ISSN 1682-8356
ansinet.org/ijps

INTERNATIONAL JOURNAL OF POULTRY SCIENCE

ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorijps@gmail.com

International Journal of Poultry Science 6 (1): 59-63, 2007
ISSN 1682-8356
© Asian Network for Scientific Information, 2007

Statistical Modeling of Egg Weight and Egg Dimensions in Commercial Layers

O.T.F. Abanikannda[1], O. Olutogun[2], A.O. Leigh[1] and L.A. Ajayi[1]
[1]Department of Zoology, Lagos State University, Nigeria
[2]Department of Animal Science, University of Ibadan, Nigeria

Abstract: Egg weight and dimensions of table eggs from Harco heavy breed layers in the humid tropics of Lagos, Nigeria were measured, and relationships between Egg Weight (EGGWT), Egg Length (EGGLT), Egg Width (EGGWD) and Egg Shape Index (SHPINDX) were studied. A total of 2951 eggs obtained from layers in five different age groups were sampled. Egg weight and egg width exhibited similar pattern in their distribution across the different age groups, with steady increase from age group A (22 - 32 weeks), peaked at age group D (55 - 65 weeks) before a decline afterwards. Egg length consistently increased with increasing age of hen, while shape index consistently decreased with increasing age of hen. Correlation between egg weight & egg length, egg width and shape index was 0.78, 0.84 and -0.07 respectively, while the correlation between egg length & egg width and shape index was 0.53 and -0.60 respectively, and between egg width and shape index was 0.37. The fitted model of the study was EGGWT = -124.72 + 1.65(EGGLT) + 1.32(EGGWD) + 0.43(SHPINDX). All coefficients obtained were significant ($P<0.05$), however, it was observed that egg length and egg width were better predictors of egg weight when compared to shape index. Analysis of variance revealed that effects of all factors studied (age group, egg length, egg width, shape index and egg length x egg width interaction) were highly significant ($P<0.01$) on egg weight except for shape index which was significant ($P<0.05$). Egg dimensions were good estimators of egg weight.

Key words: Egg weight, dimensions, statistical model

Introduction

Poultry breeding is generally acceptable to people all over the world and provides an excellent source of protein especially for poor rural communities, because it requires little capital, labour and land. Poultry birds are good converters of feed into useable protein in meat and egg. The production cost per unit is low relative to other types of livestock and the return on investment is high, thus farmers need just a small amount of capital to start poultry. Also meat produced is very tender, so it is palatable and acceptability to consumer is high. Poultry has a short production cycle (i.e. pay back period) through which capital is not tied down over a long period.

The egg of chicken is a biological structure intended by nature for reproduction and it also provides a complete diet for the developing embryo. However, in the developing countries, egg is more affordable by the common man than other sources of animal protein and as such this gives poultry more advantage over other livestock (Ojo, 2000; Okeke, 2000).

Egg weight is an important egg trait, which influence egg quality as well as grading (Farooq *et al.,* 2001). It is a parameter which could be determined about the egg without breaking the egg (Wilson and Suarez, 1993; Farooq *et al.,* 2003). The weight of an egg is a direct proportion of albumen, yolk and shell it contains and this varies significantly between strains of hen (Pandey *et al.,* 1986) and the hens' age affects this proportion of yolk, albumen and shell produced, thus egg weight increases with hens age, reaching a plateau by the end of the laying cycle (Danilov, 2000).

Egg length is also referred to as the height of the egg. It is the longest portion observed on the external surface. The egg length is also referred to as the long border. Conversely, egg width is the shorter portion of the egg. The dense mass of egg (yolk) is situated at the center of the egg which is also responsible for the wideness of the width. The width of an egg is also referred as the breadth or the short border (Gunlu *et al.,* 2003). The relationship between egg weight, egg length and egg width was reported by Choprakarn *et al.* (1998).

The shape of birds' egg is a matter of natural convenience rather than aesthetic consideration and the overall shape of an egg should be smooth in order to assist in laying.

