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Research Article
Hatchability Prediction in Chickens Using Some External Egg Quality Traits

V.U. Oleforuh-Okoleh

Department of Animal Science, Rivers State University of Science and Technology, Nkpolu-Oroworukwo, PMB 5080, Port Harcourt, Nigeria

Abstract
The aim of this study was to predict hatchability using external egg quality traits. Seven hundred and twenty eggs were collected from inbred populations of three strains of layer-type chickens comprising of two exotic strains: Black Olympia (BO), H and N brown nick (H and N) and the Nigerian Local Chicken (NLC) at 40 weeks of age. The external egg quality traits measured include Egg Weight (EW), Egg Shape Index (ESI), Shell Weight (SW) and Shell Thickness (ST). Highly significant variations existed between the two exotic strains (BO and H and N) and the NLC in all traits expect actual hatchability. Eggs from BO and H and N were 27.76 and 28.34% heavier than those from the NLC ($p<0.01$). Actual hatchability percentage ranged between 87.73-88.24%. All egg quality traits studied were negatively correlated with hatchability (EW-0.27, ESI-0.38, SW-0.24 and ST-0.68). The correlation between ESI, ST and hatchability were significant ($p<0.01$). The multiple linear regression analysis revealed that all the traits except EW had significant ($p<0.01$) linear effect on hatchability with a coefficient of determination (R^2) of 0.698. The estimated hatchability prediction model was $\bar{y} = 124.169-0.007EW-0.358ESI+0.639SW-37.283ST$. The high R^2 obtained in this study indicates that the variables employed in predicting the model were adequate and therefore suggests the likelihood that the various external egg quality traits influenced hatchability and could be interpreted in an integrated manner, rather than from a mutually exclusive individual basis.

Key words: Egg shape index, egg weight, shell thickness, shell weight, chickens, hatchability prediction

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Corresponding Author: V.U. Oleforuh-Okoleh, Department of Animal Science, Rivers State University of Science and Technology, Nkpolu-Oroworukwo, PMB 5080, Port Harcourt, Nigeria

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The major products of the poultry industry are meat and egg. Both are not just of economical importance to the growth of the world's food industry but are rich sources of animal protein to a large populace. The economic potentials of poultry are substantially derived from the productivity of the breeding hen. Compared to other important meat producing animals, poultry can be expanded at an extremely rapid rate. This rapid rate of reproduction of offspring is a major reason for the efficiency of poultry in the production of food for man. The poultry breeder, thus, aims at optimum fertility and hatchability.

The fertility and hatchability estimates encompass the union of the spermatozoa and the ova, the initiation of development and the hatching of a viable chick at the end of incubation (Etches, 1996). Estimates of fertility and hatchability not only serve as important yardstick in evaluating the economic efficiency of parent stocks but also serve as a measure of the genetic/reproductive fitness of individual birds and/or breed in a population. Hatchability is a very important trait in breeding program having a great economical impact in the poultry industry as well as insuring the sufficiency of day-old chicks (Abou El-Ghar, 2013). Hatchability being a function of number of chicks hatched is affected by numerous factors such as genetic factors (Liptoi and Hidas, 2006), season of the year (Jayarajan, 1992), fertility, health, nutrition (Alemayehu *et al*., 2015), age of the flock (Zita *et al*., 2009), egg storage duration and conditions (Heier and Jarp, 2001; Demirel and Kirikci, 2009) and management conditions during incubation and hatching (Farooq *et al*., 2001a). It is also significantly influenced by the quality of the fertile egg (Wolc *et al*., 2010), since the avian egg is a biological system projected to warrant the safety of the embryo and its successful hatching into a fully developed chick (Reijrink *et al*., 2009).

Abou El-Ghar (2013) suggested that a model encompassing some egg quality traits may be used for predicting hatchability as closely as possible to the realized hatchability. Experimental studies have shown that predicting hatching rate may depend, among other factors, on the main physical characteristics of eggs (Peruzzi *et al*., 2012). The relevance of the external egg quality traits as production traits in poultry breeding programmes is of high economic importance. Egg weight, egg shape, shell weight and shell thickness are external indicators of egg quality (Alkan *et al*., 2008). Kamali *et al*. (2007) noted that egg weight is important for broiler breeders because of the close relation between egg size and chick weight and the persistency of this relationship as the flock ages. The shell enables the egg withstand considerable biological and mechanical abuse while still maintaining its structural integrity and the wholesomeness of its contents (Parsons, 1982). The present study aimed at using information obtained from external egg quality traits to develop a model for predicting hatchability.

