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Genetic parameters and consequences of selection for short-term egg production traits in Japanese quail in a tropical environment

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The current study was conducted to investigate the effect of selection for short-term (30 days) egg production trait in Japanese quail (*Coturnix coturnix japonica*) over three generations (G_0 , G_1 and G_2). Heritabilities were estimated using the mixed model least squares and maximum likelihood computer programme. Fertility percentages of 76.29, 70.06, and 65.98% and hatchability percentage of 57.89, 63.75 and 69.12% were obtained for G_0 , G_1 and G_2 generations, respectively. The average egg weight for G_0 , G_1 and G_2 generations were 11.41, 10.84 and 9.33 g, respectively. Body weight at first egg (BWTFE) was 135.61, 150.02 and 154.64 g for the G_0 , G_1 and G_2 generations respectively. Egg number differed significant ($p < 0.05$) between generations. Heritability estimates for egg number, egg weight and BWTFE studied were low to moderate and ranged from 0.11 to 0.48. Realized genetic gains of 1.60 and 2.86 eggs were obtained for egg number while realized correlated responses of -0.18 and -1.17 g for egg weight and -6.03 and -15.14 g for BWTFE were obtained respectively in G_0 and G_1 generations. The experiment indicates that mass selection improved egg number in Japanese quail.

Key words: Fertility, hatchability, heritability, realized genetic gain.

INTRODUCTION

Over the years, there has been a significant gap between the production and supply of animal protein to feed the ever-growing population in Nigeria. To halt this negative trend, efforts have been directed towards boosting the livestock industry with micro-livestock having prolific tendency, short gestation period, short generation interval and rapid growth (Owen and Amakiri, 2010). Among the micro-livestock, is the Japanese quail, which is farmed for meat and egg production (Panda and Singh, 1990). Japanese quail breeding programs rely on knowledge of genetic relationships and variation among individuals. Breeders aim to exploit these forms of variation by taking into account additive, non-additive, and environmental factors. Variation and co-variation within and among po-

pulations provide the basis for development of selection strategies. Selection for productive traits (egg number) could affect the performance of reproductive traits and might directly affect commercial production (Buis et al., 1994).

Fertility and hatchability (reproductive traits) is one of the most important attributes of parent stock performance (Hunton, 1971). Fertility is defined 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 on the other hand is the ratio between fertile eggs that produce viable birds and unfertilized eggs. Hatchability is the composite of the embryos' ability to survive and the maternal contribution towards embryo survival (Savegnago et al., 2011). The relationships between productive traits (body weight at first egg and egg production) and reproductive traits (fertility and hatchability) are of interest in Japanese quail breeding because if the relationships are strong, they may affect

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progress of selection. Selection for productive traits could affect the performance of reproductive traits and might directly affect commercial performance, as in the case of meat poultry, for which hatchability is one of the most important attributes of parent stock performance (Savagnano et al., 2011).

Establishment of breeding and selection programs necessitates estimation of genetic parameters for different productive and reproductive traits. Poultry, especially Japanese quail, have received less attention relative to other livestock species; although some work, have been reported on Japanese quail (Aggrey et al., 2003; Megeed and Younis, 2006; Kumari et al., 2009; Alkan et al., 2010). Bahie El-Dean et al. (2008) reported age at sexual maturity in Japanese quail females to range between 42.98 to 61.89 days. Abdel-Fattah et al. (2006) found that heritability for growth rate ranged from 0.01 to 0.71, while, Bahie El-Dean et al. (2008) recorded heritability estimates 0.76, 0.08 and 0.06 for early, medium and late age at sexual maturity groups; respectively.

Maurice and Gerry (2005) indicated that Japanese quail subjected under proper management weighs about 100 to 140 g (male), while the females are heavier, weighing from 120 to 160 g. The average egg weight is about 10 g while the average egg number is about 100 to 200 eggs per bird per year (Onyimonyi and Okeke, 2000). It is quite possible that when these birds are subjected to selection and improved management, production will be better. Therefore, the aim of the current study was to estimate heritability and selection response of egg production traits (egg number and egg weight), and BWTFE over three generations of selection.

