Agric Res J **61** (4): 520-530, *August* 2024
DOI: 10.5958/2395-146X.2024.00065.X

INFLUENCE OF SIXTH-WEEK BODY WEIGHT ON EGG PRODUCTION AND QUALITY DURING EARLY LAY PERIOD IN JAPANESE QUAIL

O M A Jesuyon[1]*, K L Akinsola[1] and S O Oseni[2]

[1]*Department of Animal Production and Health,*
Faculty of Agriculture, Federal University, P.M.B. 373, Oye-Ekiti, Ekiti State, Nigeria
[2]*Department of Animal Sciences,*
Obafemi Awolowo University, P. M. B. 138, Ile-Ife, Osun State, Nigeria

ABSTRACT

This study investigated the effects of body weight at the 6th week (point of lay) and lay-period on quail egg production and quality during the early laying phase in Ikole, Nigeria. The objective was to assess whether these factors, either independently or interactively, influence egg productivity and quality traits. A total of 180 quail birds, all at six weeks of age, were randomly assigned to three body weight groups (123-130 g, 131-137 g, and 138-144 g), with each group consisting of six replicates of ten birds. Birds were fed a common diet from the 6th to the 15th week. Data on body weight, feed intake, egg production, and internal and external egg quality traits were collected following standard procedures. A two-way ANOVA based on a factorial design was used to analyze the interaction between body weight (Factor 1) and lay-period (Factor 2), with the General Linear Model (GLM) and Duncan's Multiple Range Test (DMRT) applied for mean separation. Results showed significant (*$p = 0.036\text{-}0.050$*) effects of the interaction between body weight and lay-period on average body weight, egg height, egg surface area, albumen quality index, yolk quality index, and Haugh unit. The findings suggest that optimizing body weight and lay-period factors can enhance quail performance and egg quality, providing farmers with practical insights for improving resource allocation and profitability.

Keywords: Albumen and yolk quality, Body weight, Egg surface area, Haugh unit, Quail production, Sexual maturity

Quail farming offers several advantages, including low investment costs, minimal labour requirements, small space needs due to the birds' compact size, and relatively easy management compared to other poultry types. Quail birds are not only highly productive but also more resilient and disease-resistant than many other poultry species. The practice is gaining popularity in Nigeria, driven by its economic benefits, including low startup costs, the excellent nutritional profile of quail eggs and meat, and the affordability for low-income earners (Jesuyon *et al.*, 2021).

Egg production in poultry is significantly influenced by body weight (Ashour *et al.*, 2015) as well as age-related factors, such as physiological age, stage of lay, or lay-period (Bourin *et al.*, 2022). In laying quails, sexual maturity is reached early, making body weight and age at sexual maturity critical for initiating egg production at the earliest possible time. Achieving the required body size and weight for early lay can be influenced by several factors, including age, proper brooding, nutrition, feeding levels, breed, optimal environmental conditions, body weight uniformity, genetics, species, season, hormonal levels, light duration and intensity, stress, and broodiness (Dumoulin, 2019; Wang *et al.*, 2017). An optimal and uniform body weight is essential for high, early, and pre-peak egg production. Flocks with greater body weight uniformity tend to exhibit higher egg production compared to those with more variation (Suawa, 2015; Hyline, 2024). To achieve high egg production at early sexual maturity (ESM), quails must attain appropriate and consistent body weight during their growth or rearing period (Aviagen, 2020). The body weight of Japanese quail at 6 weeks of age has been reported to be between 168-174 g per bird (Bagh *et al.*, 2016), and this weight at sexual maturity significantly influences egg weight (Filho *et al.*, 2016). Furthermore, body weight uniformity in laying poultry affects egg production, fertility, and hatchability (Suawa, 2015). While body weight uniformity is not the primary focus of this study, quails were assigned to uniform weight groups at the start of the sixth week (early sexual maturity age) to enhance uniformity within these groups.

The lay period in poultry refers to distinct phases or stages of the production cycle, which have effects separate from those of age. Understanding the lay period provides insights into the events and interventions needed as egg production increases or declines at different stages of the production cycle.