MATERIALS AND METHODS

Experimental site and animals: The study was carried out at the Poultry Teaching and Research Unit, Department of Animal Science Farm, Ebonyi State University, Abakaliki, Nigeria. A total of 210 hens and 21 cocks aged 40-week old randomly selected from an inbred population of three strains of chicken, Black Olympia (BO), H and N brown nick (H and N) and Nigerian Local Chicken (NLC), maintained in the poultry unit were used. Each strain of chicken was reared in seven replicate deep litter pens. Mating was at random using a mating ratio of 1 cock to10 hens. The cocks were allowed to run with the hens for two weeks before eggs were collected for incubation. The eggs were collected twice daily, identified according to pedigree per population and stored in a room with controlled temperature (18–20°C) and relative humidity (75-80%) for five days before incubation. The eggs were set in three locally fabricated incubators (still-air incubator) of 250 eggs capacity such that each incubator had 80 eggs per pedigree/population. Prior to incubation, the incubator was thoroughly cleaned and disinfected using formaldehyde. A temperature of 37.5–38.5°C was maintained within the incubator at a relative humidity of 70% until hatching. Eggs were hand turned every 4 h. Candling was done on the 7th day of incubation to remove infertile eggs. On the 21st day, hatched chicks were removed from the incubator. The birds were fed *ad libitum* on a standard layer's diet, containing 17% CP and 2800 Kcal ME kg^{-1} feed (manufactured by Topfeed, Benin City, Nigeria). Water was also given *ad libitum*. A lighting schedule of 14 h day^{-1} was provided.

Data collection and statistical analysis: Data were collected from a sample of 180 eggs randomly selected from each population within the week incubation was done. The external egg quality traits measured Included, Egg Weight (EW), Egg Shape Index (ESI), Shell Weight (SW) and Shell Thickness (ST). Egg weight was taken as soon as the eggs were collected using a sensitive electronic weighing scale (Mettler P2010 g pan analytical balance) of 0.01 g sensitivity. The egg length and breadth were obtained using an electronic vernier caliper. Values got were then used in estimating the egg shape index (expressed as the ratio of the egg breadth to the egg length).

The egg shell thickness was obtained as the average of three different regions using an electronic micrometer screw gauge. The shell weight (with the shell membrane) was obtained using the sensitive electronic weighing scale. Hatchability was calculated with reference to fertile eggs as:

$$\text{Hatchability of fertile eggs st (\%)} = \frac{\text{Number of chicks hatched}}{\text{Number of fertile eggs set}} \times 100$$

Data collected from all traits were subjected to a one-way analysis of variance (ANOVA). Mean differences were deemed to be significant at $p<0.05$ and were separated using Bonferroni. Pooled data from the three inbred strains were used to estimate phenotypic correlation between hatchability and the egg quality traits studied, and also to carry out a multiple linear regression analysis to predict hatchability, such that:

$$\hat{y} = \beta_0+\beta_1x_1+\beta_2x_2+\beta_3x_3+\beta_4x_4$$

where, $\hat{y}$ is the response variable (hatchability), β_0 is the intercept (constant), β'_s is regression coefficients of the explanatory variables and x's the observation for the independent variable (x_1 is egg weight, x_2 is egg shape index, x_3 is shell weight and x_4 is eggshell thickness). Data were analyzed using SPSS Statistics Base 17.0 SPSS (2010) statistical software.

