimation in this study is given by [21] expressed as:

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

where:

K = Number of record per bird
R = Repeatability
N = Number of eggs

3. Results and discussions

3.1. Descriptive statistics of egg production traits

With a view to achieving the objectives of this study, several statistical analyses were carried out. The descriptive statistics of egg quality traits of the bird at 25, 51 and 72 weeks of age are presented in Tables 1–3. Egg length recorded 4.05 cm at 25 weeks, 4.44 cm at 51 weeks and 4.64 cm at 72 weeks show

Table 3 Descriptive statistics of egg shape index.

Egg shape index	N	Mean	Standard deviation	Standard error	Coefficient of variation
Combine	450	58.92	7.99	0.38	13.56
Age of bird					
25	150	61.87	7.57	0.62	12.23
51	150	57.71	7.35	0.60	12.73
72	150	57.19	8.24	0.67	14.41

Table 4 Variance component, estimates, *K*-value and repeatability estimates ± standard error for egg length for combined ages of bird, at 25, 51 and 72 weeks of age for Model 1 analysis (age of bird excluded), combined ages of bird for Model 2 analysis (age of bird excluded).

Egg length (cm)	K-value	Variance component	Estimates	Percentage (%)	[1]R ± SE
Combine (age included)	15	Bird	0.01158	4.779	0.43 ± 0.026
		Age	0.09173	37.85	
		Error	0.13902	57.37	
Combine (age excluded)	15	Bird	0.00721	3.407	0.034 ± 0.0093
		Error	0.20455	96.59	
Age groups (age excluded)					
25	5	Bird	0.05690	21.24	0.02 ± 0.0388
		Error	0.21095	78.76	
51	5	Bird	0.01044	6.445	0.06 ± 0.0427
		Error	0.15152	93.55	
72	5	Bird	0.00050	2.180	0.21 ± 0.0536
		Error	0.02241	97.82	

[1]R ± SE represents repeatability ± standard error and *K*-value is the number of bird per record.

an increasing trend. These are in agreement with Oyeagu et al. [22] who observed that egg length increased with age recorded values of 4.16–4.91 cm for Nera Black and 3.99–4.69 cm for Shaver Brown Hens at 28–60 weeks of age. While Tatsuhiko et al. [23] reported that egg length ranged from 3.45 to 4.64 cm for Onagadori layer at 20–34 weeks of age and 4.31–5.09 cm for white Leghorns at 20–34 weeks for both breeds. There was a progressive decrease in standard error of egg length with increasing age of the hen that is, 0.04 cm at age 25 weeks, 0.03 cm at 51 weeks and 0.01 cm at 72 weeks with a corresponding value of 0.02 cm for combined ages of the hen. These results agree favorably with 0.00 cm obtained by Toye et al. [9] at 18 weeks; 0.18 cm recorded by Ijaiya et al. [24] at 8 weeks and 0.01 cm estimated by Pradeepta et al. [25] at 52 weeks; 0.29 cm obtained by Alipanah et al. [26] at 16 weeks and 0.24 cm reported by Dinesh et al. [27] for standard error of egg length. Maximum value of 12.75% was recorded for coefficient of variation of egg length while at 72 weeks of age the birds had the minimum coefficient of variation of egg length value of 3.26%. There was a successive decrease with increasing age of the hen that is, 12.75% at age 25 weeks, 9.05% at 51 weeks and 3.26% at 72 weeks with a corresponding mean value of 10.51% for combined ages. The range of coefficient of variation of egg length 3.26–12.75% in this study is similar to 13.4% reported by [28].

