HERITABILITY AND RESPONSE TO SELECTION OF EGG PRODUCTION AND EGG QUALITY TRAITS IN THREE GENERATIONS OF JAPANESE QUAIL (*Cortunix cortunix japonica*)

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A DESSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA NIGERIA
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JULY, 2017

DECLARATION

I declare that the research work titled "HERITABILITY AND RESPONSE TO SELECTION OF EGG PRODUCTION AND EGG QUALITY TRAITS IN THREE GENERATIONS OF JAPANESE QUAIL (*Cortunix cortunix japonica*)" was carried out by me at the Teaching and Research Farm of the Department of Animal Science, Faculty of Agriculture, Ahmadu Bello University Zaria, Nigeria under the supervision of Prof. G. N. Akpa and Dr. I.I. Adedibu. The information obtained from literature has been duly acknowledged in the text and a list of references provided. No part of this Dissertation has been previously presented for another degree or diploma at any University.

ABBAYA HASSAN YOHANNA	_____	_____
Name	Signature	Date

CERTIFICATION

This Dissertation titled "HERITABILITY AND RESPONSE TO SELECTION OF EGG PRODUCTION AND EGG QUALITY TRAITS IN THREE GENERATIONS OF JAPANESE QUAIL (*Cortunix cortunix japonica*)" by ABBAYA, HASSAN YOHANNA meets the regulations governing the award of the degree of Masters of Science in Animal Science of the Ahmadu Bello University, Zaria and is approved for its contribution to scientific knowledge.

Prof. G. N. Akpa Chairman, Supervisory Committee	_____ Signature	_____ Date
Dr. I. I. Adedibu Member, Supervisory Committee	_____ Signature	_____ Date
Prof. S. Duru Head, Department of Animal Science Ahmadu Bello University, Zaria	_____ Signature	_____ Date
Prof. S. Z. Abubakar Dean, School of Postgraduate Studies, Ahmadu Bello University, Zaria	_____ Signature	_____ Date

DEDICATION

I dedicate this Dissertation to God Almighty and the family of my elder brother Dr and Mrs Joel Yohanna and the family (Jessica, Juanita and Jennie)

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ABSTRACT

This experiment was conducted to study the heritability and response to selection of egg production and quality traits in three generations of Japanese quail (*Cortunix cortunix japonica*). A total of 300, 450 and 420 adult Japanese quails mated at seventh week of age and in the ratio of 1:2 male to female ratio were used. A total of 4906 eggs (2461, 1365 and 1080) in base population, Generation One and Generation Two were collected and incubated. Egg collection for egg quality analyses was done at ninth week of age. At mating, Sire body weight was weighed and grouped into four weight groups. Selection for egg number was carried out and the correlated response estimated. Traits measured included body weight of sire at mating, egg number and egg internal and external quality traits. The egg quality trait was carried out using the breakout analysis. Data was analyzed using SAS Statistical Software. The effect of sire bodyweight at mating and the generation of selection on reproductive performance as well as phenotypic correlation between egg quality traits after two generations of selection were also estimated. Selection was carried out for two generations G_1, G_2 along with a base population G_0. The generations of selection for egg production significantly ($P<0.05$) increased egg number, yolk length, yolk index and shell thickness; while egg weight, egg length, and shell weight significantly ($P<0.05$) decreased. Sire body weight at mating does not significantly affect all the measured reproductive traits ($p>0.05$) but there was a significant effect of generation of selection ($p<0.05$) on early embryonic mortality (13.46, 12.86 and 5.91) and late embryonic mortality (16.63, 17.44 and 11.40), respectively. There was a significant effect ($p<0.05$) of interaction between sire body weight at mating and generation of selection on all the traits measures. Phenotypic correlation between egg quality traits varied in magnitude and direction (-0.90-1.00) also, heritability estimates of egg production and quality traits ranged from low to high (0.09-0.77). Correlated responses among the egg production and quality traits also varied in magnitude

and direction. It was observed that egg number improved by 2.37 and 1.56 in generation one and two respectively, as a result of selection. It was concluded that short term selection for increased egg number lead to increased yolk length, yolk index and shell thickness but decreased egg weight, egg length, and shell weight. In addition, heritability and response of egg production and its correlated response with egg quality can be maximized in quail egg improvement program. It is therefore recommended that medium to heavy eggs should be used in hatcheries for better hatchability and reduced embryonic mortality. Also, correlation between traits should be considered in selection designs.

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CHAPTER ONE

1.0 INTRODUCTION

Livestock diversification using animals with short generation interval will be a viable tool in ameliorating shortage of protein among the populace in developing countries (NVRI, 1994). Quails are the most efficient biological machine for converting feed into animal protein of high biological value and hence are the cheapest source of animal protein for human diet (Muthukumar and Dev Roy, 2005). Japanese quail (*Coturnix coturnix japonica*) is considered a pilot bird for poultry breeding studies because it is the smallest avian species farmed for meat and egg production (Baungartner, 1994; Panda, 1996; Akpa *et al*., 2008) and it has thus been used widely in many biological experiments. The main advantages for considering Japanese quail as a pilot animal are its rapid growth which makes it marketable for consumption at about 5-6 weeks of age, early sexual maturity resulting in short generation interval, high rate of lay and much lower feed and space requirements than other domestic fowls (Oluyemi and Roberts, 2000).

Selection programmes in poultry has placed much emphasis on rapid early growth rates and increase in body size which result in a significant reduction in the number of days required to grow birds to market weight with indirect improvement in feed conversion (Aboul-Seoud, 2008). Therefore, the merits of selection methods to increase genetic gain depend not only on direct response alone but also on associated changes in other economically or biologically important traits such as egg quality traits as a result of correlated responses to selection (Aboul-Seoud, 2008). Selection for a certain trait may indirectly affect other traits not considered in the programme due to the fact that the improved trait is correlated with these other traits.

Reproductive traits (fertility and hatchability) are the most important attributes of parent stock performance (Sezer, 2008) hence; selection is possible if sufficient additive genetic variance exists in population or selected lines of those traits (Kaye, 2014). Knowledge of heritability of traits is therefore essential for understanding how individual characteristics change across generations in response to selection (Falconer and Mackay, 1996).

Eggs and meat are classified among the most nutritious food; and eggs are rated with milk among the best foods rich in protein, vitamins, essential amino acids, saturated fatty acids, unsaturated fatty acids, phospholipids, iron (Fe) and vitamins (Oluyemi and Roberts, 2000; Muthukumar and Dev Roy, 2005). Egg quality is a term which refers to general standard that define both internal and external quality such as egg weight, length, width, index, shell weight and thickness, albumen height and width, yolk height, index and haugh unit (Scott and Silversides, 2001). The findings of Islam *et al*. (2001) and Sezer (2008) indicated that the external and internal egg quality traits can affect the future generations and their performance.

Reports from various authors (Abdel-Fattah, 2006, Aboul- Seoud, 2008, Okenyi *et al*., 2013) indicate that heritability estimates for egg quality differ with age and are also affected by environment, experimental conditions and methods of analysis. Akpa *et al*. (2008) reported the relationship between laying age and repeatability of egg quality traits in Japanese quails. Ojo *et al*. (2011) reported the effect of egg weight on hatchability and hatching weight in Japanese quail while Ojo and Ayorinde, (2011) also reported the effect of divergent selection for 35th day body weight on growth and egg quality traits of Japanese quails.

1.2 Justification of the study

Most studies on quails were aimed at increasing meat and egg production (Ani *et al*., 2009). With this goal, new breeds of quails have been obtained for meat and egg type. For egg type quails the intention has been to increase total egg mass, to get an earlier sexual maturity and to optimize egg production in order to increase laying performance (Camci *et al*., 2002).

Positive correlations between egg weight, shell weight and shell thickness have also been reported by Farooq *et al*. (2001) and Khurshid *et al*. (2013) but there are scanty works on the trend of relationships that exist between egg quality traits over generations of selection, the effect of bodyweight at mating on reproductive traits as well as heritability and response to selection of egg production and quality traits of Japanese quails.

1.3 Objectives of the study

The broad objective of this study is to determine the heritability and response to selection of egg production and quality traits in Japanese quails

The specific objectives of this study are to determine the:

1. Effect of bodyweight of male quails at mating on reproductive performance of Japanese quails.
2. Trend of relationship between the external and internal egg quality traits over two generations in quails.
3. Heritability (h^2_S) of egg production traits and response (R) to selection of egg production and egg quality traits in Japanese quails.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and Distribution of Japanese Quails.

The Japanese quail belongs to the order Galliformes, family Phasidae, genus Coturnix, and species japonica. Different from the common quail (*Coturnix coturnix*), the scientific nomenclatu re for Japanese quail is *Coturnix japonica* (Thear, 1998; Mitzutani, 2003). The Japanese quail is also known with other names, Stubble quail, Pharaoh quail, Eastern quail, Asiatic quail, Grey quail, Red quail, Japanese migratory quail, King quail and Japanese king quail (Kayang *et al*., 2004). Even though the first wild Japanese quail appeared in the eight century in Japan, they were originally domesticated around 11^{th} century for their ability to sing (pet song birds) and later as egg and meat producers (Mitzutani, 2003; Kayang *et al*., 2004).

The plumage colour of the wild type is predominantly dark cinnamon brown. However, adult (4-6 weeks) females have pale breast feathers that are speckled with dark coloured spots. Adult males on the other hand have uniform dark rusted red feather on the breast and cheek (Mitzutani, 2003) and recently, colour has been used for auto sexing in quail industry. The adult male *coturnix* weighs about 100-140g while the females are slightly heavier, weighing from 120-160g. Males also have a cloacal gland, a bulbous structure located at the upper edge of the vent which can be used to assess the reproductive fitness of the male (Mitzutani, 2003).

Japanese quails have a variety of uses in several countries. For instance, egg production is important in Japan and South East Asia while meat is the main product in Europe (Baungartner, 1994; Minvielle, 1998; Nastrollah, 2008). The first egg lines were developed in Japan and later

introduced to America, Europe and Middle East between 1930– 1950 where specific lines were bred for egg and meat production (Ashok and Prabakaram, 2012).

In Nigeria, Japanese quails were introduced in 1992 with a view to diversify the poultry subsector and help supplement chicken production with massive quail farming by farmers(NVRI, 1994) with this, several efforts have been directed towards boosting the livestock industry with micro-livestock having prolific tendencies, short gestation periods, short generation interval, rapid growth, low cost of maintenance, resistance to disease and high egg production (Baungartner,1994;Yalchin*et al*., 1995; Oguz and Minvielle, 2001; Mitzutani, 2003; Kayang *et al*., 2004; Owen and Amakiri, 2010). With these characteristics of Japanese quails, most studies on them have been aimed at increasing meat and egg production. With this goal, new breeds and strains of quails have been obtained for meat and egg types (Camci *et al*., 2002) and distributed all over the World. The Table 2.1 describes the general characteristics of Japanese quails.

Table 2.1: General Characteristics of Japanese quails

Trait	Range
Body weight at day old	6-8g
Adult male	100-130g
Adult female	120-160g
Egg weight	9-10g
Egg no./ 100days	80-90
Age at sexual maturity	38-42 days
Life span	3-7 years
Generation interval	3-4 months

Adapted from Mitzutani, 2003

2.2 Sexual Characteristics of Male Japanese Quails

Reports by Oruwari and Brody (1988) and Reddish *et al*. (2002) showed that lean body weight is not critical for initiation of selection in sexual maturity, but abdominal fat pad weight expressed as absolute weight or as percentage of body weight can significantly be used as criteria for sexual maturity in generations of selection. They reported that there is a minimum body fat threshold needed for sexual maturity in male quails. Also, Yannakopoulos *et al*. (1995) reported that fat deposition is an important factor in the process of sexual maturation. Selection for high body weight will enable quails to reach their adipose threshold well before other physiological system would reach their minimal stage of development needed for the onset of egg production (Reddish *et al*., 2002; Akbas *et al*., 2004). Therefore, body weight and selection aspect of body composition must excel a threshold value in order for sexual development to proceed (Soller *et al*., 1984).

2.3 Productive and Reproductive Traits of Japanese quails

A common occurring problem in all avian species is the relatively poor reproductive performance of birds selected for increased growth rate (Aboul-Seoud, 2008). This poor performance is usually reflected as a decrease in total egg production as well as an increase in the number of unsuitable eggs for setting (Aboul-Seoud, 2008). Reproductive and egg productive performance therefore, are mostly assessed in avian species through the observation of numerous phenomena such as; age at first egg, fertility, hatchability, egg production over certain period of time and sometimes egg production curve which is mostly affected by genetic and non-genetic factors such as age, body weight, adiposity, mating ratio and rate of lay (Zalenka *et al*., 1986; Aboul-Seoud, 2008; Kaye, 2014).

For commercial layers, egg number among other reproductive traits is the major index of performance. It accounts for about 90% of the income for the farmer (Oluyemi and Robert, 1979). Obioha (1992) also reported that egg qualities particularly egg size is another important economic traits that is used to determine the price received in any market such that the standard range of egg size for chicken egg is between 53 and 63grams. Even though the given standard is to be maintained, some factors such as temperature and humidity, nutrition, body weight are some of the factors that can affect egg production (Daghir, 1995; Lacin *et al*., 2008; Claudia, 2009; Munir and Mohammed, 2010; Olusoji, 2011; Kaye, 2014).

2.3.1. Egg number

Factors that influence egg number in Japanese quails as reported by several authors (Daghir, 1995; Lacin *et al*., 2008; Claudia, 2009; Munir and Mohammed, 2010; Olusoji, 2011; Kaye, 2014) included age at sexual maturity, managerial and climatic conditions. A number of researches carried out on egg production in Japanese quails had focused on assessing the number of eggs produced during short period of the production curve that can be used to predict the producing ability of a hen (Shama, 1981; El-Fiky *et al*., 1994). Kadry *et al*. (1986) estimated that the average egg number produced during the first 60 days of production were 38.8 and 47.7 eggs, respectively. Okuda (2013) reported that egg production in Japanese quails for 60 days period when fed alkaline phosphate for three consecutive generations were 36.55, 46.04 and 45.36 for base generation (G_0), generation one (G_1) and generation two (G_2), respectively. Aboul-Hassan and El-Fiky (1995) reported an estimate of 54.8 eggs for this trait and suggested that one unit of standard deviation is needed to increase performance to 62.3 eggs. Abdul-Hassan (2004) also reported the average estimate of egg number of eggs laid per female after 10 weeks of onset of egg production as 57.1 and 64.3 eggs for selected and control lines when selection was applied

for high body weight at six weeks. Furthermore, Aboul-Hassan (2001) reported an average number of eggs laid per female of Japanese quails during the first ten weeks of laying after 3 generations of selection for egg production as 62.1 and 58.2 eggs for selected and control lines respectively. Moreover, Abdel- Mounsef (2005) reported 58.12 to 62.82 eggs for three mating systems (full-sib, half-sib and random), 59.81 to 71.72 eggs for three sex ratios for mating parents (1:1, 1:2 and 1:3) and between 59.11 and 63.91 eggs for three parental ages (10, 16 and 22 weeks). Okenyi *et al*. (2013) reported that the means of egg production in the G_0, G_1 and G_2 were 25.34, 27.60 and 29.46 respectively for 30 days (i.e short term production) for quails selected for 30-day egg production. Kaye (2005) observed that the peak production in egg number was recorded at the 6th week of lay with 86 percent recorded for that time. The peak in hen-day production of 94.56 percent was also observed at six weeks after point of lay. Aboul-Seuod (2008) also reported an estimate of 53eggs for 60 days in lay. El-Fiky *et al*. (2000a) and Aboul-Hassan (2001) estimated egg number during 60 days production period as 61.1,52.3 and 55.9, 58.8 eggs for Brown and White strains of Japanese quails. Generally, egg production is highest when the temperatures are within neutrality range (Smith, 1990). Munir and Mohammed (2010) reported that among other factors that affect egg number, temperature plays a major role. They reported that, ambient temperature above 30^0C is considered to have detrimental effect on performance of laying hens. They further observed that ambient temperature of 21^0C and 30^0C at high relative humidity of 75% within poultry house enhanced egg production compared to birds in an ambient temperature of 35^0C. Nutritionally, Claudia (2009) reported ricket, caged layer fatigue and fatty liver syndrome as nutritional diseases that affect laying hens and accounted for a higher percentage of the flock mortality. Sanvuer and Picard (1987) reported that decline in egg

production and egg weight as well as reduced feed intake resulted from exposure to high ambient temperature.

