Nig. J. Anim. Prod. 2022, 49(4): 20-32. https://doi.org/10.51791/njap.v49i4.3700

Nigerian Journal of Animal Production

Laying Performance and Blood Parameters of Japanese Quails (*Coturnix coturnix japonica*) At Different Stocking Densities

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Abstract

Human pressure on agricultural land resources has lured many poultry farmers to increase the capacity of the poultry pen through increase in the stocking rate despite the high environmental temperature of the tropical environment. This study was carried out to assess the laying performance and blood parameters of Japanese quails (Coturnix coturnix japonica) at different stocking densities in the heat period. A total of two hundred and ninety-six day-old sexed and apparently healthy Japanese quails were used for the experiment which lasted eight weeks in a completely randomized design with four treatments replicated four times. The birds were divided into four stocking densities of 252.20cm^2/bird (11birds), 173.43 cm^2/bird (16 birds), 132.10 cm^2/bird (21birds), and 106.73 cm^2/bird (26 birds) which represented Treatments 1-4 respectively. The results revealed that stocking density affected the number of eggs laid per quail. HDEP and HHEP decreased as stocking density increased with no quail mortality across the treatments level during the laying period. Stocking density significantly affected ($p<0.05$) egg weight, eggshell with membrane thickness and egg surface area though better for Japanese quails stocked at 132.10cm^2/bird. Internal egg quality parameters across treatments differed significantly ($p<0.05$) except the yolk weight and percentage. However, internal egg quality parameters, except the yolk weight and percentage were better in quails stocked at 173.43cm^2/bird. Similarly, albumin, glucose, cholesterol, LDL, triglycerides and creatinine levels were better in quails stocked at 173.43cm^2/bird and compared favourably with those stocked 132.10cm^2/bird. Therefore, stocking densities of 173.43cm^2/bird and 132.10cm^2/bird could be considered for quail egg production without compromising the health of quails.

Keywords: *Laying performance; Egg quality parameters; Haematological parameters; Stocking density; Japanese quail.*

Performance De Pose Et Parametres Sanguins Des Cailles Japonaises (Coturnix coturnix japonica) A Differentes Densites De Stockage

Résumé

La pression humaine sur les ressources foncières agricoles a attiré de nombreux producteurs de volaille à augmenter la capacité du stylo volaille par une augmentation du taux de stockage malgré la haute température environnementale de l'environnement tropical. Cette étude a été réalisée pour évaluer les performances de pose et les paramètres sanguins des cailles japonaises (Coturnix coturnix japonica) à différentes densités de stockage pendant la période de chaleur. Un total de deux cent quatre-vingt-dix-six jours de cailles japonaises sexuelles et apparemment saines ont été utilisées pour l'expérience qui a duré huit semaines dans une conception complètement randomisée avec quatre traitements reproduits quatre fois. Les oiseaux ont été divisés en quatre densités de stockage de 252,20 cm2 / oiseau (11 *oiseaux), 173,43 cm2 / oiseau (16 oiseaux), 132,10 cm2 / oiseau (21 oiseaux) et 106,73 cm2 / oiseau (26 oiseaux) qui ont représenté les traitements 1-4 respectivement. Les résultats ont révélé que la densité de stockage affectait le nombre d'œufs posés par caille. Le HDEP et le HHEP ont diminué à mesure que la densité de stockage augmentait sans mortalité par caille à travers le niveau des traitements pendant la période de pose. La densité de stockage a affecté de manière significative (P <0,05) le poids des œufs, la coquille d'œuf avec une épaisseur de membrane et la surface des œufs, mais mieux pour les cailles japonaises stockées à 132.10 cm2 / oiseau. Les paramètres de qualité des œufs internes entre les traitements différaient significativement (p <0,05), à l'exception du poids et du pourcentage du jaune. Cependant, les paramètres de qualité des œufs internes, à l'exception du poids et du pourcentage du jaune, étaient meilleurs dans les cailles stockées à 173,43 cm2 / oiseau. De même, l'albumine, le glucose, le cholestérol, les LDL, les triglycérides et les niveaux de créatinine étaient meilleurs dans les cailles stockées à 173,43 cm2 / oiseau et ont comparé favorablement avec ceux qui ont stocké 132.10cm2 / oiseau. Par conséquent, les densités de stockage de 173,43 cm2 / oiseau et 132.10cm2 / oiseau pourraient être envisagées pour la production d'œufs de caille sans compromettre la santé des cailles.*