Kimber (2005) investigated the height/width ratio of birds' eggs, a proportion which is more a result of function than artistic perfection, while Panda (1996) and Gunlu *et al.* (2003) defined egg shape index as the ratio of the short border relative to the long border.

It is therefore the objective of this study to estimate the statistical measures of weight, length, width and shape index of egg, investigate the relationship between the variables, and fit a statistical model for predicting weight of an egg using egg dimensions.

Materials and Methods

This study was conducted at the Department of Zoology, Lagos State University, Ojo-Lagos, Nigeria. The eggs used in this study were obtained from a commercial poultry farm located on the fringes of Lagos State, bordering Ogun State in the humid tropics of south western part of Nigeria, during the period of November and December 2006.

Experimental animals and management: The eggs used in this study were laid by Harco black strain of chicken which were sourced from the same hatchery and raised under similar management techniques. The farm had birds at different stages of lay.

Day old pullets were purchased from reputable hatcheries and kept on litter till about 18 weeks before they are moved to the battery cage. During the first four weeks of development, the chicks were protected from cold by placing electric bulbs in their pens, which has polythene sheets attached to the sides to provide warmth during brooding.

During lay, the birds are fed twice daily with compounded ration containing 16% crude protein, other constituents of their feed includes vitamins, minerals and amino acid. Water is provided *ad libitum*.

The birds are routinely vaccinated at certain stages of development against diseases such as Newcastle, Gumboro, Coccidiosis etc.

Egg collection at farm was usually done in the evening around 5.00pm, and egg measurements are done the next day in the laboratory.

Experimental design: A total of one hundred trays of eggs were sampled. This comprises of twenty trays from each of the five distinct age groups. For ease of comparison, the birds are classified into five nominal groups based on their ages (Table 1). Each tray holds 30 eggs. Despite the intent for a balanced design, some eggs were eliminated from the study due to their physical state (broken or cracked), thus, a total of 2,951 eggs were eventually used in the analyses.

Data collection and statistical analyses: The eggs were identified and labeled by pasting a masking tape with appropriate identification tag around the sharp end of the egg.

Egg weight was measured using a 0.0g sensitive digital scale. This is done by gently placing the egg on the flat surface of the scale ensuring that the scale is set to 0.0g before measurement. Egg length and egg width of the egg were measured with electronic digital Vernier caliper sensitive to 0.00mm. Shape Index is estimated using Panda (1996) formula;

$$\text{Shape Index} = [\text{egg width} / \text{egg length}] \times 100$$

All statistical analyses were done using S-Plus (2001) statistical software.

Descriptive statistics and basic exploratory analyses were done using the summary statistics sub-routine of the computer program. Measures obtained includes: minimum, maximum, mean, number of observation, standard deviation, standard error of the mean and the confidence limits at 95%.

Table 1: Age grouping of laying hens

Age groups	Age intervals (weeks)
A	22-32
B	33-43
C	44-54
D	55-65
E	66-76

The relationship amongst the four parameters under study was estimated using the linear correlation procedures.

Linear regression of the different variables (egg length, egg width and shape index) on egg weight was carried out. The model that describes the regression analysis is given as:

$$\hat{Y} = \beta_0 + \beta_1 L + \beta_2 W + \beta_3 S$$

Where Y is the estimated Egg weight and L, W and S are the Length, Width and Shape index.

Factors affecting the weight of eggs were studied and the statistical model describing the analysis of variance is given as;

$$Y_{ijklm} = \mu + A_i + L_j + W_k + S_l + (LW)_{jk} + e_{ijklm}$$

Where

Y_{ijklm} = the observed egg weight

μ = population mean

A_i = i^{th} fixed effect of age group (I=1-5)

L_j = j^{th} covariate of egg length

W_k = k^{th} covariate of egg width

S_l = l^{th} covariate of shape index

$(LW)_{jk}$= interaction of egg length by egg width

e_{ijklm} = residual random error.