2.3.2 Egg weight

Average weight of a Coturnix egg is approximately 10g with range of 7-14g (Singh and Panda, 1986; Asasi and Jaafar, 2000; Ali *et al*., 2002; Mitzutani, 2003; Abdel- Azeem, 2005). This is about 8% of the hen's body weight compared to approximately three and one percent respectively for chicken and turkey (Woodard and Abplanalp, 1967). From the point of view of consumers, egg weight is the most essential quality trait. In Japanese quails, this trait is related to genetic structure (Rajkumar *et al*., 2009), sexual maturity (Kumar *et al*., 2000), production type (Panda and Sigh, 1990), nutrition (Güçlü *et al*., 2008), the stage of production cycle (Silverside and Scott, 2001; Nowaczewski *et al*., 2010) and housing density (Bhanja *et al*., 2006). Inal *et al*. (1996) studying divergent selection for body weight at five weeks (BW5) in five generations, reported an estimate that ranged between 10.94 and 13.23g. Similarly, Hrnčári *et al*. (2014) reported higher value (13.06g) obtained for meat type as compared to laying type (11.48g) quails in the study on the effect of genotype on egg quality characteristics of Japanese quails. The Least Square Means for egg weight at day 35, 42,49 and 63 days were reported to range between 8.1-12 g respectively (Song *et al*., 1999). Kul and Seker (2004) and Kaye (2014) reported an estimate of egg weight as 8.4g, 9.9g and 10.1g for three generations of selection (G_0, G_1 and G_2) for egg weight at first egg. The Table 2.2 shows the egg weight recorded after generations of selection by some authors.

Table 2.2: Egg characteristics for generations of selection as reported by some Authors

	G_0	G_1	G_2	Source
Egg weight(g)	8.30	9.90	10.10	Kaye, 2014
Egg length(cm)	2.90	3.40	3.80	Kaye, 2014
Egg width(cm)	2.40	2.60	2.90	Kaye, 2014
Yolk weight(g)	3.70	4.10	4.40	Kaye, 2014
Yolk length(cm)	1.30	1.60	1.60	Kaye, 2014
Yolk width (cm)	2.20	2.30	2.30	Kaye, 2014
Albumen weight(g)	3.20	3.30	3.60	Kaye, 2014
Albumen length(cm)	1.00	0.30	0.30	Kaye, 2014
Albumen width(cm)	3.00	3.10	3.30	Kaye, 2014
Shell thickness(mm)	0.30	0.20	0.20	Kaye, 2014
Shell weight(g)	0.40	0.40	0.30	Kaye, 2014
Egg weight(g)	8.89	9.15	9.04	Okuda, 2013
Albumen weight(g)	4.55	4.50	4.47	Okuda, 2013
Haugh unit	58.98	59.88	59.11	Okuda, 2013
Yolk weight(g)	3.22	3.01	3.18	Okuda, 2013
Egg width(cm)	2.04	2.27	2.20	Okuda, 2013
	11.41	10.84	9.33	Okenyi *et al*., 2013

2.3.3 Egg mass

The average daily egg mass during the first week of laying were reported by Sabri *et al*. (1993) and El-Fiky and Aboul- Hassan (1994) to range between 9.8 and 11.8g daily. However, Aboul-Hassan (2001) estimated the same trait as 9.5 and 8.3g/day for selected and control lines when selection was applied for increased egg production. El-Fiky *et al*. (2001) and Aboul- Hassan (2001) reported average daily egg mass during the same period of egg production as 8.5g - 9.3g for brown strains and 8.4 -9.5g for White strains of Japanese quails. Furthermore, Abdel-Mounsef (2005) reported an estimates ranging between 8.31 to 9.38g/day for three mating systems and between 8.11 to 8.99g/day for three sex ratios for mating parents; and between 8.45g/ day for three parental ages.

2.3.4 Egg composition

Egg composition of Coturnix eggs have been reported by Mohmod and Coleman, (1967) as 47.4 percent albumen, 31.9percent yolk and 20.71percent shell and membranes. Same authors reported that the shell thickness and shell membranes were 0.197 and 0.06mm, respectively. However, Hrnčári *et al*. (2014) reported higher percentages for quails egg composition as 58.78percent albumen, 32.43percent yolk and 58.39 percent albumen and 35.85percent for laying type hen and meat types, respectively. Egg shell thickness was 0.22 and 0.23mm for laying and meat type, respectively (Hatman *et al*., 2000). The content and composition of an egg can directly affect the hatchability, chick quality and even the future performance (Hatman *et al*., 2000)

2.4Fertility and Hatchability

Fertility and hatching characteristics of birds are among the major reproductive traits that determines the profitability of any poultry production venture. Fertility as defined by Daikwo *et*

al. (2011) is a proportion of fertile eggs to the number of egg set. Okenyi *et al*. (2013) on the other hand defined fertility as the interaction between maternal and paternal gametes to produce a viable zygote and can be expressed as the number of fertile eggs per bird. Hatchability is defined as proportion of the number of chicks hatched out of the total number of eggs set (Daikwo *et al*., 2011). Okenyi *et al*. (2013) defined hatchability as the ratio between fertile eggs that produce viable birds and unfertilized eggs. Savegnago *et al*. (2011) defined hatchability as the composite of the embryo's ability to survive and the maternal contribution towards embryo survival. Daikwo *et al*. (2011) stated that fertility, hatchability and embryo mortality are important indices for producing chicks from a breeding flock. Fertility is affected by factors such as mating ratio(Umar *et al*., 2013), age of the parents(Mitrovic *et al*., 2005;Abiola *et al*., 2008; Olusoji, 2011), rate of lay, climate and environmental conditions (Davis *et al*., 1993), method of mating (Ojo and Ayorinde, 2011), egg weight (Seker *et al*., 2005; Alkan *et al*., 2010), nutrition (Park *et al*., 2004; Laila *et al*., 2012), routine management (Malago and Baitilwake, 2009) and health (King'ori, 2011).

Factors affecting hatchability as reported by authors include nutrition, rate of laying, parental age, pre-incubation storage, egg weight, mating ratio, physical characteristics of egg, poor incubation technique(Chang-Reissig *et al*., 2001;Nurishin and Romanov, 2002; Seker *et al*., 2004; Daikwo *et al*., 2011; Laila *et al*., 2012).

2.4.1 Fertility percentages

Ojo and Ayorinde(2011) reported that floor mating ensures more effective mating than the cage rearing and thus gave higher percentages of fertility. Seker *et al*. (2005) reported fertility rates of 61.7 percent, 58.8 percent and 78.8 percent in egg weight groups (9.6-10.5g, 10.51-11.5g and 11.51-12.50g) respectively with the largest egg weight group having the highest fertility rate.

However, Alkan *et al*. (2010) reported lower fertility rates of 46.0 percent , 50.0, 46.0, 36.0 and 39.0%) in egg weight groups(10g, 10.1g, 11.0g, 11.1-12.0g, 12.1-13.0g and >13.0g), respectively. The fertility percentages in Japanese quails reported by Ojo and Ayorinde, (2011) were 79.4, 73.5 and 65.9 percent, respectively. Umar *et al*. (2013) reported higher fertility (75%) for mating ratio of 1:1 of Japanese quails supplemented with Vitamin E and Selenium compared to mating ratios 1:2, 1:3 and 1:4 which gave fertility rates of 74 percent, 70 percent and 70 percent, respectively. Daikwo *et al.* (2011) reported a fertility estimate of 85.41 percent in Japanese quails in the tropical environment. El- Fiky *et al*. (1994) reported that fertility rates in Japanese quails ranged almost between 75.7 and 81.0 percent. Higher estimates of 81.7, 83.4, 84.0 and 93.9 percent were reported for this trait in Japanese quails by Gildersleeve *et al*., (1987); El-Fiky (2002). However, El-Fiky and Aboul-Hassan (1994) reported estimates ranging between 66.4 and 85.8 percent for the same trait during three consecutive generations of Japanese quails.

2.4.2 Hatchability percentages

Seker *et al*. (2005) reported the hatchability of fertile eggs of Japanese quails to be 75.2, 99.2 and 86.2 percent in egg weight groups of 9.5-10.5g, 10.51-11.50 and 11.51g, respectively while Ojo and Ayorinde (2011) reported an estimate of hatchability for incubated eggs of Japanese quails to be 52.7, 48.7 and 19.4 in large, medium and small egg weight groups, respectively. Woodard and Abplanalp (1967) reported an estimate ranging between 80.2 and 88.4 for hatchability of fertile eggs from 9-10 weeks old Japanese quails.

El-Fiky *et al*. (1996) reported a wider range for this trait (68.2-78.5 percent) during three consecutive generations. Lower ranges of estimates were reported for hatchability in Japanese quails by Marks (1978) who reported 44.5 and 50.8 percent for selected and unselected lines.

Daikwo *et al*. (2011) reported an estimate of 71.52 and 61.31 percent for hatchability of fertile eggs and hatchability of total eggs set in Japanese quails in the tropical environment. Okenyi *et al*. (2013) reported estimates of 57.89, 63.73 and 69.12 percent as percentages of hatchability in G_0, G_1 and G_2 for selection for short term egg production traits in Japanese quails. Gildersleeve *et al*. (1987) reported estimate of 73.0, 79.2, 82.9 and 86.0 percent hatchability estimates in four generations of Japanese quails and concluded that hatchability increased from 73 to 86% from G_1 to G_4. Erensayin and Camci (2002) reported that the hatchability of fertile eggs in age groups of 10 and 20 weeks of Japanese quails were respectively 74.72 and 69.44 percent, in addition, the hatchability of fertile eggs was also observed higher in young group compared with the older group. Umar *et al*. (2013) reported higher hatchability of 78 percent for mating ratio of 1:1 than 70.70 percent observed for mating ratios of 1:2 and 1:3 while least hatchability (64%) observed for the 1:4 group supplemented with vitamin E and selenium. Islam *et al.* (2014) reported hatchability estimates of 71.01, 55.01, 54.94 and 31.03% for Japanese quails for White, Brown and Black genotypes of quails. Seker *et al*. (2005) reported estimates of 90.39, 88.74, 67.96, 50.31 and 73.97% for hatchability for (3, 46, 7-9, 10-12, and 13-15 days) of storage periods.

Daikwo *et al*. (2011) also reported that the average percentages for hatchability of fertile eggs and that of total egg sets were 71.52 and 61.31%, respectively in Japanese quails. Olusoji, (2011) reported an estimates of 61.18, 59.85 and 56.81 % for hens grouped into three age groups (9, 13 and 17 weeks) respectively. In the same vein, he reported estimate of 56.44, 63.14 and 56.81 respectively for small, medium and large eggs.

Gonzalez *et al*. (1999) suggested the setting of eggs of average weight in other to achieve good hatchability. Abiola *et al*. (2008) reported best hatchability results of 96.67% for medium sized eggs. Munir and Mohammed (2010) reported an increase in percent fertility and hatchability of

Arbor Acres White and Lohmann Brown hybrid layers between the ages of 24-45 weeks followed by decrease when the birds advanced in age between 50-60weeks.

2.4.3 Embryonic mortality.

Embryo mortality can be regarded as a direct fitness trait that can reduce reproductive efficiency thereby increasing production cost (Daikwo *et al*., 2011). Embryo mortality therefore has been defined as the proportion of dead embryos out of the number of fertile eggs. Ayman (2011) further stated that early embryonic mortality can be defined as recorded mortality from zero to seven days of incubation, mid embryonic mortality are mortalities recorded from 8^{th} to 14^{th} day of incubation while the late embryonic mortality are mortality recorded from 15th to 17th days of incubation of Japanese quails eggs.

The effect of pre-incubational egg storage on embryonic viability depends on storage time environmental conditions, hen age and strain of the hen (Brake *et al*., 1997; Seker *et al*., 2005) and shell colour (Ayman, 2011). Some researchers reported that decrease in viability of the embryo may be caused by changes in the embryo or by changes in certain physical aspects of the egg namely albumen pH (Meijerhof, 1994). Arora and Kosin (1966) reported that the pre-incubational egg storage leads to morphological changes in the blastoderm and malformations in the embryo. Novo *et al*. (1997) reported that the embryo mortality is more pronounced in eggs of the older laying hens as compared to younger ones. Similarly, Sahan and Ipek (2000) reported that the parental age had influence on embryo mortality in early, middle and late periods and this rate was excessive in hens of 66 weeks of age. In the study by Elibol *et al.* (2002) in broiler chickens, it was noted that the embryo mortality in early period for the eggs obtained from hens of 31 and 52 weeks old was 6.1 and 6.9 percents respectively. The embryo mortality in the late period was between 3.8 and 6.6 %. Kucukyilmaz *et al*. (2001) grouped the hatching eggs of

Japanese quails as 9.00- 9.99, 10.00- 10.99, 11.00-11.99, 12.00- 12.99 and >13g; which were stored until the 9th day and they reported the embryo mortality as 38.7, 22.0, 21.0, 29.0 and 30.7 percent, respectively. Islam *et al.* (2014) reported dead in shell (embryonic mortality) for four different genotypes of quails (Japanese, White, Brown and Black) to be 27.03, 42.44, 43.18 and 64.07, respectively with a significantly higher value observed for Black genotype. Seker *et al.* (2005) suggested that the use of medium or heavy weight eggs for hatching may reduce early embryonic mortality rate.