RESULTS AND DISCUSSION

The observed Mean±SEM of the external egg quality traits and hatchability from the three strains of chickens are presented in Table 1. The heaviest egg weight was obtained from the exotic strains (BO and H and N). Eggs from BO and H and N were 30.09 and 30.24% heavier than those from the NLC ($p<0.05$). Similar trend was observed in the means of shell weight and shell thickness. The result of the present findings is as expected with respect to the variations observed between the exotic strains and the local chickens. Variation amongst breeds/strains is a function of the genetic constitution of the strains of birds, the environment and interaction of both factors. Genotype has been noted to significantly affect egg weight (Afifi *et al*., 2010). Udeh *et al*. (2013) attributed the variation in the egg weight of the exotic and local chickens to the fact that the exotic chicken have been selected and improved for decades whereas, the local chicken in Nigeria remains mostly unselected and unimproved for most economic traits. The present findings with regards to the NLC vary from those of Ewa *et al*. (2005) and Adeolu and Oleforuh-Okoleh (2011) who reported smaller egg weights of (39.33 and 38.99 g, respectively) in a population of Nigerian local chicken. Oleforuh-Okoleh (2013) reported an average egg weight of 37.13 g for the Nigerian light local chicken ecotype after three generations of selection. The disparity could be attributed to the age of the hens when the eggs where collected. Whereas the findings of Oleforuh-Okoleh (2013) were based on mean egg weight from hens of about 32-34 weeks of age those of the present study were from hens of about 40 weeks of age. Wolc *et al*. (2010) reported that the egg weight depends on the section of the production curve for which eggs are contributed for analysis. The egg weight obtained for the NLC is close to the report of Malago and Baitilwake (2009) who observed a mean egg weight of 41.18 g in a population Tanzanian local chicken. Abou El-Ghar (2013) reported a mean egg weight of 49.70 g in a cross of Gimmizah and Bandarah chickens of Egypt.

Table 1: Mean±SE of external egg quality traits and hatchability of the three genotypes

Parameter	BO	H and N	NLC	SE
EW (g)	57.26[a]	57.39[a]	40.03[b]	0.30
ESI (%)	75.46[a]	75.17[a]	74.63[b]	0.23
Shell weight (g)	5.34[a]	5.16[a]	3.74[b]	0.09
Shell thickness (mm)	0.34[a]	0.33[a]	0.30[b]	0.01
Actual hatchability (%)	87.73	87.94	88.24	0.23
Predicted hatchability (%)	87.69	87.98	88.24	1.73

[a,b]Different superscripts on some row are significantly different at $p<0.01$, SE: Standard error, EW: Egg weight, ESI: Egg shape index, BO: Black olympia, H and N: H and N brown nick, NLC = Nigerian local chicken

Table 1 also shows that there existed genetic variations between the ESI of the exotic eggs and the eggs from the local chicken ($p<0.01$). The BO and H and N had similar egg shape index (75.46 and 75.17%, respectively) which varied from that of the NLC (74.63%). This affirms the findings of Iraqi (2002) that genotype significantly affect egg shape index. The shell weight and shell thickness from the different strains were significantly different. Heavier and thicker shells were obtained from the exotic strains. Abou El-Ghar *et al*. (2009) reported variations in shell weight and shell thickness of eggs obtained from different strains of chicken, implying that the genes play significant roles in the phenotypic manifestation of these traits. The result of the present study differs from the findings of Alabi *et al*. (2012) which showed that egg shape index tended to increase as egg weight decreased in a population of indigenous Venda chickens.

The physical characteristics of the egg play an important role in the processes of embryo development and successful hatching (Narushin and Romanov, 2002). Kingori (2011) suggested that fertility and hatchability are interrelated traits that vary among breeds, varieties or individuals in a breed or variety. The result of the present study, as in Table 1, revealed a similarity ($p>0.05$) in hatchability of the three strains. Though, there were no variations in egg hatchability of the three strains, the present finding suggests that the NLC possess high hatchability and confirms the reports of Dunya *et al*. (2014) who observed high hatchability percentage (76.90‒100%) in a population of Nigerian local chicken despite poor housing, inadequate resource base and general management. Farooq *et al*. (2001a) reported that the desi chicken had a significantly higher percent hatchability on the basis of total eggs set than the Rhode Island Red. This result, however, contradicts the report of Ng'ambi *et al*. (2013) who reported that heavier eggs had higher hatchability values in indigenous Venda chickens.