Results

Egg weight: The mean egg weight for the combined ages in this study is 55.99±0.11g (Table 2). The 95% lower confidence limits of egg weight are 55.76, 49.54, 56.00, 56.46, 58.18 and 57.68g for the combined, group A,-E respectively. While the 95% upper confidence limits are respectively 56.21, 50.34, 56.71, 57.56, 59.09 and 58.41.

Egg length: The mean egg length for the combined ages in this study is 56.27±0.05mm (Table 2). The 95% lower confidence limits of egg length are 56.17mm, 53.69mm, 56.00mm, 56.43mm, 57.06mm and 57.23mm for the combined, group A, group B, group C, group D and group E respectively. While the 95% upper confidence limits are respectively 56.37mm, 54.03mm, 56.33mm, 56.86mm, 57.48mm and 57.62mm.

Table 2: Means ± Standard Errors for the Variables Studied

Age group (weeks)	N	Egg weight (g)	Egg length (mm)	Egg width (mm)	Shape index (%)
A (22-32)	596	49.94 ± 0.20^{c}	53.86 ± 0.09^{d}	40.91 ± 0.06^{d}	76.02 ± 0.12^{a}
B (33-43)	599	56.35 ± 0.18^{b}	56.16 ± 0.08^{c}	42.53 ± 0.05^{c}	75.79 ± 0.12^{ab}
C (44-54)	564	57.01 ± 0.28^{b}	56.65 ± 0.11^{b}	42.77 ± 0.07^{bc}	75.58 ± 0.13^{ab}
D (55-65)	596	58.63 ± 0.23^{a}	57.27 ± 0.10^{a}	43.15 ± 0.11^{a}	75.47 ± 0.16^{b}
E (66-76)	596	58.05 ± 0.19^{a}	57.43 ± 0.11^{a}	42.90 ± 0.05^{b}	74.81 ± 0.13^{c}
Combined	2951	55.99±0.11	56.27±0.05	42.45±0.03	75.53±0.06

Means with different superscript in the same column differs significantly (P<0.05)

Egg Width: Mean egg width for the combined ages in this study is 42.45±0.03mm (Table 2). The 95% lower confidence limits of egg length are 42.39mm, 40.79mm, 42.42mm, 42.62mm, 43.01mm and 42.80mm for the combined, group A, group B, group C, group D and group E respectively. While the 95% upper confidence limits are respectively 42.51mm, 41.03mm, 42.63mm, 42.91mm, 43.31mm and 43.01mm.

Shape Index: The mean shape index for the combined ages in this study is 75.53±0.06% (Table 2). The 95% lower confidence limits of egg length are 75.41%, 75.78%, 75.55%, 75.32%, 75.16% and 74.55% for the combined, group A, group B, group C, group D and group E respectively. While the 95% upper confidence limits are respectively 75.65%, 76.26%, 76.03%, 75.84%, 75.78% and 75.07%.

Relationship amongst correlates studied: Correlation amongst the four variables studied, are presented in Table 3. Egg weight had a high positive correlation with egg length and egg width and very low negative correlation with shape index. This implies that relationship between egg width and egg weight is stronger than association between egg length and egg weight.

Discussion

Egg Weight: Age group A recorded the least mean egg weight while Age group D had the maximum mean egg weight. There was a consistent increase in egg weight with increasing age of hen before it peaked at age group D, thereafter there was a decline in the egg weight at age group E. With the exception of age group A that was statistically different from the other four age groups, there was no statistical difference (p>0.05) in the mean egg weight of age groups B and C and similarly, there was no significant difference (p>0.05) in the mean egg weight of age groups D and E (Table 2).

With advancing age, mean egg weight consistently rise from age group A to age group D and then declines afterwards. This observation is in agreement with the works of O'Sullivan *et al.* (1991); Bermudez *et al.* (1992); Gous *et al.* (2000); Peebles *et al.* (2000); Silversides and Scott (2001).

The mean egg weight of 49.94g for Age group A (22-32 weeks) obtained in this study is in consonance with the mean egg weight of 49.80g obtained by Choprakarn *et al.* (1998) who worked on Thai indigenous hens aged 21-35 weeks. The mean egg weight of 56.35g recorded for the age group B is close to 55.95g mean egg weight reported by Monira *et al.* (2003) who worked on Rhode Island Red of similar age in Bangladesh, and also the 56.72g obtained by Bunchasak *et al.* (2005) who worked on Babcock B-308 laying hen in Thailand.

