COMPARATIVE EVALUATION OF GREEN SHANKED INDIGENOUS CHICKEN FOR PRODUCTION AND EGG QUALITY TRAITS

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN TROPICAL ANIMAL PRODUCTION OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

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ABSTRACT

A study was undertaken at Sokoine University of Agriculture to investigate the influence of shank colour on egg quality traits and production performance. The study involved green shanked Indigenous (GSI) chickens, yellow shanked Indigenous (YSI) chickens and Rhode Island Red (RIR) genetic groups. The genetic groups were reared under the same environment and management. A total of 240 blood plasma samples were used in assessment of plasma cholesterol content while, 120 egg samples were used to assess egg yolk cholesterol and other egg quality traits. RIR differed significantly (P≤0.05) from GSI and YSI genetic groups in terms of egg number, egg weight, egg mass, laying intensity, yolk ratio and yolk albumin ratio. However, there was no significant difference between the indigenous genetic groups for these parameters as well as fertility, hatchability, growth rate and survival rate. The mean egg weights were 40.1 ± 0.8, 42.3 ± 0.9 and 52.0 ± 0.7 gm while the laying intensities were 46.7 ± 1.76, 46.8 ± 1.7 and 76.7 ± 1.7% for GSI, YSI and RIR genetic groups, respectively. There was no significant difference in egg yolk cholesterol, whilst plasma cholesterol differed significantly between RIR and indigenous types. The mean egg yolk cholesterol were 196.2 ± 7.2, 210.1 ± 7.2 and 201.8 ± 7.2 mg/dl for GSI, YSI and RIR respectively, while the blood plasma cholesterol were 210.4 ± 7.5, 196.5 ± 7.5 and 152.1 ± 7.5 mg/dl for GSI, YSI and RIR, respectively. Furthermore, the study revealed that, egg yolk cholesterol increased gradually with age while plasma cholesterol decreased with age in all genetic groups of this study. Total blood plasma cholesterol level increased when indigenous types entered into brooding stage resulting in cyclic pattern between laying and brooding.
DECLARATION

I, Leonard Joseph, do hereby declare to the Senate of Sokoine University of Agriculture that the work presented here is my original work and has neither been submitted nor being concurrently submitted for degree award in any other institution.

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Leonard Joseph                Date
(MSc. Tropical Animal Production Candidate)

The above declaration confirmed by

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Dr. S.H. Mbaga                Date
(Supervisor)
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DEDICATION

This work is firstly dedicated to my Almighty God for His abundance blessings and secondly to my beloved wife Flora, my sons Isaiah and Ian for their love, patience and encouragement during the whole period of my study. My Mother Yosina Marwa, my late Father Joseph Marwa as well as my brothers and sisters for having laid down the foundation of my studies.
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<th>Description</th>
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<tbody>
<tr>
<td>AR</td>
<td>Albumen Ratio</td>
</tr>
<tr>
<td>AW</td>
<td>Albumin Weight</td>
</tr>
<tr>
<td>BWSM</td>
<td>Body Weight at Sexual Maturity</td>
</tr>
<tr>
<td>C.V</td>
<td>Coefficient of variation</td>
</tr>
<tr>
<td>COSTECH</td>
<td>Commission of Science and Technology</td>
</tr>
<tr>
<td>CP</td>
<td>Crude Protein</td>
</tr>
<tr>
<td>DASP</td>
<td>Department of Animal Science and Production</td>
</tr>
<tr>
<td>DF</td>
<td>Degree of freedom</td>
</tr>
<tr>
<td>EDTA</td>
<td>Ethylene Diamine Tetra acetic Acid</td>
</tr>
<tr>
<td>EM90D</td>
<td>Egg Mass at First 90-Days</td>
</tr>
<tr>
<td>EN90D</td>
<td>Egg Number at First 90-Days</td>
</tr>
<tr>
<td>ESI</td>
<td>Egg Shape Index</td>
</tr>
<tr>
<td>EV</td>
<td>Egg Volume</td>
</tr>
<tr>
<td>EW</td>
<td>Egg Weight</td>
</tr>
<tr>
<td>GLM</td>
<td>General Linear Model</td>
</tr>
<tr>
<td>GSI</td>
<td>Green Shanked Indigenous</td>
</tr>
<tr>
<td>L</td>
<td>Egg Length</td>
</tr>
<tr>
<td>LDL</td>
<td>Low Density Lipoprotein</td>
</tr>
<tr>
<td>LI90D</td>
<td>Laying Intensity at First 90 Days</td>
</tr>
<tr>
<td>ME</td>
<td>Metabolisable energy</td>
</tr>
<tr>
<td>MLDF</td>
<td>Ministry of Livestock Development and Fisheries</td>
</tr>
<tr>
<td>NBS</td>
<td>National Bureau of Statistics</td>
</tr>
<tr>
<td>OTC</td>
<td>Ox-tetracycline</td>
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</tbody>
</table>
PC  Plasma Cholesterol
r.p.m. Revolution per minute
RIR  Rhode Island Red
SAS  Statistical Analysis Systems
SE  Standard Error
SR  Shell Ratio
SUA  Sokoine University of Agriculture
SW  Shell Weight
W  Egg Width
WHO  World Health Organization
wt  Weight
YAR  Yolk Albumin Ratio
YC  Yolk Cholesterol
YR  Yolk Ratio
YSI  Yellow Shanked Indigenous
YW  Yolk Weight
Poultry accounts for more than 30% of all animal protein requirement worldwide (Pernin and Pedersen, 2000) and it is estimated that the sector will account for 40% or more in 2020 due to a dramatic shift in preference from red meat to poultry meat and their products (Rosegrant et al., 2001). In Tanzania, chicken population is estimated to be 43.7 million of which 41.9 million (96%) are indigenous, 1.3 million (2.7%) are layers and 0.6 million (1.3%) are broilers (NBS, 2012). The chickens are kept in many parts of the world irrespectively of the traditions, life standards or religious taboos concerning consumption of eggs and/or chicken meat (Tadelle, 2003).

Indigenous chickens are widely distributed due to their high degree of adaptability to prevailing condition in rural environments. They possess high genetic variance in their performance, hardiness, disease tolerance and ability to breed naturally with ability to survive on little or no inputs and adjust for fluctuations in feed availability (Adedeji et al., 2008; Ajayi, 2010). They attain the market body weight of 1 kg and above at about 16 and 20 weeks of age under intensive and extensive management systems, respectively. Their market weight is attained at rather late ages compared to 8 weeks for meat type chickens, and 12 weeks for the crosses between local chickens and meat type chickens under intensive management (Theerachai et al., 2003). However, indigenous chickens possess some inherent advantages which include better flavour of meat and egg, good fertility and hatchability. On top of that their
meat and egg taste are preferred over those of exotic chickens (Dessie and Ogle, 2001; Adedeji et al., 2008).

The indigenous chickens have been contributing considerably to household income, nutrition and cultural aspect for the majority of rural people (Pedersen, 2002; Mlozi et al., 2003; Muchadeyi et al., 2005; Alabi et al., 2006). Nutritionally, they are also good source of calcium, phosphorus, retinol, \( \alpha \)-tocopherol and folate. In addition vitamin B and D are also found in plenty particularly in eggs (Ekue et al., 2002).They exist in different phenotypic groups representing different genetic entities with different productivity potentials (Msoffe et al., 2004). Their performance vary substantially and no single genetic group meets all the attributes of high egg production, good egg quality traits, fertility, hatchability, survivability, high growth rate and heavy weight at slaughter (Msoffe et al., 2001; Fayeye et al., 2005). The phenotypic expression of some traits is likely to have effects on egg quality traits including internal egg quality traits such as sterols, phospholipids, and triglycerides, which in turn, influence the egg cholesterol level.

1.2 Problem Statement and Justification

Despite of their nutritive value, eggs are considered to be the major source of dietary cholesterol with the consequence of higher risk of arteriosclerosis and coronary heart disease (Kritchevsky and Kritchevsky, 2000; Kritchevsky, 2004). The presence of cholesterol in eggs has created a negative attitude of consumers towards eggs as documented by Chen et al., (2005). According to Ramesh et al., (2009), the quantity of egg intake should be within the safety limits.
Thus, there is a need to explore ways of producing eggs of low cholesterol content. According to Baumgartner et al., (2008), cholesterol content could be reduced through different approaches including genetic selection strategy. Some breeds have natural low egg cholesterol content. For example, the Green Legged Partridge which is native to Poland is reported to have green shanks, but also a good forager, broodier and lay cream-white to pale grey eggs and their eggs are of low cholesterol content (Partyka et al., 2007). In Tanzania green legs/shanks have been observed in some indigenous chicken genetic groups. However, no studies have been carried out to explore, evaluate and understand their relationships with production traits and egg quality traits including cholesterol content.

This study aimed at assessing and comparing the influence of shank colour gene of Indigenous chicken on blood and egg yolk cholesterol as well as production traits. The established information is expected to be useful to poultry breeders in designing breeding strategies for production of eggs of high quality traits so as to satisfy the health consciousness of a wide range of consumers.

1.3 Objectives

1.3.1 Main objective

The main objective of this study was to explore the association of shank colour gene with improved egg quality and production traits of indigenous chickens.