*Corresponding author: oluwatosin.jesuyon@fuoye.edu.ng
Date of receipt: 11.08.2023, Date of acceptance: 04.07.2024

Research on the effects of lay period in quail is limited, as there has been relatively little investigation in this area. After the peak of egg production, egg numbers typically decrease, while egg weight, yolk size, and feed consumption tend to increase with body weight in both heavy and light hens (Anene *et al.*, 2020). A key strength of this study lies in its examination of quail birds with closely uniform body weights from the point of sexual maturity across different lay periods, rather than focusing solely on age. This type of study has not been extensively explored in existing literature. The primary research question was: Does the interaction of 6th week body weight and lay period influence egg productivity and egg quality traits in quail? Consequently, the aim of the present study was to investigate how the interaction between 6th week body weight and lay period affects egg production and quality. The research hypothesis proposed that this interaction would influence the response traits evaluated in the study.

MATERIALS AND METHODS

The study was conducted at the Research Unit of the Animal Production and Health Department, Federal University Oye-Ekiti (FUOYE), Ekiti State, Nigeria. The experimental procedures were reviewed and approved by the FUOYE Institutional Animal Care and Use Committee (IACUC), ensuring adherence to animal ethics and welfare standards with approval number IACUC/APH/SS1020/2021/05.

Quail management

A total of 252, 3-week-old mixed-sexed *Coturnix coturnix japonica* (quail) birds were used for the experiment. These birds were sourced from the National Veterinary Research Institute, Vom, Ikire Out-station, Osun State, Nigeria. Before the birds were stocked, the housing and cages were thoroughly cleaned and disinfected. The cages were then lined with wood shavings as bedding material, which was replaced weekly throughout the study.

Upon arrival, the chicks were given a glucose solution (15g per liter of water) to replenish their energy reserves. Initially, the chicks were housed at a density of 15 birds per cage (dimensions: 75 × 48 × 45 cm³) and allowed to acclimate to their new environment until they reached 6 weeks of age. At this point, males were culled from the flock based on breast plumage colouration. The quail birds were then weighed and grouped into three weight classes (123-130g, 131-137g, and 138-144g) to enhance body weight uniformity. These groups were randomly assigned to six replicates within each weight class, with 10 birds per replicate. Each replicate was provided with 360 cm² of space in the cages, including sufficient room for both the birds and the feeding equipment. The three weight groups interacted with three lay periods (6-8, 9-11, and 12-15 weeks) as the birds progressed through egg production, resulting in a 3×3 factorial treatment design.

Routine management practices, including feeding, provision of water, cleaning, and egg collection, were uniformly conducted across all replicates from the 6th to the 15th week of age. From weeks 3 to 6, the birds were provided with a high-quality chick starter diet, formulated to meet standard energy and nutrient requirements, including 2664.5 kcal/kg of metabolizable energy (ME), 24.0% protein, 1.5% calcium, 1.06% lysine, 0.55% methionine, and 0.48% available phosphorus. From the 6th week onward, all birds were switched to a compounded layer mash diet, which supplied 2564.5 kcal/kg ME, 18% protein, 3.13% calcium, 0.96% lysine, 0.45% methionine, and 0.42% available phosphorus.

Traits measured

Production data were collected weekly for each replicate, including measurements of feed intake (g), body weight (g), egg weight (AEW, g), and the number of eggs laid. Water was provided *ad libitum*. Daily feed intake (DFI, g) was calculated as the difference between the amount of feed offered and the feed residue. Eggs were collected and counted twice daily (morning and evening) within each replicate to determine the total number of eggs laid per day.

From above direct measurements, traits below were derived within replicate. Average daily feed intake (DFI, g) was estimated as total feed intake for the week divided by (total number of birds x 7). Average body weight (ABW, g) was calculated as total body weight of birds divided by number of birds within replicate; Average body weight gain (ABG, g) was determined as average body weight in current week minus average weight in previous week; Feed conversion ratio to eggmass (FCRem) was taken within replicate as: Kg feed intake for the week/kg egg produced. Feed conversion efficiency to eggmass (FCEem, %) was determined within replicate as: FCEem, % = {(kg egg mass produced ÷ kg feed intake) x 100}; where kg egg produced is total weekly egg weight x total number of eggs layed (kg). Average egg number per bird (AEN) was determined as total number of eggs laid divided by (number of birds x 7); Hen-day egg production (HDP, %) was determined as {(total number of eggs laid x 100), divided by (number of hens x 7)}; Average egg weight (AEW, g) was determined as total egg weight divided by total number of eggs weighed; and egg weight gain (EWG, g) was taken as average weight in current week minus average weight in previous week.