Mots-clés: *performances de pose; Paramètres de qualité des œufs; Paramètres hématologiques; Densité de stockage; Caille japonaise.*

Introduction

Consumption of protein of animal source by humans is an important factor that ensures healthy living because of its richness in essential amino acids. The daily requirement for protein intake for an adult human being as recommended by Food and Agricultural Organization varies between 65 and 85g per head/day of which 35g/day must be from animal source (Mba, 1983; Joseph and Ajayi, 2002). However, about 10g/day of animal protein reportedly consumed by an average Nigerian is far less than FAO recommendation Esobhawan *et al.,* (2008). To meet up with the FAO recommendation of daily protein intake, there is a need for alternative animal protein source from other livestock species that requires little space for rearing with no or reduced hazards of environmental pollution and within the capacity of low income households. Quail rearing is one of the species of livestock that fits in this description because of its relatively small body size, hardy and fairly disease resistant (NRC, 1991), besides its fast growth rate, early sexual maturity at about six weeks and short generation interval (Anon, 1991). Quails are also known for high rate of egg production between 200-300 eggs in 360 days (NRC, 1991). It is therefore a good and economical source of quality animal protein (Seker, 2003).High environmental temperature impairs performance and productivity in poultry such as reduced feed intake, decreased nutrient utilization, reduced growth rate, egg production, egg quality and feed efficiency (Guo-YuMing *et al.* 1998) which purposely lead to economic losses in poultry. Quest of man for infrastructural development which mounts pressure on agricultural land had lead farmers to increase the use of any available land for increased poultry production thereby leading to increasing the stocking density in poultry housing. Stocking density is expressed as mass per unit space (Thaxton *et al.,* 2006). It is the number of birds calculated on a weight basis per unit space. Increase in stocking density has resulted in heat build-up and consequently lead to heat stress (Adebiyi *et al.,* 2011) in poultry pen. It thus affect behavioural and physiological indicators such as plasma corticosterone and heat shock protein 70 in birds (Mashaly *et al.,* 1984; Belmore *et al.,* 2010).Overstocking of birds in poultry house will lead to competition among birds for feeds, water and space with the resultant poor feed efficiency and reduced productivity (Ramnath *et al.,* 2008). The combined effect of high environmental temperature and high stocking densities during upsurge in environmental temperature of transition from dry to rainy season is required to understand the performance of laying Japanese quails reared under these conditions. Specifically, the objective of this study was to assess the laying performance and blood parameters of Japanese quails (Coturnix coturnix japonica) reared under different stocking densities during period of transition from dry to rainy season.

Materials and Method

Experimental site and management of birds

The study was carried out at the Poultry Section of Teaching and Research Farm, Federal University of Technology, Akure, Ondo State, Nigeria during the heat period of transition from dry to rainy period (February to April) in the year 2019.

A total of two hundred and ninety-six day-old sexed and apparently healthy Japanese quails were used for the study for a period of eight weeks. They were divided into four stocking densities of 252.20cm^2/bird (11birds); 173.43 cm^2/bird (16 birds), 132.10 cm^2/bird (21birds), and 106.73 cm^2/bird (26 birds) that represented Treatments 1-4 respectively in a completely randomized design. The treatments were replicated four times. Both sexes were housed together in a battery cage system and fed ad-libitum with formulated quail layer diet containing 20.00 %CP and 2620 ME Kcal / Kg based on the feed requirements of laying Japanese quail outlined in NRC (1994)for 8 weeks.

To determine the egg qualities of Japanese quail, egg were collected at 4th week of laying with five (5) eggs per replicate per day for three consecutive days and the egg were weighed on each day of collection with a high precision Kerro Electronic Compact Scale Series P1 BL2000I in grams.