1.3.2 Specific objectives

i. To evaluate the effect of shank colour on plasma and egg yolk cholesterol
ii. To determine the effect of shank colour on egg production
iii. To determine the effect of shank colour on external and internal egg qualities
iv. To evaluate the effect of shank colour on growth and survival rate
CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Productive Performance of Indigenous Chicken

Indigenous chickens have been associated with low productivity in comparison with exotic layers and broilers. This is mainly due to their inherent genetic traits as documented by Pedersen (2002). Their weight at sexual is in the range of 1600 – 2000 g (ARC, 2005). The study done by Lwelamira et al., (2008a) reported the weight of 1647 g for medium ecotype of Tanzania under intensive management and was attained after 168 days. Comparative study done by Sarkar et al., (2008) under intensive management system shows that indigenous chicken attain the weight of 1250 g at 90 days while exotic cockerel layers and broilers attain the same weight at 70 and 28 days respectively.

Indigenous egg production varies among ecotypes as reported by Lwelamira et al., (2008b). For example the medium ecotype of Tanzania produces 49 eggs with 42g at the first 90 days of production while kuchi ecotype produces 45 eggs with 45g. Apart from their differences in productive performance, the inputs for indigenous chicken are very minimal as they have ability to scavenge for their feeds.

2.2 Egg Quality Traits

Statesman, (1977) described egg quality as the characteristics of an egg that affect its acceptability by the consumers. A number of factors influence the egg quality; these include breed/strain/variety, temperature, relative humidity, rearing practices and season (Washburn, 1990).
The knowledge and information on the structure of egg and its various parameters is essential for an understanding of egg quality, fertility, embryo development and diseases of the poultry (Islam and Dutta, 2010). Many studies have revealed significant differences in internal and external egg quality traits across the genotypes of both indigenous and exotic strain of chicken (Islam et al., 2001; Basmacioulu and Mustafa, 2005; Olawumi and Ogunlade, 2008; Malago and Baitilwake, 2009; Rajkumar et al., 2009; Islam and Dutta, 2010; Sola-Ojo, et al., 2011). However, some other findings have reported statistical insignificant difference in internal and external egg quality traits across the genetic groups. For example Bonekamp et al. (2010) found that the egg mass of the brown heavy breed and the white light breed are insignificantly different. Furthermore, Garcaoa-Lapez et al., (2007) reported the statistical insignificant difference in weights of egg, yolk and egg shell for Plymouth Rock, RIR and their Hybrids while Sanjeewa et al., (2011) found no difference in egg quality parameters between village chickens and the commercial strain except for ash and fat contents. Other authors reported differences due to genotype and environment of rearing (Nahar et al., 2007; Onagbesan et al., 2007; Jones et al., 2010; Momoh et al., 2010).

External egg quality traits, particularly egg weight, shell weight, width and length are important parameters to consider during selection for improvement in live weight of the local chicken (Paulo et al., 2011). Egg weight influences egg quality and reproductive fitness of the chicken. It plays a significant role in the process of embryo development and successful hatching while the size of the hatching egg influences body weight of chicks up to maturity (Islam et al., 2001; Farooq et al., 2001).
Egg weight in local chickens can be predicted using egg width, egg length and shell weight as these factors are significantly correlated (Proudfoot and Hulan, 1981). The egg weight gradually increases as hen’s age increases reflecting the positive correlation between egg weights and age of the laying hen (Niranjan et al., 2008). This weight is positively correlated to yolk, albumen and shell that the egg contains and varies with genetic groups of chickens (Pandey et al., 1986).

Egg yolk accounts for slightly over 30% of total egg weight. However, albumen represents the largest proportion of the egg being estimated to be 58.5% of the total egg of which 88% is water and 12% is protein (Hunton, 1987). The yolk also contains substantial amount of vitamin A and D arising from the feed (Robinson, 1987). Other nutritional profile includes proteins, vitamins, fat and antioxidant contents. Due to the presence of fat and antioxidant contents, yolk mass is related to the amount of cholesterol in egg (Abdullahi et al., 2003; Sparks, 2006).

### 2.3 The Egg Lipids

Cholesterol and triglycerides are the major storage lipid forms of energy in animals (McDonald et al., 1996). Cholesterol is a precursor of several bioactive steroids such as sex hormones and adrenal hormones and bile acid. In chicken’s egg, high levels of cholesterol are found in the yolk serving as the important source of cholesterol esters in the developing embryo (Shrimpton, 1987). Eggs have been shown to be the largest source of dietary cholesterol whereby as one egg contains about 200 – 250 mg of cholesterol depending on its size (Griffin, 1992). In human, the diet with high level of cholesterol has a great influence on the elevation of blood cholesterol levels.
(Weggemans et al., 2001; Olugbemi et al., 2010). According to Weggemans et al., (2001) human body normally produces cholesterol for its normal function, but the blood cholesterol levels elevate when dietary cholesterol is increased.

2.4 Impact of Egg Yolk Cholesterol on Egg Acceptability

Human sensitivity towards food safety requirement has been a challenge towards food products and diets including egg and egg products. The negative publicity of dietary cholesterol on human health has caused a significant decrease in egg consumption per capita in the world (Herron and Fernandez, 2004; Elkin, 2006; Sparks, 2006). This is possibly due to the awareness that egg is in the group of foods with high dietary cholesterol levels and the general knowledge that high dietary cholesterol levels result in high blood cholesterol and consequently a higher risk of arteriosclerosis and coronary heart disease (Kritchevsky and Kritchevsky, 2000; Kritchevsky, 2004).

For a heath person to avoid the elevation of blood cholesterol level and reduce the risk of coronary heart disease, the daily dietary cholesterol consumption should not be more than 300 mg per capita/day as recommended by WHO (Baumgartner et al., 2008). The person with cardiovascular disease, diabetes or high LDL (low density lipoprotein) is advised to limit the cholesterol intake to not more than 300 mg per day (Simopoulos, 2000; Weggemas et al., 2001). This implies that, consumption of one egg per day will raise the blood cholesterol level by 200-250 mg which can cause healthy risk for persons with cardiovascular disease, diabetes or high LDL. In order to overcome overconsumption of cholesterol, people need to reduce or eliminate
other source of cholesterol for the rest of the day and the likely food to be omitted is the egg.

2.5 **Egg Cholesterol and Poultry Breeding**

Cholesterol level differs between eggs. The differences are principally influenced by genetics of the laying hen (Elkin, 2006; Chowdhary *et al.*, 2002), age and environment of rearing such as free ranging or cage rearing (Shafey *et al.*, 1998 and Zemkova *et al.*, 2007) and the dietary habits of the laying chicken (Chowdhary *et al.*, 2002; Pistekova *et al.*, 2006; Yildiz *et al.*, 2006).

Investigations of the lipid metabolism of the laying chicken have shown that most of the cholesterol found in the egg is synthesized in the liver (Connor *et al.*, 1965; Weiss *et al.*, 1967; Andrews *et al.*, 1968; Naber, 1976, 1983; Kuksis, 1992). Naber, (1983) found that a hen weighing 1.7 kg and fed a cholesterol-free diet typically synthesizes 300 mg of cholesterol per day and according to Simopoulos, (2000) a large egg contains 220 mg of cholesterol. Thus, the egg represents a major excretory route for cholesterol elimination from the hen while faecal neutral sterols and bile acids form the secondary route (Burczak *et al.*, 1980; Sim *et al.*, 1980; Naber, 1983; Cho *et al.*, 1987).

Egg cholesterol is accumulated in the egg yolk. Thus, the yolk mass is related to the amount of cholesterol in the egg and it varies with age of the laying hen (Abdullahi *et al.*, 2003; Sparks, 2006). Variation in egg yolk cholesterol concentrations among different genetic groups of chicken might be due to inherent genetic differences or the interaction between diets and strain (Han and Lee, 1992; Chowdhary *et al.*,...
Findings from other studies (Naber, 1976; Elkin, 2006) have indicated that yolk cholesterol content can be decreased either genetically (by selection), or by nutrition profile or by the combination of both approaches. According to Baumgartner et al., (2008), very few selection experiments have been conducted and only in short term. The main limiting factor being a very laborious and expensive analysis of yolk cholesterol. Despite of the cost, a research with any reduction in cholesterol content in egg yolk is worthy because the lower the yolk cholesterol content in egg, the more eggs will be recommended for consumption.
CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

The study was carried out at Department of Animal Science and Production, Sokoine University of Agriculture (SUA). The University is situated in Morogoro municipality at latitude 5.7 to 10°S and longitude 35.6 to 39.5°E, with an elevation of 525 m above sea level. The relative humidity at the study area is about 81%, with monthly mean minimum and maximum temperatures of 18.7°C, and 30.1°C, respectively. Sokoine University of Agriculture was selected as the study area due to the convenience of accessibility to the laboratory and infrastructures.

3.2 Management of Experimental Chickens

Both the Green Shanked Indigenous (GSI) Chickens and Yellow Shanked Indigenous (YSC) Chicken for the study were sampled from the same eco-climatic region in Singida District, at Mtinko division, Kijota and Ilongero wards whereby three villages were involved namely Sekoutule (from Ilongero ward), Nduu and Mitonto (from Kijota ward). The chickens were all phenotypically characterized as medium sized birds with multi-variety plumage and mixed combed types but with unique distinctive shank colour. The source for Rhode Island Red (RIR) exotic layers was the Interchick Company. Pullets bought were those that had just attained maturity age before the first egg. The active breeding cocks were also sampled. The local ecotype fowls were transported to SUA where the study was done. All experimental chickens were maintained on floor pens in a deep litter system being supplied with standard layers mash (Table 2). Water was provided *ad libitum* and
routine disease management were done. Vaccinations were done against Newcastle and fowl pox.

