Influence of egg weight, breed and age of hens on weight loss of hatching broiler eggs

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SUMMARY

Physiological processes that take place during incubation of eggs often resulted in changes in egg weight during the period. This study investigated the effects of breed, age of hen and egg size on weight loss at three points between incubation and hatching viz: pre-incubation, 18th day of incubation, chick weight at hatching. A total of 1002 hatching eggs from three strains; Anak (n=361), Marshall (n=359) and Ross (n=282) of broiler breeders were weighed and measured using digital weighing scale and digital calliper. Weight, length and width were taken prior to incubation, while shape index was also computed. Weight losses from incubation to 18 days (WtLoss1), 18th day to hatching (WtLoss2) and incubation to hatch (WtLoss3)] were computed. The JMP(R) statistical software was used for basic descriptives, regression analyses and statistical modelling of the data. The model used for the regression analysis was described by $Y_{ij} = \mu + \alpha i + \beta j + \varepsilon_{ij}$ describing each of the three response variables. Egg weight was between 44.60g and 81.70g, while egg length ranged between 49.99mm and 69.98mm, and egg width was between 38.54mm and 56.75mm, while shape index was between 61.44% and 99.02% across the three strains studied. The largest source of variation was breed effect which was highly significant (P<0.001) on all four variables. Similarly, breed significantly (P<0.001) impacted on WtLoss1 and WtLoss3 but was not a significant (P>0.05) source of variation on WtLoss2. All the predictor variables were significantly (P<0.05) correlated to the response variables except shape index which had negative and non-significant (P>0.05) correlation with the weight losses. The very low negative and non-significant correlation between egg weight and egg weight loss up to the 18th day of incubation indicated that weight loss was slower in bigger eggs compared to relatively smaller eggs. The study revealed that breed was a significant source of variation on weight loss at the 18th day of incubation (WtLoss1) and throughout the entire period of incubation and hatching (WtLoss3) but was not significant on weight loss after

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the 18th day (WtLoss2). The study also revealed that hatchability of eggs has an inverse relationship with weight loss.

Keywords: breed, broiler, egg, incubation, weight loss, Nigeria

INTRODUCTION

Meat and eggs being acceptable forms of animal protein to most people, has endeared poultry as the most popular option to reduce the problem of malnutrition in Nigeria. Moreover, there is no socio / religious / cultural restrictions associated with consumption of poultry products when compared with other classes of animals.

The broiler is a type of chicken raised specifically for meat production. It has a very efficient feed conversion ratio and reaches table weight quickly, in about 6-8 weeks. The success of the broiler enterprise is largely dependent on the quality and quantity of broiler eggs produced by the breeder hens and this among other factors have been identified to greatly impact on the final weight of the birds. Factors such as breed, egg weight and incubation conditions have been reported (Suarez et al., 1997) to influence the chick weight at hatching which significantly affects the growth rate and final weight of the birds.

Egg weight loss that occurs during incubation of eggs is almost entirely due to water diffusion through the shell (Tona et al., 2001). Most of the energy needed for the embryonic development is taken from the fat stores of the yolk and for every gram of fat burned an almost equal mass of metabolic water is generated. Incubation egg weight losses are a function of egg characteristics (shell structure, membrane structure, and initial egg weight) and interacting incubation conditions (temperature, humidity and air velocity) under which the eggs were set (Christensen and McCorkle, 1982 and Gonzalez et al., 1999).

During incubation of broiler and turkey eggs, between 12% and 14% of water is lost (Rahn et al., 1981) which consequently affect the chick weight and thus it becomes imperative to investigate these weight changes in egg during incubation and its consequent impact on chick weight at hatching. To this end, this study aims to achieve the following:

- Examine weight changes in incubated eggs at three different points prior to hatching.
- Assess the effects of breed on weight loss during the incubation of broiler eggs.
- Investigate the influence of hen age on egg weight losses.
- Examine the relationship between egg measurements and egg weight losses across the three breeds.
- Predict chick weight from egg weight across the three breeds.
- Suggest standard weight range for eggs meant for incubation.