Egg width and Egg length (mm): were measured using digital Venier's calipers calibrated in millimeter (mm). The values were used to calculate the Egg Shape Index (ESI) Laseinde (2011).

$$\text{Egg shape index (ESI)} = \frac{\text{Egg width (mm)}}{\text{Egg length (mm)}} \times 100$$

Interior egg quality: For the interior egg quality, each egg was carefully opened and content poured into a flat non-absorbent surface. The albumen and yolk were carefully separated using a table spoon and the heights of each were measured manually by dipping an improvised broomstick into it at the highest height and reading the point of impression against a ruler in millimeter (mm). Each of the albumen and yolk were then weighed and their percentages were calculated based on the respective weight of the whole egg.

Percentage Yolk index: were calculated by dividing yolk height with its diameter Yannakopoulos and Tserveni-Gousi, (1986).

$$\text{Yolk index} = \frac{\text{Yolk height (mm)}}{\text{Yolk diameter (mm)}} \times 100$$

To determine eggshell weight and thickness, eggshell were cleaned of albumen in running water and then air dried for three days. The eggshell weight were measured using sensitive digital scale and its thickness was determined as average thickness measured at three points (air cell, equator and sharp end) using micrometer screw guage Yannakopoulos and Tserveni-Gousi, (1986).

$$\text{Eggshell thickness} = \frac{\text{Thickness at (air cell, equator and sharp end)}}{3}$$

Haugh's unit (HU): was determined using the albumen height and egg weight, which was applied to the equation: $HU = 100\log(H + 7.57 - 1.7W^{0.37})$ Nesheim et al. (1979).

Where H = albumen height (mm); W = egg weight (g); 7.57 = correction factor for albumen height; 1.7 = correction factor for egg weight.

Egg specific gravity (ESG) was determined with the formula of Paganelli et al., (1974) as shown.

$ESG = 1.038W^{0.006}$. Where, W is Egg Weight.

At the 8th week, blood samples were collected from 2 females and 2 males from each replicate of the treatments. Before blood collection, the birds were fasted overnight and the blood was collected from the jugular vein using sterile needles and syringes into EDTA bottle for haematological evaluation while that of serum biochemistry were collected into plain bottles. The haematological and serum parameters were analyzed following standard laboratory procedure and using commercially available diagnostic kits.

Statistical analysis

All the data obtained were analyzed using linear procedure for one way analysis of variance (ANOVA) using a completely randomized design (CRD) of SPSS Version 16. Means with difference were separated using Duncan's Multiple Range Test of the same statistical package at 0.05 % level of significance.

Results and Discussion

Egg production performance of Japanese quails reared under different stocking densities

The results of egg production performance of Japanese quails reared under different stocking densities are presented in Table1. The number of eggs laid per bird decreased as stocking densities increased. Quails reared at lower stocking density had more access to feed with little or no competition and therefore had more nutrient intake that was mobilized for egg production. High stocking density might cause reduction in feeding area and imposed physiological stress in birds with resultant decrease in egg production. This result was in agreement with the findings of these authors (Adams and Craig, 1985; Ozbey *et al.*, 2004; Gharib *et al.,* 2005) that increase in cage density resulted in a significant reduction in egg production and egg mass. Faitarone et al. (2005) also found a linear reduction ($P \leq 0.05$) in egg weight, percent of egg production and egg mass of quails with high stocking density. The age at first lay varied from 48.25±0.48 to 52.2±50.63days. Age at first lay of eggs by quails was earlier at an average of 48days in T2,and slightly lower compared to 49days observed in T1and T4, respectively, while egg laying for quails in T3 started late at an average of 52days. The age at first lay could imply that the quails have attained sexual maturity. The age at first lay in this study is in agreement with Bahie El-deen *et al.* (2008) who reported 42.90 and 50.05 days for early and intermediate age at sexual maturity and Mizutani (2003) who reported 38 to 48 days. Age at first lay of egg is species specific and influenced by genetics, environmental, nutrition, body composition and physiological factors such as photoperiodic Broody *et al.* 1984; Asuquo and Okon, 1993). The Average weight of quail egg in this study varied from 9.36 to 9.39g which is typically specific for quail. Mortality of quails was not recorded during the laying period of this study. Although, Abdel-Azeeem, (2010) and Seker *et al.* (2009) reported that mortality rate of Japanese quail increases with increasing population per square cm which is contrary to the reports of Turkyilmaz (2008) and Ayoola *et al.* (2014). Good management practices of quail adopted in this study might be a reason why there was no mortality. Inadvertently, the hen-day egg production (HDP) and hen-house egg production (HHEP) was similar and decreased from 82.24% in T1 to 67.04% in T4 as stocking density increased. The higher HDP and HHEP observed for quails stocked at lower cage density might be due to more space that was available per quail which advertently could have reduced competition and associated physiological stress. This supports the findings of several authors (Ozbey et al., 2004; Gharib et al., 2005; Onbasilar and Aksoy, 2005). Feed conversion ratio was the best in quails with the least stocking density and gradually increased as the socking density increased. However, feed efficiency (FE) indicated a reverse with the highest value of 0.49 in T1 and lowest values (0.37) in T3 and T4 respectively. This corroborated the reports of Nahashon et al. (2006) that birds reared at low stocking density resulted in low FCR compared to those stocked at high stocking density. Davidson and Leighton (1984) also reported that high population density reduced feed efficiency than did a relatively low population density. However, Erensayin (2001) concluded that feed conversion ratio was better in quails with increasing group size.