3.3 Experimental Set Up

Forty eight pullets, i.e. 16 GSI, 16 YSIC and 16 RIR of approximately 6 months old were used in the study. Eight indigenous cocks (4 GSI and 4 YSI cocks) were incorporated in the study for breeding. The pullets were randomly allocated to 4 replicates using a Completely Randomised experimental Design.

Table 1: Calculated composition of chicken feeds

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Percent in diet of chicken feeds</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Chicks’ mash</td>
</tr>
<tr>
<td>Maize</td>
<td>35.0</td>
</tr>
<tr>
<td>Maize bran</td>
<td>25.0</td>
</tr>
<tr>
<td>Rice polishing</td>
<td>0.0</td>
</tr>
<tr>
<td>Fish meal</td>
<td>15.0</td>
</tr>
<tr>
<td>Sunflower seed cake</td>
<td>15.0</td>
</tr>
<tr>
<td>Cotton seed cake</td>
<td>8.0</td>
</tr>
<tr>
<td>Bone meal</td>
<td>0.7</td>
</tr>
<tr>
<td>Limestone</td>
<td>0.7</td>
</tr>
<tr>
<td>Broiler premix</td>
<td>0.3</td>
</tr>
<tr>
<td>Layers premix</td>
<td>0.0</td>
</tr>
<tr>
<td>Salt</td>
<td>0.3</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
</tr>
<tr>
<td>CP (%)</td>
<td>19.1</td>
</tr>
<tr>
<td>ME (MJ/Kg)</td>
<td>11.3</td>
</tr>
</tbody>
</table>

Each replicate was allocated with 4 pullets and one cock of the same shank colour. In each treatment, replicate birds were assigned identification numbers and wing
tagged. All experimental chicken were housed under the same feeding regime. A preliminary period of 30 days was instituted before data collection to allow acclimatization of the birds to confinement and experimental diet as well as attaining the maturity weight (the weight at first egg). After attaining maturity weight, egg quality traits were assessed for 8 weeks while egg production assessment was done in 12 weeks. Concurrently, eggs from YSI and GSI were collected, labelled and incubated. After hatching, data for hatchability, growth and survival rates in hatched chicks from YSI and GSI for 5 consecutive weeks.

3.4 Cholesterol Determination

3.4.1 Yolk cholesterol determination

A total of 120 egg samples were used in yolk cholesterol determination. Two eggs were collected from each replicate group at a time and the data were collected in 5 times with intervals of 14-days. The sampled eggs were used in the yolk cholesterol study.

A commercial diagnostic cholesterol reagent kit (Erba Diagnostic Mannheim GmbH) was used for cholesterol determination. The sampled eggs were broken to separate the yolks and then 1ml of the yolk was drawn with a pipette and diluted with 1ml buffer pH 7.4 (10 mmol sodium phosphate/l, 100 mmol NaCl/l). Then, 1000µl of a working reagent (supplied in the kit) was diluted with 10 µl of distilled water and placed in a cuvette and then inserted into a spectrophotometer set at 670 nm in order to take the blank absorbance reading. Then 1000 µl of the working reagent was again mixed with 10 µl of the calibrator and put in a cuvette and then placed in the
spectrophotometer to obtain the absorbance of the calibrator. Lastly, 1000 µl of the working reagent was mixed with 10 µl of the test sample from each sample and incubated at room temperature for 10 minutes, there after the sample was taken and put in a cuvette and the absorbance read. The addition of the yolk sample to the reagent resulted into plain to purple colours of various degrees depending on the concentration of cholesterol in the sample. The absorbance of the test sample was then recorded.

Yolk cholesterol concentration was calculated using the following formula;

\[ \text{Ch}_c, \text{mg/dl} = \left( \frac{A_{ts}}{A_c} \right) \times C_c \times D_f \]

Where \( \text{Ch}_c = \) Cholesterol concentration

\( A_{ts} = \) Absorbance of test sample

\( A_c = \) Absorbance of calibrator

\( C_c = \) concentration of calibrator

\( D_f = \) Dilution factor

### 3.4.2 Blood plasma cholesterol determination

A total of 240 blood samples were used in the blood plasma cholesterol study. The blood samples of four birds per replicate were collected at a time. The data were collected in 5 times with intervals of 14 days. The blood samples were taken from the wing vein of the birds by using a sterile needle where by 1 ml of blood was extracted from each bird and placed in individual vacutainer test tube containing Ethylene diamine tetra acetic acid (EDTA). The samples were properly shaken to mix with the EDTA in order to prevent coagulation of the blood and within two
hours of collection the samples were taken to the laboratory for blood plasma cholesterol analysis. The vacutainer tubes were placed in a centrifuge and centrifuged at 3000 r.p.m. for 10 minutes in order to separate the plasma. A commercial diagnostic cholesterol reagent kit (Erba Diagnostic Mannheim GmbH) was used for plasma cholesterol determination using the same procedure as described in yolk cholesterol determination. The spectrophotometer was set at 505nm. Plasma cholesterol was determined using the formula as described in section 3.4.1 above.

3.5 **Weight at Sexual Maturity**

Weight of birds at sexual maturity was taken when at least 50% of the purchased pullets in each of the genetic groups had started laying.

3.6 **Egg Production, Fertility and Hatchability**

Egg production was assessed as the total number of eggs for the first 90 days of laying (early egg production phase), just after sexual maturity of GSI, YSI and RIR genetic groups. Number of eggs produced per bird, average egg weight and laying intensity for the first 90 days of laying was determined.

The reproductive traits assessed were fertility and hatchability of the GSI and YSI genetic groups. A total of 180 eggs from indigenous genetic groups were incubated over four different periods in order to determine the fertility and hatchability. Candling of the incubated eggs was done twice at 7 and 14 days after incubation. The percentage fertility of the eggs was calculated as follows:

\[ \text{Fertility} = \left( \frac{T_{eg} - T_{infeg}}{T_{eg}} \right) \times 100 \]
Where $T_{eg}$ was the total number of eggs incubated and $T_{infeg}$ the total number of infertile eggs.

The percentage hatchability of the eggs was calculated using formula below:

$$\text{Hatchability} = \left( \frac{T_{ heg}}{T_{veg}} \right) \times 100$$

Where $T_{heg}$ was the total number of hatched eggs and $T_{veg}$ the total number of viable eggs (after the first candling).

### 3.7 Egg Quality Assessment

A total of 120 egg samples were used in the study of egg yolk cholesterol and other egg quality traits. Two eggs were taken randomly from each replicate five times at 5 intervals of 14 days (ie 0, 14, 28, 42, and 56th day). In each period 24 eggs were taken, eight from each genetic group. The eggs were numbered according to genetic groups and replication for easy identifications during egg traits study.

#### 3.7.1 External egg quality traits

Eight external egg quality traits were studied. The traits were gross egg weight, egg length, egg width, egg volume, shell weight, Shell thickness, shell ratio, and egg shape index. All weights were measured by digital electronic balance in gram. Length and width of the eggs were measured by a vernier caliper in millimetre, Shell thickness was measured using micrometer screw gauge at the broad end, middle portion and narrow end of the shell and the average of the three measurements was taken as shell thickness in millimetre.

Egg volume was determined according to Islam and Data (2010), using the following formula:
EV = \pi \times L \times W^{2/6}

Where;
EV = egg volume
L = egg length
W = egg width

Egg length was taken as the distance from one end to the other. Egg width was determined at the widest diameter.

3.7.2 Internal egg quality traits

Five internal egg quality traits were evaluated namely; yolk cholesterol concentration (YC), yolk weight (YW), albumin weight (AW), yolk ratio (YR) and albumen ratio (AR).

Each egg was carefully broken and its contents poured into a petri-dish. The yolk and albumen were separated carefully with the help of a spoon and placed in separate petri-dishes of known initial weight. The weight of yolk was taken using digital electronic balance. The shells of the broken eggs were rinsed in warm water, air dried for 48 hours and weighed to determine the shell weight (SW). The AW was calculated by subtracting yolk weight and Shell weight (SW) from the gross egg weight (EW) as documented by Islam and Dutta (2010) as described bellow.

AW = EW - (YW + SW)

Other egg quality traits were obtained as documented by Olawumi and Ogunlade (2008) by using the following formulas;

Shell ratio, SR (%) = (SW/EW) \times 100
Egg shape index, ESI (\%) = (W/L) × 100
Yolk ratio, YR (\%) = (YW/EW) × 100
Albumen ratio, AR (\%) = (AW/EW) × 100
Where;
CY = yolk cholesterol concentration
YW = yolk weight
AW = albumin weight
YR = yolk ratio and
AR = albumen ratio

3.8 Productivity and Reproductive Performance Assessment
Parameters on weight at sexual maturity, egg production, fertility and hatchability were measured from the purchased pullets, while growth rate and survival rate were assessed on the hatched chicks. The fertility, hatchability, growth rate and survival rate assessment were done in indigenous genetic groups.