2.5 Egg Quality Characteristics

Egg quality is a term which refers to general standards that define both internal and external quality such as egg weight, length, width, index, shell weight and thickness, albumen height and width, yolk height, index and haugh unit (Scott and Silversides, 2001). Egg quality has also been defined as the characteristics of an egg that affect its acceptability by consumers (Hrnčári *et al*., 2014). Egg quality traits determine the acceptability and market value of table egg (Oluyemi and Robert, 2000). Egg production enterprise is of great economic importance and its success depends on the total number of quality eggs produced. The physical characteristics of the egg play an important role in hatching (Narushin and Romanov, 2002). The most influential parameters for successful hatching in their order of importance are egg weight, shell parameters (especially thickness and porosity), shape index and consistency of its content (Tsarenko and Kurova, 1989). The consistency of the egg contents is estimated from the indices of albumen, yolk and haugh units. Furthermore, Nurushin and Romanov (2002) reported that any major abnormality in the physical characteristics of the egg can lead to a collapse in its main physiological function of providing the best condition of the developing embryo. In breeding, the quality of breeding eggs has an overall significance for an economic breeding. This is because

traits related to the external qualities of the eggs have effect on hatchability and development of chicks (Tserveni- Gousi, 1986; Sogut *et al*., 2001; Khushid *et al*., 2004).

Egg shell has been reported as one of the most important external characteristics of the egg and reports show that egg weight has a positive correlation with shell thickness and shell weight (Stadelman, 1986; Nurushin and Romanov, 2002). The percentage of shell is related to total egg weight, with larger eggs frequently having proportionately less shell percentages. Some egg quality traits include; egg weight, length, width, index, shell weight and thickness, albumen height and width, yolk height, index and haugh unit (Scott and Silversides, 2001). External and internal quality traits are significant in the poultry breeding for their influence on the yield features of the future generations, breeding performances, and quality and growth of the chicks (Altinel *et al*., 1996). Some egg quality traits such as weight of egg shell, albumen and the yolk form the egg such that their values affect the price of the product (egg) in the egg processing enterprise (Altinel *et al*., 1996). External factors such as cleanliness, freshness, weight and shell quality of the egg are important factors that affect acceptability of the egg by the consumers. In addition to the external factors, interior characteristics such as yolk index, albumen index, proportions of egg components and chemical composition are also important (Song, 2000). Means of some external and internal egg quality traits of Japanese quail as reported by some authors is shown in Table 2.3.

Table 2.3: Means of some external and internal egg quality traits as reported by some authors

EW (g)	EL(cm)	EWD (cm)	EI (%)	SW (g)	ST (m)	AW (g)	AL (cm)	AWD (cm)	YW (g)	YL (cm)	YWD (cm)	YI (%)	HU	Reference
11.28	3.34	2.5	74.90	0.23	0.84	6.75	4.63	3.58	3.69	0.93	_	36.70	85.7	Kul and seker, 2004
11.00	_	_	77.00	_	0.00	0.00	_	_	_	_	_	6.00	83.00	Đukić-Stojčić *et al.*, 2012
7.73	3.04	2.32	76.29		0.23		3.25	3.11	3.72	_	2.30	45.41	85.63	Daikwo *et al.*, 2013
11.48	3.35	2.57	76.70	1.02	0.25	_	5.01	3.83	6.75	1.12	2.59	43.22	87.28	Hrnčári *et al.*, 2014
13.06	3.45	2.69	78.18	1.16	0.23	6.75	4.98	3.83	4.28	1.21	2.64	43.22	87.56	Sezer, 2007
11.06	_	_	_	0.96	1.75	_	_	_	3.38	_	_	_	89.98	Sezer, 2007
11.66	_	_	_	_	_	6.73	_	_	_	_	_	46.47	_	Sezer, 2008

EW= Egg weight; EL= Egg length; EWD =Egg width; EI= Egg index; SW= Shell weight; ST= Shells thickness; AW= Albumen weight; AL= Albumen length; AWD= Albumen width; YW= Yolk weight; YL= Yolk length; YWD= Yolk width; YI= Yolk index; HU= Haugh unit

2.6 Selection Studies

Breeders aim at exploiting variations and genetic relationships by taking into account additive, non-additive and environmental factors. Variations and co-variation within and among populations provide the basis for development of selection strategies and selection for reproductive traits such as egg number and this can affect the performance of other reproductive traits and might directly affect commercial production (Buis *et al*., 1994)

Random bred control populations is one of the ways used by many investigators to provide a means for correcting for environmental trends or fluctuations that occur along genetic changes brought about by artificial selection (Hill, 1972). Theoretical aspects of the design and efficiency of such control populations have been discussed (Hill, 1972) and there were indications that several possible source of error exist in the use of such controls for estimating genetic changes. These include:

1. Random genetic drift in the control and selected populations because of restriction in the size of population used
2. Genetic trends in the control caused by natural selection
3. Differential response of control and selected lines to environmental changes (i.e. genotype and environmental interaction)
4. Error of estimation of genotypic means from phenotypic means in populations.

Hill (1972) stated that with more control populations, both genetic drift and natural selection can be expressed as a trend in the mean genotype of the control population over time. If the environment remains unchanged over a period of generations and no trend developed in the

control population, there is evidence, although not proven, that it has undergone no appreciable genetic change.

Many researches on selection to improve egg production for quails' flock focused mostly on egg number and egg weight laid through different periods of production. For instance, Aboul-Hassan, (2001) reported that the egg number produced from the females of selected line for high egg number was increased highly significantly (P□ 0.01) from 55.2 eggs in the first generation to 64.1 after three generations of selection. There was no significant increase or decrease in egg number among females of control line yet the females of the selected lines laid 10.9 percent more than those of the control females by the third generation of selection. As a result of selection for egg number, the other production traits correlated with the selected traits. Both egg number and daily egg mass (DEM) were increased from 454.8g, 8.2g/day in the first generation to 498.2g, 9.4g/day after three generations of selection with a significant increase of 9.54g, 1.63g/day per generation (Aboul-Hassan, 2001).

Charppa *et al*. (1998) on the other hand reported that females of selected line produced 5.7 eggs lower than control line while egg weight increased by 2.9 compared to the control line. Kosba *et al*. (2003) selected for high body weight at six weeks (BWT6) over 17 generations and reported that both selected and control line had same average egg weight in the base and first generation of selection. They reported further that the selected line laid significantly larger eggs than the control, such that in generation zero, egg weight was 9.9g among the control lines and increased to 11.7g and 10.3g after 17 generations of selection. There was also a significant increase for egg weight across generations of selection for high body weight in both selected and control lines which indicated that some environmental factors in addition to selection might have been

responsible for increasing egg weight and that selection for high body weight at six weeks resulted in cumulative selection response of 0.05g per generation for egg weight.

Aboul-Hassan (2001) while selecting for Age at Sexual Maturity and Body weight at sexual maturity observed a decrease from 54.2 days, 210.2g in the first generation to 49.8 days, 192.1g after three generation of selection.

Okenyi *et al*. (2013) reported that body weight at first egg significantly improved with generation. They reported 135.61, 150.2 and 154.64g in G_0, G_1 and G_2 generations, respectively. They reported that average body weight and egg number differed significantly. Egg weight was affected by body weight and the ratio of egg weight to body weight, but not by egg production. They reported that high and low weights significantly affected selection for improved egg size in Japanese quails (Noda *et al*., 2003). Abdel-Tawab (2006) also ran selection for increased egg weight over three generations and reported that the average egg weight produced among the first ten weeks of lay for females of selected line was increased from 10.78g in generation zero to 12.96g at the third generation, while the control line had no significant differences in egg weight with the first ten weeks of laying. They reported 11.28g at generation zero and 11.14g at the third generation for egg weight. They also reported that females of the selected line produced average of heavier (16.34%) egg weight than those produced from females of control line at the third generation of selection.

Kaye (2014) reported that egg quality characteristics improved in subsequent generations of selection except shell weight which was lowest in G_2 and shell thickness which was highest in G_0. Albumen weight however decreased in subsequent generations while albumen length was highest in G_0 but remained similar in G_1 and G_2 (Kaye, 2014). Okuda (2013) reported that egg

weight for G_0, G_1 and G_2 to be 36.55, 46.04 and 45.36, respectively and that egg number increased significantly from G_0 to G_1 but remained the same from G_1 to G_2.

2.7 Genetic Parameters.

Studies of genetic parameters are useful in designing efficient and successful breeding system (Aboul-Seoud, 2008; Daikwo, 2011). The accurate estimates of genetic parameters are therefore essential for constructing effective breeding program (Pirchner, 1983). Genetic parameters as reported by Falconer (1960) generally include heritability, repeatability, genetic and phenotypic correlation. Some of the estimated genetic parameters for various traits of domestic Japanese quails were reported by several authors (Alipanah *et al*., 2013; Daikwo *et al.*, 2013; Okenyi *et al*., 2013; Okuda, 2013; Kaye, 2014).

2.7.1Heritability

Heritability expresses the proportion of the total variance that is attributable to the average effects of genes which determines the degree of resemblance between relatives (Aboul-Seoud, 2008). Heritability of different traits is necessary to understand how each traits change over generation so as to predict the breeding value of individual for good and effective breeding plan (Okuda, 2013). Heritability of a trait according to McPhee (2001) and Kosum *et al*. (2004) could be low (0-0.19), moderate (0.2-0.39) and high (>0.40). Traits which have high heritability can be improved through selection while traits having low heritability imply that more emphasis should be placed on cross breeding rather than selection (McPhee, 2001; Kosum *et al*., 2004).

Heritability estimates are also useful in making practical decisions such as the type of mating that will allow for fastest improvement in selection experiment. Different estimates for heritability for certain traits in the same population may show a wide range of variation, some of

which may reflect real differences between populations, due to the condition under which they are studied, method of estimation, strain, sampling error due to small data set or sample size and measurement errors which can also result in fluctuations of estimates (Pirchner, 1983). A change in any of this condition can affect heritability estimate (Prado-Gonzalez *et al*., 2003). Reproductive characters are also known to have low heritability estimates while characters that are connected to production are adjudged to have high heritability estimates (Falconer, 1989)

Various techniques / methods are employed to estimate heritability of different quantitative traits. Pirchner (1983) reviewed most commonly used methods in avian species. He summarized them as;

1. Paternal half–sib correlation ($4\sigma^2S / \sigma^2P$).
2. Maternal half-sib correlation ($4 \sigma^2D / \sigma^2P$).
3. Full –sib correlation [$2(\sigma^2S + \sigma 2D) / \sigma^2P$].
4. Parental–offspring regression (σ_{OP} / σ^2P).
5. Realized heritability (R/S).

Where;σ^2S and σ2D =The estimated sire and dam components of variance, respectively,

σ^2P is the phenotypic variance, σ_{OP} is the parent-offspring covariance,

(R) is the response to selection and (S) is the selection differential.

The heritability estimates reported by some researchers in the literature for egg production and reproductive traits in quails are summarized in Tables 2.4-2.6

Table 2.4: Heritability estimates for egg production (Number) among different periods of laying in quail

Period of laying	Method of estimation			Reference
	h^2_S	h^2_D	h^2_{S+D}	
	0.05-0.81			El-fiky, (1991)
12-15 weeks	0.16-0.28			Yehia, (1992)
70 days	0.75			El-fiky and Aboul- Hassan,(1995)
			0.15	Shebl *et al*., (1996)
13 weeks	0.39			Minvielle *et al*.(1997)
	0.32-0.39			Minvielle, (1998)
70 days	0.18	0.54	0.36	El-fiky *et al*. (2000b)
70 days	0.13	0.20	0.15	Aboul- Hassan, (2001)
70 days	0.30-0.41			Tawefeuk, (2001)
	0.18-0.29	0.41- 0.57	0.27-0.46	Aboul-Seoud, (2008)
45 days				Bahi-Eldeen *et al*. (2008)
30 days	0.12-0.48			Okenyi *et al*. (2013)

Table 2.5: Heritability estimates for egg mass in quail

Method of estimation			Reference
h^2_S	h^2_D	h^2_{S+D}	
0.25			Abdel-Naby *et al*. (1993)
0.16-0.28			Baungartner, (1994)
0.35			El-fiky *et al*., (1994)
0.17-0.94	0.25-0.85	0.37-0.73	Aboul-Hassan, (2000)
0.14-0.24	0.43-0.44	0.25-0.33	El-fiky *et al*., (2000)
0.14-0.21			Aboul-Hassan, (2001)
0.01	0.16	0.13	Abdel-Mounsef, (2005)
0.12	0.50	0.31	Saatci *et al*., (2006)

Table 2.6: Heritability estimates from sire component for some internal egg qualities in Japanese quail

EW (g)	EL (cm)	EWD (cm)	EI (%)	SW (g)	ST (mm)	AW (g)	AL (cm)	AWD (cm)	YW (g)	YL (cm)	YWD (cm)	YI (%)	HU	Reference
0.50	-	-	-	0.60	-	-	-	-	-	-	-	-	-	Minvielle *et al*., 1997
0.40	-`	-	-	0.78	-	-	-	-	0.68	-	-	-	-	Minvielle, 1998
0.83	0.72	-	0.59	0.08	0.53	-	-	-	-	-	-	-	-	Sezer, 2008
0.01	-	-	-	-	-	-	-	-	-	-	-	0.01	-	Alipanah *et al*.,2013
0.11-	-	-	-	-	-	-	-	-	-	-	-	-	-	Okenyi *et al*., 2013
0.37	0.15	0.46	0.46	-	0.52	-	-	0.23	-	-	0.11	0.30	-	Daikwo *et al*., 2013
0.69	0.51	0.61	-	0.60	0.75	0.77	0.62	-	0.61	0.24	-	-	-	Kaye, 2014

EW= Egg weight; EL= Egg length; EWD =Egg width; EI= Egg index; SW= Shell weight; ST= Shells thickness; AW= Albumen weight; AL= Albumen length; AWD= Albumen width; YW= Yolk weight; YL= Yolk length; YWD= Yolk width; YI= Yolk index; HU= Haugh unit

2.7.2 Phenotypic Correlation

The phenotypic correlation between any two quantitative traits describes the extent to which individuals above average for one trait tend to be above, below or near the average for the other trait (Pirchner, 1983). It measures the linear association between traits; it predicts the deviation from the population mean in one trait of an individual as a function of its deviation from the population mean of other when both traits are measured in their respective phenotypic standard deviation units (Aboul- Seoud, 2008). Hazel (1943) reported that the knowledge of correlations among productive traits is essential for the construction of selection indices designed to maximize the rate of genetic improvement. The phenotypic correlation among various productive and reproductive traits in Japanese quail has been studied using different combinations of the traits. The reported estimates of phenotypic correlation among different traits of Japanese quail tend to be low or moderate in magnitude depending on the traits involved as cited in the literatures. Bobbo *et a*l. (2013) reported that there is a negative correlation (-0.64) between albumen length and albumen width, (-0.76) between albumen width and haugh unit in the eggs of Frizzle feathered hens. Sezer (2008) reported correlation between egg quality traits such that egg weight and yolk diameter had 0.61 correlation value. Daikwo *et al.* (2013)reported phenotypic values for different egg equality traits; egg weight and egg length (0.74), egg width (0.59), egg shape index (-0.10), shell thickness (0.02), albumen weight (0.29), yolk weight (0.43) and Yolk height (0.30); egg length and egg width (0.41), egg shape index (-0.49), shell thickness (-0.14), albumen weight (0.22), haugh unit (0.09) and yolk weight (0.31) respectively.