Table 1: Egg production performance of Japanese quails reared under different stocking densities in the transition from dry to rainy season.

Parameters	T1	T2	T3	T4
Number of Hens	23.00±0.00	31.00±0.00	41.00±0.00	56.00±0.00
Age at first lay (days)	49.00±2.12^{b}	48.25±0.48^{c}	52.25±0.63^{a}	49.00±1.91^{b}
Number of eggs laid per bird	28.65±2.17^{a}	25.23±2.80^{b}	23.93±1.30^{b}	23.46±1.43^{c}
Total weight of egg laid (g)	269.02±3.45^{a}	236.24±1.22^{b}	224.46±2.23^{b}	220.05±1.92^{c}
Average egg weight (g)	9.39±1.50^{a}	9.36±2.50^{c}	9.38±1.44^{b}	9.38±2.26^{b}
Hen-Day Production (%)	82.24±2.01^{a}	69.22±2.69^{b}	68.36±2.17^{b}	67.04±3.61^{b}
Hen-Housed egg production	82.24±2.01^{a}	69.22±2.69^{b}	68.36±2.17^{b}	67.04±3.61^{b}
Total Feed Intake (g/bird)	600.32±2.36^{b}	607.44±0.78^{a}	605.34±6.69^{a}	597.48±4.09^{c}
Feed Conversion Ratio	2.23±0.03^{c}	2.57±0.01^{b}	2.70±0.02^{a}	2.71±0.03^{a}
Feed Efficiency	0.49±0.00^{a}	0.39±0.0^{b}	0.37±0.01^{c}	0.37±0.01^{c}
Mortality rate	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

$^{a, b, c,}$ = Means on the same rows with different superscripts are significant ($p<0.05$).

T1 =252.20cm^2/bird(11 birds), T2 = 173.43 cm^2/bird (16 birds), T3 = 132.10cm^2/bird (21 birds) and T4 = 106.73cm^2/bird (26 birds).

External quality parameters of Japanese quail eggs reared under different stocking densities

The results of the external egg quality parameter of quail presented in Table 2 revealed that stocking density does not affect all the external egg quality parameters in an orderly trend. Egg weight of quails T3 stocked at 132.10cm^2/bird (21 birds/cage) was significantly higher than weight of quail eggs from other stocking densities though egg length and egg width were not significantly different. It clearly showed that stocking density in this study had no effect on egg weight, egg length and egg width in quail. This aligns with El-Shafei (2012) who reported no significant difference in the external parameters of eggs from hens subjected to different stocking densities and contradicts the findings of El-Tarabany (2014) who reported a significantly ($p< 0.05$) higher estimates for the external parameters of eggs from birds with the lowest stocking density. Egg shell with membrane thickness, shell weight, egg shell percentage were affected by stocking density during heat period with quail in the highest stocking density of 26quails/cage having the lowest (0.10±0.00cm). The combined effects of high environmental temperature and high stocking negatively affect the mobilization of calcium and its deposition for eggshell formation in quail. Egg size increases more rapidly than the shell weight (Butcher *et al.,* 1991) and this affects calcium deposition in eggshell (Curtis *et al.,* 1985). However, there was no significant difference in the quail egg specific gravity among the various stocking densities. Specific gravity of an egg is a measure of the quantity of eggshell relative to other egg components and decline as the age of bird increases. This study thus showed that stocking density has no effect on egg specific gravity.