MATERIAL AND METHODS

The eggs used in the study were sourced from three Parent Stock Farms (S&D Farms, Obasanjo Farms and UNAAB-Leventis farms) in Ogun and Oyo States of Nigeria. A total of 1002 fertile eggs from three strains [Anak (361), Marshall (359) and Ross (282)] were used in the study.

Management practices differ across the three farms where the eggs were sourced. In one farm, natural mating of hens in cages was practiced, while in the other farm, cocks roam freely with hens on floor while the third farm strictly practiced artificial insemination of hens in cages.

Eggs from the Anak strain were obtained from breeders at four different ages (39, 43, 66 and 106 weeks), while eggs from Marshall strain were from two age groups (39 and 50 weeks) and the eggs from the Ross strain were from breeders at uniform age of 47 weeks. The eggs were appropriately tagged by pasting a paper tape with appropriate identification on the tape. The tagging took into consideration the breed types, age of hen and source of egg. After sorting, the eggs were packed into trays to reduce mechanical damage like cracking or breaking and excessive shaking was also avoided. Eggs were collected from the farm and were stored in the cold room with the pointed end up in trays at a temperature of 14^{o}C and relative humidity of about 75% to avoid exposure of eggs to high temperature during measurements. Measurements of egg weight, egg length, egg width, vertical circumference and horizontal circumference was taken using digital scale and Vernier calliper.

After the routine cleaning of the incubator, all eggs were set in the incubator at the same time under optimum incubator conditions.

Candling was done at the 18th day of incubation to cull out infertile eggs and eggs with dead embryo and fertile eggs were re-weighed. Fertile eggs were placed in the hatching trays that were partitioned into individual cells to prevent the chick crossing at break-out.

Data preparation entailed the entry of data into an excel worksheet and statistical manipulation of the data to compute some of the indices that were not directly measured on either the eggs or chick.

Shape index was computed using Panda (1996) as;

$$\text{Shape Index} = \left[\frac{\text{Egg Width}}{\text{Egg Length}}\right] \times 100$$

Weight was measured at three different times (pre-setting, candling and hatching) for the egg and the chick. The three weight losses were computed as follow:

$$\text{Weight Loss1 (WTLoss1)} = \left[\frac{\text{Pre-Setting Egg Weight - 18 Day Egg Weight}}{\text{Pre-Setting Egg Weight}}\right] \times 100$$

$$\text{Weight Loss 2 (WTLoss2)} = \left[\frac{\text{18 Day Egg Weight - Chick hatch Weight}}{\text{18 Day Egg Weight}}\right] \times 100$$

$$\text{Weight Loss 3 (WTLoss3)} = \left[\frac{\text{Pre-Setting Egg Weight - Chick hatch Weight}}{\text{Pre-Setting Egg Weight}}\right] \times 100$$

Preliminary descriptive statistical analyses were done before statistical modelling and analysis. All statistical analyses were done using JMP (2010) Statistical Software.

Statistical analyses conducted include basic exploratory analysis, Pearson's correlation matrix, regression analysis and statistical modelling. The statistical model describing each of the regression for the weight losses was given as; $Y_{ijk} = \alpha_i + \beta_j + e_{ijk}$ **,** where Y_{ijk} is the observed measure, α_i is the intercept, β_j is the coefficient and e_{ijk} is the residual random error, while the General Linear Model describing the ANOVA was given as; $Y_{ijkl} = \mu + \alpha_i + \beta_j + \delta_k + e_{ijkl}$ **,** where Y_{ijkl} is the observed measure, μ is the overall mean, α_i is the fixed effect of breed, β_j is the random effect of hen's age, δ_k is the covariate effect of egg weight and e_{ijkl} is the residual random error. The Tukey's procedure for mean comparison was used after a significant effect is observed.

RESULTS AND DISCUSSION

A preliminary descriptive analysis conducted on the data for the six egg measures across the three breeds is given below (Table 1).