At 25 weeks of age the birds recorded the minimum mean egg breadth value of 2.47 cm was registered while at 72 weeks of age the birds had the maximum mean egg breadth value of 2.66. There was a progressive increase in egg breadth with increasing age of the hen. The values obtained in this study was in consonance with the values 2.37 cm recorded for Nera Black at 28 weeks reported by [22]. However, the mean values were lower than 4.38 cm for Heavy Harco Black and 4.27 cm for Heavy Lohman Brown layers and 4.36 cm for white Leghorn at 18 weeks for both breeds obtained by [9]; and 4.36 cm for white Leghorn obtained by Anderson et al. [29]. This variation could be attributed to the difference in breed used for the study. The standard deviation of egg breadth in this study shows a successive increase with increasing age of the hen with a corresponding value of 0.28 for combined ages of the hen. These value compares favorably with the value of 0.29 cm recorded by [28]. The standard error of egg breadth in this study follows a consistent increase with increasing age of the hen with a corresponding value of 0.01 cm for combined ages of the hen. The results in this study are similar with 0.00 cm obtained by [9] at 18 weeks; 0.09 cm recorded by [27] at 8 weeks and 0.07 cm estimated by [25] at 52 weeks. There was a successive increase in coefficient of variation of egg length with increasing age of the hen with a corresponding value of 10.78% for combined ages. The results are within the range of 12.7% reported by [28].

The egg shape index follows a decreasing trend at different ages of the birds. At 25 weeks of age the birds recorded the maximum mean egg shape index value of 61.87 while at 72 weeks of age the birds had the minimum mean egg shape index value of 57.19. The same observation was recorded by [25] for white Leghorns at 52 weeks. The standard deviation, standard error and coefficient of variation of egg shape index

Table 5 Variance component, estimates, *K*-value and repeatability estimates ± standard error for egg breadth for combined ages of bird, at 25, 51 and 72 weeks of age for Model 1 analysis (age of bird excluded), combined ages of bird for Model 2 analysis (age of bird excluded).

Egg breadth (cm)	*K*-value	Variance component	Estimates	Percentage (%)	[1]R ± SE
Combine (age included)	15	Bird	0.00117	1.486	0.13 ± 0.016
		Age	0.00874	11.19	
		Error	0.06882	87.41	
Combine (age excluded)	15	Bird	0.00075	0.994	0.010 ± 0.0074
		Error	0.07506	99.01	
Age groups (age excluded)					
25	5	Bird	0.00003	14.82	0.15 ± 0.0498
		Error	0.00019	85.18	
51	5	Bird	0.00417	6.926	0.07 ± 0.0416
		Error	0.05604	93.07	
72	5	Bird	0.03202	21.29	0.21 ± 0.0536
		Error	0.11840	78.71	

[1]R ± SE represents repeatability ± standard error and *K*-value is the number of bird per record.

Table 6 Variance component, estimates, *K*-value and repeatability estimates ± standard error for egg shape index for combined ages of bird, at 25, 51 and 72 weeks of age for Model 1 analysis (age of bird excluded), combined ages of bird for Model 2 analysis (age of bird excluded).

Egg shape index (cm)	*K*-value	Variance component	Estimates	Percentage (%)	[1]R ± SE
Combine (age included)	15	Bird	4.18282	7.313	0.16 ± 0.018
		Age	6.20243	9.395	
		Error	55.6363	84.27	
Combine (age excluded)	15	Bird	3.88747	6.079	0.061 ± 0.0113
		Error	60.0666	93.92	
Age groups (age excluded)					
25	5	Bird	11.5981	20.15	0.20 ± 0.0528
		Error	45.9749	79.85	
51	5	Bird	1.98700	3.677	0.04 ± 0.0408
		Error	52.0548	96.32	
72	5	Bird	13.0850	19.18	0.19 ± 0.0225
		Error	55.1366	80.82	

[1]R ± SE represents repeatability ± standard error and *K*-value is the number of bird per record.

of the bird at 25, 51 and 72 weeks with the corresponding combined age of the bird recorded irregular pattern of values with increasing age of bird. The same trend was observed by [28] for egg shape index.

3.2. Estimates of variance components and repeatability for the combined age and different age groups

Each component of the variance component contributes a certain percentage to the total variance, *K*-value, repeatability estimate and standard error for combined ages of birds at 25, 51 and 72 weeks for quality traits using Model 1 analysis (age of bird excluded) and Model 2 (age of the bird included) as shown in Tables 4–6. Moderate and low repeatability estimates were obtained for combined age of the bird (age of the bird included) and combined ages of the bird (age of the

bird excluded). Generally, low repeatability estimates were observed for birds at 25, 51, 72 weeks as shown in Tables 4–6. The low estimates were due to the removal of age variance which is a major factor that determines the growth and development of egg quality traits. This resulted in decrease in the bird variance and increase in the error variance at different age groups. This agrees with the record of Ojo et al. [30] that repeatability estimates of egg quality traits were observed to increase with age.