3.8.1 Growth rate
Chicks’ body weights for both YSI and GSI genetic groups were taken at the age of 0, 1, 2, 3, 4, and 5th weeks (0 being the hatch weight). The daily growth rate was calculated as:

Daily growth rate (gm/day) = (W_{t2} - W_{t1})/7

Where W_{t1} was the weight at the beginning of the week; W_{t2} was the weight at the end of the week.
3.8.2 Survival rate

The records for survival during the rearing period (1st - 5th weeks) were computed using the formula;

Survival rate (%) = (Ts/Th) x 100

Where Ts = Total survived chicks

Th = Total hatched chicks

3.9 Statistical Analysis

Significance of genetic group effects and the interactions with time on egg quality traits, egg and blood plasma cholesterol levels, productive and reproductive performance were assessed by using the General Linear Model (GLM) of Statistical Analysis Systems (SAS, 2004) and the following models were used:

The fixed effect of shank colour and genetic group on egg quality and egg production were analysed in accordance with the statistical model (1) below:

\[ Y_{ijk} = \mu + G_i + W_j + (GW)_{ij} + e_{ijk} \]

Where:

\( Y_{ijk} \) = Observation of egg quality and production traits on i\(^{th}\) shank colour/ genetic group at j\(^{th}\) week of laying.

\( \mu \) = General mean

\( G_i \) = Effect of i\(^{th}\) genetic group (i=1, 2, 3, ie green shanked indigenous, yellow shanked indigenous and exotic layers).

\( W_j \) = Effect of j\(^{th}\) week of laying (j=0, 2, 4, 6, and 8\(^{th}\) week of laying)

\( (GW)_{ij} \) = Effect of interaction between i\(^{th}\) genetic group with j\(^{th}\) week of laying

\( e_{ijk} \) = Residual effect
The fixed effect of shank colour and genetic group on overall egg quality and egg production were analysed in accordance with the statistical model (2) bellow:

\[ Y_{ij} = \mu + G_i + e_{ij} \] ................................. (2)

Where:
\[ Y_{ij} = \text{Observation of egg quality and production traits on } i^{th} \text{ shank colour/genetic group} \]
\[ \mu = \text{General mean} \]
\[ G_i = \text{Effect of } i^{th} \text{ genetic group (i=1, 2, 3. ie green shanked indigenous, yellow shanked indigenous and exotic layers).} \]
\[ e_{ij} = \text{Residual effect} \]

The effect of shank colour trait on fertility and hatchability was analysed by model (3) bellow

\[ Y_{ij} = \mu + g_i + e_{ij} \] ................................. (3)

Where: \[ Y_{ij} = \text{Observation on fertility and hatchability and survival rate taken on the } i^{th} \text{ genetic group.} \]
\[ \mu = \text{overall mean} \]
\[ g_i = \text{fixed effect of the } i^{th} \text{ genetic group} \]
\[ e_{ij} = \text{Residual effect} \]

The fixed effect of shank colour trait on growth rate were analysed by using model (4) bellow:

\[ Y_{ijk} = \mu + g_{ij} + (X_2 - X_1) + e_{ijk} \] ................................. (4)

Where:
Where: \[ Y_{ij} = \text{Observation on growth rate on the } i^{th} \text{ genetic group.} \]
\[ \mu = \text{overall mean} \]
gi = fixed effect of the i\textsuperscript{th} genetic group

X2 = Final genetic group mean weight after k\textsuperscript{th} period

X2 = Initial genetic group mean weight after k\textsuperscript{th} period

eij = Residual effect

In addition, correlation analysis was done between some internal egg quality traits, particularly egg yolk cholesterol with plasma cholesterol, egg weight and yolk weight. Chi square was used to analyse the significance difference among genetic groups in survival rate and hatchability. Furthermore covariate was included in growth rate analysis.
CHAPTER FOUR

4.0 RESULTS

4.1 Health Status of the Birds

The birds were in good health throughout the experimental period. However, there were some occasions in which running nose and fowl typhoid were observed on some birds in which fluban and OTC 20% were administered. Greenish and yellowish intensity of the shanks were found to diminish with time after confinement of the birds during the experiment. The intensity colouration decreased with time indicating the significant contribution of scavenging diet to the intensity of shank colouration.

4.2 Production Performance Assessment

4.2.1 Growth performance

Least squares means for weekly body weights of chicks belonging to the two indigenous genetic groups (YSI and GSI) are shown in Table 2 while daily mean body weight gains are shown in Table 3 and Fig.1. The mean hatch weight were 29.82 and 29.94 g for GSI and YSI, respectively while the weight at week 5 were 196.96 and 201.09 g for GSI and YSI, respectively. There were no significant difference (P>0.05) between YSI and GSI chickens (P>0.05) in hatch weight, average daily gain and body weight at the 5th week of age. The effects of genetic group on body weight at sexual maturity (Table 4) show no significant difference (P>0.05).
Table 2: Least square means for body weight measurements up to 5th week for Indigenous chicken

<table>
<thead>
<tr>
<th>Genetic group</th>
<th>Weekly weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hatch wt</td>
</tr>
<tr>
<td>GSI</td>
<td>29.82 ± 0.37</td>
</tr>
<tr>
<td>YSI</td>
<td>29.94 ± 0.40</td>
</tr>
<tr>
<td>Overall</td>
<td>29.88 ± 0.27</td>
</tr>
</tbody>
</table>

<sup>a,b</sup> means within column with the same superscript are not significantly different (P>0.05)

Where; wt=weight

Figure 1: Growth rate for GSI and YSI genetic groups

Table 3: Mean body weight gain measurements up to 5th week for Indigenous chicken genetic groups

<table>
<thead>
<tr>
<th>Genetic group</th>
<th>Growth rate (g/day)</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Week 1</td>
<td>Week 2</td>
</tr>
<tr>
<td>GSI</td>
<td>1.85 ± 0.14</td>
<td>4.87 ± 0.24</td>
</tr>
<tr>
<td>YSI</td>
<td>2.46 ± 0.16</td>
<td>5.32 ± 0.26</td>
</tr>
<tr>
<td>Overall</td>
<td>2.12 ± 0.11</td>
<td>5.07 ± 0.18</td>
</tr>
</tbody>
</table>
4.2.2 Egg production traits

The study revealed a significant difference (P≤0.05) in egg production traits between RIR and the indigenous genetic groups. RIR produced 27 more eggs than the indigenous ones in the first 90 days. However, there were no significant difference between GSI and YSI (P>0.05). Rhode Island Red chicken had the highest egg weight, egg number and egg mass and laying intensity in the first 90 days of laying while GSI had the lowest (Table 4). The Rhode Island Red differed significantly (P≤0.05) with both GSI and YSI genetic groups in egg weight, egg number, egg mass and laying intensity. The laying intensity for RIR was 29.9% higher than both indigenous genetic groups. However, GSI did not differ significantly (P>0.05) from YSI chickens in egg weight, egg number, egg mass and laying intensity in the first 90 days of laying.

Table 4: Least square means for productive traits in GSI, YSI and RIR chickens

<table>
<thead>
<tr>
<th>Productive traits</th>
<th>GSI</th>
<th>YSI</th>
<th>RIR</th>
</tr>
</thead>
<tbody>
<tr>
<td>BWSM, (g)</td>
<td>1457.1 ± 43.1a</td>
<td>1440.3 ± 43.1a</td>
<td>1440.3 ± 43.1a</td>
</tr>
<tr>
<td>EW, (g)</td>
<td>42.4 ± 0.6b</td>
<td>42.3 ± 0.6b</td>
<td>52.4 ± 0.6a</td>
</tr>
<tr>
<td>EN90D, (egg)</td>
<td>42.0 ± 1.0b</td>
<td>42.1 ± 1.0b</td>
<td>69.1 ± 1.a</td>
</tr>
<tr>
<td>EM90D (g)</td>
<td>1780.4 ± 43.6b</td>
<td>1781.9 ± 43.6b</td>
<td>3618.9 ± 43.6a</td>
</tr>
<tr>
<td>LI90D (%)</td>
<td>46.7 ± 1.7b</td>
<td>46.8 ± 1.7b</td>
<td>76.7 ± 1.7a</td>
</tr>
</tbody>
</table>

*ab* means within rows with the same superscript are not significantly different (P>0.05)

BWSM, EW, EN90D, EM90D, LI90D = body weight at sexual maturity, egg weight, egg number at first 90-days, egg mass at first 90-days and laying intensity at first 90 days respectively.
4.2.3 Survival rate for chicks

The study revealed insignificance difference between the GSI and YSI genetic groups for survival rate as shown in Table 5. The survival rates in this study were 89.13 and 90.48% for GSI and YSI respectively.

4.3 Reproductive Performance Assessment

Both fertility and hatchability for GSI and YSI genetic groups of chickens were not significantly different as shown in Table 5 and Fig.2. The hatchability was 77.42 and 75.00% for GSI and YSI, respectively. Fertility was 93.55 and 93.33% for GSI and YSI, respectively.