Table 1: Basic descriptives of egg measurements by breed

Breed	N	Egg weight (g) Mean ± SE	Egg length (mm) Mean ± SE	Egg width (mm) Mean ± SE	Vertical circum. (cm) Mean ± SE	Horizontal circum. (cm) Mean ± SE	Shape Index (%) Mean ± SE
Anak	361	58.66^c ± 0.30	57.38^b ± 0.15	42.93^c ± 0.09	16.38^b ± 0.04	14.07^b ± 0.03	74.92^b ± 0.19
Marshall	359	60.33^b ± 0.30	57.40^b ± 0.15	43.62^b ± 0.09	16.28^b ± 0.04	14.08^b ± 0.03	76.15^a ± 0.19
Ross	282	66.02^a ± 0.34	59.65^a ± 0.17	45.41^a ± 0.10	16.72^a ± 0.04	14.40^a ± 0.04	76.24^a ± 0.22
Combined	1002	61.33 ± 0.21	58.02 ± 0.09	43.87 ± 0.06	16.44 ± 0.02	14.17 ± 0.02	75.73 ± 0.12

Means with different superscript within the same column are statistically (P<0.05) different

Egg Weight: Breed effect was highly significant (P<0.001) on the weight of eggs with the Ross breed having the heaviest eggs while Anak had the lightest (Table 1). Breed alone accounted for 21.59% of the total variation in egg weight and this further confirms the result of Wolanski et al., (2007) who also reported breed differences in the weight of eggs. The mean egg weight of 61.33g in this study is close to the value reported by Wolanski et al., (2007). The Ross breed was 12.55% higher than Anak, 9.43% higher than Marshall while Marshall was 2.85% higher than Anak.

Since only two of the three breeds studied had different age groups, the effect of interaction between breed and age group could not be included in the model for the entire study. However, the effects of hen age within the Anak and Marshall breed are as presented in Table 2.

Table 2: Basic descriptives of egg measurements by age of hen within breed

Breed	Age (Weeks)	N	Egg weight (g) Mean ± SE	Egg length (mm) Mean ± SE	Egg width (mm) Mean ± SE	Ver. circum. (cm) Mean ± SE	Hor. circum. (cm) Mean ± SE	Shape index (%) Mean ± SE
Anak	39	147	57.07^{b} ± 0.41	56.50^{b} ± 0.20	42.40^{b} ± 0.12	16.26^{b} ± 0.05	14.02^{b} ± 0.05	75.13^{ab} ± 0.28
	43	52	56.32^{b} ± 0.70	56.30^{b} ± 0.33	42.57^{b} ± 0.21	16.45^{b} ± 0.09	14.30^{a} ± 0.09	75.67^{a} ± 0.47
	66	104	60.35^{a} ± 0.49	58.16^{a} ± 0.24	43.42^{a} ± 0.15	16.24^{b} ± 0.06	13.81^{c} ± 0.06	74.80^{ab} ± 0.34
	106	58	61.75^{a} ± 0.66	59.16^{a} ± 0.32	43.69^{a} ± 0.20	16.87^{a} ± 0.08	14.48^{a} ± 0.08	73.93^{b} ± 0.45
Marshall	39	185	56.00^{b} ± 0.35	55.22^{b} ± 0.17	42.80^{b} ± 0.11	15.68^{b} ± 0.04	13.70^{b} ± 0.04	77.58^{b} ± 0.25
	50	174	64.95^{a} ± 0.36	59.71^{a} ± 0.18	44.49^{a} ± 0.11	16.92^{a} ± 0.04	14.48^{a} ± 0.04	74.62^{a} ± 0.26

Means with different superscript within the same breed in the same column are statistically ($P<0.05$) different

In the Anak breed, there was a slight decline in egg weight at the 43 weeks age group albeit not significantly different from the values obtained at 39 weeks, which may be as a result of lower number of hens within that category or the fact that hens in each age group are independent populations. Egg weight thereafter steadily increases with increasing hen age. Older hens (50 weeks old) in the Marshall group had significantly ($P<0.001$) larger eggs which was almost 16 percent heavier than those from the 39 weeks age group. Age alone accounted for 14.33% of the total variation in egg weight within the Anak breed and 46.71% in the Marshall breed. The difference in egg weight by hens at different ages especially at the younger stages is a reflection of the continuing physiological development of the hen at that stage.