Table 2: External quality parameters of Japanese quail eggs reared under different stocking densitiesin the transition from dry to rainy season.

Parameters	T1	T2	T3	T4
Egg Weight (g)	9.07 ± 0.12^{c}	9.24 ± 0.10^{b}	9.41 ± 0.09^{a}	9.07 ± 0.10^{c}
Egg Length (mm)	29.38±0.19	29.52±0.15	29.79±0.14	33.73±4.33
Egg Width (mm)	23.84±0.11	23.13±5.03	24.02±0.07	23.79±0.10
Egg Shape Index (%)	81.28±0.48	78.35±0.89	80.71±0.34	79.98±1.37
Egg Shell Weight (g)	0.83±0.01	0.89±0.02	0.87±0.01	0.80±0.01
ES+M Thickness (cm)	0.20 ± 0.01^{a}	0.20 ± 0.01^{a}	0.20 ± 0.03^{a}	0.10 ± 0.00^{b}
Egg specific gravity (gcm^{-3})	1.05±0.00	1.05±0.00	1.05±0.00	1.05±0.00
Egg surface area (cm^2)	20.78 ± 0.18^{b}	21.05 ± 0.15^{ab}	21.31 ± 0.14^{a}	20.79 ± 0.15^{b}
Egg shell percentage (%)	9.20±0.13	9.26±0.08	9.23±0.09	8.86±0.10

$^{a,\ ab,\ b,\ c,}$ = Means on the same rows with different superscripts are significant ($p<0.05$).

ES +M = Egg shell with Membrane.

T1= 252.20cm^2/bird (11birds), T2= 173.43 cm^2/bird (16 birds), T3= 132.10cm^2/bird (21 birds) and T4= 106.73cm^2/bird (26 birds).

Internal quality parameters of Japanese quail eggs reared under different stocking densities

The results of internal quality parameters of Japanese quail eggs reared under different stocking density are presented in Table 3. It showed that quails in T2 (173.43cm2) with 16birds/cage have highest values in all the internal quality of quail egg. This observation disagreed with Faitarone *et al*. (2005) who reported a non-significant effect of stocking density on internal egg quality such as albumen ratio, yolk ratio, yolk weight and albumen weight. The albumen height, yolk height, yolk diameter and Haugh's unit also differed significantly in an inconsistent manner across the stocking densities. This disagreed with the report of Faitarone *et al*. (2005) that internal quality of quail egg is better at high stocking density. This indicates that high stocking density during heat period with the associated stress does not have significant impact on internal quality of quail eggs.

Haematological profile of laying Japanese quails reared under different stocking densities

The results of haematological parameters of laying Japanese quail reared under different stocking densities during heat period presented in Table 4 showed that erythrocyte sedimentation rate (ESR) were very low and differed significantly among the stocking densities with the highest in T1 (1.94±0.72) and lowest in T3 (0.69±0.09). Erythrocyte sedimentation rate is useful in diagnosis of disease condition such as auto-immune diseases which is affected by both inflammatory and non-inflammatory conditions. The values of ESR, though lower for laying quails in this study suggest that stocking density did not predispose quail to diseases and infections during the laying period, which could also have been a reason for zero mortality during the laying

Table 3: Internal quality parameters of Japanese quail eggs reared under different stocking densities in the transition from dry to rainy season.