2.8 Selection Response

Selection significantly improves production traits in Japanese quail. Proper selection and breeding techniques coupled with improvements in the environmental and managerial conditions can help improving overall egg production (Chahil *et al*., 1975). Direct response to selection is the change of the line means that is produced by selection. In other words, it is the difference between the offspring phenotypic mean of selected trait and the corresponding value of their selected parents of the previous generation. Fayeye (2014) reported that the magnitude of response to selection for a trait depends on the magnitude of selection differential and that of the heritability for the trait. Selection experiments for improving a certain trait have frequently resulted in changing one or more of unselected traits (Falconer, 1989). The correlated response is the change in one trait as a result of selection for another trait; it can be estimated as a deviation from the control line among the regression coefficients of the correlated traits on generation number (Aboul-Seoud, 2008). These associated changes of unselected trait which occur during artificial selection for a particular trait are due to the genetic effects, environmental influences and a combination of both. The genetic effects are caused by pleiotropy and linkage. Pleiotropy is probably the main cause of permanent genetic associations, while these caused by linkage are transient (Lerner, 1958; Falconer, 1989). The response of correlated characters can be predicted if the genetic correlation and the heritability of the two characters are known. Conversely, if the correlated response is measured experimentally and the two heritabilities are known, the genetic correlation can be estimated (Falconer, 1989). Noda *et al*. (2003) reported that egg weight was affected by body weight and the ratio of egg weight to body weight, but not by egg production rate in the high and low weights on their study of the effective selection for improving the proportion of standard egg size in Japanese quail.

Abdel-Tawab (2006) selected for increased EW over three generations and reported that the average egg weight produced among the first ten weeks of laying (EW) produced from the females of selected line 33 was increased highly significantly ($P<0.01$) from 10.78 g at generation number zero to 12.96 g at the third generation, while there was no significant increase and/or decrease in the average egg weight among the first ten weeks of laying through the females of control line, where (EW) was 11.28 g at generation number zero and 11.14 g at the third generation. They reported also, that females of the selected line produced average egg weight heavier by 16.34 % than those produced from females of control line at the third generation of selection.

2.9 Generation Interval

In quantitative genetics, generation intervals are generally defined as the average age of parents at birth of their offspring. In this definition, generation interval is based on the contributions of parental age classes to newborn offspring; i.e., the average age of parents is calculated as the sum of ages at birth of offspring weighted by the contribution of each age class to newborn offspring (Bijma and Woolliams, 1999).Generation interval can also be defined on the basis of full or half sib family as the average age of the parents when the offspring were born (Fayeye, 2014)

In most cases, it is about 3 years in cattle, 12 months in pigs, sheep and goat and 6 months in chicken (Fayeye, 2014). However, if selective advantage model (e.g., breeding value) is partly inherited, selection in a subsequent generations may affect the genetic contribution of parental age classes to future generations. Thus there may be a difference between generation interval based on contributions to newborn offspring, and generation interval based on contributions to future generations. It has been suggested, therefore, to calculate generation intervals on the basis

of selected offspring only (Bichard *et al*., 1973). However, contributions of ancestors to future generations may still deviate from contributions to selected offspring.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Location

This study was conducted at the Poultry Unit of the Department of Animal Science Experimental Farm, Faculty of Agriculture, Ahmadu Bello University Zaria. Zaria is located in the Northern Guinea Savannah ecological zone of Nigeria. The area lies between Latitude $11^{o}11'$N and Longitude $7^{o}38'$E, at an attitude of 686 m above sea level. The climate is relatively dry, with a mean annual rainfall of 700-1400 mm, occurring between the month of April and September. The dry season begins around the middle of October, with dry cold weather that ends in February. This is followed by relative hot, dry weather from March to April, when the rain begins. The mean minimum and maximum daily temperature is about 14° and 24°C during the cool season and 19° and 36°C during the hot season. The relative humidity varies between 19% in the dry season and between 63% and 80% in the wet season as reported by (Akpa *et al*., 2002; Ovimaps, 2015).

3.2 Management of Experimental Birds

Birds were fed *ad-libitum* on diets of 24% CP, 2904 ME Kcal/Kg throughout the starter phase (from hatch to four weeks), after which they were fed a breeder diet containing 21% CP and 2800 ME Kcal/Kg (Kaye, 2014) from the 5th week of age to the end of the experiment in all the three generations. The feed composition was as shown below.

Table 3.1: Starter and Breeders diet used for the experiment

Ingredient	Starter diet (%)	Breeder diet (%)
Maize	53.00	55.25
Groundnut cake	25.00	24.00
Soya bean cake	18.20	12.00
Bone meal	3.00	3.00
Limestone	0.00	5.00
Salt	0.20	0.25
Methionine	0.25	0.20
Lysine	0.10	0.10
Vitamin premix	0.25	0.20
Total	100.00	100.00

3.2.1 Establishment of the foundation stock

The foundation stock refers to the reference population. A total number of 300 adult (5 weeks old) Japanese quails (*Coturnix coturnix japonica*) were obtained from the National Veterinary Research Institute (NVRI) Vom, Plateau State. The foundation stock comprised 200 females and 100 male adult quail. The experimental birds were placed in individual wooden wire mesh cages measuring 35 x 30cm.

3.2.2 Experimental stock

The birds in the foundation stock and subsequent generation were mated at seven (7) weeks of age. The mating ratio of 1:2 was used for improved fertility (Dogan *et al*., 2013) such that the male was mated to two females over three generations. This was achieved by allowing the female bird in the male cage for a day before changing it. The bodyweights of males were taken at the time of mating using electronic sensitive scale (g) (Electronic Pocket Scale, EHA251, 500G Capacity) and were grouped into four: W_1=70-90g, W_2 =91-110g, W_3 =111-130g and W_4= > 130g. Egg collection for hatching was done at 9^{th} weeks because higher rates of fertility and hatchability of Japanese quail eggs are achieved between 9 - 19 weeks of age (Daikwo, 2011). Eggs for incubation were collected twice a day for period of seven days and were labeled according to the sire and dam pen number. The eggs were weighed on a sensitive electronic scale (g)(Electronic Pocket Scale, EHA251, 500G Capacity). Eggs collected for hatching were sorted to remove damaged and deformed eggs. On the seventh day, whole labeled eggs were taken to Umar Hatchery at Galma along Jos Road, Zaria where they were fumigated and placed in an incubator (37.8°C; 65-75% humidity). On the 15th day of incubation, the eggs were candled. The number of infertile eggs were removed and recorded, while fertile eggs were transferred for the last 3 days of incubation to the hatcher (37.8°C; 90% humidity) in marked compartment

according to sire and dam number. On the 18th day (day of hatching), the percent hatched, percent dead in shell and percent fertile eggs were calculated using breakout analysis of un-hatched eggs. The chicks were individually weighed and identified by their dam and sire number. The chicks were wing tagged and brooded together. Percent fertility and hatchability and dead in shell were calculated using the following equations:

Fertility (%) = $\frac{Number\ of\ fertile\ eggs \times 100}{Total\ number\ of\ eggs\ incubated}$

Hatchability of incubated eggs (%) = $\frac{Number\ of\ chicks\ hatched \times 100}{Total\ number\ of\ eggs\ incubated}$

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

Early embryo mortality (%) = $\frac{Number\ of\ dead\ in\ shell\ from\ 8th\ to\ 15th\ day \times 100}{Total\ number\ of\ eggs\ incubated}$

Late embryo mortality (%) = $\frac{Number\ of\ dead\ in\ shell\ from\ 15th\ to\ 17th\ day \times 100}{Total\ number\ of\ eggs\ incubated}$

The total numbers of 450 chicks gotten from the foundation stock were divided into two groups: the selected line and the control line. 200 female quails and 100 male quails were used as selected line while 100 female and 50 males were used as unselected/control lines in the experiment. The control was maintained as non-selected population throughout the studies in G_1 and G_2 respectively.

3.3 Data Collection

Data on the following traits were collected:

1. Weight of egg (g): The egg was placed on an electronic sensitive scale calibrated in grams and the weight was recorded.

2. Egg number: Eggs laid by each female quail were collected daily and recorded.
3. Egg length (cm): The two long ends of the egg measured with vernier caliper
4. Egg width (cm): The two short ends of the egg measured with vernier caliper calibrated to the nearest 0.01mm.
5. Yolk weight (g): Was obtained by separating the yolk from the albumen and measured with weighing balance.
6. Yolk height (cm): The height of the yolk determined with vernier caliper calibrated to the nearest 0.01mm
7. Albumen weight (g): This is calculated as the difference between the yolk weight and egg weight.
8. Albumen length (cm): The two long ends of the albumen measured with vernier caliper.
9. Albumen width (cm): This was measured with vernier caliper across the yolk, calibrated to 0.01mm
10. Shell + membrane weight (g): Shell with membrane of each egg was collected, air dried for one hour and weighed with a digital weighing balance.
11. Shell + membrane thickness (mm): Micrometer screw gauge were used to determine the thickness of the dried shell + membrane calibrated to 0.01mm
12. Body weight at mating (g): An electronic sensitive scale calibrated in grams was used to weigh birds at mating.
13. Egg shape index was calculated using the method of Anderson *et al*. (2004), yolk index (%) was measured on the basis of the ratio of the yolk height (mm) to the yolk width (mm) by the method of Funk (1948).

Some expressions that were used to determine some egg quality traits were:

Egg shape index: this was calculated as the ratio of egg width to length (%) by the method of Anderson *et al*. (2004). Egg Shape index= $\frac{\text{Egg widtht x } 100}{Egg\ lenght}$

Yolk index (%) was measured on the basis of the ratio of the yolk height (mm) to the yolk width (mm) by the method of Funk (1948) using micrometer with 0.01mm accuracy.

Yolk index $= \frac{Yolk\ width \times 100}{\text{Yolk length}}$

Haugh unit was calculated according to the procedure of Haugh (1937).

Haugh unit = 100Log (H+7.57-1.7W0.37)

Where H = albumen height

W= egg weight

3.4 Data Analysis

Data collected were analyzed using the General Linear Model (GLM) procedure SAS 9.0 (SAS, 2002) and means with significant difference for generations 0, 1 and 2were compared using Duncan Multiple Range Test (Duncan, 1955). Phenotypic correlations between traits were evaluated using the correlation procedure of the same Sas software. Principal Component analysis was also generated using the same software.

Model equation for the trial was Nested design with the following model

$Y_{ijklm} = \mu + G_l + B_k + D_j + S_i + (GxB)_{ik}\ e_{ijklm}$

Where;

Y_{ijklm}= observation of the m^{th} offspring of the j^{th} dam mated to the i^{th} sire with the k^{th} body weight in the l^{th} generation

μ= the overall mean

G_l = effect of the l^{th} generation (G= 0, 1, 2)

B_k= effect of the k^{th} sire bodyweight on productive and reproductive traits

D_j = effect of the j^{th} dam mated to the i^{th} sire

S_i = effect of the i^{th} sire

$(GxB)_{ik}$= interaction effect between the l^{th} generation and the k^{th} sire bodyweight

e_{ijklm} = random error

3.4.1Phenotypic correlations (r_p) between traits

The phenotypic correlation between two characters is the correlation between their observed values that arise from correlation between genetic and environmental effects affecting the two characters. The phenotypic correlations between pairs of traits considered was determined using equation described by Becker (1984):

$$r_p = \frac{COV_w + COV_s}{\sqrt{\left(\sigma^2_{w(x)} + \sigma^2_{s(x)}\right)\left(\sigma^2_{w(y)} + \sigma^2_{s(y)}\right)}}$$

S.E. (r_p) = $\frac{COV_{xy}}{\sigma^2_x.\sigma^2_y}$

Where;

COVw = within sire covariance components

COV_S = sire covariance components

σ^2w(x); σ^2w(y) = within variance component for traits x and y.

σ^2s(x); σ^2s(y) = Sire variance component for traits x and y, respectively.

Heritability estimates in generation 1 and 2 was estimated using sire variance and calculated according to Becker, (1984).

Here individual families within lines were considered as groups, the group sum/trait was assigned to each family as individual observations. All variance components were generated and were used to evaluate heritability due to sire using this expression:

$$h^2_R = \frac{4\sigma^2 s}{\sigma^2 s + \sigma^2 w}$$

Where h^2_R = Realized heritability, using sire model, σ^2s= Sire variance component

σ^2w = error variance component

Standard error (S.E.) of the estimate given by Becker, (1984) was used and is as follows:

$$\text{S.E. } (h^2_R) = \sqrt[4]{\frac{2(1-t)^2[1+(k-1)t]^2}{k\,(k-1)(s-1)}}$$

Where; t = interclass correlation

$$= \frac{\sigma^2 s}{\sigma^2 w + \sigma^2 s}$$

K = number of offspring per sire

S = number of sires

3.3.4 Expected and realized response to selection.

The expected response to selection for egg production and quality traits was calculated using the formula;

Response (R) = $ih^2\sigma p$

Where: i = intensity of selection

h^2 = heritability

σp = phenotypic standard deviation of the trait under selection

Realized responses were estimated using the formula below:

For phenotypic response

$R_p = S_t - S_0$

Where R_p = phenotypic response

S_t = mean of the i^{th} generation of selection

S_0 = mean of the base generation

3.3.5 Selection differential

Selection differential SD was estimated using the formula bellow;

SD = $\overline{Ps} - \bar{P}$

Where SD = selection differential

$\overline{Ps}$ = mean of selected individuals for desired trait

$\overline{P}$ = mean of the population before selection

CHAPTER FOUR

4.0 RESULTS

4.1 Mean (±SE) and Coefficient of Variation for pooled egg production and egg quality characteristics of Japanese quail egg for base generation

Table 4.1 shows the summary statistics (mean and coefficient of variation) of egg production and quality traits in the base population. The coefficient of variation ranged from (2.66 – 39.25) and the most variable traits being yolk index (CV=39.25) followed by the yolk width (CV=38.95) while the least variable trait was shell thickness(CV=5.60).

4.2 Mean (±SE) and Coefficient of Variation for pooled egg production and egg quality cha racteristics of Japanese quail egg for Generation one

Mean ±SE and coefficient of variation of pooled egg production and quality traits in Generation one is shown on Table 4.2. The coefficient of variation ranged from (2.13 – 46.90). The most variable trait in Generation one was yolk index (CV=46.90) followed by the yolk width (CV=46.50) while the least variable trait was shell thickness (CV=2.13).

4.3 Mean (±SE) and Coefficient of Variation for pooled egg production and egg quality cha racteristics of Japanese quail egg for Generation two

Table 4.3 shows the summary statistics (mean and coefficient of variation) of pooled egg production and quality traits in generation two. The coefficient of variation ranged from (7.20 – 64.36).The most variable trait in Generation two was shell weight (CV=64.36) followed by the yolk index (CV=31.07) while the least variable trait was shell thickness (CV=7.20).