Egg Length: Breed effect was significant on the length of eggs with the Ross breed having the highest egg length while Anak had the least (Table 1). Breed alone accounted for 11.53% of the total variation in egg length. The Ross breed was 3.96% and 3.92% higher than Anak and Marshall respectively while Marshall was 0.035% higher than Anak. This difference might be as a result of the bigger size of the Ross breeders when compared to the other two breeds.

Influence of age on egg length within the Anak breed followed the same trend as that of egg weight and the same reason adduced for the initial dip in the weight of eggs can be extended to egg length. The unequal number of hens within each age group and the fact that the hens at the different age groups are independent may be advanced for this slight decline in egg length between the 39 and 43 weeks age groups. In the Marshall breed, there was an increase in egg length with increasing age of hen, with eggs from older hens been 8.13% longer than eggs from the younger group (Table 2). Age alone accounted for 17.08% and 48.74% of the total variation in egg length within the Anak and Marshall breeds respectively.

The 58.02mm obtained on mean egg length in this study is higher than 56.27mm reported by Abanikannda et al., (2007) who worked on table eggs. Age alone accounted for 34.73% of total variation in egg length.

Egg Width The effect of breed was highly significant on the egg width with Ross having the highest and Anak the lowest. The mean egg width obtained in this study is 43.87mm which is close to the 43.61mm reported by Anderson et al., (2004). Breed alone accounted for 27.09% of the total variation in egg width. The Ross breed was 5.78% and 4.10% higher than Anak and Marshall respectively while Marshall was 1.61% higher than Anak breed.

In the Marshall breed, age alone accounted for 25.74% of the total variation in egg width, while in the Anak breed, age accounted for only 11.56% of total variation. There was a consistent increase in egg width with increasing hen age as a result of decreased resistance of tissues in the uterus, thus allowing bigger eggs to be formed.

Vertical Circumference: The mean vertical circumference of 16.44cm obtained in this study is very close to the 16.42cm reported by Adeseko (2008).

Breed effect was significant on the vertical circumference of eggs with Ross having the highest and Marshall the lowest. Breed alone accounted for 6.54% of the total variation in vertical circumference (Table 1). The Ross breed was 2.08% and 2.70% higher than Anak and Marshall respectively while Anak was 0.61% higher than Marshall.

Within the Anak and Marshall breeds, age alone accounted for 11.46% and 60.16% of the total variation in vertical circumference. The wide difference in the influence of hen age across the two breeds could be explained by the fluctuation in vertical circumference across age groups within the Anak breed and pronounced difference within the Marshall breed (Table 2).

Horizontal circumference Breed effect was significant on the horizontal circumference with the Ross Breed having the highest while Anak had the least. The mean horizontal circumference of 14.17cm obtained in this study is close to the 14.06cm reported by Adeseko (2008) who worked on similar breeds of birds. Breed alone accounted for 5.81% of the total variation in horizontal circumference in this study. The Ross breed was 2.35% and 2.27% higher than Anak and Marshall respectively while Marshall was 0.07% higher than Anak breed.

Age of hen within breed impacted significantly on horizontal circumference, accounting for 13.01% and 39.74% of the total variation in horizontal circumference of the Anak and Marshall breed respectively. Whilst there was fluctuation in this measure within the Anak breed, probably due to unequal subclass sizes, it was fairly steady within the Marshall breed.

Shape index Breed effects was significant on the shape index with the Ross breed having the highest while Anak had the lowest (Table 1). The mean shape index of 75.73% obtained in this study corroborated the value reported by Abanikannda et al., (2007). Breed alone accounted for 2.69% of the total variation in shape index recorded in the study. This low contribution of shape index to total variation observed across breeds is due to the fact that the index was computed from two separate attributes (egg width and egg length) across the breeds. Ross breed had the highest values while Anak had the lowest. The Ross breed was 1.76% and 0.12% higher than Anak and Marshall while Marshall was 1.64% higher than Anak.