Three eggs per replicate were weighed and evaluated for external and internal quality traits within replicate weekly, from 6 to 15 weeks. The external quality traits observed were Average egg weight (EWT, g) determined as above; Egg height (EHT, mm) determined as external distance between the two polar ends of the egg; Egg diameter (EDM, mm) was taken as external distance round the mid-region of the egg.

Derived external egg quality traits were:

Egg shape index (ESI, %) = (EDM ÷ EHT) x 100. The original formula modified by Bagh (2016) was used as stated. ESI values <72, 72-76, >76 were regarded as Sharp, Normal and Round egg respectively (Duman *et* al., 2016)…… ….(1)

Egg surface area (ESA, cm^2) = 4.835 x AEW $^{0.667}$, an approximate method by Paganelli *et al.* (1974)…..….(2)

The egg shell weight with membrane was measured on the Mettler balance after removal of the whole content, rinsing with water and subsequent air-drying to obtain constant weight. Average shell weight (SWT, g) was determined as sum of shell weights for replicate divided by number of shells for replicate …………(3)

Average shell percentage (SPT, %) was determined as (weight of air-dried egg shells divided by weight of fresh eggs) = (dry SWT/EWT) x 100…..……..…(4)

Internal components of the egg were obtained by carefully making openings with a scalpel round the sharp end of the eggs, large enough to allow passage of the albumen and the yolk without mixing together. Albumen height (ALH, mm) was determined as height of the fresh thick albumen (egg white) that immediately surrounds the yolk. Yolk colour (YCL) was determined visually by comparing with DSM/Roche standard yolk colour fan. Yolk height (YHT, mm) was taken as the length of the longitudinal side of the yolk; yolk diameter (YDM, mm) was taken as the distance across the equatorial section of the yolk.

For derived internal egg traits, albumen weight (AWT, g) was calculated by subtracting YWT and SWT from the weight of the whole egg, as: AWT = Whole EWT – YWT – SWT…………(5)

Albumen percentage (APT, %) was determined as (albumen weight divided by whole egg weight) x 100 ………….………(6)

Albumen quality index (AQI, %) was determined as: (AHT ÷ AWT) x 100, as modified from that presented by Altuntas & Aydin (2014). It measures the freshness of eggs …………..(7)

Yolk weight (YWT, g) was determined by difference as (weight of Petri-dish + weight of egg yolk) – weight of Petri-dish………..(8)

Yolk percentage (YPT, %) was estimated as (yolk weight divided by whole egg weight) x 100…………...(9)

Yolk quality index (YQI, %) was determined as (YHT ÷ YDM) x 100 (Onunkwo & Okoro, 2015). This index measures the freshness of eggs. YQI values <0.28, 0.28-0.38 and >0.38 indicate Fresh, Regular and Extra-fresh eggs respectively…………..(10)

Yolk albumen percent (YAP, %) was determined as (YWT ÷ AWT) x 100 …..(11)

Haugh unit (HUT, %) was determined as [100 x log (ALH + 7.57)] – (1.7 x $EWT^{0.37}$), (Jesuyon *et al.,* 2021), where ALH is albumen height (mm) and EWT is egg weight (g). The Haugh unit measures the egg-white viscosity and thus its quality……….....(12)

The equipment and tools used were digital balance (Model: Emperors_EK5350, Camry, Zhongshan, China) of 500 g capacity with 0.1 g sensitivity that was used for weighing. Digital vernier calliper (sensitivity = 0.01 mm, Bombay Pvt Ltd., India) was used to measure egg traits; DSM/Roche standard yolk colour fan; Mettler Toledo balance (Model: ME104, Mettler, Singapore). Micrometre screw gauge used to measure egg traits.

Experimental design and statistical analyses

The factorial treatment design was adopted. Body weight was considered as Factor 1 with three classes (i = 123-130, 131-137, 138-144, g) and laying period as Factor 2 with three periods (j = 6-8, 9-11, ≥12 weeks of age) in order to study the interaction effect between the two factors. The completely randomized design (CRD) in a 3 x 3 treatment factorial was adopted for the study.