Table 4.1: Descriptive Statistics for egg production and egg quality characteristics of Japanese quail egg for generation zero (G_0)

Characteristics	Mean ± SE	CV
Egg number	21.24±0.28	17.83
Egg weight (g)	10.03±0.09	12.84
Egg length(cm)	3.14±0.03	10.81
Egg width(cm)	2.44±0.02	10.45
Egg shape index (%)	77.71±0.63	10.34
Shell thickness(mm)	0.34±0.00	5.60
Shell weight (g)	1.44±0.01	12.48
Albumen weight (g)	4.97±0.05	13.95
Albumen length(mm)	4.10±0.31	10.23
Albumen width (cm)	2.73±0.03	14.48
Yolk weight (g)	3.17±0.03	14.32
Yolk length(cm)	2.35±0.02	8.76
Yolk width(cm)	1.33±0.04	38.95
Haugh unit (%)	83.87±0.16	2.66
Yolk index (%)	56.60±1.64	39.25

SE= Standard error, CV= Coefficient of Variation

Table 4.2: Descriptive Statistics for pooled egg production and egg quality characteristics of Japanese quail egg for generation one (G_1)

Characteristics	Mean± SE	CV
Egg number	23.61±0.18	9.58
Egg weight (g)	9.49±1.10	13.17
Egg length(mm)	3.04±0.27	8.00
Egg width(mm)	2.38±0.20	8.31
Egg index (%)	78.29±0.62	9.60
Shell thickness(mm)	0.34±0.02	4.38
Shell weight (g)	1.42±0.13	8.07
Albumen weight (g)	4.74±0.68	13.74
Albumen length(mm)	3.82±0.54	14.16
Albumen width (mm)	2.70±0.39	13.96
Yolk weight (g)	3.04±0.45	14.93
Yolk length(mm)	2.40±1.41	13.42
Yolk width(mm	1.03±0.47	46.50
Haugh unit (%)	83.10±1.93	2.13
Yolk index (%)	42.92±1. 61	46.90

SE= Standard error, CV= Coefficient of Variation

Table 4.3: Descriptive Statistics for pooled egg production and egg quality characteristics of Japanese quail egg for Generation two (G_2)

Characteristics	Mean± SE	CV
Egg number	25.17±0.15	7.81
Egg weight (g)	9.38±1.12	11.06
Egg length(mm)	3.00±0.25	7.20
Egg width(mm)	2.41±0.20	7.45
Egg shape index (%)	80.33±0.65	7.74
Shell thickness(mm)	0.63±0.28	39.28
Shell weight (g)	0.70±0.62	64.36
Albumen weight (g)	4.61±0.90	19.80
Albumen length(mm)	3.74±0.52	13.360
Albumen width (mm)	2.68±0.35	13.04
Yolk weight (g)	2.93±0.51	17.43
Yolk length(mm)	2.29±0.23	10.79
Yolk width(mm)	1.50±0.57	30.78
Haugh unit (%)	82.58±5.82	7.97
Yolk index (%)	65.50±0.43	38.41

SE= Standard error, CV= Coefficient of Variation

4.4 Least square means for egg characteristics of Japanese quail at different generations

The least square means (± standard error) for egg traits of Japanese quail over three generations of selection (Table 4.4). There were significant differences ($P<0.05$) among the means of egg number, egg weight, egg length, yolk index, haugh unit, shell weight and shell thickness as the generation of selection increases. Egg number (21.24, 23.16 and 25.17) increased progressively as the generation of selection increased from G_0, G_1 to G_2, while yolk width (1.33, 1.13 and 1.66), yolk index (56.92, 50.14 and 73.33) and shell thickness (0.34, 0.34 and 0.70) were constant in base population and generation one but increased significantly in generation two (G_2). Egg weight (10.07, 9.25 and 9.22), egg length (3.14, 3.02 and 2.97), and shell weight (1.45, 1.41 and 0.81) decreased progressively as generation of selection increased from G_0, G_1 and G_2, respectively.

4.5 Hatching characteristics of Japanese quail eggs over three generations of selection

The mean (± standard error) of the hatching characteristics of Japanese quail eggs over three generations of selection (Table 4.5). The Coefficient of Variation ranges from 32.80 to 65.27 in G_0, 33.73 to 65.98 in G_1 and 40.79 to 60.42 in G_2, respectively.

Table 4.4: Least square means(± SE) for egg characteristics of Japanese quail at different generations

Traits	Generation		
	G_0	G_1	G_2
Egg number	21.24±0.28^c	23.61±0.18^b	25.17±0.15^a
Egg weight(g)	10.03±0.09^a	9.25±0.10^b	9.22±0.08^b
Egg length(cm)	3.14±0.03^a	3.02±0.02^b	2.97±0.02^c
Egg width(cm)	2.43±0.02	2.40±0.02	2.37±0.01
Egg shape index	77.38±0.63	79.47±0.62	79.79±0.48
Shell weight (g)	1.45±0.00^a	1.41±0.00^b	0.81±0.02^c
Shell thickness(mm)	0.34±0.01^b	0.34±0.01^b	0.70±0.02^a
Albumen weight (g)	4.96±0.05	4.61±0.05	4.50±0.07
Albumen length(cm)	4.10±0.31	3.73±0.04	3.65±0.04
Albumen width (cm)	2.73±0.03	2.69±0.03	2.67±0.03
Yolk weight (g)	3.17±0.03	2.97±0.04	2.88±0.04
Yolk length(cm)	2.35±0.02	2.29±0.03	2.28±0.02
Yolk width(cm)	1.33±0.04^c	1.13±0.04^b	1.66±0.04^a
Haugh unit (%)	83.87±0.16	83.10±0.14	82.58±0.51
Yolk index (%)	56.59±1.64^b	49.34±1.92^c	72.81±1.76^a

abc= Means with different superscript in the same rows are statistically different; G_0= Base population; G_1= Generation 1, G_2=Generation 2; SE= Standard error

Table 4.5: Fertility traits of Japanese quail eggs over three generations of selection

Traits	Mean ±SE G_0	CV G_0	Mean ±SE G_1	CV G_1	Mean ±SE G_2	CV G_2
Fertility (%)	79.51±1.08	32.80	78.76±1.03	33.73	78.53±1.25	40.79
Hatchability of fertile eggs (%)	69.64±1.87	43.64	69.64±1.16	43.11	74.93±1.57	53.97
Hatchability of total eggs set(%)	52.51±1.08	54.70	53.12±1.05	50.70	64.00±1.51	60.42
Early embryo mortality of fertile eggs (%)	13.46±0.87	65.27	12.86±0.83	65.98	5.91±0.81	54.48
Late embryo mortality of fertile eggs (%)	16.63±0.95	45.86	17.44±1.01	48.66	11.40±1.15	46.50

G_0= Base population; G_1= Generation 1, G_2=Generation 2; SE= Standard error, CV= Coefficient of Variation

4.6 Effect of sire bodyweight at mating and generations of selection on reproduction characteristics of Japanese quail eggs over three generations

Table 4.6 shows the effect of sire bodyweight at mating and generation of selection on reproductive characteristics of Japanese quail eggs over three generations. Sire bodyweight at mating did not significantly affect all the measured reproductive traits ($p>0.05$) but there was a significant effect of generation of selection ($p<0.05$) on early embryonic mortality (Table 4.6) and late embryonic mortality (Table 4.6), respectively. There was a significant effect ($p<0.05$) of interaction between sire bodyweight at mating and generation of selection on all the traits measured. The highest recorded percent fertility was in G_0xW_1 (87.49) and G_1xW_1 (87.67) and G_1xW_1 (85.63) while the least was in G_1xW_4 (65.74). The highest recorded percent hatchability of incubated eggs was G_2xW_3 (65.24) and G_2xW_2 (63.81). The highest recorded hatchability of fertile egg was in G_2xW_3 (76.29), G_1xW_3 (74.54) and G_0xW_3 (74.86) while the least was in G_0 xW_1 (65.02), G_0xW_4 (66.53), G_1xW_1 (65.00), G_1x W_4 (65.76) and G_2xW_1 (66.67). The highest recorded values for early embryonic mortality was in G_0 xW_1 (16.60), G_2 x W_1 (16.36) while the least was in G_2 xW_2 (6.53), G_2xW_3 (5.45) andG_2xW_4 (7.14). The highest recorded value for late embryonic mortality was in G_2xW_1 (26.19) and the least for the same trait was in G_2xW_3(10.61), respectively.

Table 4.6: Effect of Sire body weight at mating and generations of selection on reproduction characteristics of Japanese quail eggs over three generations

Factor	Weight group(g)	F (%)	H I E (%)	HFE (%)	EE M (%)	LEM (%)
Body weight		Ns	Ns	ns	ns	ns
	70-90 (W_1)	86.40±1.81	55.63±2.45	65.10±2.57	16.15±1.89	18.54±1.98
	91-110(W_2)	77.48±1.57	56.74±1.73	71.95±1.78	9.47±1.06	15.48±1.46
	111-130(W_3)	78.58±0.83	57.30±0.95	72.82±1.01	10.09±0.63	14.94±0.79
	>130(W_4)	77.52±1.69	54.00±1.78	67.76±1.90	12.27±1.35	14.68±1.41
Generation		Ns	ns	ns	*	*
	G_0	79.17±1.02	52.52±1.08	69.64±1.19	$13.46±0.87^{a}$	$16.63±0.95^{ab}$
	G_1	78.76±1.03	53.12±1.05	69.48±1.16	$12.86±0.82^{a}$	$17.44±1.01^{a}$
	G_2	78.53±1.25	64.12±1.51	74.93±1.58	$5.91±0.82^{b}$	$11.40±1.15^{b}$
Interaction		*	*	*	*	*
	G_0 XW_1	87.49^{a}	55.40^{b}	65.02^{c}	16.60^{a}	18.03^{b}
	G_0 XW_2	76.42^{b}	52.45^{b}	71.51^{ab}	11.22^{b}	16.36^{cd}
	G_0XW_3	78.30^{b}	52.11^{b}	70.86^{ab}	13.54^{ab}	16.81^{cd}
	G_0XW_4	79.56^{b}	52.01^{b}	66.53^{c}	13.60^{ab}	15.41^{d}
	G_1XW_1	87.67^{a}	56.28^{b}	65.00^{c}	16.36^{a}	18.29^{b}
	G_1XW_2	75.78^{b}	53.04^{b}	72.26^{b}	11.03^{b}	17.20^{c}
	G_1 X W_3	78.32^{b}	52.67^{b}	70.54^{ab}	12.35^{b}	17.91^{c}
	G_1X W_4	77.74^{b}	52.71^{b}	65.76^{c}	14.26^{ab}	15.58^{d}
	G_2XW_1	65.63^{c}	52.08^{b}	66.67^{c}	10.42^{bc}	26.19^{a}
	G_2XW_2	79.90^{b}	63.81^{a}	72.08^{b}	6.53^{c}	12.95^{e}
	G_2 X W_3	79.04^{b}	65.24^{a}	76.29^{a}	5.45^{c}	10.61^{f}
	G_2X W_4	74.17^{ab}	59.00^{ab}	72.74^{b}	7.14^{c}	11.83^{ef}
	SEM	2.56	4.21	1.68	1.86	0.86

abc= Means with different superscript in the same column; are statistically different, G_0= Base population, G_1= Generation 1, G_2=Generation, F= Fertility, HIE= Hatchability of incubated eggs, HFE= Hatchability of fertile eggs, EEM=Early embryonic Mortality, LEM= Late period embryonic mortality; SEM= standard error of mean, ns= not significant.

4.7 Phenotypic correlations of external egg quality traits for Japanese quails over three generations

The phenotypic correlation between external egg qualities in G_0, G_1 and G_2 is shown on Table 4.7. The phenotypic correlation shows that egg weight was significantly correlated ($p<0.05$) with egg length, shell weight, and shell thickness, egg length in generation three, egg width ($p<0.05$; r=0.34-0.37) in generation one and two, shell weight ($p<0.05$; r=0.27-0.36) in G_O, G_1 and G_2 and shell thickness ($p<0.05$; r=0.37-0.39) in G_O, G_1 and G_2. Egg length was significantly negatively correlated ($p<0.05$; r= -0.39- -0.49) with egg width in G_0 and G_1, egg shape index ($p<0.05$; r= -0.54- -0.59) in G_0, G_1 and G_2, shell weight ($p<0.05$; r=0.76-0.87) in G_0 andG_1, shell thickness ($p<0.05$; r= -0.41 -0.50) in G_O and G_2, respectively. Egg width was significantly correlated with egg shape index ($p<0.05$-0.01; r=0.46-0.67) in G_O, G_1 and G_2, shell weight ($p<0.01$; r=0.79-0.86) in G_O, G_1 and perfectly correlated with shell thickness ($p<0.001$; r=1.00) in all the three generations of selection. Egg shape index was significantly correlated with shell thickness ($p<0.05$-0.01; r=0.46-0.67) in all the three generations of selection while shell weight was significantly correlated with shell thickness ($p<0.01$; r=0.80-0.86) in G_O and G_1.There were consistent significant ($p <0.05$) positive relationships (egg weight with shell weight and shell thickness), (egg width with egg shape index and shell weight) and (egg shape index with shell thickness) while consistent negative relationships (egg length with egg shape index) as generation of selection for egg number increased.

Table 4.7: Phenotypic correlations among External egg quality traits in Japanese quails over three generations

Generation		EW	EL	EWD	EI	SW	ST
G_O	EW	-					
	EL	0.22	-				
	EWD	0.37*	0.49*	-			
	EI	0.14	-0.54*	0.46*	-		
	SW	0.34*	0.87**	0.86**	-0.05	-	
	ST	0.41*	0.50*	1.00***	0.46*	0.86**	-
G_1	EW	-					
	EL	0.23	-				
	EWD	0.18	0.20	-			
	EI	-0.03	-0.59**	0.67**	-		
	SW	0.27*	0.76*	0.79**	0.08	-	
	ST	0.24	0.21	1.00***	0.66**	0.80**	-
G_2	EW	-					
	EL	0.42*	-				
	EWD	0.34*	0.39*	-			
	EI	-0.05	-0.54*	0.56**	-		
	SW	0.36*	0.22	0.10	-0.24	-	
	ST	0.39*	0.41*	1.00***	0.54*	0.12	-

Key:*** = correlation is significant at 0.001 level** = correlation is significant at 0.01 level, * = correlation is significant at 0.05 level;G0= Base population; G1= Generation 1, G2=Generation 2; EW= Egg weight; EL= Egg length; EWD= egg width; EI= Egg Shape Index; SW= Shell Weight; ST= Shell Thickness

4.8 Phenotypic correlations of Internal egg quality traits for Japanese quail by Generation

Table 4.8 shows the phenotypic correlations between internal egg quality traits for Japanese quail in three generations of selection. The phenotypic correlation between internal egg qualities for the three generations of selection ranges from low, moderate and high and differed in magnitude and direction (-0.46 - 0.97).Albumen weight significantly correlated with albumen length ($p<0.05$: r= 0.31-34) in G_0 and G_2, yolk weight ($p<0.05$-0.01 r= 0.45-0.73) in G_0 and G_2. Albumen length correlated with albumen width ($p<0.05$: r= 0.25-0.40) in G_0, G_1 and $G_2$and yolk index ($p<0.05$: r= -0.26- -0.46) in G_0 and G_2 and yolk width ($p<0.05$: r= -0.42) in G_1. Albumen width correlated with haugh unit ($p<0.05$: r= -0.25- -0.34) in G_1 and G_2, yolk weight ($p<0.05$: r= 0.34) in G_1 and yolk length ($p<0.05$: r= 0.26) in G_2. Haugh unit correlated with yolk index ($p<0.05$: r= -0.27) G_2. Yolk weight correlated with yolk length ($p<0.05$: r= 0.31) and yolk index ($p<0.05$: r= -0.26) in G_2.Yolk length correlated with only yolk index ($p<0.05$: r= -0.28) in G_2, while yolk width correlated with yolk index ($p<0.05$: r= 0.94-0. 97) in G_0, G_1 and G_2.It was observed that the relationship between internal egg qualities was not consistent as the generation of selection for egg number increases except the relationship between albumen length and albumen width and yolk width and yolk index that maintained a significantly positive relationship across all the generations of selection.