Age of hen significantly affected shape index of egg. This is probably due to the fact that older hens tend to lay longer eggs and shape index has an inverse relationship with egg length (Table 2). Thus the older a hen, the longer its egg and the smaller the egg shape index. Within the Anak breed, age accounted for a meager 2.20% of the variation in shape index, while in Marshall it was 16.00%.

Incubation Weight Losses

Weight Loss 1 (WTLoss1): Breed effect was highly significant (P<0.001) on percentage weight loss 1 (WTLoss1) accounting for 5.21% of the total variation.

The Anak breed had the highest weight loss 1 while the Ross breed had the lowest with the Anak breed losing 17.62% and 6.92% more weight than Ross and Marshall respectively while Marshall lost 10% more than Ross. It indicated that Anak which had the smallest egg weight recorded the largest weight loss when compared to the other two breeds in the first 18 days of incubation. There is an inverse relationship between egg weight and weight loss between egg setting and candling at 18th day (WTLoss1). The results on the mean percentage loss 1 are close to a loss of 11.40% reported by Reis et al. (1997).

The influence of hen age on percentage weight loss 1 was not significant (P>0.05) in the Anak breed, but was highly significant (P<0.01) in the Marshall breed. In the Anak breed, though there was slight increase in weight loss with increasing age before a decline at the last age group (Table 4), the unequal subclass sizes might be attributed to this observation. In the Marshall group, eggs from the 50 weeks old hens lost 6.09% more weight than hens from the younger age group.

Weight Loss 2 (WTLoss2):

The effect of breed was not significant (P>0.05) on percentage loss 2 (WTLoss2) accounting for 0.26% of the total sources of variation. Although the Anak breed had the highest while Marshall had the lowest but the difference is not large enough to be statistically significant (P>0.05). The Anak breed lost 4.90% and 0.87% more than Marshall and Ross respectively while Ross lost 4% more than Marshall. The Anak breed with smallest egg weight also lost more than other breeds. This implies that weight loss after the 18th day candling was similar across the three breeds.

However, age of hen was a significant source of variation in the weight loss between the 18th day candling and hatching in the both the Anak and Marshall breeds (Table 4). The irregular pattern observed in the Anak breed might be due to the unequal sample size, but there was increase in weight loss in the Marshall breed as age increases. Eggs from older Marshall hens lost 17.77% more weight than eggs from the younger Marshall hens. This sharp difference might be due to the very large difference in egg weight from these two sub-group and the fact that what was actually lost during incubation was water content of the egg.

Table 3: Egg weight losses at different periods by breed.

Breed	N	Weight Loss 1 (%) Mean ± SE	Weight Loss 2 (%) Mean ± SE	Weight Loss 3 (%) Mean ± SE
Anak	361	$13.75^{a} \pm 0.18$	22.06 ± 0.47	$32.87^{a} \pm 0.40$
Marshall	359	$12.86^{b} \pm 0.19$	21.03 ± 0.48	$31.22^{b} \pm 0.40$
Ross	282	$11.69^{c} \pm 0.21$	21.87 ± 0.54	$31.10^{b} \pm 0.45$
Combined	1002	12.85 ± 0.11	21.63 ± 0.28	31.78 ± 0.24

Means with different superscript within the same column are statistically (P<0.05) different

Table 4: Percentage weight loss by age of hen

Breed	Age (Weeks)	N	Weight Loss 1 (%) Mean ± SE	Weight Loss 2 (%) Mean ± SE	Weight Loss 3 (%) Mean ± SE
Anak	39	147	13.32 ± 0.29	23.24[a] ± 0.82	33.59[a] ± 0.67
	43	52	14.16 ± 0.49	21.30[ab] ± 1.38	32.46[ab] ± 1.13
	66	104	14.35 ± 0.35	23.09[a] ± 0.97	34.22[a] ± 0.80
	106	58	13.42 ± 0.47	17.88[b] ± 1.30	28.99[b] ± 1.07
Marshall	39	185	12.49[b] ± 0.20	19.36[b] ± 0.66	29.46[b] ± 0.56
	50	174	13.25[a] ± 0.21	22.80[a] ± 0.68	33.10[a] ± 0.58

Means with different superscript within the same breed in the same column are statistically (P<0.05) different