Parameters	T1	T2	T3	T4
Albumen Height (cm)	0.36 ± 0.01^{c}	0.53 ± 0.01^{a}	0.45 ± 0.01^{b}	0.46 ± 0.01^{b}
Albumen Weight (g)	4.49 ± 0.10^{c}	5.07 ± 0.07^{a}	4.86 ± 0.07^{ab}	4.75 ± 0.08^{b}
Yolk Weight (g)	3.63±0.10	3.54±0.08	3.67±0.05	3.65±0.07
Yolk Height (cm)	0.84 ± 0.02^{c}	0.97 ± 0.02^{a}	0.85 ± 0.01^{ab}	0.89 ± 0.02^{b}
Yolk diameter (cm)	2.50 ± 0.03^{b}	2.41 ± 0.03^{c}	2.62 ± 0.03^{a}	2.54 ± 0.02^{b}
Yolk index	0.34 ± 0.01^{c}	0.41 ± 0.01^{a}	0.32 ± 0.00^{c}	0.35 ± 0.01^{b}
Yolk percentage (%)	40.11±1.03	38.28±0.63	39.00±0.49	40.32±0.68
Albumen percentage (%)	50.69 ± 1.01^{c}	52.46 ± 0.64^{a}	51.77 ± 0.69^{b}	50.82 ± 0.72^{c}
Haugh's Unit	61.17 ± 0.23^{b}	62.66 ± 0.17^{a}	61.50 ± 0.17^{b}	62.19 ± 0.15^{a}

$^{a, ab, b, c,}$ = Means on the same rows with different superscripts are significant ($p<0.05$).

T1= 252.20cm^2/bird (11birds), T2= 173.43 cm^2/bird (16 birds), T3= 132.10cm ^{2}/bird (21 birds) and T4= 106.73cm^2/bird (26 birds).

Table 4: Haematological profile of laying Japanese quails reared under different stocking densities in the transition from dry to rainy season.

Parameter	T1	T2	T3	T4
ESR (mm/hr)	1.94 ± 0.72^{a}	1.38 ± 0.55^{a}	0.69 ± 0.09^{b}	0.88 ± 0.18^{b}
Packed cell volume (%)	39.75 ± 2.96^{b}	36.50 ± 5.16^{b}	46.50 ± 1.98^{a}	44.38 ± 2.46^{a}
Red blood cell (x10^6/µl)	4.75 ± 0.48^{b}	4.87 ± 0.42^{b}	5.56 ± 0.31^{a}	5.58 ± 0.50^{a}
Haemoglobin (g/dl)	13.21 ± 0.98^{b}	13.64 ± 0.76^{b}	15.46 ± 0.66^{a}	14.76 ± 0.82^{a}
Lymphocyte (%)	56.88±0.30	56.75±0.45	56.88±0.44	56.75±0.53
Heterophil (%)	38.63±2.66	38.25±0.62	36.00±0.53	36.75±0.37
Monocyte (%)	5.63 ± 0.42^{a}	5.38 ± 0.42^{a}	5.38 ± 0.26^{a}	4.75 ± 0.31^{b}
Basophil (%)	0.38 ± 0.18^{b}	0.25 ± 0.16^{c}	0.50 ± 0.19^{a}	0.38 ± 0.18^{b}
Eosinophil (%)	1.00±0.00	1.38±0.18	1.25±0.16	1.38±0.18
Mean corpuscular vol. (fl)	85.57 ± 0.03^{a}	76.46 ± 0.10^{c}	84.38 ± 0.03^{a}	81.38 ± 0.03^{b}
Mean corpuscular Hb. (pg)	28.44±0.01	28.59±0.01	28.05±0.01	27.07±0.01
MCHC (%)	33.24±0.03	33.67±37.40	33.25±0.01	33.26±0.02
H:L ratio	0.68±0.05	0.67±0.01	0.63±0.01	0.65±0.01

$^{a, b}$ = Means on the same rows with different superscripts are significant ($p<0.05$).

ESR=Erythrocyte Sedimentation Rate; MCHC= Mean Corpuscular Haemoglobin Concentration; H:L= Heterophil/Lymphocyte ratio.