Table 4.8: Phenotypic correlations among Internal egg quality traits in Japanese quail over three Generations

	Internal traits	AlbW	AlbL	AlbWD	HU	YW	YL	YWD	YI
G_0	AlbW	-							
	AlbL	0.31*	-						
	AlbWD	0.10	0.25*	-					
	HU	0.07	0.19	-0.20	-				
	YW	0.45*	0.23	0.21	-0.10	-			
	YL	0.01	0.07	0.14	-0.08	0.17	-		
	YWD	-0.13	-0.24	0.01	-0.19	-0.09	0.02	-	
	YI	-0.14	-0.26*	-0.04	-0.14	-0.16	-0.21	0.97**	-
G_1	AlbW	-							
	AlbL	0.17	-						
	AlbWD	0.34*	0.40*	-					
	HU	-0.23	0.03	-0.25*	-				
	YW	0.73**	0.18	0.34*	-0.09	-			
	YL	-0.23	0.03	0.04	-0.07	0.03	-		
	YWD	-0.16	-0.21	0.08	-0.11	-0.09	-0.01	-	
	YI	-0.16	-0.23	0.04	-0.13	-0.11	-0.23	0.97**	-
G_2	AlbW	-							
	AlbL	0.39*	-						
	AlbWD	0.18	0.36*	-					
	HU	0.13	-0.24	-0.34*	-				
	YW	0.21	0.19	0.21	-0.07	-			
	YL	0.02	0.13	0.26*	-0.23	0.31*	-		
	YWD	-0.21	-0.42*	-0.08	-0.27*	-0.15	0.04	-	
	YI	-0.21	-0.46*	-0.17	-0.16	-0.26*	-0.28*	0.94**	-

Key:** = correlation is significant at 0.01 level, * = correlation is significant at 0.05 level; G_0= Base population; G_1= Generation 1, G_2=Generation 2; AlbW= Albumen weight; AlbL= Albumen Length; AlbWD= albumen width; HU= haugh Unit; YW= Yolk Weight; YL= Yolk Length; YWD= Yolk Width; YI= Yolk Index

4.9 Phenotypic correlations between External and Internal egg quality traits of Japanese quails

The phenotypic correlations between external and internal egg quality traits for Japanese quails over three generations are shown in Table 4.9. Egg weight significantly correlated with albumen weight ($p<0.05$-0.01: r= 0.43-0.77) in G_0, G_1 and G_2, haugh unit ($p<0.05$:r= -0.34 - -0.49) in G_0, G_1 and G_2, Albumen width ($p<0.05$:r= 0.27-0.36) in G_1 and G_2, yolk weight ($p<0.05$-0.01: r= 0.49-1.00) in G_0, G_1 and G_2, yolk width ($p<0.05$:r=0.30) and yolk index ($p<0.05$: r=-0.36) in G_2. Egg length correlated with haugh unit ($p<0.05$-0.01: r = 0.26-0.85) in G_0, G_1 and G_2, yolk weight ($p<0.05$: r= 0.25) in G_1, albumen length ($p<0.05$: r=0.33) in G_2, yolk width and yolk index ($p<0.05$: r=-0.30) in G_2. Egg width only correlated with albumen width, haugh unit and yolk weight ($p<0.05$: r= 0.27, 0.28 and 0.44), respectively, in G_0. Egg shape index correlated with haugh unit ($p<0.0.05$-0.01: r= -0.51-0.59) in G_0 and G_1, yolk width ($p<0.05$: r =0.27) and yolk index ($p<0.05$: r= 0.27-0.29) in G_1 and G_2. Shell weight correlated with haugh unit ($p<0.05$-0.01: r =0.53-0.66) in G_0 and G_1, yolk weight ($p<0.05$: r=0.29-0.40) in G_0 and G_2, yolk width and yolk index ($p<0.01$: r= -0.87 and -0.90) respectively, in G_2. Shell thickness correlated with albumen, haugh unit ($p<0.05$: r= 0.26) and yolk weight ($p<0.05$: r =0.48) in G_1. It was observed that as generation of selection for egg production increased, relationship between egg weight and albumen weight maintained a significant positive relationship also, a significant (but decreasing) positive relationship between egg length and haugh unit was maintained while the relationships between other external and internal egg quality traits were not consistent with increased generation of selection.

Table 4.9: Phenotypic correlations between External and Internal egg quality traits for Japanese quails

	Internal traits	External traits					
		EW	**EL**	**EWD**	**EI**	**SW**	**ST**
G_0	Alb W	0.43*	0.14	0.22	0.05	0.21	0.23
	Alb L	0.04	0.06	0.27*	0.20	0.19	0.26*
	Alb WD	0.11	0.01	-0.08	-0.10	-0.04	-0.07
	HU	-0.34*	0.85**	0.28*	-0.59**	0.66**	0.26*
	YW	1.00	0.25*	0.44*	0.18	0.40*	0.48*
	YL	0.12	0.12	-0.12	-0.22	-0.11	0.00
	YWD	0.06	-0.01	-0.08	-0.06	-0.08	-0.05
	YI	0.03	-0.03	-0.05	-0.02	-0.05	-0.04
G_1	Alb W	0.77**	0.26*	0.12	-0.11	0.24	0.16
	Alb L	0.17	0.05	0.10	0.03	0.10	0.11
	Alb WDT	0.36*	-0.05	0.03	0.06	-0.12	0.05
	HU	-0.39*	0.76**	0.08	-0.51*	0.53*	0.06
	YW	0.94**	0.22	0.15	-0.05	0.24	0.20
	YL	0.03	0.09	-0.01	-0.08	0.05	-0.01
	YWDT	-0.18	-0.15	0.12	0.27*	0.04	0.18
	YI	-0.18	-0.18	0.18	0.29*	0.01	0.17
G_2	Alb W	0.49*	0.22	0.11	-0.10	0.16	0.13
	Alb L	0.37*	0.33*	0.14	-0.16	0.43*	0.15
	Alb WDT	0.27*	0.22	0.05	-0.15	0.29*	0.06
	HU	0.03	0.26*	0.03	-0.22	-0.08	0.03
	YW	0.49*	0.15	0.16	0.03	0.29*	0.18
	YL	0.21	0.05	-0.06	-0.07	0.15	-0.04
	YWD	-0.30*	-0.30*	0.03	0.27*	-0.87**	0.00
	YI	-0.36*	-0.30*	0.03	0.27*	-0.90**	0.01

Key:** = correlation is significant at 0.01 level, * = correlation is significant at 0.05 level;G_0= Base population; G_1= Generation 1, G_2=Generation 2; EW= Egg weight; EL= Egg length; EWD= egg width; EI= Egg Shape Index; SW= Shell Weight; ST= Shell Thickness; AlbW= Albumen weight; AlbL= Albumen Length; AlbWD= albumen width; HU= haugh Unit; YW= Yolk Weight; YL= Yolk Length; YWD= Yolk Width; YI= Yolk Index

4.10 Principal component analyses for egg production and quality traits

Table 4.10 shows the principal component analyses for egg production and quality traits. Five principal components were extracted; Principal component (PC) 1, 2 and 3 accounted for 25.109, 16.606 and 10.510 percent variance, respectively, which amounted to the cumulative percentage variations of 52.23 (Table 4.10). PC 1 has high loadings for, egg number, shell thickness, shell weight, yolk width and yolk index. PC 2 has high loading for egg weight, egg width and yolk weight. PC3 has high loading for egg shape index, albumen width and haugh unit. It was deduced that PC 1 could serve as index for determining egg production and quality characteristics, PC2 and PC3 as index for egg weight and freshness characteristics.

4.11 Realized (h^2_R) Heritability estimates of egg traits in Japanese quail in Generation one and two

The heritability estimates with standard error of heritability of egg production and quality traits of Japanese quails in Generation one and two (Table 4.11). The heritability estimates of egg production and egg quality traits in Generations one and ranges from low to high. Egg number, egg length, shell thickness, albumen width and haugh unit had a low heritability estimates (h^2_R = 0.01-0.16). Egg weight, egg width, egg shape index and albumen length had moderate heritability estimates (h^2_R= 0.21- 0.27) while shell weight, albumen weight, yolk weight, yolk length, yolk width and yolk index had high heritability estimates (h^2_R= 0.45-0.77) in Generation one. In generation two, egg number, albumen width and haugh unit had low heritability estimates (h^2_R=0.01-10), egg width, shell thickness, albumen weight and yolk width had moderate heritability estimates (h^2_R=0.23-0.31), while egg weight, egg length, egg shape index, shell weight, albumen length, yolk weight, yolk length and yolk index had high heritability estimates (h^2_R= 0.42-0.67). There was an increase in heritability from low to moderate (shell thickness;

0.16-0.28), moderate to high (egg weight; 0.27-0.45, egg shape index; 0.21-0.67, albumen length, 0.23-0.47) from generation one to two. Decreasing trend of heritability estimate from high to low (albumen weight; 0.51-0.24, yolk width; 0.77-0.23) was also observed as generation of selection increased from G_1 to G_2.

Table 4.10: Principal component analyses for egg production and quality traits

Traits	Components			Communalities
	1	2	3	
Egg number.	-0.585	-0.117	0.049	0.431
Egg weight	0.574	0.671	-0.117	0.801
Egg Length	0.533	0.282	-0.099	0.865
Egg Width	0.200	0.693	0.397	0.724
Egg Shape index	-0.131	0.306	0.787	0.862
Shell Thickness	-0.768	0.363	-0.244	0.795
Shell Weight	0.872	-0.163	-0.086	0.800
Albumen Weight	0.199	0.130	0.062	0.201
Albumen Length	0.148	0.096	0.234	0.500
Albumen Width	0.084	0.287	-0.521	0.391
Yolk Weight	0.545	0.618	-0.160	0.722
Yolk Length	0.139	0.039	-0.078	0.827
Yolk Width	-0.830	0.408	-0.030	0.865
Haugh unit	0.258	-0.177	0.612	0.717
Yolk index	-0.846	0.357	0.033	0.856
Eigen value	4.219	2.094	1.607	
Percent variance (%)	25.11	16.61	10.51	
Cumulative percent variance	25.11	41.72	52.23	52.23

Table 4. 11: Realized Heritability estimates of egg traits in Japanese quail in generation one and two

Trait	$h^2_R \pm SE_{h2R}(G_1)$	$h^2_R \pm SE_{h2R}(G_2)$
Egg number	0.11±0.07	0.09±0.01
Egg weight(g)	0.27±0.13	0.45±0.01
Egg length(cm)	0.01±0.00	0.43±0.02
Egg width(cm)	0.25±0.13	0.31±0.02
Egg shape index	0.21±0.17	0.67±0.11
Shell thickness(mm)	0.16±0.10	0.28±0.11
Shell weight (g)	0.76±0.53	0.42±0.26
Albumen weight (g)	0.51±0.17	0.24±0.15
Albumen length(cm)	0.23±0.18	0.47±0.29
Albumen width (cm)	0.05±0.01	0.06±0.28
Yolk weight (g)	0.59±0.07	0.45±0.01
Yolk length(cm)	0.50±0.20	0.47±0.19
Yolk width(cm)	0.77±0.03	0.23±0.04
Haugh unit (%)	0.02±0.03	0.10±0.18
Yolk index (%)	0.45±0.26	0.43±0.32

h^2_R= heritability; SE_{h2R}= standard error of heritability

4.12 Actual and expected Selection Differential of Egg Production and Egg Quality Traits in Generation one

The selection differential of egg production and egg quality traits as a result of selection for egg number in Generation one is presented on Table 4.12. Positive values were obtained for egg number (2.27), haugh unit (1.02) and yolk index (0.44) while negative values were obtained for egg weight (-0.29), shell weight (-0.02), albumen weight (-0.12), albumen length (-0.06), albumen width (-0.02), yolk weight (-0.09) and yolk length (-0.17) while, egg length, egg width, shell thickness and yolk width had 0.00. The actual selection differential was greater than the expected selection differential for albumen length and width.

4.13 Selection Differential of egg production and egg quality traits in generation two

Table 4.14 shows the selection differential of egg production and egg quality traits as a result of selection for egg number in generation two. Positive values were obtained for egg number (1.32), egg weight (0.05), egg width (0.02), egg shape index (0.33), albumen width (0.04), yolk width (0.08) and yolk index (2.89) while negative values were obtained for egg length (-0.04),albumen weight (-0.05), albumen length (-0.08), yolk weight (-0.07),yolk length (-0.01) and haugh unit (-0.21) while, shell weight and shell thickness had 0.00

Table 4.12: Actual and expected Selection Differential of Egg Production and Egg Quality Traits in Generation one

Traits	Mean of the selected parents	Mean of population before selection	Actual Selection Differential	Expected Selection Differential
Egg number	23.61	21.44	2.17	0.90
Egg weight(g)	9.22	9.51	-0.29	0.45
Egg length(cm)	3.02	3.02	0.00	-0.10
Egg width(cm)	2.38	2.38	0.00	-0.05
Egg shape index	79.04	78.62	0.42	0.58
Shell weight (g)	1.38	1.40	-0.02	-0.01
Shell thickness(mm)	0.38	0.34	0.00	-0.05
Albumen weight (g)	4.60	4.72	-0.12	0.07
Albumen length(cm)	3.75	3.81	-0.06	-0.28
Albumen width (cm)	2.67	2.69	-0.02	-0.04
Yolk weight (g)	2.97	3.06	-0.09	0.21
Yolk length(cm)	2.31	2.48	-0.17	0.04
Yolk width(cm)	1.13	1.13	0.00	-0.24
Haugh unit (%)	83.09	82.07	1.02	-0.74
Yolk index (%)	49.83	49.39.	0.44	-9.33

Table 4. 13: Selection Differential of egg production and egg quality traits in generation two

Traits	Mean of the selected parents	Mean of population before selection	Actual Selection differential	Expected selection Differential
Egg number	25.16	23.84	1.32	1.54
Egg weight(g)	9.27	9.22	0.05	0.05
Egg length(cm)	2.98	3.02	-0.04	-0.04
Egg width (cm)	2.40	2.38	0.02	0.02
Egg shape index	80.79	80.46	0.33	1.75
Shell weight (g)	0.58	1.39	0.00	0.00
Shell thickness(mm)	0.34	0.34	0.00	-0.81
Albumen weight (g)	4.53	4.58	-0.05	-0.06
Albumen length(cm)	3.67	3.75	-0.08	-0.08
Albumen width (cm)	2.70	2.67	0.04	0.04
Yolk weight (g)	2.90	2.97	-0.07	-0.07
Yolk length(cm)	2.30	2.31	-0.01	-0.01
Yolk width(cm)	1.62	1.54	0.08	0.48
Haugh unit (%)	82.78	82.57	-0.21	-0.32
Yolk index (%)	70.93	68.04	2.89	21.11

4.14 Realized and Expected Selection Response for egg production and egg quality in Japanese quails

The realized and the expected selection response for egg number and some correlated response for egg quality traits in Japanese quails is shown on Table 4.12. Egg number increased progressively from 21.24 in the base population to 25.17 in the second generation of selection. Other correlated responses were observed as a result of selection for egg number. There were no (0.00) responses in egg width and albumen width as egg number increased with the generation of selection. Negative responses were observed in egg weight, egg length, egg width, albumen weight, albumen length, albumen width, yolk weight, yolk length and haugh unit while there was a positive response in egg shape index, shell thickness, yolk width and yolk index. The positive response observed among egg production and quality traits indicated that they are favorably correlated. The negative responses suggest a negative correlation between traits while zero response indicate independent relationship among traits.