Weight Loss 3 (WTLoss3):

The effect of breed was significant on the percentage loss 3. It accounted for 1.15% of the total variation in the weight loss. The Anak breed lost the highest while Ross lost the lowest (Table 3). The Anak loss was 5.29% and 5.69% more than Marshall and Ross respectively while Marshall was 0.39% higher than Ross. The Anak breed with smallest egg weight lost more weight than other breeds from egg to chick weight. The result is in line with Wilson (1991) who reported that chick weight is 62-78% of egg weight. It also corroborated Wolanski et al., (2007) who reported a loss of 31.23% in a broiler strain.

Age of hen significantly (P<0.01) affected weight loss 3 in both breeds (Marshall and Anak). Although the irregular trend in weight loss in the Anak breed can be explained by the unequal sample sizes in the breed, however, there was an increase in percentage loss in eggs from the older Marshall hens than younger hens. Eggs from older Marshall hens lost 12.36% more than eggs from younger hens. This result contradicted the report of Tona et al., (2001) who worked on Cobb broiler breeders and reported that there was no significant relationship between age of hen and weight loss.

Fertility and hatchability of eggs

Highest fertility was recorded in the Marshall breed while the least fertility was recorded in the Ross breed (Figure 1) and the method of rearing the birds might be adduced for this wide difference. Whilst the Marshall were floor mated with cocks permanently being raised with the hens, cocks were being introduced to the Anak breed only during mating, whereas the Ross were strictly artificially inseminated.

The dismally low fertility recorded in the Ross breed might be due to the fact that the birds were not inseminated for a long period of time and the time lag between insemination and egg collection was too short due to the exigencies of the research.

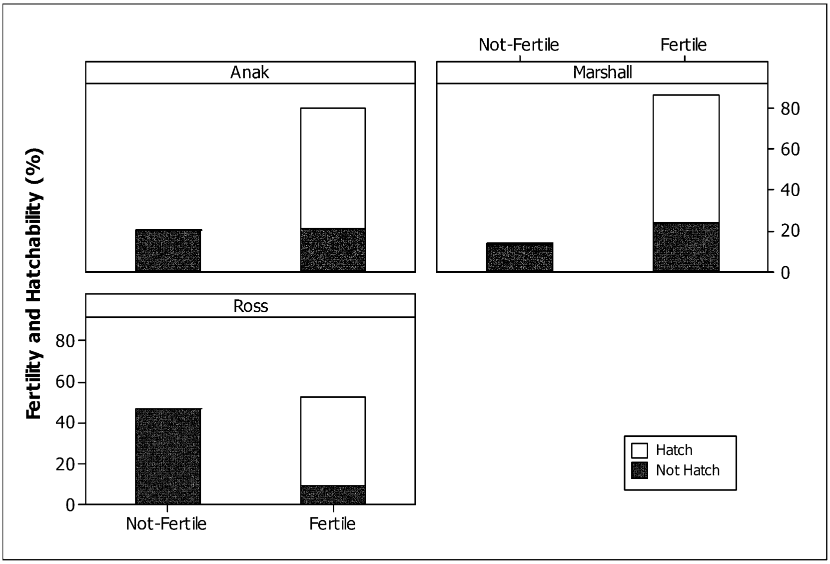

Figure 1. Fertility and hatchability of eggs by breed of hen

Hatchability relative to the total number of eggs set [Hatchability (T)] followed the same pattern as fertility (Figure 2) among the three breeds, while the Ross breed had the highest hatchability relative to fertile eggs [Hatchability (F)] and the Marshall breed had the least. This observation can be explained by the fact that the Ross breed had the least weight loss in the first 18 days of incubation (Weight Loss 1) and similarly the least weight loss between egg setting and chick hatching (Weight Loss 3) as presented in Table 3. This is in consonance with earlier reports that weight loss in eggs affect hatchability of eggs in broiler breeders (Tona et al., 2001).

Correlations amongst measures

The measure of relationship between all measured variables across the age groups with respect to the strength and direction of the association is presented in Table 5.

Table 5: Correlation matrix of egg measurements and weight losses.