T1= 252.20cm^2/bird (11birds), T2= 173.43 cm^2/bird (16 birds), T3= 132.10cm ^{2}/bird (21 birds) and T4= 106.73cm^2/bird (26 birds).

period. The red blood cell, packed cell volume and haemoglobin values for quail in this study were observed to be relatively high at high stocking density and were within the range of 2.78 x10^6/µl, 36.83% and12.13 g/dl reported by Pandian *et al.,* (2012) for red blood cell, packed cell volume and haemoglobin respectively. The values obtained for these parameters were also higher than values of haematological parameters for domestic species of birds (Turkey, Guinea fowl and Geese) reported by Pandian *et al.,* (2012). This might be due to species difference (Oyewole and Ogwuegbu, 1987) and Japanese quail being excessively active than any other species of domesticated birds (Kundu *et al.,* 1993; Pandian *et al.,* 2012). The lymphocyte and eosinophil fraction of the white blood cell were not significantly different across the stocking densities while heterophil and monocyte decreased as the stocking density increased. However, the basophil fraction which differed significantly does not follow a particular trend. The basophil and eosinophil values in this study were lower than the values of basophil and eosinophil (0.13% and 2.13%) respectively obtained by Mihailow, (1999) while heterophil and lymphocyte were respectively higher than the values of 21.87% and 75.50% reported by the same author. The differences in values may be on account of difference in rearing zone, environmental temperature and season of rearing. The Mean Corpuscular Volume (MCV) was different among the stocking densities with the highest mean value in quails reared at a stocking density of 252.20cm^2 (11quails/cage). These values are lower compared to what Pandian *et al.,* (2012) documented for quails. Significant differences ($p \geq 0.05$) were not observed in Mean Corpuscular Haemoglobin (MCH) and Mean Corpuscular Haemoglobin Concentration (MCHC). The values of MCH in the present study are lower than what Pandian *et al.,* (2012) reported for Japanese quails however, MCHC values are in accordance with the values obtained by the same authors and Pampori and Saleem, (2007). The MCV, MCH and MCHC are indicators of anemia, dehydration, infection and aspergillosis in birds (Campbell, 1995). The heterophil/lymphocyte (H:L) ratio in this study was not different ($p \geq 0.05$) across the stocking densities. Heterophil/Lymphocyte is a measure of physiological stress in poultry (Post *et al.,* 2003; Zulkifli *et al.*2003). The H:L in this study does not follow a regular trend but was observed to be high in quails stocked at low stocking density. The result of this study corroborated Spinu *et al.* (2003) that reported that there is no significant difference ($p \geq 0.05$) in the H:L ratio between different stocking densities in broiler breeders in summer. Higher H:L ratio in birds reared in high stock density is an indication of increased stress in poultry (Feddes *et al.,* 2002). H:L ratio is influenced by housing condition such as stocking density and food form (El-Lethey *et al.*2000).

Serum biochemical indices of laying Japanese quails reared under different stocking densities.

The results of serum biochemical indices presented in Table 5 revealed that serum total protein was not different ($p>0.05$) across the stocking densities. Albumin, glucose, cholesterol and alkaline phosphatase were highest in quails stocked at 173.43cm^2/bird (16quails/cage). However, glucose and cholesterol level inT1, T2 and T3 were not significantly different ($p \geq 0.05$). Meanwhile, the quails, T4, with the highest stocking density had the least values for albumin, glucose and cholesterol. Globulin levels of quails, T4 stocked at a density of 106.73cm^2/bird was highest compared to other groups. The globulin values of 0.97 to 3.66gm/dl were obviously lower than the globulin values of (3.22 to 3.55gm/dl) reported by Doaa *et al.* (2017) and 11.92 to 15.20gm/dl of Aro *et al.* (2021) but consistent with 1.94gm/dl with a range of (1.00 to 3.11) reported by Agina *et al.* (2017). High Density lipoprotein (HDL), creatinine and urea values decreased with increased stocking density. HDL of laying quails in this study was similar to the 22.90 to 41.04mg/dl of Aro *et al.* (2021) while Low Density lipoprotein (LDL) values were lower to the report obtained by the same authors. However, serum triglycerides, creatinine and urea values obtained from this study were higher than values obtained by Aro *et al. (*2021); Kouassi *et al.* (2021). Aspartate Aminotransferase (ALT) and Aspartate Aminotransferase (AST) in this study were at variance with findings by the same authors but agreed with El- Shafei *et al.* (2012) who reported insignificant differences across the stocking densities. The lower AST and ALT indicated that the laying quails used for the study were not predisposed to auto-immune diseases such as hepato-toxicity as documented (Grunwaldt *et al,* 2005). Serum calcium and phosphorous concentration across treatments did not follow a specific trend as the stocking density increased. The Ca:P ratio was recorded to be highest in T3 with value of (0.74±0.02) followed by T2 (0.47±0.01) while T1 (0.32±0.02) and T4 (0.31±0.02) values were not significantly different and lower.