The statistical model employed was of the form:

$Y_{ijk} = BW_i + LP_j + (BW×LP)_{ij} + \mathcal{E}_{ijk}$……….. (13)

where Y_{ijk} = observed response due to body weight i, in lay-period j, in replicate k; BW_i is the effect of body weight $_i$ (i = 1, 2, 3); LP_j is the effect of laying-period $_j$ (j=1, 2, 3); $(BW×LP)_{ij}$ is the interaction effect of body weight $_i$ and laying period $_j$; and $\mathcal{E}_{ijk}$ = random error effect ~ nid (0, δ^2). Data collected were subjected to 2-way ANOVA $_{(\alpha = 0.05)}$ procedures of General Linear Model (GLM) and regression $_{P<0.05}$ of SAS® (2013). Significant means were separated by Duncan Multiple-Range Test (DMRT) $_{a<0.05}$. Regression model for comparing between body weight classes and between lay-periods was of the form: $Y = a + bX_1 + cX_2 + dX_3 + \mathcal{E}$, where Y= response of a trait within body weight class /lay-period, a = constant mean; b, c, d = power of covariation of trait (X_{1-3}) with Y; where X_1 to X_3 = predictor traits.

Null hypothesis: These was no significant interaction of 6th week body weight and lay-period for response traits evaluated.

Alternate hypothesis: There was significant interaction between 6th week body weight and lay-period for response traits evaluated.

RESULTS AND DISCUSSION

Interaction of 6th week body weight and lay-period

Significant interaction effects of 6th-week body weight and lay-period on body weight and egg quality traits in experimental quails (*p = 0.005–0.050*, *95% CI: 0.30-6.91*) were observed (Table 1). The average body weight (ABW) showed a tendency to increase across lay periods within each body weight class. The lowest body weight was observed during the early lay-period (6-8 weeks, 123-130 g body weight), while the highest body weight was recorded during the late lay-period (12-15 weeks, 138-144 g body weight) ($p < 0.045$, *95% CI: 2.61*). Two external egg quality traits, eggshell thickness (EHT) and eggshell area (ESA), exhibited significant interactions between body weight and lay-period. EHT followed a bell-shaped trend, with the highest values recorded during the mid lay-period (9-11 weeks, 123-130 g body weight). However, in the medium and high body weight classes, EHT increased progressively across lay periods ($p < 0.005$, *95% CI: 0.30*). ESA demonstrated a general increase across lay periods in the 123-130 g and 138-144 g weight classes, with a peak value observed during the mid lay-period (9-11 weeks, 131-137 g body weight) ($p < 0.049$, *95% CI: 0.34*). Among internal egg quality traits, albumen quality index (AQI), yolk quality index (YQI), and Haugh unit (HUT) showed significant interactions between body weight and lay-period ($p < 0.05$, *95% CI: 6.91, 2.36, 1.44, respectively*). Both AQI and HUT displayed a linear increase across lay periods within the early body weight class and followed a similar trend in the middle (131–137 g) and high (138–144 g) body weight classes, with minimum values recorded during the mid lay-period (9–11 weeks). In contrast, YQI reached its lowest values during the mid lay-period (9–11 weeks) across all weight classes.

The interaction between 6th-week body weight and lay-period is critical for optimizing egg productivity, quality, and quail breeding management. This study revealed that quails generally exhibited an increase in body weight from the early to the late lay-period. A similar increasing trend was observed for the interaction values of average body weight (ABW) and eggshell thickness (EHT). These improvements may be attributed to the progressive increase in daily feed intake (DFI) and feed conversion efficiency (FCE) across body weight classes and lay periods. These findings highlight the importance of tailored nutrition and feeding strategies that adjust to the birds' developmental phases to enhance body weight and EHT. The eggshell area (ESA) values also increased across lay periods within body weight classes, likely due to the enhanced DFI and FCE. However, the ESA value recorded at the mid lay-period (9-11 weeks, 131-137 g body weight) appeared to be optimal for achieving higher ESA. Quail farmers could aim for an optimal ESA of 21 cm² or more to maximize productivity. For internal egg quality traits, the increasing trends of the albumen quality index (AQI), yolk quality index (YQI), and Haugh unit (HUT) across lay periods within each weight class were similarly attributed to high DFI and FCE. However, the lower values recorded during the mid lay-period (9-11 weeks) in medium (131-137 g) and high (138-144 g) weight classes might have been caused by stress factors, such as heat, nutritional imbalances, or poor management, which can reduce feed intake. These stressors have been reported to negatively affect albumen height, yolk colour intensity, albumen pH, and the overall composition of albumen and yolk, ultimately diminishing egg appearance and quality (El-Tarabany, 2016; DSM, 2022). YQI serves as a secondary indicator of egg freshness. Notably, yolk quality in eggs produced during the late lay-period (12-15 weeks, 131-137 g body weight) was classified as "extra fresh" (DSM, 2022), highlighting the potential for achieving superior egg quality during this phase.