Table 5: Reproductive performance and survival rate for GSI and YSI chickens

<table>
<thead>
<tr>
<th>Genetic group</th>
<th>Fertility (%)</th>
<th>Hatchability (%)</th>
<th>Survival rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSI</td>
<td>93.55</td>
<td>77.42</td>
<td>89.13</td>
</tr>
<tr>
<td>YSI</td>
<td>93.33</td>
<td>75.00</td>
<td>90.48</td>
</tr>
<tr>
<td>Chi-Square</td>
<td>0.9617</td>
<td>0.7536</td>
<td>0.8351</td>
</tr>
</tbody>
</table>

Figure 2: Reproductive performance
4.4  Egg Quality Traits Assessment

4.4.1  External egg quality traits

Results on external egg quality traits show that RIR differed significantly (P≤0.05) from both GSI and YSI genetic groups in gross egg weight (EW). The EW for RIR was 10.0 and 9.9 g higher than GSI and YSI respectively (Table 4). Other external egg quality traits also differed significantly between RIR and both indigenous genetic groups as indicated in Tab. 6. The RIR were found to have higher values than the Indigenous genetic groups in EW, L, W, V and SW but were lower in STH, and SR. Egg volume in RIR was higher than YSI and GSI genetic groups by 9.64 and 9.43 cm³ respectively. On the other hand, there was no significant difference between GSI and YSI in all egg quality parameters for the indigenous genetic groups.

Table 6: Least squares means for external egg quality traits in GSI, YSI and RIR chickens

<table>
<thead>
<tr>
<th>Genetic group</th>
<th>N</th>
<th>L (cm)</th>
<th>W (cm)</th>
<th>V (cm³)</th>
<th>SW (g)</th>
<th>STH (mm)</th>
<th>SR (%)</th>
<th>ESI (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSI</td>
<td>40</td>
<td>4.94</td>
<td>3.63</td>
<td>33.85</td>
<td>4.27</td>
<td>0.35</td>
<td>10.07</td>
<td>73.43</td>
</tr>
<tr>
<td></td>
<td></td>
<td>± 0.03ᵇ</td>
<td>± 0.02ᵇ</td>
<td>± 0.56ᵇ</td>
<td>± 0.13ᵇ</td>
<td>± 0.01ᵃ</td>
<td>± 0.22ᵃ</td>
<td>± 0.63ᵃ</td>
</tr>
<tr>
<td>YSI</td>
<td>40</td>
<td>4.91</td>
<td>3.62</td>
<td>33.64</td>
<td>4.41</td>
<td>0.36</td>
<td>10.43</td>
<td>73.78</td>
</tr>
<tr>
<td></td>
<td></td>
<td>± 0.03ᵇ</td>
<td>± 0.02ᵇ</td>
<td>± 0.56ᵇ</td>
<td>± 0.13ᵇ</td>
<td>± 0.01ᵃ</td>
<td>± 0.22ᵃ</td>
<td>± 0.63ᵃ</td>
</tr>
<tr>
<td>RIR</td>
<td>40</td>
<td>5.37</td>
<td>3.93</td>
<td>43.28</td>
<td>4.68</td>
<td>0.33</td>
<td>8.9</td>
<td>73.27</td>
</tr>
<tr>
<td></td>
<td></td>
<td>± 0.03ᵇ</td>
<td>± 0.02ᵇ</td>
<td>± 0.56ᵃ</td>
<td>± 0.13ᵃ</td>
<td>± 0.01ᵇ</td>
<td>± 0.22ᵇ</td>
<td>± 0.63ᵃ</td>
</tr>
</tbody>
</table>

ᵃᵇ means within column with the same superscript are not significantly different (P>0.05)

Where; N = Sample size, L = Egg length, W = Egg width, V = Egg volume, SW Egg shell weight, STH = Egg shell thickness, SR = Egg shell ratio, ESI = Egg shell index ratio.
4.4.2 Internal egg quality traits

Internal egg quality traits assessed were yolk weight (YW), albumin weight (AW), yolk albumin ratio (YAR), yolk ratio (YR) and albumin ratio (AR) as presented in Table 7. The study revealed that the gross YW did not differ significantly among the genetic groups of chickens (P>0.05) though the trend showed a significant difference (P≤0.05) in YR where by indigenous genetic groups had higher YR than RIR by 7.22 and 7.26%. But when AW and AR were compared across GSI, YSI and RIR chickens, RIR had the highest values for the traits and differed significantly (P≤0.05) from both GSI and YSI genetic groups. The RIR was higher by 8.44% than GSI in AR. To the contrary RIR had significantly (P≤0.05) lower values for YR and YAR, whilst GSI did not differ significantly from YSI.

Table 7: Least squares means for internal egg quality traits in GSI, YSI and RIR genetic groups

<table>
<thead>
<tr>
<th>Genetic group</th>
<th>YW (g)</th>
<th>AW (g)</th>
<th>YAR (%)</th>
<th>AR (%)</th>
<th>YR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSI</td>
<td>14.93±0.23a</td>
<td>23.18±0.45a</td>
<td>0.65±0.01b</td>
<td>54.61±0.48a</td>
<td>35.31±0.41b</td>
</tr>
<tr>
<td>YSI</td>
<td>14.93±0.23a</td>
<td>22.97±0.45a</td>
<td>0.65±0.01b</td>
<td>54.31±0.48a</td>
<td>35.27±0.41b</td>
</tr>
<tr>
<td>RIR</td>
<td>14.65±0.23a</td>
<td>33.07±0.45b</td>
<td>0.45±0.01a</td>
<td>63.05±0.48b</td>
<td>28.05±0.41a</td>
</tr>
</tbody>
</table>

abLeast square means within column with the same superscript are not significantly different (P>0.05)

Where YW, AW, YAR, AR and YR refers to yolk weight, albumin weight, yolk albumin ratio, albumin ratio and yolk ratio respectively.

4.5 Cholesterol Assessment

4.5.1 Egg yolk cholesterol content

The results did not show a clear trend in the means egg yolk cholesterol concentration for the three genetic groups of chickens. Egg yolk cholesterol
concentration of the three genetic groups of chickens in the 1st and 2nd period of the experiment was in the order: GSI< RIR<YSI and there were significant differences (P≤0.05) among the three genetic groups (Table 8). In period 1 and 2, egg yolk cholesterol content was higher in YSI than GSI by 55.29 and 23.82 gm/dl respectively. However, there were no significant differences (P>0.05) among all three genetic groups in cholesterol concentration for the 3rd, 4th and 5th periods of the experiment. The overall average of yolk cholesterol at the end of experiment revealed no significant difference (P>0.05) though the YSI was slightly higher(210.11 gm/dl) than GSI (196.16 gm/dl). In general, the study revealed no significant difference (P>0.05) between the genetic groups in mean egg yolk cholesterol content, however an increase in egg yolk cholesterol concentration with age was revealed in all the three genetic groups (Fig. 3).

Table 8: Least square means for egg yolk cholesterol in GSI, YSI and RIR genetic groups

<table>
<thead>
<tr>
<th>Genetic group</th>
<th>Period 1</th>
<th>Period 2</th>
<th>Period 3</th>
<th>Period 4</th>
<th>Period 5</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSI</td>
<td>86.30±</td>
<td>164.53±</td>
<td>194.53±</td>
<td>259.16±</td>
<td>276.22±</td>
<td>196.16±</td>
</tr>
<tr>
<td></td>
<td>7.29c</td>
<td>7.12b</td>
<td>8.87a</td>
<td>16.92a</td>
<td>23.72a</td>
<td>7.15a</td>
</tr>
<tr>
<td>YSI</td>
<td>141.59±</td>
<td>188.35±</td>
<td>197.72±</td>
<td>260.90±</td>
<td>262.06±</td>
<td>210.11±</td>
</tr>
<tr>
<td></td>
<td>7.29a</td>
<td>7.12a</td>
<td>8.87a</td>
<td>16.92a</td>
<td>23.72a</td>
<td>7.15a</td>
</tr>
<tr>
<td>RIR</td>
<td>109.63±</td>
<td>181.10±</td>
<td>191.68±</td>
<td>267.53±</td>
<td>259.11±</td>
<td>201.83±</td>
</tr>
<tr>
<td></td>
<td>7.29b</td>
<td>7.12a</td>
<td>8.87a</td>
<td>16.92a</td>
<td>23.72a</td>
<td>7.15a</td>
</tr>
</tbody>
</table>

abc Least square means within column with the same superscript are not significantly different (P>0.05)
4.5.2 Blood plasma cholesterol assessment

The study revealed a significant difference (P≤0.05) in mean blood cholesterol concentration between RIR and the indigenous genetic groups, but there were no statistical differences (P>0.05) in period 1, 3 and 4 between GSI and YSI (Table 9). However, the significance differences was expressed in period 2 and 5 where the blood plasma cholesterol content for GSI was higher than YSI by 37.57 and 62.18 gm/dl respectively. The means for blood plasma cholesterol of the three genetic groups of chickens were in the order: GSI>YSI>RIR, though there were some fluctuations with age as illustrated in Fig.4. However, the results show a general trend of decreasing of the plasma cholesterol with age. The overall average of plasma indicated that, RIR had the lowest content (152.09 mg/dl while GSI had the highest level (210.37 mg/dl).