Table 5: Serum biochemical indices of laying female Japanese quails reared under different stocking densities in the transition from dry to rainy season.

Parameter	T1	T2	T3	T4
Total Protein (mg/dl)	10.94±3.46	13.68±3.54	11.83±3.47	9.27±4.56
Albumin (mg/dl)	9.58±3.03^{b}	12.38±3.20^{a}	10.86±3.18^{ab}	6.02±2.93^{c}
Globulin (mg/dl)	1.36±0.46^{b}	1.30±0.42^{b}	0.97±0.35^{c}	3.26±1.72^{a}
Glucose (mg/dl)	51.47±18.24^{a}	70.33±22.01^{a}	56.31±19.77^{a}	31.06±15.27^{b}
Cholesterol (mg/dl)	44.55±14.44^{c}	61.10±15.91^{a}	56.75±16.71^{b}	35.60±17.38^{d}
High Density lipoprotein (mg/dl)	32.62±11.50^{a}	13.65±8.09^{b}	11.20±5.08^{b}	1.24±0.86^{c}
Low Density lipoprotein (mg/dl)	1.77±0.66^{b}	4.42±1.25^{a}	3.91±1.18^{ab}	2.92±1.43^{b}
Triglycerides (mg/dl)	10.16±2.28^{c}	43.03±6.57^{a}	41.64±10.15^{a}	31.44±15.09^{b}
Creatinine (mg/dl)	10.31±3.43^{a}	9.85±2.63^{a}	9.41±3.05^{a}	7.34±3.60^{b}
Urea (mg/dl)	32.42±22.60^{a}	13.45±5.99^{ab}	8.20±2.94^{b}	2.92±1.75^{c}
Aspartate Aminotransferase (U/L)	52.17±17.06	68.20±20.28	68.75±21.98	59.08±29.91
Alanine Aminotransferase (U/L)	0.62±0.24	1.01±0.39	0.44±0.18	1.04±0.06
Alkaline Phosphatase (U/L)	47.90±19.49	56.38±17.80	54.86±19.25	48.99±33.09
Calcium (mg/dl)	16.97±7.31	39.70±16.41	29.61±12.45	29.40±21.20
Phosphorus (mg/dl)	52.11±0.19	84.01±0.26	39.91±0.57	96.01±0.60
Ca:P	0.32±0.02^{c}	0.47±0.01^{b}	0.74±0.02^{a}	0.31±0.02^{c}

$^{a, ab, b, c}$ = Means on the same rows with different superscripts are significant (p<0.05).

T1= 252.20cm^2/bird (11birds), T2= 173.43 cm^2/bird (16 birds), T3= 132.10cm ^{2}/bird (21 birds) and T4= 106.73cm^2/bird (26 birds).

Conclusion

The number of egg per bird and hen-day house production as stocking density increased while the feed conversion ratio and feed efficiency were better at high stocking. Stocking density had no great impact on external quality parameter of quail eggs though were better at stocking density of 132.10cm^2/bird (T3) while internal egg quality parameters were remarkable at 173.43cm^2/bird (T2). High stocking density did not predispose the quails to disease and mortality. Haematological parameters were revealed to be better at T3 level. It can be concluded that quails in T2 and T3 (173.43 cm^2 and 132.10 cm^2/quail bird) with 16 and 21 quails/cage compared favourably and is suggested for cage stocking of quail for better performance and productivity without impacting negatively on the health of quails.

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Date received: 18th February, 2022.
Date accepted: 29th October, 2022.