	EggWt	EggLt	EggWd	ShpInd	Vercir	Horcir	PerLoss1	PerLoss2	PerLoss3
EggWt	1.0000	0.7743**	0.8189**	-0.0780*	0.7790**	0.6781**	-0.0573^{ns}	0.2804**	0.2662**
EggLt	0.7743**	1.0000	0.4753**	-0.6164**	0.7845**	0.4091**	-0.0671*	0.2348**	0.2143**
EggWd	0.8189**	0.4753**	1.0000	0.3974**	0.5283**	0.6348**	-0.1186	0.2319**	0.1919**
ShpInd	-0.0780*	-0.6164**	0.3974**	1.0000	-0.3502**	0.1370**	-0.0361^{ns}	-0.0385^{ns}	-0.053^{ns}
Vercir	0.7790**	0.7845**	0.5283**	-0.3502**	1.0000	0.7134**	-0.0249^{ns}	0.2613**	0.2557**
Horcir	0.6781**	0.4091**	0.6348**	0.1370**	0.7134**	1.0000	-0.0137^{ns}	0.2124**	0.2094**
PerLoss1	-0.0573^{ns}	-0.0671*	-0.1186**	-0.0361^{ns}	-0.0249^{ns}	-0.0137^{ns}	1.0000	-0.2348**	0.1328**
PerLoss2	0.2804**	0.2348**	0.2319**	-0.0385^{ns}	0.2613**	0.2124**	-0.2348**	1.0000	0.9305**
PerLoss3	0.2662**	0.2143**	0.1919**	-0.0531^{ns}	0.2557**	0.2094**	0.1328**	0.9305**	1.0000

^{ns} = not significant (P>0.05); * = P<0.05; ** = P<0.001

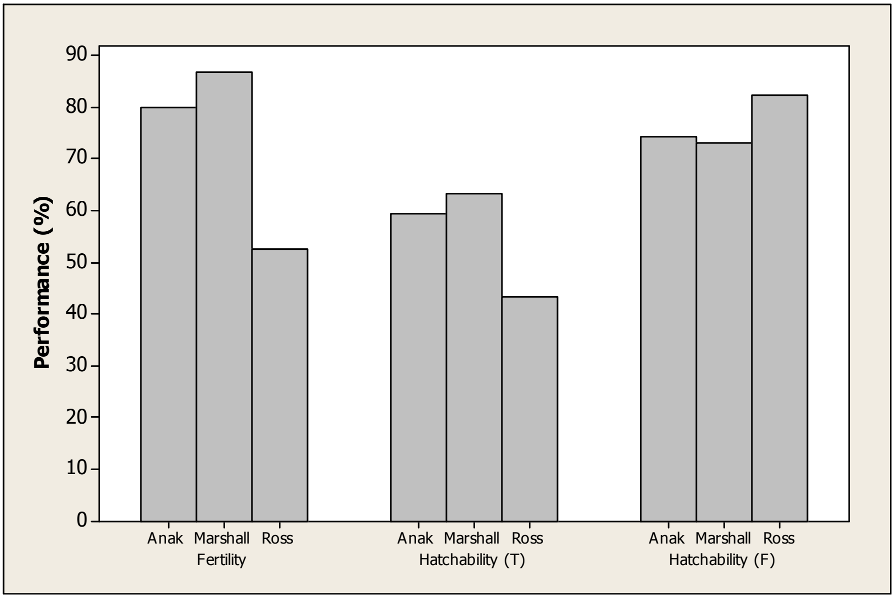

Figure 2: Fertility and hatchability relative to total eggs set and fertile eggs. Hatchability (T) = Hatchability relative to total eggs set; Hatchability (F) = Hatchability relative to fertile eggs.

The relationships among the variables were direct (positive) except for shape index which had a negative correlation with most of the variables. Percentage loss 1 was also negatively correlated with most of the variables.

Egg weight is highly positively correlated with egg length, egg width, vertical circumference but had a very low correlation with percentage loss 2 and 3 and is highly significant.