Table 4. 14: Realized and expected Selection response for egg production and egg quality in Japanese quails

Traits	Generation			Realized response		Expected Response to selection (ΔGg)	
	G_0	G_1	G_2	G_1	G_2	G_1	G_2
Egg number	21.24	23.61	25.17	2.27	3.93	0.10	0.14
Egg weight(g)	10.03	9.25	9.22	-0.78	-0.81	0.12	0.02
Egg length(cm)	3.14	3.02	2.97	-0.12	-0.17	-0.00	-0.02
Egg width(cm)	2.43	2.40	2.37	-0.03	-0.06	-0.01	0.01
Egg shape index	78.03	78.97	80.94	0.94	2.91	0.12	1.20
Shell weight (g)	1.45	1.41	0.81	-0.04	-0.64	-0.00	0.00
Shell thickness(mm)	0.34	0.34	0.70	0.00	0.36	-0.04	-0.34
Albumen weight (g)	4.96	4.61	4.50	-0.35	-0.46	0.03	-0.02
Albumen length(cm)	4.10	3.73	3.65	-0.37	-0.45	-0.06	-0.04
Albumen width (cm)	2.73	2.69	2.67	-0.04	-0.06	-0.00	0.00
Yolk weight (g)	3.17	2.97	2.88	-0.2	-0.29	0.12	-0.03
Yolk length(cm)	2.35	2.29	2.28	-0.06	-0.07	0.02	-0.01
Yolk width(cm)	1.33	1.13	1.66	-0.20	0.33	-0.19	0.11
Haugh unit (%)	83.87	83.04	82.28	-0.83	-1.59	-0.02	-0.03
Yolk index (%)	56.92	50.14	73.33	-6.78	16.41	-4.20	9.01

G_0= Base population; G_1= Generation 1, G_2=Generation 2

CHAPTER FIVE

5.0DISCUSSION

5.1 Descriptive Statistics for Egg Production and Egg Quality Characteristics of Japanese quail's Eggs for Base population

The high coefficient of variation observed for yolk index and yolk width observed in this study in the base population suggest that there are more room for improvement of these traits (Adedibu *et al.*, 2016). The value of egg number (21.24g) obtained in this study is lower than those in the base population (23.13, 25.34 and 36.55) reported by Momoh *et al*., (2014), Okenyi *et al*., (2013) and Okuda, (2013), respectively when they selected for high body weight and high egg number in Japanese quails over 30 days. These differences may be attributed to differences in climate and managerial conditions under which different flocks were reared. Also due to possible differences in genetic make-up of the different flocks, bodyweight and ages could differ for different population.

The value of egg weight (10.03g) recorded in this study was within the ranges of 9.76 and 11.63g reported for Japanese quail eggs (Asasi and Jaafar, 2000; Mitzutami, 2003; Abdel-Azeem, 2005). Baumgartner *et al*., (2007) also reported egg weight of 10.39, 10.65 and 10.79g for three different lines of Japanese quails. Higher and lower values were also reported by several authors(Aboul-Seoud, 2008; Daikwo *et al*., 2013; Tuleun *et al*., 2013; Okenyi *et al*., 2013; Okuda, 2013; Kaye, 2014) for egg weight in the base population. Discrepancies in the present reports with other reports could be as a result of differences in environment and selection design (Okuda, 2013; Kaye, 2014).The value of egg length, egg width, egg shape index, shell thickness, shell weight, Albumen weight, Albumen length, Albumen width, Yolk weight, Yolk length, Yolk width, Haugh unit and yolk index recorded in this study falls within the range reported by other

researchers (Kul and Seker, 2004; Sezer, 2007; Sezer, 2008; Đukić-Stojčić*et al*., 2012; Hrncari *et al*., 2014) except for lower values (0.00) of shell thickness and shell weight reported by Đukić-Stojčić *et al*., (2012) and 0.93 cm for yolk length reported by Kul and Seker, (2004). The differences between the results of this research and the results of other researches could be due to differences in genetic composition, health condition, flock age, use of different content diets in feeding, and the differences in the care and management conditions of the quails.

5.2 Descriptive Statistics for Egg Production and Egg Quality Characteristics of Japanese quail Eggs for Generation One

There was an increase in the pooled value of egg number from base generation to two as seen Table 4.2). This implies that selection for egg production brought about an increase in the pooled egg number. Higher values (27.60 and 36.55) were reported by Okenyi *et al*., (2013) and Okuda, (2013) respectively, for egg number in generation one for Japanese quails. The differences observed in this study could be as a result of differences in the selection intensity and the number of days which differed from the present study.

The value of egg weight obtained in this study (9.49g) is similar to the reports of Paganelli *et al.* (1974) who reported that the initial weight of eggs of specie *Coturnix coturnix* (Japanese quail) is 9.62. Higher (10.88, 10g and 10.1g) and lower (9.04g) values were reported (Randall and Bolla, 2008; Okenyi *et al*., 2013; Kaye, 2014) and (Okuda, 2013) and for egg weight in generation one of selection. The reduction in the pooled egg weight in this generation indicates that as selection for egg number continues, the egg weigh will progressively decrease. This also confirmed the earlier established fact that egg number is negatively correlated with egg weight (Okenyi *et al*., 2013). The variations in results reported by different authors could be as a result of differences in feed composition, selection purpose and climatic factors.

The values of egg length, egg width, egg shape index, Shell thickness, Shell weight, Albumen weight, Albumen length, Albumen width, Yolk weight, Yolk length, Yolk width, Haugh unit and yolk index recorded in this study falls within the range reported by Kul and Seker, 2004; Sezer, 2007; Sezer, 2008; Đukić-Stojčić *et al*., 2012 and Hrncari *et al*., 2014 except for lower values (0.00) for shell thickness and shell weight reported by Đukić-Stojčić *et al*., (2012) and 0.93 cm for yolk length reported by Kul and Seker, (2004). The differences observed between the result of this study and other reports may be attributed to differences in feeding system, environment and genotype of the birds used. However, the result shows that there was a slight increase in the pooled egg shape index, shell weight and yolk length as generation increases from G_0 to G_1 while the pooled egg length, egg width, albumen weight, albumen length, albumen width, yolk weight, yolk width, haugh unit and yolk index decreases in G_1. This implied that those traits that increased with the generation of selection have positive correlated response with egg number while the egg quality traits that decreased in G_1 have negative correlated response with egg number. Also, yolk width and yolk index had more room for improvement than other egg quality traits.

5.3Descriptive Statistics for egg production and egg quality characteristics of Japanese quail egg for Generation two

Similar result trend for egg number and egg weight were reported by Okuda, (2013) and Okenyi *et al*. (2013). The value of egg weight obtained in this study is consistent with the reports of Paganelli *et al*., (1974) that the initial weight of eggs of specie *Coturnix coturnix* (Japanese quail) is 9.62. Also Okenyi *et al*., (2013) and Okuda, (2013) reported 9.04g and 9.33g, respectively for generation two of selection but it differs from that recorded by Randall and Bolla, (2008) and Kaye, (2014) 10g and 10.1g which is about 8% of the bodyweight of the quail

hen. It also differ from the overall least-squares means for egg weight score (13.71 g and 10.89g) reported by Punya, (2008) and Elnagar *et al*., (2009). These results were higher than the mean of egg weights of this investigation and this may explain due to the genetic differences of quail strains and the selection design (Falconer, 1960).

The values for egg length, egg width, Shell thickness, Shell weight, Albumen weight, Albumen length, Albumen width, Yolk weight, Yolk length, Yolk width, Haugh unit and yolk index obtained in this study, falls within the values reported by other researchers (Sezer, 2008; Đukić-Stojčić *et al*., 2012; Hrncari *et al*., 2014) except for lower values (0.00) of shell thickness and shell weight reported byĐukić-Stojčić *et al*., (2012) and 0.93 cm for yolk length reported by Kul and Seker, (2004).

The increase in shape index and shell thickness recorded in G_2 in this work confirmed the earlier report by Yannakopoulos and Tserveni-Gousi, (1986) who reported that the egg shape index would be used as a criterion for determining the stiffness of eggshell. Haugh unit (83.87) and yolk index (56.92) recorded in this study falls within range reported by other researchers (Kul and Seker, 2004; Sezer, 2007; Sezer, 2008; Đukić-Stojčić *et al*., 2012; Hrncari *et al*., 2014) except for lower values (0.00) of shell thickness and shell weight reported by Đukić-Stojčić *et al*., (2012) and 0.93 cm for yolk length reported by Kul and Seker, (2004). According to the results obtained in this research, the pooled egg production and quality traits can be affected by selection in various degree and magnitude.

5.4 Least Square Means for Egg Characteristics of Japanese quail at Different Generations

The decreasing trend observed for egg weight, egg length and shell weights over generations of selection reflect a negative correlated responses in the egg traits due to selection for increased

egg production, while the increasing trend observed for yolk width, yolk index and shell thickness over generations of selection reflect a positive correlated responses in the traits due to selection for increased egg production and could be as a result of the fact that these traits are controlled by same gene (pleiotropy) at various generation (Adelaja, 2012;Okenyi *et al*., 2013, Adedibu *et al*., 2016). Okenyi *et al*. (2013) and Okuda *et al*. (2013) also reported an increase in egg number with corresponding decrease in egg weight as generation of selection increased from G_0 to G_2. Kaye *et al*. (2016) reported significant positive effect of selection for bodyweight on egg quality traits in Japanese quails. Baumgartner *et al*. (2008) observed that there were a positive but insignificant increase in albumen weight, shell weight and weight of the edible part of egg of Japanese quails when subjected to selection for low cholesterol in yolk over 19 generations. Furthermore, Nwagu *et al*. (2007) reported a significant increase in egg number in both female and male lines of Rhode Island Chickens Selected for Part Period Egg Production. The decreasing trend observed for egg weight, egg length and shell weights over generation of selection confirms the already established fact that weight of an egg is a direct proportion of shell, albumen and yolk that it contains and this varies significantly between breeds or strains of the bird species (Jones *et al*., 2010; Momoh *et al*., 2010). Also the decreasing trend observed in egg weight as egg number increased is an indication that egg number and egg weight are negatively correlated genetically thus, increased egg number would on the average lead to reduced egg weight (Nwosu, 1990; Okenyi *et al*., 2013).

5.5 Fertility Traits of Japanese quail Eggs over three Generations of Selection.

The percentage fertility for three generations observed in this study was within the range of 71.3-81.0% as reported by some authors (Daikwo *et al*., 2011; Ojo and Ayorinde, 2011; Umar *et al*., 2013). Dogan *et al*. (2013) reported that fertility of Japanese quail is high when they were mated

in the ratio of 1: 2. Also, higher and lower rates were reported by Gildersleeve *et al.*, (1987) (81.7- 93.9%) and Alkan e*t al*., (2010) (36-50%). El-Fiky *et al*. (1996) reported estimates ranging between 66.4 and 85.8 percent for the same trait during three consecutive generations of Japanese quails which is within the range obtained in this study. Higher values (86.33 and 91.36) were reported by Kaye *et al*. (2016) for the same trait in generation one and two. Also, Adelaja, (2012) also reported (66.76 and 73.51) in the base population and Generation one.

The percent hatchability of incubated eggs observed in this study agreed with Ojo and Ayorinde, (2011) but disagreed with the reports of Daikwo *et al*., (2011) and Islam *et al*., (2014). Seker *et al*. (2005) also reported that the hatchability of fertile eggs were 75.2, 99.2 and 86.2% in egg weight groups of 9.6-10.5g, 10.51-11.5g and 11.51-12.50g). Okenyi *et al*. (2013) reported estimates of 57.89, 63.73 and 69.12 percent for base generation (G_0), Generation one (G_1) and Generation two (G_2) as percentages of hatchability in G_0, G_1 and G_2 for selection for short term egg production traits in Japanese quails. Gildersleeve *et al*. (1987) reported estimate of 73.0, 79.2, 82.9 and 86.0 percent hatchability estimates in four generations of Japanese quails and concluded that hatchability increased from 73 to 86% from G_1 to G_4. Erensayin and Camci (2002) reported that the hatchability of fertile eggs in age groups of 10 and 20 weeks of Japanese quails were respectively 74.72 and 69.44 percent, in addition, the hatchability of fertile eggs was also observed to be higher in young group compared with the older group. This could be due to age at mating, mating ratio, method of mating, bodyweight groupings for the selection process.

The percent hatchability of fertile eggs recorded in this study (69.64, 69.64 and 74.93%) shows that there increased from G_1 to G_2. This implies that as generation of selection increased, hatchability of fertile eggs also increased. El -Fiky *et al*., (1996) reported a wider range of 68.2-78.5%. Meanwhile, Aboul–Hassan *et al*., (1995) reported estimates of 64.2 and 70.2% for

hatchability of fertile eggs in selected and control lines after 3 successive generations of selection for increased 6 weeks body weight. Furthermore, El-Fiky (2002) estimated this trait as 73.9%, which is almost similar to 73.2% reported by Narahari *et al*., (1988). The differences observed in this study with other authors may be attributed to differences in selection design employed.