MATERIALS AND METHODS

The experiment was carried out in a curtained quail coop located at the Research and Teaching Unit in Department of Animal Science, Faculty of Agriculture, University of Nigeria, Nsukka. Nsukka town is located on latitude 05° 22' North and longitude 07° 24' East with annual rainfall ranging from 986-2098mm (Ndofor-Foleng et al., 2010). The farm is situated within the equatorial rainforest belt of the tropics and falls specifically within the derived savanna vegetation zone. It has well-defined rainy season (April - October) and dry season (November - March) (Ohagenyi et al., 2011). The base population of Japanese quail was obtained as two-week old chicks from National Veterinary Research Institute (NVRI), Vom, Plateau State, Nigeria and transferred to Animal Science Departmental Farm, University of Nigeria, Nsukka in furtherance of the breeding programme.

Breeding programme

In order to generate enough birds for the experiments, mating was carried out within the base population in a ratio of one male to two females. This ratio was chosen to ensure the highest fertility as suggested by El-Fiky (2002). Eggs were collected, pedigreed (identified according to sire) and hatched to obtain the G₀ generation. Hatched chicks were wing banded and raised. Feed and water were

provided *ad-libitum*. The experimental diet contained 28% protein and 2920k cal-ME/Kg until two weeks of age and 25% protein with 2850 k cal-ME/Kg during 3 to 6 weeks of age.

From the foundation population (280 females and 100 males), two randomly sampled sub populations namely: the population under selection (200 females and 50 males) and a random breeding control population (40 females and 40 males) were established. The random breeding control was maintained as non-selected pedigreed population to correct for environmental trends and/or fluctuations brought about by random genetic drift (Havenstein et al., 1988). Quail chicks in the control were reared intermingled with the population under selection throughout generations of selection to also minimize environmental variation. At six weeks of age, female quails were moved into individual laying cages for egg production study. During egg production, the birds were fed with a layer ration containing 20% crude protein with 2820 kcal-ME/Kg. At all stages and across the generations of selection, the same diets were provided to all the birds.

Selection in the Go generation

After two weeks of stabilization of lay, females were mass selected based on their individual laying performance (egg number) over a period of 30 days, while males were selected based on their individual body weight. Sixty percent (60% or 120 females) were selected from the G₀ population to become the parents of G₁ generation, which in turn, yielded the parents of G₂ generation.

Variables measured

Fertility

Fertility was tested at the 11th day of incubation by directing candle light across an egg in the dark. Fertile eggs showed a dark spot at the center with radiating streaks of blood vessels, mimicking the structure of spider. Infertile eggs were removed. Fertility percentage was recorded for each sire family and calculated as:

$$\text{Fertility percentage} = \frac{\text{Total number of fertile eggs}}{\text{Total number of}} \times \frac{100}{1}$$

Hatchability Percentages (Scientific) was recorded for each sire family by the following formula:

$$\text{Hatchability percentage} = \frac{\text{Total number of chicken hatched}}{\text{Total number of fertile egg}} \times \frac{100}{1}$$

Production traits

The body weight of each quail on the day of first egg was recorded as the body weight at first egg (BWTFE). During egg production, eggs were collected twice daily, recorded in an egg chart and weighed to obtain the egg weight.

Statistical analysis

Data on Body weight at first lay, egg number and egg weight were analyzed using the General Linear Model (GLM) procedure of the Statistical Analysis System (SAS, 2002) in a completely randomized design (CRD). The means were separated using Duncan's New multiple range test (Duncan, 1955).

Table 1. Fertility and Hatchability percent of Japanese quail eggs by generations of selection.

Parameter	Generation		
	G ₀	G ₁	G ₂
Fertility percentage	76.29 ^a	70.06 ^b	65.98 ^c
Hatchability percentage	57.89	63.75	69.12

^{a, b, c}, Row means with different superscripts are significant at 5 % ($P < 0.05$).

Model: $X_{ijk} = \mu + S_i + G_j + e_{ijk}$

Where, X_{ijk} = the record of the j^{th} progeny of the i^{th} generation, μ = the overall mean; S_i = effect of sire; G_j = effect of generation; e_{ijk} = error.

Analysis variance component and heritability estimates

Components of variance were estimated using the mixed model least squares and maximum likelihood computer programme of Harvey (1990).

Genetic response (ΔG) was calculated as the difference between the mean of the progeny of the selected parents and the mean of the contemporary reared control population (Falconer, 1989).

$$\Delta G = XS - XC$$

Where, ΔG = Genetic response; XS = mean phenotypic value of the progeny of the selected individual; XC = the mean of the control population.