The highest repeatability estimate for the combined data was found to be egg length of 0.45 ± 0.026 (age of bird included) using Model 2. This is because egg length contributed the highest component of 40.80% for age variance, the moderate bird variance of 4.701% and the lowest error variance of 54.37% of the total variance for the combined data (age of bird included and age of bird excluded), while the low-

est repeatability estimate of 0.13 ± 0.016 was registered for egg breadth. This is attributed to the contribution (lowest) bird variance to the overall variance component of the traits. This moderate and low estimate is similar to moderate and low repeatability estimate of 0.58 and 0.24 recorded for egg length and egg breadth respectively for white Leghorn by [23].

The trait with the highest repeatability estimates of 0.06110 ± 0.0113 when the age of bird was excluded was found to be egg shape index. This is as a result of highest composition of bird variation (6.079%) and lowest contribution of error variance (93.92%) to the total variance component.

However, egg breadth recorded the least repeatability estimate of 0.010 ± 0.0074 from combined estimate of the bird when the age of bird was excluded. This was primarily caused by the contribution of the total variance components in the trait. The bird variance contributed 0.994% while the error variance contributed 99.01%. As the age variance was excluded from the traits, it reduces the contribution of bird variance from 1.486% when the age was included (Model 2) to 0.994% when age of the bird was excluded (Model 1). This observation is in line with the reports [30] that repeatability estimate of birds was observed to increase with age, implying that age is an indicator of growth and physiological development.

Low repeatability estimates were observed for birds at 25, 51 and 72 weeks using model 1 which range from 0.02 to 0.21 as shown in Tables 4–6. This is due to the removal of age variance which is a major factor that determines the growth and development of repeatability estimates of egg quality traits. This resulted in decrease in the bird variance and increase in the error variance at different age groups. Lower estimates obtained at different age groups in this study agreed with the report of [17] for egg length and egg shape index. The reverse was however, the case of Sanusi [16] that recorded higher repeatability estimates at peak egg production and low estimates at later periods. [16] reported that the small hens are more efficient egg producers since they have lower body maintenance requirement and their egg size relative to body size is greater.

Traits with the highest repeatability estimates for different age groups are 0.21 ± 0.0536 for egg length and breadth at 72 weeks of age. While egg length at 25 weeks of age was found to be the lowest repeatability estimates of 0.02 ± 0.0388 when age variance of the bird is excluded. This confirms that age is major determinant in the growth and development of egg quality traits. This tread was equally observed by [30].

Generally, it was observed that age variance exerts great influence on the estimated value of repeatability suggested for combined data and different age groups considered in this study. The higher the age variance, the lower the bird variance and the lower the error variance thereby resulting in high estimate of repeatability and vice versa. Excluding the age variance, lowers the bird variance and increases the error variance and finally lowers the estimate of repeatability.

Therefore, in a bird where age variance is appreciable, considerable change in repeatability values would result by excluding the effect of age thereby obtaining a more realistic estimates of repeatability of egg quality traits.

4. Conclusion

The results of this study revealed that as the age of the laying increases, the egg quality trait increases, while the shape index decreases with increasing age of the laying hens. Moderate and low repeatability estimates of the egg quality traits were recorded at combined ages of the bird, 25, 51 and 72 weeks when the age was excluded using model 1. The influence of age and its contribution to the estimate of repeatability of egg quality traits is appreciable, considerable change in repeatability values would result by the removal of the influence of age variance thereby obtaining a more realistic estimate of repeatability. Therefore, the improvement in the production environment, collection of additional records and improvement of non-genetic factors influencing egg production will improve the accuracy of predicting the inherent transmitting ability of the layers in the lowly repeatable traits. This will enable the producers to make early selection among birds since good birds will repeat their performance in subsequent selection.

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