The early and late embryo mortality recorded in this study shows a consistent reduction with increase in generation. This implied that as generation of selection for body weight for sires at mating and egg number for dams increased, early and late embryonic mortalities would decrease progressively. Abdel-Mounsef (2005) estimated the actual means of embryonic mortality percentages through different mating systems i.e. random, full and half – sib mating as 5.82, 6.92, 6.31% for early embryonic mortality, 15.11, 19.18, 16.86% for lately embryonic mortality and 20.93, 26.10, 23, 17% for total embryonic mortality. Factors such as pre- incubational storage time, environmental conditions, age and strain (Ayman, 2011)

5.6 Effect of Sire Bodyweight at Mating and Generations of Selection on Reproduction Characteristics of Japanese quail Eggs over three Generations

The significant effect of generation of selection on early and late embryonic mortality recorded shows that there was a decrease in both early and late mortality as the generation of selection increased from G_0, G_1 to G_2 which is a positive trend. Similar trend was also observed by Hedianto *et al*., (1991) who estimated early embryonic mortality as 5.62 and 2.38% among inbred and random bred lines of Japanese quail. Furthermore, Kaye *et al*. (2016) reported a reduction in percent dead in shell of 13.54 in G_1 to 8.09 in G_2. Aboul-Seoud, (2008) however, reported that reproductive traits: fertility rate (%) and hatchability (%) were decreased significantly from 74.46 and 66.08% in the first generation to 67.26 and 60.53% after three generations of selection with a significant decrease equal to 10.70 and 11.12%, while EEM%,

LEM% and TEM% were increased significantly (P<0.05) from 6.98, 17.02 and 24.00% in the first generation to 7.94, 17.98 and 25.92% after three generations of selection with a significant increase equal to 13.75, 5.64 and 8.00%.The improvement in embryonic mortality recorded in this study by generation of selection could be due to improvement in yolk size (which is sufficient to supply enough nutrients for proper growth and development of embryo) egg yolk composition by generation of selection(Aboul-Seoud, 2008; Kaye *et al*., 2016).

The interaction between sire weight groups and generations showed significant effect on all the reproductive characteristics measured. The highest recorded percent fertility was in G_0xW_1 and G_1xW_1while the least was in G_2xW_1. It showed that fertility was better in eggs laid by lighter parents in both generations because there is usually a decrease in fertility of Japanese quail eggs with increase in body size (Alkan *et al*. 2010). This implies that hatchability of eggs in all generations increased with increase in bodyweight at mating (Okenyi *et al*., 2013). Seker *et al.* (2004) reported that parental age had significant effect on hatchability of eggs with very old parents having the least hatchability estimates.

This implies that embryo mortality were more in eggs from sires having lesser body weight at mating than those having high body weights at mating. This could be as result of smaller content of the yolk which was not sufficient to supply enough nutrients for proper growth and development of embryo since egg yolk composition is relative to the age and bodyweight of both parents (Sahan and Ipek, 2000; Elibol *et a*l., 2002; Seker *et al*., 2005). Also, Seker *et al*., (2005) suggested that the use of medium or heavy weight eggs for hatching may reduce embryo mortality rate.

5.7 Phenotypic correlations of External egg quality traits for Japanese quails over three generations

The significant positive relationships observed between egg weight and egg width, shell weight and shell thickness recorded in the base generation is an indication of pleoitropic effect. This implies that those traits are controlled by the same gene. Thus, increase in one trait would result in an increase in the other traits that are correlated. Similar observation were reported by several authors (Kul and Seker, 2004; Sezer, 2007; Alkan *et al*., 2010) who variously reported that egg weight is often positively correlation with most egg quality traits except haugh unit, shell thickness and egg shape index, thus selection for egg weight can be used for egg quality to aid hatchability and presentation of internal qualities (Seker, 2004). The non-significant negative correlation obtained between egg weight and egg shape index disagreed with the values obtained by Iscan and Akcan, (1995) in hen, Ozcelik, (2002) and kul and Seker, (2004) who reported a significant negative correlation between the traits in the quail eggs, respectively. This suggests that the relationship between egg weight and egg shape index are controlled by environmental factors rather than genetic factors.

The significant negative correlation between egg length, egg shape index in G_0 and G_2suggested that an increase in one trait would result to a decrease in the other trait in all the three generations. Bobbo *et al*., (2013) also reported a negative correlation between egg length, egg shape index in local chickens. Significant positive correlation between shell weight and egg weight, shell weight and egg width, egg index and egg width in all the three generations implied that those traits are under the same gene effect (pleiotropy) throughout the three generations. Similar result was reported by several authors (Olawumi and Ogunlade, 2008; Yakubu *et al*., 2008) in egg quality of Local Chickens. Yannakopoulos and Tserveni-Gousi, (1986) reported

that egg shape index could be used as a criterion for determining stiffness of eggshell. The varying magnitude and directions observed between egg quality traits were supported by the findings of several authors on quail eggs (Iscan and Akcan, 1995) in hen and (Ozcelik, 2002; Kumari *et al*., 2008; Adelaja, 2013; Okuda, 2013)in Japanese quails. In this study, egg width is indicated to be good estimator of egg shape index because of the perfect correlation exhibited in all the three generations.

5.8 Phenotypic Correlations of Internal Egg Quality Traits for Japanese quail by Generation

In this study, only the relationship between albumen length and albumen width and that of yolk width and yolk index maintained consistency in all the three generation of selection; thus indicating that selection for egg production does not influence the relationships between the two traits and also that these two traits are consistently under the same gene effect. Positive significant correlation between these traits were also reported by other researchers (Kul and Seker, 2004; Adelaja, 2013) in Japanese quails eggs, (Yakubu *et al*., 2008, Olawumi and Ogunlade, 2008) in Local chickens except for negative correlation reported by Bobbo *et al*., (2013) for albumen height with albumen width (-0.64), albumen width with haugh unit (-0.64) and yolk width with yolk index (-0.76) in the eggs of Frizzle feather hens. Kul and Seker (2004) also reported a significant negative correlation between the albumen height and the yolk ratio among the internal quality traits of the egg and positive phenotypic correlation was found between the inner quality traits except yolk diameter. This result indicated that as albumen weight increased, albumen length and yolk weight also increased and as yolk width increased, yolk index which is a ratio of yolk length to yolk width as expressed in percentage also increased, thus increasing the viability and morphological changes in the blastorderm which

would later improve survivability of the embryo, hatchability and the future performance of the bird (Islam *et al*., 2001; Sezer, 2008).

5.9 Phenotypic Correlations between External and Internal Egg Quality Traits of Japanese Quails

In this study, as a result of phenotypic correlation determined between the internal and external quality traits of the egg (Table 4.9), it was understood that there was an increase in the relationship between egg weight and albumen weight but decrease in the haugh unit in G_0 to G_1.

Ozcelik (2002) also obtained statistically important positive correlation in eggshell weight and the internal quality traits. This is similar to the result of Kul and Seker, (2004) who reported an increase and decrease in some qualities of Japanese quail when the external and internal qualities were correlated. The statistically significant increase, in the other traits except for the egg shape index and the haugh unit reported by Kul and Seker, (2004) was in contrast with the results obtained in this study for correlation between egg external and internal qualities. Similarly significant positive correlation was between albumen length and shell thickness and haugh and shell thickness are in harmony with Yakubu *et al*. (2008) and Bobbo *et al*. (2013). The significant correlation between albumen width and egg weight obtained in this study contradicts the significant correlation reported between albumen width and egg weight, albumen width and egg width and albumen width and shell weight in local chickens by (Olawumi and Ogunlade, 2008; Bobbo *et al*., 2013). This could be due to the fact that genotype influences these traits and that the traits that were moderately to highly correlated can be inherited together and could be controlled by the same sets of genes (McPhee, 2001; Kosum *et al*., 2004; Adedibu *et al*., 2016). The varying magnitude and directions observed between egg external and internal quality traits were supported by the findings of several authors (Iscan and Akcan, 1995) in hen, Ozcelik, 2002;

Kumari *et al*., 2008; Adelaja, 2013; Okuda, 2013) in Japanese quails. Also, the differences observed between the results obtained in this experiment with other researchers may be as a result of differences in the selection design and artificial selection which the present study was subjected to which some of the experiments were not subjected to.

5.10 Principal Component Analyses for Egg Production and Quality Traits

PC 1 could serve as index for determining egg production and quality characteristics. PC2 and PC3 could serve as index for egg weight and freshness characteristics. Haugh unit is a general representation of egg freshness which reflects a series of complex chemical changes within the egg (Lin *et al*., 2011) and the parameters for measuring quality traits in eggs are at maximum when the eggs are freshly laid and decrease with increased storage time (Panigraphi *et al*., 1989). Also the higher the yolk index and the Haugh unit, the more desirable is the egg quality (Mudhar *et al*., 2011). The aggregation of egg quality traits into principal components might be as a result of the possibility that the traits that are strongly associated with each other are under the same gene action (pleiotropy). Multivariate techniques (principal components) have been found useful for a quantitative measure in animals which is desirable for reliable genetic parameters for these traits to be estimated and permits its inclusion in breeding predictions (Yakubu *et al*., 2009; Adedibu *et al*., 2016). Apart from albumen weight, all the traits that accounted for variations in egg production and quality traits in this study could be used for selection predictions in quail birds.

5.11Heritability Estimates of Egg Traits in Japanese quail in Generation One and two

The heritability of egg number in generation one and two is low. This is because heritability for egg number and fertility traits are normally low (McPhee, 2001; Kosum *et al.*, 2004). Several

researchers (El-fiky *et al*., 2000a; Aboul–Hassan, 2001; Adeogun and Adeoye, 2004; Aboul-Seoud, 2008; Okenyi *et al.*, 2013; Okuda, 2013; Kaye *et al*., 2016) also reported heritability range between 0.05-0.18 for the same trait in Japanese quails. Higher estimates (0.40-0.88) of heritability of egg number were reported by several authors (Yehia, 1992 Aboul- Seoud, 2008; Mommoh *et al.*, 2014) in Japanese quails. Most heritability estimates of egg production reported in literatures ranged from low especially when estimated from sire variance. This is an indication that variability due to additive gene action is probably smaller than the non-additive components (Okuda, 2013).

There was an increase in heritability estimates of egg weight in this study from moderate in G_1 to high in G_2 (0.27-0.45) in Japanese quail. This values were lower than the 0.48, 0.51, and 0.69 reported respectively by Kocak *et al*.(1995), El-Fiky, (2002) and Kaye, (2014) but higher than 0.01, 0.11 and 0.19 respectively reported by Alpanah *et al*., (2013), Okenyi *et al*., (2013) and Daikwo *et al*., (2013). The low heritability estimates recorded for egg length, shell thickness, albumen width and haugh unit (0.001-0.16) in this study for G_1 was similar to 0.15 reported by Daikwo *et al*., (2013) in Japanese quails. Sezer, (2007) also reported that generally, traits related with the shell had lower heritability estimates than the traits related to egg size.

5.12 Actual and expected Selection Differential of Egg Production and Egg Quality Traits in Generation one and two

Positive and negative values were obtained for egg production and quality traits as a result of selection for egg number in this study. The variability in the selection differential recorded in this study could be due to differences in the units of the traits measured (Fayeye, 2014). The positive high selection differential indicates that few animals will be needed for breeding replacement stock and the selection pressure will be high (Fayeye, 2014). The actual selection differential

corresponded well with the expected for egg weight, egg length, albumen length, shell length, yolk weight and yolk length in generation two. Aboul-Seoud, (2008) also reported strong agreement between the actual and expected selection differential for selection for egg weight in HTEW10 and LTEW10 lines. This means that the distribution of egg quality conformed with the properties of a normal distribution closely enough to allow fairly accurate prediction. The same trend was reported by Aboul-Hassan, (2001) and Abdel-Tawab, (2006) when they selected Japanese quail for increased TEN10 and EW10.

5.13 Realized and Expected Selection Response for Egg Production and Egg Quality in Japanese quails

The response to selection obtained in Generation 1 and 2 for egg number indicated that there was improvement in egg number as a result of selection for high egg number, because the actual response to selection for high egg number increased as generation of selection increases (Aboul-Hassan, 2001). Okuda, (2013) reported a fluctuating values of 9.49 in the first generation and 8.81 in the second generation. Narendra *et al*., (2011) reported response for egg number up to 18 weeks of age as 6.66 and 9.85 for response up to 24 weeks of age in Japanese quails. The difference in the number of eggs and the trend for response to selection reported here may be as a result of the difference in duration of the selection. Other responses were observed as a result of selection for egg number. The negative response for egg weight, egg length, egg width, shell weight, albumen weight, albumen length, albumen width, yolk weight, yolk length and haugh unit, respectively, for generation one and two indicates that as egg number increased across the generation of selection, those egg qualities decreased while the positive responses for egg shape index, for shell thickness, for yolk width and for yolk index, respectively, for generation one and two indicates that as egg number increased across the generation of selection, those traits also

increases, thus implying that the same set of genes have control the traits (pleoitropy) and that they could be selected together. Egg shape index remained constant implying an independent relationship between egg number and egg shape index. Narendra *et al*. (2011) and Okuada (2013) also reported negative correlated responses between egg number and some economically important traits in Japanese quails. The irregularities in response to selection in this study might have been due to genetical or environmental factors (Falconer, 1954). Differences in natural selection differential, fertility and/or genetic environment interaction on egg quality might cause such irregularity in selection response especially in such small numbers of generations as it was the case in the present study.

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 Summary

A short term selection for egg production and response to selection of egg production and quality traits in two generations of Japanese quails was undertaken to determine the egg production, egg quality and reproductive traits in Japanese quails.

From the results obtained, There was significant difference in the means of egg number, egg weight, egg length, yolk index, haugh unit, shell weight and shell thickness as the generation of selection increased. Increasing trend was observed for egg number, yolk length, yolk index and shell thickness while there was a decreasing trend in egg weight, egg length, and shell weight as generation of selection increased.

Sire body weight at mating does not significantly affect all the measured reproductive traits but generation of selection affected early and late embryonic mortalities, respectively. Interaction between sire body weight at mating and generation of selection affected on all the traits measured, indicating that interaction effect between sire bodyweight at mating and generation of selection can serve as a tool for assessing reproductive characteristics.

The phenotypic correlation between the egg quality traits varied in magnitude and direction across the generations of selection. Also, five principal components were extracted which amounted to the cumulative percentage variations of 69.03 thus, apart from albumen weight, all the traits that accounted for variations in egg production and quality traits in this study could be used for selection predictions in quail animal breeding in Nigeria.

Heritability estimates obtained for egg production and quality ranged from low to high while the response to selection and selection differential for egg production and quality traits varied widely in magnitude and direction.

6.2 Conclusion

1. Bodyweight at mating and generation of selection could not be used to assess the reproductive characteristics of Japanese quails, the interaction between bodyweight and generation was more effective in assessing reproductive characteristics of sires.
2. Heritability and response to selection of egg production and its correlated response with egg quality could be maximized in quail's egg improvement program.
3. Short term selection for increased egg production over three generations of selection in this study led to increase in egg number, yolk length, yolk index and shell thickness but decrease in egg weight, egg length, and shell weight as generation of selection increased.
4. Selection for increased egg number was achieved in generation one (2.37) and two (1.56)
5. Low to high phenotypic correlation and the five principal components extracted between external and internal egg quality traits are indication of pleiotropic effect of egg quality genes; thus could be used for selection predictions in quail animal breeding in Nigeria.

6.3 Recommendation

1. It is therefore recommended that correlation should be considered in selection designs.
2. Medium to heavy (9-11g) eggs should be used in hatcheries for better hatchability and reduced embryonic mortality.

3. Further research should be conducted on the effect of sire bodyweight at mating making the dam bodyweight constant from ninth (9^{th}) week to sixteenth week (16^{th}) week (high fertility period) to establish the optimum period for highest fertility in Japanese quails.
4. Further research on long term selection for egg production should be done to see its correlated response on the egg quality traits and other economic important traits in Japanese quails as a result of selection for egg production

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