RESULTS AND DISCUSSION

The various results obtained for the variables (mean egg number, average egg weight, body weight at first egg as well as fertility and hatchability percentages over three generations) are shown. Table 1 shows the fertility of 76.29% for G₀, 70.06% for G₁ and 65.98% for G₂ of selection. A significant difference ($p < 0.05$) was observed in fertility percentage between the generations of selection. There was a decrease in fertility percentage as the number of generations increased. These results agree with those of El-Hammady et al. (2001) and Magda et al. (2010) who found significant differences for fertility percentages among generations. The decrease in fertility in this study could be the result of the negative correlated response observed during selection for increase egg production in females and body weight in males. It was expected that lower estimates would be found for fertility, because, reproductive traits have a low heritability estimate (Savegnago et al., 2011), and are highly influenced by environmental factors (Austic and Neshim, 1990). For instance, Khaldari et al. (2010) reported estimates of 67.00 and 72.90% for fertility percentages during 5 and 3 consecutive generations of selection for increasing six and four weeks body weight respectively. Similarly, El-Fiky et al. (1996) reported a wide range (66.70 to

85.80%) for the same trait. Higher estimates of 80.60 and 81.70% were however reported for these traits by El-Fiky (2002) respectively for young quail flock. It seem generally that these birds are highly fertile, a characteristics, which should be utilized efficiently for quail meat production.

Hatchability percentage of 57.89, 63.75 and 69.12% were obtained for G₀, G₁ and G₂ generations respectively. Significant differences among generations were recorded for hatchability percentages. Unlike fertility, hatchability increased with generation. The third generation represented the highest significant percentage (69.12 %), while the lowest was recorded for the first generation (57.89 %) (Table 1). Different pattern of results was recorded by El-Hammady et al. (2001) and Magda et al. (2010) who reported the lowest hatchability percentage in the second generation (69.70%) and the highest (82.30%), in the third generation.

The increase in hatchability could be attributed to improved incubating conditions over generations. The values reported for the two traits are below the range reported in the literature. Narahari et al. (1988) and Bunaciu et al. (1994) reported 72.20% and 73.20% respectively for hatchability percentage in Japanese quail. Furthermore, El-Fiky et al. (1996) and Adeogun and Adeoye (2004) reported a wide range for this trait (68.20 to 78.50%) during three consecutive generations while lower ranges of 45.50 and 50.80% were reported by Marks (1979). The wide differences in reported values for fertility and hatchability could be attributed to water loss during incubation and other environmental differences. Water loss is a normal process during incubation; usually 11.32% of water is lost in quail eggs. However, too low or too high water loss influences embryo development, and, consequently, egg hatchability (Vasconcelos et al., 2008).

Egg number, average egg weight and body weight at first egg

The means for egg number, average egg weight and BWTFE are shown in Table 2. The mean egg production in the G₀, G₁ and G₂ were 25.34, 27.60 and 29.46, respectively. The corresponding generational means for egg weight were 11.41 g, 10.84 g and 9.33 g respectively.

Table 2. Descriptive statistics of egg number for 30 days (short egg production) egg weight and BWTFE of Japanese quail over three generations.

Statistic	Generation		
	G ₀	G ₁	G ₂
Mean egg number	25.34 ± 0.60 ^a	27.60 ± 0.71 ^b	29.46 ± 0.52 ^c
BWTFE (g)	154.64 ± 2.06 ^a	150.02 ± 1.66 ^b	135.61 ± 1.32 ^c
Average egg weight	11.41 ± 0.10 ^a	10.84 ± 0.11 ^b	9.33 ± 0.11 ^c

^{a, b, c}, Row means with different superscripts are significant at 5 % ($P < 0.05$).

Table 3. Heritability estimates of egg production traits.

Trait	Generation		
	G ₀	G ₁	G ₂
BWTFE (g)	0.46±0.54	0.32±0.47	0.30±0.30
Egg Number	0.12±0.36	0.33±0.47	0.48±0.54
Egg weight (g)	0.19±0.34	0.11±0.34	0.12±0.30

There were significant differences ($p < 0.05$) in egg number and egg weight between the generations. While egg number increased progressively with generations, egg weight decreased. The upper trend in egg number over generations of selection was expected because egg number was the trait considered during selection and the gain in this trait indicates a positive response. The decreasing trend observed for egg weight over generation reflects a negative correlated response in egg weight due to selection for increased egg production.

Mean body weight at first egg of 154.64, 150.02 and 135.61 g of G₀, G₁ and G₂ generations respectively were obtained (Table 2). There were significant differences ($p < 0.05$) in the body weights at first egg among the three generations with a decreasing trend over generations. This result indicates a negative correlated response in BWTFE following selection for improved egg production.