However, Monira *et al.* (2003) who also worked on White Leghorn reported a mean egg weight of 58.38g which was 2.39 percent higher than the mean egg weight observed for this age group in the Harco black strain in this study. This variation may be attributed to the different breeds of laying hen, different nutrition plan and the total number of the population sampled (Choprakarn *et al.*, 1998).

Egg Length: There was consistent increase in egg length across the ages from group A to group E. The highest mean egg length was recorded in age group E, while the least egg length was recorded in age group A. The consistent increase in mean egg length with age of laying hen observed in this study agrees with reports of Anderson *et al.* (2004) and Gunlu *et al.* (2003).

The mean egg length of age group E is 6.21% higher than that of age group A. The mean egg length obtained in this study is in coherence with the 56.20mm obtained by Monira *et al.* (2003) who worked on White Rock breed of layers but a variation of 2.90mm was observed by Monira *et al.* (2003) who also studied White Leghorn breed, where he reported a mean egg length of 59.10mm. This variation could be as a result of the differences in the breeds studied.

Choprakarn *et al.* (1998) who carried out study on Thai indigenous pullets of similar age as the age group A, obtained a mean egg length of 54.00mm which is close to the value obtained in this study.

Egg width: There is striking similarity in the distribution of egg weight and egg length suggesting an initial relationship between the two variables. The egg width steadily increases from age group A to group D before it declines at age group E, albeit not statistically different (P>0.05). Egg width increases with increasing age of hen and it peaked at about a year old before it declines. This may be due to the fact that, during the process of egg formation, as the content of the egg travels down the oviduct it becomes encased by the shell and forced out

Table 3: Correlation coefficient matrix of variables studied

	Egg weight	Egg length	Egg width	Shape Index
Egg weight	1.000	0.784	0.839	-0.065
Egg length		1.000	0.527	-0.590
Egg width			1.000	0.366
Shape index				1.000

Table 4: Analysis of variance of factors affecting egg weight

Sources	df	Mean Square
Age group	4	7294.12***
Egg Length (L)	1	42529.00***
Egg Width (W)	1	25080.62***
Shape Index (S)	1	29.70*
Egg Length * Width (LW)	1	104.74***
Error	2942	5.01

*** = P< 0.001, ** = P< 0.01; * = P <0.05

through the vent. In pullets, the oviduct tends to be narrower such that only a small width of shell can be forced along with the egg content thereby resulting in slimmer egg width. Subsequently, as the hen grows older, the oviduct becomes wider allowing a larger width and consequently, the egg width increases with age. Decrease at later ages of the hen may be due to the decreased calcium deposition for egg shell by the aging hen.

The mean egg width obtained in this study is similar to the 43.61mm obtained by Anderson *et al.* (2004) who worked on the single comb White Leghorn of similar age and also close to the 41.00mm obtained by Choprakarn, *et al.* (1998) who worked on Thai indigenous hens.

Shape index: The consistent decrease in shape index with increasing hen age (Table 2) revealed that the shape index of the eggs decreased with age because shape index is directly proportional to egg width and it is inversely related to egg length, which implies that with increasing age, the rate at which eggs becomes longer is faster than rate of being wider. This observation is in agreement with the studies of Brand, *et al.* (2004); Choprakarn *et al.* (1998) and Gunlu *et al.* (2003).

The combined mean shape index obtained in this study is similar to the 75.60% reported by Hasnath (2005) who worked on Fayoumi hens and also close to the 75.08% observed by Brand *et al.* (2004) who worked on Isa Waren Layers. However, it is 1.43% higher than the mean shape index of 74.10% observed by Monira *et al.* (2003) who worked on White Rock Layers.