Egg length is moderately correlated with egg width and horizontal circumference but its correlation with weight losses 2 and 3 was very low albeit highly significant. Its inverse association with shape index may be due to the fact that egg length is the denominating factor in the estimation of shape index. This observation agrees with report of Abanikannda et al., (2007).

Egg width shows a positive correlation with shape index. This is because it is directly related to shape index as the numerator.

Vertical circumference is highly associated with egg weight, egg length and highly significant but has a low association with the percentage losses and highly significant except for percentage loss 1.

Percentage loss 2 had a low correlation with all variables but was highly correlated with percentage loss 3 and was highly significant. Percentage loss 3 also had a low correlation with all variables and which was highly significant.

Table 6: Regression equations for predicting chick weight loss from egg weight by breed.

Breed	N	Regression Equation Weight Loss 1	Regression Equation Weight Loss 2	Regression Equation Weight Loss 3
Anak	361	^{ns}PerLoss1 = 15.05 - 0.02*EggWt	**PerLoss2 = -24.27 + 0.79*EggWt	**PerLoss3 = -5.37 + 0.65*EggWt
Marshall	359	^{ns}PerLoss1 = 10.39 + 0.04*EggWt	**PerLoss2 = -8.40 + 0.49*EggWt	**PerLoss3 = 3.23 + 0.46*EggWt
Ross	282	^{ns}PerLoss1 = 5.60 + 0.09*EggWt	^{ns}PerLoss2 = 17.10 + 0.07*EggWt	^{ns}PerLoss3 = 22.32 + 0.13*EggWt
Combined	1002	^{ns}PerLoss1 = 14.79 - 0.03*EggWt	**PerLoss2 = -2.23 + 0.39*EggWt	**PerLoss3 = 12.62 + 0.31*EggWt

^{ns} = not significant (P>0.05); * = P<0.05; ** = P<0.001

Statistical Modeling of Weight losses by breed

The various regression equations are presented in Table 6.

The percent weight loss for each of the breed, at each of the three points of measurement (setting-candling [Weight Loss 1], candling-hatching [Weight Loss 2], and setting-hatching [Weight Loss 3]) is as presented. Consistent with the earlier results obtained in this study, breed exerted no significant difference on weight loss 1 and consequently the regression of egg weight on weight loss was not significant across the three breeds.

With these equations, it is possible to estimate the expected weight difference between an egg prior to incubation and the chick weight at hatching. However, it is worthy of note that the regression equations were not significant for estimating weight losses at the three points for the Ross breed, which may be due to the very high weight of eggs from this breed (Table 6).

CONCLUSIONS

The following conclusions can be drawn from this study;

- Breed significantly (P<0.01) impacted on all six egg measures studied, with the Ross breed consistently having the largest value for all six measures and Anak consistently having the least for all measures except vertical circumference.
- Age of hen significantly affected all six egg measures studied and the hens peaked at between 47 and 50 weeks of age in all measures. There was an initial decline at the earlier ages and later stages of the hen's productive life.
- The largest weight difference between egg weight at setting and egg weight at 18th day candling (Weight Loss 1) was recorded in the Anak breed, while there was no statistical (P>0.05) difference in weight changes between 18th day candling and hatching. Consistent with Weight Loss 1, the weight

change between egg setting and hatching (Weight Loss 3) was statistically ($P<0.01$) different across the three breeds studied.

- The proportion of weight loss in eggs increases with hens' age, thereby making older hens producing relatively smaller chicks despite their relatively larger eggs.
- With the exception of relationship between Weight Loss 1 and Weight Loss 3, all other correlation with Weight Loss 1 were inverse. Aside from shape index, all other egg measures had between moderate to high correlation with one another.
- Fertility varied widely among the three breeds with the Marshall breed which was naturally pen mated having highest fertility and Ross which was artificially inseminated having the least fertility.
- Hatchability relative to total eggs set followed the same trend as fertility but the Ross breed was superior when hatchability relative to fertile eggs was computed.
- Regression to predict weight losses varied across the three points and three breeds studied. While the regression for Weight Loss 1 was not significant ($P>0.05$) across the breeds, other weight losses were significant except in the Ross breed.

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