Egg number and egg weight are negatively correlated genetically thus, increase egg number will on the average lead to reduced egg weight (Nwosu, 1990). Panda and Singh (1990) determined an egg weight in quails either subjected to selection for meat or egg traits as 10.58 and 9.76 g, respectively. Asasi and Jaafar (2000) reported a range of 9.76 to 11.63 g while Khaldari et al. (2010) reported that, egg weight was 13.40 and 12.80 g in the selected and control populations respectively, during selection for increased body weight at four weeks. Also, Inal et al. (1996) using selection for body weight at 5 weeks of age reported higher estimates for egg weight that ranged from 10.94 to 13.23 g over 5 generations. These higher values reflect positive correlated responses in egg weight due to selection for improved body weight, which agrees with the positive genetic correlation between body weight and egg weight.

Age at sexual maturity influences BWTFE, egg number to a particular age and egg weight. Selection for increased laying potential encourages early sexual maturity (lower age at sexual maturity) which means lower body weight at sexual maturity (lower BWTFE). Thus, BWTFE and egg number are negatively correlated (Saatci et al., 2006).

Heritability

Heritability estimates for egg number and egg weight and BWTFE derived from sire components of variance are shown in Table 3. Heritability estimates for egg number, egg weight and BWTFE were 0.12 ± 0.36, 0.33 ± 0.47 and 0.48 ± 0.54; 0.19 ± 0.34, 0.11 ± 0.34 and 0.12 ± 0.30; 0.46 ± 0.54, 0.32 ± 0.47, and 0.30 ± 0.30, respectively, were obtained for G₀, G₁ and G₂ generation respectively. Thus, heritability values were low to high for egg number and BWTFE but low for egg weight across the generations. Heritability values for egg number show an upward trend across generations while those of egg weight and BWTFE show a downward trend. The increase in heritability estimates for egg number across generations indicates increasing additive genetic variance across generations (Falconer, 1989). The estimate of heritability reported in the present study is however within the range normally reported for the respective traits in this species (Adeogun and Adeoye, 2004).

Genetic response to selection

The genetic response to selection (realized genetic gain) for short-term egg production over three generations of

Table 4. Realized genetic response of egg production traits and BWTFE over generations of selection.

Trait	Generation		
	G ₀	G ₁	G ₂
BWTFE (g)	-6.03	-15.14	-
Egg Number	1.60	2.86	-
Egg weight (g)	-0.18	-1.17	-

selection is shown in Table 4. A realized genetic gain of 1.60 and 2.86 eggs were obtained for egg number in G₀ and G₁ generations respectively. The realized genetic response for body weight at first egg and average egg weight were -6.03, -15.14 g and -0.18 g, -1.17 g for G₀ and G₁ generations respectively. The results reflect positive responses to selection, for egg number and negative correlated responses for BWTFE and egg weight. Clearly, the realized genetic gains from this experiment did not measure up to expectations. This could be attributed to the question of refractory response to continued selection for egg number. Abdullah and Aktan (2011) reported that the most likely causes of this might be genetic “slippage” due to fluctuation of environmental trends and negative genetic correlations between components of performance. By “genetic slippage”, Abdullah and Aktan (2011) implied that selection is mainly directed towards non additive genetic effects of over dominance, epistasis, and genotype X environment interactions, which dissipate in the next generation; this could well account for the “non-response” in egg weight and BWTFE.

Aboul-Seoud (2008) using selection based on high egg weight found an irregular selection response averaging 12.24 g, 11.59 g and 10.06 g in the first second and the third generation. This irregularity of the selection response has been observed in many selection experiments reported in literature. However, Abdel-Tawab (2006) reported that the actual response to selection for high egg weight was 1.22 g after the first generation of selection and fluctuated to be 0.68 g after the third generation of selection. Falconer (1954) has shown that the irregularity in response to selection might have been due to many genetic or environmental factors. Differences in natural selection differential, fertility and/or genetic environment interaction might be because of such irregularities in selection response (Aboul-Seoud, 2008) especially in such small numbers of generations as it was the case in the present study.

Conclusion

Egg production traits (egg number and egg weight) in the Japanese quail are lowly to moderately heritable while BWTFE is moderately to highly heritable. Values

obtained in heritability estimate of egg number, egg weight and BWTFE indicate that direct selection for these traits could lead to genetic improvement as was observed for egg number in the present study. However, where simultaneous improvement is required for traits, a multiple trait selection index could be used with appropriate weighting factor for each trait. It could be concluded that mass selection improved egg number in Japanese quail on the other hand, improving fertility and hatchability could be done through adjusting the environmental factors.