Table 9: Least squares means ± SE for blood plasma cholesterol in GSI, YSI and RIR genetic groups

<table>
<thead>
<tr>
<th>Genetic group</th>
<th>Period 1</th>
<th>Period 2</th>
<th>Period 3</th>
<th>Period 4</th>
<th>Period 5</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSI</td>
<td>251.95 ±18.18</td>
<td>204.52 ±12.18</td>
<td>173.47 ±14.37</td>
<td>201.26 ±10.74</td>
<td>220.66 ±13.04</td>
<td>210.37 ±7.49</td>
</tr>
<tr>
<td>YSI</td>
<td>282.89 ±18.18</td>
<td>166.95 ±14.37</td>
<td>195.32 ±10.74</td>
<td>178.68 ±13.04</td>
<td>158.48 ±7.49</td>
<td>196.47 ±7.49</td>
</tr>
<tr>
<td>RIR</td>
<td>202.57 ±12.18</td>
<td>176.77 ±12.18</td>
<td>128.45 ±14.37</td>
<td>123.08 ±10.74</td>
<td>129.60 ±13.04</td>
<td>152.09 ±7.49</td>
</tr>
</tbody>
</table>

Least square means within column with the same superscript are not significantly different (P>0.05)
The study revealed a significant weak negative correlation between egg yolk cholesterol and blood plasma cholesterol for all genetic groups of the study being
-0.32, -0.34 and -0.31 for GSI, YSI and RIR, respectively. On the other hand the study revealed weak positive correlation between yolk cholesterol and yolk weight with egg weight (Table 13). The results indicate that, the correlation values were statistically not significant (p>0.05) for all genetic groups except for RIR where the correlation between yolk cholesterol and yolk weight was significant (P≤0.05). However, the correlation was weak (0.32610).

Table 10: Correlation between egg yolk cholesterol with plasma cholesterol, egg weight and yolk weight

<table>
<thead>
<tr>
<th>Genetic groups</th>
<th>YC vs. PC</th>
<th>YC vs. EW</th>
<th>YC vs. YW</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSI</td>
<td>-0.31952*</td>
<td>0.20986**</td>
<td>0.12375**</td>
</tr>
<tr>
<td>YSI</td>
<td>-0.34417*</td>
<td>0.11650**</td>
<td>0.20687**</td>
</tr>
<tr>
<td>RIR</td>
<td>-0.31303*</td>
<td>0.09118**</td>
<td>0.32610*</td>
</tr>
<tr>
<td>Local</td>
<td>-0.30630**</td>
<td>0.16793**</td>
<td>0.15826**</td>
</tr>
<tr>
<td>All genetic groups</td>
<td>-0.28477**</td>
<td>0.07801**</td>
<td>0.21238**</td>
</tr>
</tbody>
</table>

YC, PC, EW, YW and vs. = Yolk Cholesterol, Plasma Cholesterol, Egg Weight, Yolk Weight and versus respectively.

*Correlation is significant at P≤ 0.05 Probability Level

**Correlation is significant at P≤ 0.01 Probability Level

ns Not significant at P>0.05
CHAPTER FIVE

5.0 DISCUSSION

5.1 Productive Performance

5.1.1 Growth rate

The results show that shank colour had no effect on hatch weight and growth performance. The study revealed no significant difference in body weight between GSI and YSI up to the 5th week of age. The observed hatch weight of 30.2 and 30.0 g for GSI and YSI, respectively, are comparable with N’zenzegere, Tanga and Unguja chicken ecotyes as reported by Msoffe et al., (2004) for indigenous chicken of Tanzania.

The average body weight of 151.48 g and 161.38 g for GSI and YSI respectively at 4th weeks of age in this study are comparable with that of Tanga, Pemba and Morogoro-medium ecotypes reported by Msoffe et al., (2004) for Indigenous chicken of Tanzania. However, the body weight in the 4th week in this study was lower than that of Mbeya ecotype, but higher than Ching’wekwe and N’zenzegere as documented by Msoffe et al., (2004). The differences are possibly due to genetic variations between the different genetic groups. Whilst the non significant difference in terms of body weight from the 2nd week to 5th week indicate that GSI and YSI chickens have the same genetic potential for growth, the difference being at the shank colour loci. Nonetheless YSI chickens tended to have slightly higher weight and growth rate than GSI.
5.1.2 Body weight at sexual maturity

There were no significant differences in terms of body weight at first egg lay (BWFE) among the two indigenous genetic groups of experimental chicken. The values for GSI and YSI chickens of 1457.1 and 1440.3 g respectively are lower than the value (1647 g) obtained by Lwelamira et al., (2008a) for medium ecotype of Tanzania under intensive management. The weights are also lower than the range of 1600 – 2000 g obtained for South African local chickens (ARC, 2005). However, the values observed are in agreement with the range of 1136 -1520 g reported by Theerachai et al., (2003) for local chickens of Thailand and Malaysia. On the other hand the weights are higher than the value of 1300 g obtained by Demeke (2003) for Ethiopian local chickens.

The results also show significant difference in BWFE between the RIR and the other two indigenous genetic groups. The mean BWFE for RIR is higher than that (1394 g) reported by Hassen et al., (2006). The variation in body weight at sexual maturity between this study and others is probably due to differences in genetic makeup as well as environmental factors including nutrition and management systems.

5.1.3 Egg number

In the current study, average egg number for the first 90 days of laying was significantly higher in RIR genetic group than in the two Indigenous genetic groups. The value of 42.0 and 42.1 eggs for GSI and YSI respectively observed in the present study are lower than the value (48.9 eggs) reported by Lwelamila et al., (2008) for medium ecotype of Tanzania under intensive management. These values correspond
to laying intensities of 46.7% and 46.8% for GSI and YSI chickens respectively. The laying intensity in the current study in both GSI and YSI genetic groups are within the range of 40 to 55% as documented for local chickens of Sudan (Mohammed et al., 2005), but lower than the 54% for medium ecotype of Tanzania reported by Lwelamila et al., (2008). The laying intensity of 76.7% for the RIR is expected, despite being lower compared with the results obtained by by Lalev et al., (2012). Higher laying intensity in RIR is due to the fact that this breed has been selected for higher egg number, since the breed is a commercial egg type.

5.1.4 Egg weight

The mean egg weight for all three genetic groups of chicken in the current study are consistent to the values observed in Tanzania indigenous chickens, within the range of 37.7 to 45.6 g reported by Msoffe et al., (2001). In this study egg weight differed significantly between RIR and the Indigenous chicken. The value of 42.4 g and 42.3 g for egg weight (EW) obtained in GSI and YSI chicken genetic groups, respectively, are higher than the value (37.7 g) reported by Msoffe et al., (2004) for Ching’wekwe indigenous ecotype chicken of Morogoro-Tanzania, and the value of 37.3 g in Nigeria local chickens (Adedokun and Sonaiya 2001; Momoh,2008;). However, both GSI and YSI values are lower than that of Mbeya indigenous ecotype chicken (49.3 g) reported by Msoffe et al., (2004). Moreover, the results for both GSI and YSI chickens agree closely to the values of about 40 g given by Pedersen (2002), Fayeye et al., (2005), and Momoh (2008) for local chickens of Zimbabwe, Nigeria, and heavy local chicken of Nigeria respectively. The values also agree with the value 42.4 g documented by Lwelamira and Kifaro (2010) for medium ecotypes of
Tanzania under intensive management and the value (42.47 g) of Faruque et al., (2010) in Bangladesh. Moreover, the difference between the EW in two indigenous genetic groups in this study was not significant implying that shank colour does not affect egg weight.

On the other hand the results for EW of 52.0 g for RIR were lower than the values of 60.58, 59.40 and 55.95 g reported by Malago and Baitilwake (2009), Wardęcka et al., (2003) and Monira et al., (2003) respectively. As expected, there was a significant difference between RIR and the Indigenous ecotypes on egg weight. Higher egg weight of RIR birds is due to their superior genetic potential for the production of large sized eggs due to continuous selective breeding for better egg size which have been done for many generations.

5.1.5 Egg mass
The similarity of the egg mass of GSI and YSI genetic group is unquestionable because egg mass represents the product of egg number and egg weight. The RIR genetic group recorded higher number of eggs with higher weight. Egg mass reflects egg off take in metric kilograms/grams. The egg mass in RIR was twice as much compared with Indigenous ecotypes (3618.9 versus 1781.2 g).

5.1.6 Survival rate for chicks
The study revealed a non significant difference in survival rate between the two indigenous genetic groups of chickens. The observed results in this study show a slightly lower survival rate than the rate reported by Malago and Baitilwake (2009)
for indigenous chicken of Tanzania. However, other studies (Permin and Pedersen, 2000; Mwalusanya et al., 2002; Abdelqader et al., 2007) have shown high mortalities of up to 50% in local chickens even after vaccination against Newcastle disease. Most of death in indigenous chicks for their studies were tied to mishandling and improper rearing conditions at an early age, Newcastle disease outbreaks, predation and cold weather. The high survival rate in this study was attributed by improved handling and proper rearing management during the first month of growth.

5.2 Reproductive Performance.

The study revealed a non significant difference in both fertility and hatchability between the two indigenous genetic groups of chickens. The observed values for both fertility and hatchability in GSI and YSI genetic groups in this study are comparable to the value reported by Malago and Baitilwake (2009) for indigenous chicken of Tanzania. The results of the present study indicate that GSI are potentially as fertile as YSI genetic group of chickens.