Relationship amongst correlates studied: The relationship between egg length and egg width was moderately positive, while there was an inverse association between egg length and shape index. The reason that may be advanced for this negative relationship is the fact that egg length is the denominating factor in estimating shape index according to Panda (1996) and Gunlu *et al.* (2003). This observation agrees with reports of Choprakarn *et al.* (1998). Egg width shows positive correlation with shape index albeit low, this is because shape index in directly related to egg width, and this result is similarly observed by Ozcelik (2002); Kul and Seker (2004).

The reason for this could be as a result of the denser part of the egg (yolk) occupying the width area, which translates to heavier weight for the egg. This observation agrees with reports of Choprakarn *et al.* (1998); Farooq *et al.* (2001) and Kul and Seker (2004).

Regression analysis: The regression of egg length, egg width and shape index on egg weight was highly significant (P<0.01). This observation is in agreement with Choprakarn *et al.* (1998) who reported that egg weight was positively regressed (P<0.01) to egg width and egg length, however, he reported that regression of shape index was not significant. The model describing egg weight in this study is given as;

where L, W and S are respectively the Length, Width and Shape Index of the egg.

Factors affecting egg weight: This analysis of variance (ANOVA) entails the inclusion of age group as a fixed factor and the correlates studied as covariates on egg weight.

With the exception of Shape Index which was significant at 5%, all other factors studied were highly significant (P<0.001). Egg length was the largest source of variation in this study, followed by age group and egg width (Table 4).

The significant effects of age group revealed in this study have been extensively reported by several researchers who had worked on different breeds of chicken (Coutts and Wilson, 1990; Monira *et al.,* 2003 and Gerber, 2006).

The most significant factor affecting egg weight in this study is egg length (P<0.001) and the statistical difference in the means is as presented in Table 2. This observation confirms the reports of Monira *et al.* (2003) and Anderson *et al.* (2004).

The significant effect of egg width is as reflected in the mean separation across the various age groups (Table 2), and this may be due to the fact that the denser part of the egg is located around the wide area of the egg, thereby positively contributing to the total weight of the egg. This corroborates the initial observation of the regression of egg width on egg weight.

Though significant, shape index had the least effect and is the least contributor to the sources of variation studied. This may be because shape index is a function of egg length and egg width rather than egg weight. Expectedly, the interaction of egg length and egg width exerted highly significant effect on the weight of the eggs. This is because both factors determine the volume and holding capacity of the egg and consequently the weight of the egg.

Conclusion: Based on the results obtained in this study, the following conclusions can be drawn on the relationship between egg dimensions and egg weight;

As the age of the laying hen increases, egg weight, egg length and egg width increase, while shape index decreases with age of laying hen.
Egg length and egg width had a high positive correlation with egg weight, and in the regression analysis, egg length and egg width had a high significance on egg weight (P<0.001) but shape index was only significant at 5 percent.
Age group, egg length, egg width, egg length x egg width interaction were highly significant on egg weight (P<0.001) while shape index exhibited significance at 5 percent on egg weight.

Acknowledgement

The authors sincerely appreciate the assistance of management and staff of Ibukun Farms Limited, Lagos, Nigeria, for supplying the eggs and granting us access to their facilities.

References

Anderson, K.E., J.B. Tharnington, P.A. Curtis and F.T. Jones, 2004. Shell characteristics of eggs from historic strains of single comb white leghorn Chicken and the relationship of egg shape of shell strength. Int. J. Poult. Sci., 3: 17-19.

Bermudez, J.J., M. Parez and J. Gonzalez, 1992. Effect of body weight on egg weight in White Leghorn hens. Revista Caban de ciencia Avicola, 19: 42-46.

Brand, H.V.D., H.K. Parameter and B. Kemp, 2004. Effects of housing system cout door vs cages and age of laying hens on egg characteristics. Br. Poult. Sci., 45: 745-752.

Bunchasak, C., K. Poosuwan, R. Nukrawe, K. Markvichitr, and A. Chwthesam, 2005. Effect of dietary protein on egg production and immunity response of laying hens during peak production period. Int. J. Poult. Sci., 4: 701-708.