REFERENCES

- Abdel-Fattah SA (2006). Physiological and immunological adjustments of dietary ascorbic acid and acetyl salicylic acid in heat stressed Japanese quail. *Egypt. Poult. Sci.* 12 (IV):1395-1418.
- Abdel-Tawab SK (2006). The effect of selection for egg weight on some productive traits in Japanese quail. M.Sc. Thesis Fac. Agric. Al-Azhar Univ. Cairo, Egypt.
- Abdullah NÖ, A Sedat (2011). Estimation of Genetic Parameters for Body Weight and Egg Weight Traits in Japanese Quails. *Trends Anim Vet Sci* 2 (1):17-20.
- Aboul-Seoud (2008). Divergent Selection for Growth and Egg Production Traits in Japanese quail. Ph.D Thesis Animal Production Department, Faculty of Agriculture, Al-Azhar University. 198pp.
- Adeogun IO, Adeoye AA (2004). Heritabilities and phenotypic Correlations of growth performance traits in Japanese quails. *Livestock Research for Rural Development* 16 (12):102-106.
- Aggrey SE, Cheng KM (1994). Animal model analysis of generic (co) variance for growth traits in Japanese quail. *Poult. Sci.* 73:1822-1828.
- Alkan S, Karabag K, Galic A, Karsli, T Balcioglu MS (2010). Determination of body weight and some carcass traits in Japanese quails (*Coturnix coturnix japonica*) of different lines. *Kafkas. Univ. Vet. Fak. Derg* 16(2):277-280.
- Asasi K, Jaafar AJ (2000). The effect of sex ratio on egg production, fertility and hatchability of Japanese quail. *Pajouhesh-va-Sazandegi*.45:128-131.139.
- Austic RE, Nesheim MC (1990). *Poultry Production*, 13th Edition, Lea and Febiger, Philadelphia, London. 19 (15):256 -301.
- Bahie El-Dean M, El-Tahawy WS, Attia YA, Meky MA (2008). Inheritance of age at sexual maturity and its relationships with some production traits of Japanese quails. *Egypt. Poult. Sci.* 28 (IV):1217-1232.
- Buis RC, Oldenbroek JHJ, van der werf (1994). Preserving genetic variance resources in commercial non-commercial populations. *Netherlands JI Agric. Sci.* Vol 42-1 (1994)29-36
- Bunaciu M, Bunaciu P, Cimpeanu L (1994). The influence of mating design on the reproductive performance in Japanese quail proceedings, 9th European Poultry Conference, Glasgow, UK, 7-12 Aug, 1994. Volum 1:314-315 (CAB Abstract).
- Duncan DB (1955). New Multiple Range Test. *Biometrics*, 11:1.