5.3 Egg Quality Traits

5.3.1 External egg quality traits

The study revealed no statistical difference among the genetic groups of indigenous chickens for egg length. However, there was statistical difference between Indigenous and RIR where RIR eggs were longer than those of GSI and YSI. The value of 4.94 cm for GSI and YSI chickens is closer to the value (4.83 cm) documented by Islam and Data, (2010) in indigenous chickens of Bangladesh, but higher than the value documented by Fayeye (2005) for Fulani ecotype, the native
chicken of Nigeria. Moreover, the value is lower than the value of 5.14 cm observed by Malago and Baitilwake (2009) for indigenous chicken of Morogoro, Tanzania. On the other hand, the value (5.37 cm) obtained for RIR is close to 5.66 and 5.71 cm documented by Malago and Baitilwake (2009) and Monira et al., (2003), respectively.

As for egg length, the difference in egg volume between GSI and YSI was not significant while the egg value of RIR differed significantly from that of indigenous genetic groups. The present results of 33.85 and 33.64 cm$^3$ egg volume in GSI and YSI, respectively, are lower than the value of 34.99 cm$^3$ reported in indigenous chicken of Bangladesh (Islam and Dutta, 2010), and the value of 38.43 cm$^3$ for indigenous chicken of Morogoro (Malago and Baitilwake, 2009). On the other hand the observed value (43.28 cm$^3$) for RIR in the present study is lower than the value of 59.52 cm$^3$ for RIR obtained by Islam and Dutta (2010) and 54.88 cm$^3$ reported by Malago and Baitilwake (2009).

Similarly, the egg width values of GSI and YSI were not deferent but differed significantly from those of RIR. The obtained values of 3.63 cm and 3.62 cm for GSI and YSI respectively were closer to 3.71 cm reported by Islam and Dutta (2010) for indigenous chicken of Bangladesh, but higher than the value (2.36 cm) documented by Fayeye (2005) for Fulani ecotype, the native chicken of Nigeria. Likewise, the value (3.93 cm) for RIR in the current study is lower than the value (4.43 cm) obtained by Islam and Dutta (2010) as well as the value (4.13 cm) found by of Monira et al., (2003).
The egg shape index (egg shape percentage) is an important attribute in packaging and transportation of eggs. The results of the study clearly demonstrate that the egg shape indexes of the three genetic groups of chicken were not significantly different (P>0.05). The observed values of 73.43, and 73.78% for GSI and YSI genetic groups respectively are slightly lower than the value (74.10%) observed by Lwelamila et al., (2008) for medium indigenous ecotype of Tanzania and the value (73.93%) for indigenous Kadaknath breed of India (Parmar et al., 2006). But the value (73.27%) observed in RIR is higher than the value (72.32%) observed by Monira et al., (2003). However, the results are contrary to findings of Anderson et al., (2004) who reported a genetic difference in egg shell formation characteristics between genetic groups.

Similarly, the mean shell weight values (4.27 and 4.41 g) obtained in the present study for GSI and YSI were not significantly different. However, there was significant difference in shell weight between GSI and RIR chickens where the former had a lower value than the later. The mean value for the shell weight observed in the present study are comparable to the value (4.89 g) reported by Nonga et al., (2010) for Morogoro medium ecotype in Tanzania, but lower than the value (6.41 g) reported by Islam and Dutta (2010) for Bangladesh indigenous chicken and the value (5.12g) reported by Fayeye et al., (2005) for Fulani ecotype, the native chicken of Nigeria. The observed shell weight value (4.68 g) for RIR in the study is lower than the value (9.10 g) observed by Islam and Dutta (2010). These variations in egg shell weight are possibly due to the differences in rearing systems as suggested by Nonga et al., (2010) as this may affect the uptake of calcium. Another
cause of the variation is the differences in egg weight, RIR eggs being bigger they are also expected to have heavy shell weight.

Likewise there was no significant difference in shell thickness between Indigenous ecotypes. The observed mean values (0.35 and 0.36 mm) for GSI and YSI are comparable to the value of 0.36 mm documented by Nonga et al., (2010) for Morogoro medium ecotype in Tanzania, but higher than the value (0.31 mm) reported by Parmar et al., (2006) for indigenous Kadaknath breed of India. Shell thickness is a function of dietary calcium intake. Given that all genetic groups were fed standard diet, it implies that GSI and YSI may be exploited in reducing losses due to cracked eggs. However, North and Bell (1990) observed that as egg gets larger, the shell becomes thinner to cover the larger contents.

Moreover, the study revealed a significant difference between RIR and both GSI and YSI for egg shell ratio. However, there was no significant difference between GSI and YSI genetic groups. The results for GSI show a value of 10.07% while that of YSI and RIR were 10.43 and 8.90%, respectively. High values of shell ratio connote natural selection for heavy and thick egg shells. However, the values for RIR and Indigenous genetic groups are lower than the value (16.13%) observed by Islam and Dutta (2010) for indigenous chicken of Bangladesh. Nonetheless Hatice and Ergul (2005) reported insignificant effect of genotype on egg shell ratio.
5.3.2 Internal egg quality traits

Among the internal egg quality parameters, yolk weight (YW), yolk ratio (YR), albumin weight (AW) and albumin ratio (AR) have been reported by Bain (2005) to be important from nutritional point of view while Abdullahi et al., (2003) and Sparks (2006) reported that the egg yolk is important in relation to cholesterol content.

The value of 14.93 g obtained for YW for both GSI and YSI is comparable to the value (14.65 g) documented by Islam and Dutta (2010) for indigenous chicken of Bangladesh, and the value of 14.77 g reported by Parmar et al., (2006) for indigenous Kadaknath breed of India. But, the values in this study are higher than the value (13.03 g) reported by Fayeye (2005) for Fulani ecotype native chicken of Nigeria.

RIR did not differ significantly in YW from indigenous genetic groups. However, there was a significant difference in AW between the RIR and the indigenous genetic groups of chicken, RIR having higher value (43% higher). No statistical difference was revealed in AW between GSI and YSI. The RIR are improved chicken specifically for egg production, and they produce large eggs and this might be the reason for higher AW observed in the present result. The value obtained for GSI (23.18 g) and YSI (22.97 g) are higher than the value (18.92 g) observed by Islam and Dutta (2010) for indigenous chicken of Bangladesh, and 20.25 g observed by Fayeye et al., (2005) and 20.74 g by Parmar et al., (2006) for Fulani-ecotype native chicken of Nigeria and indigenous Kadaknath breed of India, respectively. On the other hand the observed value AW (33.07 g) in this study for RIR is lower than the
value (36.10 g) documented by Islam and Dutta (2010). Differences in values obtained from this study with other studies are probably due to genetical differences between the Indigenous on one hand and exotic egg types on the other hand. With regard to content of albumen, there was also a significant difference between RIR and indigenous genetic groups in AR whereby RIR had the highest value compared to YSI and GSI mainly due to genetical differences between exotic and indigenous type. Like in the other egg traits, the difference in AR between GSI and YSI was not significant suggesting their similarity in genetic group.

5.4 Cholesterol Content

5.4.1 Egg yolk cholesterol

The study showed significant difference between GSI and YSI genetic groups for the first two periods of experiment. Likewise, RIR differed significantly from GSI and YSI. The difference is likely to be due to the carry over effect of the differences in management systems. Both GSI and YSI chickens were under scavenging while the RIR chickens were under confinement prior to the start of experiment. Sanjeewa et al., (2011) have reported that the egg yolk of normal village chicken ecotypes have a higher fat content than the commercial chicken egg yolk. Fat content is positively correlated with cholesterol concentration (Hassan et al., 2007), it is likely that during the first periods of experiment eggs of both yellow and green shanked indigenous chicken exhibited more the quality of a normal village scavenging chicken. Confinement and the use of commercial feeds was probably the cause of changes in yolk cholesterol concentration for indigenous chickens.
Results also indicate a gradual increase of egg yolk cholesterol concentration with age in all three genetic groups of chicken. As laying stage advanced there was no significant difference between genetic groups in cholesterol concentration. Since the yolk weights were similar in all genetic groups, it is assumed that under similar management, there will be no any significant difference in cholesterol content. Moreover, the results in this study have demonstrated that eggs produced by older hens have on average a heavier yolk, higher yolk cholesterol concentration and hence higher egg cholesterol. This pattern corresponds to the findings of Shafey et al., (1998). In contrast, Hatice and Ergul (2005) reported that the egg cholesterol content is contributed by genotype and other environmental factors including rearing system. They reported that egg yolk and serum cholesterol contents in brown layers (IsaBrown) are higher than in white layers (Babcock-300). Basmacioğlu and Ergul (2005) reported that egg yolk cholesterol content and egg production are negatively correlated. Abdullahi et al., (2003) revealed that cholesterol level increases as yolk and yolk albumin ratio increases implying that the egg with largest yolk and yolk:albumin ratio might be expected to contain the highest amount of cholesterol.