Choprakarn, K., I. Salangam and K. Janaka, 1998. Laying performance, egg characteristics and egg composition in Thai indigenous hens.

Coutts, J.A. and G. Wilson, 1990. Egg Quality Handbook. Queensland Department of Primary Industries Information Series. Q190014.

Danilov, R.V., 2000. Effect of hens age on quality of hatching eggs and embryonic development proceeding of 21st World's Poultry Congress 2000, Montreal, Canada.

Farooq, K.A.M., F.R. Durrani, K. Sarbiland and N. Chaud, 2003. Predicting egg weight, shell weight, shell thickness and hatching chick weight of Japanese quails using various egg traits as regressors. Int. J. Poult. Sci., 2: 164-167.

Farooq, M., M.A Mian, M. Ali, F.R. Durrani, A. Asquar and A.K. Muqarrab, 2001. Egg traits of Fayomi bird under subtropical conditions. Sarad J. Agri., 17: 141-145.

Gerber, N., 2006. Factors affecting egg quaslity in the commercial laying hen: a review . egg producers Federations of New Zealand (Inc)/Poultry industry Association of New Zealand 96D Carlton Gore Road, New Market, 1023, Auckland.

Gous, R.M., G.D. Bradford, S.A. Thouston and T.R. Morris, 2000. Effect of age of release from light or food restrictions on age of sexual maturity and egg production of laying pullets. Br. Poult. Sci., 41: 263-271.

Gunlu, A., K. Kiriki, O. Cetin and M. Carip, 2003. Some external and internal quality characteristics of patridge (*A. graeca)* eggs. Food Agri. Environ., 1: 197-199.

Hasnath, M.R., 2005. Effect of feeding system on the egg production of Fayoumi hens of model breeding unit under PLDP programme in Bangladesh.

Kimber, H., 2005. The "Golden Egg" University of Survey Guildford, England.

Kul, S. and I. Seker, 2004. Phenotypic correlation between some external and internal egg quality traits in the Japanese quail (coturnix coturnix japonica).

Monira, K.N., M. Salahuddin and G. Miah, 2003. Effect of breed and holding period on egg quality charactics of chicken. Int. J. Poult. Sci., 2: 261-263.

O' Sullivan, N.P., E.A. Dunnington and P.B. Siegal, 1991. Relationship among age of dam, egg components, embryo lipid transfer, and hatchability of broiler breeder eggs. Poult. Sci., 70: 2180-2185.

Ojo, S.O., 2000. Productivity and technical efficiency of poultry egg production in Nigeria. Int. J. Poult. Sci., 2: 459-464.

Okeke, C.E., 2000. Raising healthier poultry: Nigeria National Centre for Energy Research and Development, University of Nigeria, Nsukka.

Ozcelik, M., 2002. The phenotypic correlation among some external and internal quality characteristics in Japanese quail eggs. Vet. J. Ankara Univ., 49:67-72.

Panda, P.C., 1996. Shape and texture. In Textbook on egg and poultry technology, pp:57.

Pandey, N.K., C.M. Mahapatra, S.S. Verma and D.C. Johari, 1986. Effect of strain on physical egg quality characteristics in white Leghorn Chickens. Indigenous J. Poult. Sci., 21: 304-307.

Peebles, E.O., C.D. Zumwalt, S.M. Doyle, P.D. Gerard, Latour, M.A. Matour, C.R. Bayle and T.W. Smith, 2000. Effect of breeder age and dietary fat source and level on broiler hatching egg characteristics. Poult. Sci., 79: 698-708.

Silversides, F.G. and T.A. Scott, 2001. Effects of Storage and laying age on quality of eggs from two lines of hens. Poult. Sci., 80: 1240-1245.

S-Plus, 2001. S-Plus 6.0 Professional Release 2. Insightful Corporation. 1700 Westlake Avenue North, Suite 500, Seattle, WA 98109, USA.

Wilson, H.R. and M.E. Suarez, 1993. The use of egg weight and chick weight coefficient of variation as quality indictors in hatchery management. J. Appl. Poult. Res., 2: 227-231.