- El-Fiky FA (2002). The effect of parental age on their productivity and progeny growth in Japanese quail. *Egypt. J. Appl. Sci.* 17:13-27.
- El-Fiky FA, Aboul-Hassan MA, Shoukry HMS (1996). Effects of intensive inbreeding on some productive traits in Japanese quail // *Annals of Agric. Sci., Moshtohor* - 1996. – Vol. 34, № 1. – P. 189-202.
- El-Hammady H, Abdelnabi M, Ragheb G (2001). Effect of age, body weight and sex ratio on fertility, hatchability and egg production in the Japanese quail (*Coturnix coturnix japonica*) under subtropical conditions. Assiut University, College of agriculture, Animal and Avian Production Dept. *Egypt. Poult. Sci.* 80 (Abstract) page 264.
- Falconer DS (1954). Asymmetrical responses in selection experiments. *Symp. Genetic of population structure Intern. Union. Biol. Sci. Naples, Series B; No.15* :16-41.
- Falconer DS (1989). *Introduction to quantitative genetics* 3rd edition, Longman, London, New York: 160-174.
- Harvey WR (1990). *Mixed Model Least-squares and Maximum Likelihood Computer programme*. Ohio State University Columbus (Mimeo).
- Havenstein GB, Nestor KE, Bacon WL (1988). Comparison of pedigreed and non pedigreed randombred control systems for use with artificial selection in the Japanese quail. *Poult. Sci.* 67:357-366.
- Hunton P (1971). Genetics of hatchability and its components and some production traits of chickens. *Br. Poult. Sci.* 12:213-223.
- Inal S, Dere S, Kiirikci K, Tepeli C (1996). The effects of selection for body weight of Japanese quail on egg production, egg weight, fertility, hatchability and survivability // *Veteriner Bilimleri Dergisi* - 1996. – Vol. 12, № 2. – P. 13-22.
- Khaldari M, Pakdel A, Yegane HM, Javaremi AN, Berg P (2010). Response to selection and genetic parameters of body and carcass weights in Japanese quail selected for 4-week body weight// *Poult. Sci.* - 2010. – Vol. 89, № 9. – P. 1834-1841.
- Kumari PB, Gupta BR, Prakash MG, Reddy AR (2009). Genetic study on body weights of Japanese quails. *Indian J Poult Sci.* Vol: 44 Issue: 3. (Abst).
- Magda I, Abo Samaha, Sharaf MM, Hemeda ShA (2010). Phenotypic And Genetic Estimates Of Some Productive And Reproductive Traits In Japanese Quails. *Egypt. Poult. Sci.* Vol (30) (lii): (875-892).
- Marks HL (1979). Changes in unselected traits accompanying long-term selection for four-week body weight in Japanese quail. *Poult. Sci.* 58:269-274.
- Marks HL (1980). Reverse selection in a Japanese quail line previously selected for 4-week body weight. *Poult. Sci.* 59:1149-1154.
- Maurice R, Gerry B (2005). *MODEL Code of practice for the welfare of animals* No 83: Domes poult. (4th edition).
- Megeed MSA, Younis HH (2006). Genetic parameters of body and egg weight in Japanese quails (*Coturnix coturnix japonica*) using partial diallel analysis. *Egypt. Poult. Sci.* 26 (IV):1471-1485.
- Narahari D, Aboul-Mujeer K, Thangavel A, Ramamurthy N, Viswanathan S, Mohan B, Muruganandan B, Sundararasu V (1988). Traits influencing the hatching performance of Japanese quail eggs. *Brit. Poult. Sci.* 29:101-112.
- Ndofor-Foleng HM, Ngongeh LA, Uberu CPN, Nwosu CC (2010). Evaluation of the performance of two local chicken and the main cross ecotypes reared in Nsukka, Enugu State. *Nigeria. I.J.S.N., VOL. 1(2)*, 2010:179-182.
- Nwosu CC (1990). Review of indigenous poultry research in South – Eastern Nigeria. In: *Rural Poultry production in Africa*. Ed. Sonaiya E. B. *Proceeding of an International Workshop on rural poultry in Africa. Ile – Ife, Nigeria* 13 – 16 Nov. 62 – 77.
- Ohagenyi IJ, Nwosu CC, Ndofor-Foleng HM (2011). Genetic Parameters Of Some Biometric Growth Traits Of Purebred Heavy Ecotype Of The Nigerian Local Chicken *I.J.S.N., VOL. 2(2)* 2011:348-351
- Onyimonyi AE, Okeke GC (2000). Protein and Energy Requirement of the Japanese Quail in the humid tropics: *J Agric. Technol Educ.* 5:1-2
- Owen OJ, Amakiri AO (2010). Japanese quail (*Coturnix coturnix japonica*): its potentials, opportunities and challenges. *Proceedings of the 31st Annual Conference of the Nigerian Society for Animal Production*, 14- 17th March, 2010, University of Ibadan, Oyo State, Nigeria. pp. 333-335.
- Panda B, Singh RP (1990). Development in processing quail. *World's Poult. Sci. J.* 46:219-234.
- Saatci M, Omed H, Ap Dewi I (2006). Genetic Parameters from Univariate and Bivariate Analyses of Egg and Weight Traits in Japanese Quail. *Poult. Sci.* 85:185-190.
- SAS (2002). *Statistical Analysis Systems Institute, (2002) SAS/STAT guide for personal computers*, vers. 8. Cary, NC, USA, SAS Institute.
- Savegnago RP, Buzanskas ME, Nunes BN, Ramos SB, Ledur MC, Nones K, Munari DP (2011). Heritabilities and genetic correlations for reproductive traits in an F2 reciprocal cross chicken population. *Gene Mol Res.* 10 (3):1337-1344 (2011)
- Vasconcelos TG de Moraes, Moura Romao J, Evangelista da Silva E, Maciel Cardoso W, Buxadé Carbó C (2008). Incubation of Japanese quail eggs (*Coturnix japonica*) stored in domestic refrigerator. *Livestock Research for Rural Development* 20 (10) 2008.