5.4.2 Blood plasma cholesterol

The result from period 1 to 3 shows a steady decline in plasma cholesterol in RIR genetic group and levelling off thereafter. In GSI and YSI, the cholesterol levels also declined but started to increase in yellow and green shanked birds after period 2 and 3, respectively. The steady decline of serum cholesterol in RIR is understandable as RIR lays eggs continually. However, in Indigenous types the fluctuations are likely to be due to reduction in egg production especially when local chickens started
expressing broodiness. The fluctuation in plasma cholesterol level particularly in Indigenous type implies that, when hens start brooding, more cholesterol is retained in the blood, hence an increase in total plasma cholesterol. Thus the more the eggs produced the more the cholesterol secreted out from the body as eggs are the major route for cholesterol excretion (Sim et al., 1980; Burczak et al., 1980; Naber, 1983; Cho et al., 1987 and Elkin et al., 2003).

Turk and Barnett (1971) reported the environmental factors as one of the sources for variation in cholesterol concentration in blood. The author pointed out that stress plays a major role in increasing blood cholesterol. Thus, the raise of cholesterol concentration in blood plasma during brooding period is likely to be contributed by the stress due to brooding.

5.5 Correlation Among Traits

5.5.1 Correlation among egg quality traits

The study revealed a significant positive correlation between egg yolk cholesterol, egg weight and yolk weight. This was observed in all the genetic groups, though the correlation was statistically not significant (P>0.05) except for RIR and the overall yolk weight. The finding of this study is similar to that of Marks and Washburn (1977), Becker et al., (1977), Beyer and Jensen (1989) and Shafey (1998), but contrary to the study of other researchers (Bartov et al., 1971 and Ansah et al., 1985). These findings imply that breeders should focus on producing eggs with light yolk for less egg cholesterol level.
5.5.2 Correlation between plasma and yolk cholesterol

In the present study, a negative correlation between egg yolk cholesterol and plasma cholesterol was observed in each genetic group. Whilst the cholesterol concentration was increasing with age in egg yolk, it was decreasing in blood plasma. This indicates the possibility of reducing egg yolk cholesterol through selection of birds that produces more eggs in their younger age.

Furthermore egg yolk cholesterol was shown to be positively correlated with egg weight for all genetic groups, though the correlation coefficient was not statistically different. Similarly, yolk weight was positively correlated to yolk cholesterol concentration, though the relation was weak except in RIR. This implies that larger yolk in RIR contain high level of cholesterol than smaller ones.
CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

i. The study demonstrated that both the GSI and YSI do not differ significantly in most of the traits studied, i.e. egg yolk and plasma cholesterol, production and reproductive efficiency, external and internal egg quality traits. This implies that the shank colour has no influence on the studied traits and this suggests that the GSI is not a distinct strain from the YSI genetic group.

ii. Both GSI and YSI genetic groups differed with RIR in most of the assessed traits. Egg production (egg number) and the related egg quality traits such as egg weight and egg volume, were higher in RIR suggesting the need of mere efforts on improving the productivity of indigenous chickens through crossbreeding with exotic breeds.

6.2 Recommendations

i. Further study is recommended with pure green shanked chickens so as to establish the inheritance pattern of green shank gene because the current study used the chicken from the field whereby yellow and green shanked chickens mate randomly.

ii. The magnitude of Genetics x Environment interaction also needs to be quantified to determine whether it would have a significant effect on the performance of various shank colours and hence the biological importance of shank gene colour.
iii. Further studies are also recommended using shank colour of specified indigenous scavenging chicken eco-types from different ecological zones. Likewise, more studies are needed to explore other factors like growth performance to maturity (in terms of carcass quality), disease resistance and adaptability to harsh environment of the YSI and GSI genetic groups compared to exotic egg types.
REFERENCES


APPENDICES

Appendix 1: plasma and egg yolk cholesterol

Appendix 1a: ANOVA for dependent variable plasma cholesterol (PC)

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>F Value</th>
<th>Pr &gt; F</th>
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<tbody>
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<td>29648.44669</td>
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<td>Error</td>
<td>45</td>
<td>40418.27853</td>
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<td>Corrected Total</td>
<td>47</td>
<td>70066.72522</td>
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</table>

R-Square  C.V  Root MSE  PC Mean
---  ------  ------  --------
0.423146 16.08580 29.96972 186.3116

Appendix 1b: Dependent Variable: Egg Yolk cholesterol (YC)

<table>
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<td>787.597500</td>
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R-Square  C.V  Root MSE  YC Mean
---  ------  ------  --------
0.839440 9.980552 20.23058 202.7000
### Appendix 2: Production traits

**Appendix 2a: ANOVA for Dependent Variable: Egg Number in the first 90 days (EN90D)**

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<td>Error</td>
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<td>8463.562500</td>
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<td>0.918777</td>
<td>7.654349</td>
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**Appendix 2b: ANOVA for Dependent Variable: Laying intensity (LI)**

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<td>0.918721</td>
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Appendix 2c: ANOVA for Dependent Variable: Egg Mass in the first 90 days (EM90D)

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<td>Corrected Total</td>
<td>47</td>
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</table>

R-Square: 0.963417
C.V: 7.283676
Root MSE: 174.3505
EM90D Mean: 2393.716
Appendix 3: External egg quality traits

Appendix 3a: ANOVA for dependent variable egg weight (EWT)

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<tr>
<th>Source</th>
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<th>Mean Square</th>
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<tr>
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<td>583.2000000</td>
<td>23.605652</td>
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<td></td>
</tr>
</tbody>
</table>

R-Square | C.V | Root MSE | EWT Mean
---|-----|---------|--------|
0.923731 | 3.184612 | 1.455368 | 45.70000

Appendix 3b: ANOVA for Dependent Variable egg length

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>F Value</th>
<th>Pr &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genetic group</td>
<td>2</td>
<td>1.05583333</td>
<td>0.52791667</td>
<td>67.7</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Error</td>
<td>21</td>
<td>0.16375000</td>
<td>0.00779762</td>
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<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>23</td>
<td>1.21958333</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

R-Square | C.V | Root MSE | Egg length Mean
---|-----|---------|-----------------|
0.865733 | 1.738555 | 0.088304 | 5.079167
### Appendix 3c: ANOVA for Dependent Variable egg weight (Ewt)

<table>
<thead>
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<th>Mean Square</th>
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<tbody>
<tr>
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<td>0.44083333</td>
<td>0.22041667</td>
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</tr>
<tr>
<td>Corrected Total</td>
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<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>R-Square</th>
<th>C.V</th>
<th>Root MSE</th>
<th>Ewt Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.816988</td>
<td>1.842972</td>
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</table>

### Appendix 3d: ANOVA for Dependent Variable: Egg volume (EV)

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>Genetic group</td>
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<td>484.7449401</td>
<td>242.3724700</td>
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<tr>
<td>Error</td>
<td>21</td>
<td>38.8320059</td>
<td>1.8491431</td>
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<td></td>
</tr>
<tr>
<td>Corrected Total</td>
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<td>523.5769460</td>
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<table>
<thead>
<tr>
<th>R-Square</th>
<th>C.V</th>
<th>Root MSE</th>
<th>EV</th>
</tr>
</thead>
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<tr>
<td>0.925833</td>
<td>3.682865</td>
<td>1.359832</td>
<td>36.92321</td>
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</tbody>
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### Appendix 3e: ANOVA for Dependent Variable: Shell thickness (STH)

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<th>Mean Square</th>
<th>F Value</th>
<th>Pr &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genetic group</td>
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<td>0.00875000</td>
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<td>0.0200</td>
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<tr>
<td>Error</td>
<td>21</td>
<td>0.03875000</td>
<td>0.00184524</td>
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<td></td>
</tr>
<tr>
<td>Corrected Total</td>
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<td>0.05625000</td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>R-Square</th>
<th>C.V</th>
<th>Root MSE</th>
<th>STH Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.311111</td>
<td>12.72777</td>
<td>0.042956</td>
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### Appendix 3f: ANOVA for Dependent Variable: Albumin weight (ALWT)

<table>
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<th>Mean Square</th>
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</thead>
<tbody>
<tr>
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<tr>
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<td>1.0558333</td>
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</tr>
<tr>
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<table>
<thead>
<tr>
<th>R-Square</th>
<th>C.V</th>
<th>Root MSE</th>
<th>ALWT Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.960051</td>
<td>3.892188</td>
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### Appendix 3g: ANOVA Dependent Variable: shell weight (SW)

<table>
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<th>Mean Square</th>
<th>F Value</th>
<th>Pr &gt; F</th>
</tr>
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<tbody>
<tr>
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<tr>
<td>Corrected Total</td>
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<table>
<thead>
<tr>
<th>R-Square</th>
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<th>Root MSE</th>
<th>SW Mean</th>
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</thead>
<tbody>
<tr>
<td>0.262786</td>
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</table>

### Appendix 3h: ANOVA Dependent Variable: Shell ratio (SR)

<table>
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<th>Mean Square</th>
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<th>Pr &gt; F</th>
</tr>
</thead>
<tbody>
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</tbody>
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<table>
<thead>
<tr>
<th>R-Square</th>
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<th>Root MSE</th>
<th>SR Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.721533</td>
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### Appendix 3i: ANOVA Dependent Variable Albumin ratio (AR)

<table>
<thead>
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<th>Mean Square</th>
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</tr>
</thead>
<tbody>
<tr>
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</tr>
<tr>
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<table>
<thead>
<tr>
<th>R-Square</th>
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<th>Root MSE</th>
<th>AR Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.950960</td>
<td>1.720148</td>
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</tr>
</tbody>
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