The coefficient of correlation between hatchability and the external egg quality traits of the chickens revealed that generally there were negative and moderate relationship between hatchability and all the egg quality traits studied (Table 2). These results affirm the findings of Narkhede *et al*. (1981). Alkan *et al*. (2008) observed differences between egg weight groups and hatchability of fertile eggs in Japanese quails. They noted that hatchability of incubated eggs decreased as egg weight increased. Ramaphala and Mbajiorgu (2013) observed that egg weight did not influence the hatchability percentage of COBB 500 broiler chicken eggs.

Abiola *et al*. (2008) in their work on the effect of egg size on hatchability of broiler chicks reported a nonlinear relationship between egg weight and hatchability. Wolc *et al*. (2010) reported a negative genetic correlation of -0.213 ± 0.025 between hatchability and egg weight. Senapati *et al*. (1996) and Ng'ambi *et al*. (2013), however, reported a positive correlation between egg weight and hatchability. The relationship between egg weight and other egg quality traits studied was positive and strong ($p<0.01$).

The multiple linear regression analysis revealed a significant F-test suggesting that at least one of the external egg quality traits employed in the analysis is related to hatchability. Table 3 shows that, generally, all variables measured in the present study, except egg weight, had a combined linear effect on hatchability ($p<0.01$). The set of beta-coefficients suggest that after adjusting for the effects of other external egg quality traits, shell weight (standardized coefficient = 0.735) had the strongest effect on hatchability. This affirms Farooq *et al*. (2001b) who reported that shell weight together with egg weight is the two most important factors affecting hatchability. The relationship between hatchability and the external egg quality traits studied in form of an index is presented in Table 4. The hatchability prediction model at $p<0.001$ was estimated as follows: $\hat{y} = 124.169-0.007EW-0.358ESI+0.639SW-37.283ST$. The result reveals that the measure of fit of the model given by the multiple correlation coefficient (R) was 0.836, indicating existence of a strong correlation between the observed hatchability and those predicted by the regression model. Furthermore, a coefficient of determination (R^2) of 0.698 and adjusted R^2 of 0.67 was obtained, implying that 67% of the variation in hatchability as observed in this study was accounted for by the external egg quality traits. A mean absolute deviation (SE) of 0.38% was estimated indicating that the variation between observed hatchability and expected hatchability was small, thus confirming that the model is fit for estimating hatchability.

Table 2: Phenotypic associations between hatchability and the external egg quality traits

Traits	EW	ESI	SW	ST
Hatchability	-0.27	-0.38**	-0.24	-0.68**
EW		0.44**	0.93**	0.68**
ESI			0.43**	0.25
SW				0.70**

**p<0.01, EW: Egg weight, ESI: Egg shape index, SW: Shell weight, ST: Shell thickness

Table 3: Estimated values of statistic ($\beta\pm$SE) in relation to predicted hatchability[1]

	Unstandardized coefficients		Standardized coefficients	
Model	β	SE	β	p-value
Constant	124.169	6.391		0.000
EW	-0.007	0.019	-0.086	0.717
ESI	-0.358	0.085	-0.395	0.000
SW	0.639	0.209	-0.735	0.004
ST	-37.283	4.263	-1.034	0.000

[1]Using pooled data from the three strains of chickens, β: Estimated regression coefficient value, SE: Standard error, EW: Egg weight, ESI: Egg shape index, SW: Shell weight, ST: Shell thickness

Table 4: Multiple regression model describing the relationship between external egg quality traits and hatchability[a]

Model[b]	R	R^2	Adjusted R^2	SE of the estimate
$\hat{y}$ = 124.169-0.007EW-0.358ESI+ 0.639SW-37.283ST	0.836[a]	0.698	0.670	0.38355

[a]Predictors: constant, EW: Egg weight, ESI: Egg shape index, SW: Shell weight, ST: Shell thickness, [b]Dependent variable: Hatchability, $\hat{y}$ = Estimated hatchability from regression model

CONCLUSION

The results from this study show that it is logical to infer that hatchability is not a one-factor cause and effect phenomenon. Rather, hatchability rates among individuals of the same or diverse strains are not only consequent upon factors additive in their respective effects but also complementary in their actions. The development of the hatchability index or model from this study therefore suggests the likelihood that the various external egg quality traits influencing hatchability could be interpreted in an integrated manner, rather than from a mutually exclusive individual basis.

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