Body weight appears to be a key determinant of enhanced performance in traits such as egg surface area (ESA), albumen quality index (AQI), and Haugh unit (HUT). The interaction values for ABW, ESA, AQI, and HUT observed in the 138-144 g body weight group during the late lay-period (12-15 weeks) were superior to those in lower weight and earlier lay-period groups. These traits demonstrated an increasing trend with higher 6th-week body weight and extended lay-periods. However, the decline in trait values observed during the mid-lay period (9-11 weeks) may be attributed to production stresses, which likely impacted egg-laying ability and quality. ESA is a critical measure that quantifies the size of table eggs and facilitates the exchange of heat, metabolic gases, and water vapour, thereby determining eggshell permeability (Chang, 2021). Eggs produced by quails in the 138-144 g weight class during the late lay-period (12-15 weeks) exhibited the largest ESA, possibly allowing greater exchange of these substances. This, however, could lead to faster deterioration of such eggs unless effective preservation techniques are applied. AQI is a physical measure of egg freshness, based on the appearance of albumen when the egg is broken on a flat surface. As an egg loses freshness, the albumen spreads out due to structural weakening, resulting in a lower AQI. The AQI values observed in this study were consistently high (>88%), confirming the excellent quality of the eggs (Viswanathan *et al*., 2016). Similarly, the Haugh unit, first introduced by Raymond Haugh in 1937, remains a widely used indicator of protein quality based on albumen height and egg weight. It is considered one of the most critical egg quality metrics after shell

Table 2. Effect of 6th-week body weight and lay-period on egg productivity and external quality of *Coturnix coturnix japonica* layers in Ikole Nigeria

	Trait*	Body weight (g)					Lay-period (wks)					*P*-values		
		123-130	131-137	138-144	SEM	95% CI	6-8	9-11	12-15	SEM	95% CI	BWT	LP	B x L
Egg	DFI	24.75^{ab}	21.60^{a}	25.67^{b}	1.100	2.16	23.42	24.66	24.44	0.445	0.87	0.019	0.757	0.225
	ABW	141.54	144.51	144.83	1.430	2.80	137.48^{a}	145.49^{b}	145.82^{b}	0.649	1.27	*0.067*	*0.001*	*0.045*
Productivity	ABG	5.16^{b}	2.59^{ab}	1.24^{a}	3.800	7.45	5.40^{b}	0.83^{a}	10.83^{c}	1.522	2.98	*0.485*	*0.514*	*0.931*
	FCR	12.13	7.21	7.13	5.950	11.66	75.73^{c}	21.11^{b}	5.87^{a}	6.486	12.71	*0.672*	*0.050*	*0.763*
	FCE	895.31^{ab}	882.83^{a}	929.97^{b}	12.433	24.37	865.77^{a}	923.94^{b}	919.08^{b}	13.561	26.58	0.050	0.004	0.603
	AEN	3.54	3.45	3.19	0.248	0.49	2.42^{a}	4.10^{b}	4.03^{b}	0.308	0.60	0.733	0.005	0.292
	HDP	50.53	49.24	46.63	3.540	6.94	38.47^{a}	58.6^{9b}	54.53^{a}	1.646	3.22	*0.733*	*0.005*	*0.292*
	EWT	8.95^{ab}	8.83^{a}	9.30^{b}	0.124	0.24	8.65^{a}	9.24^{b}	9.19^{b}	0.051	0.09	0.047	0.004	0.603
	EWG	1.00	1.12	1.20	0.589	1.15	3.46^{b}	0.04^{a}	0.05^{a}	0.622	1.22	*0.806*	*0.001*	*0.950*
External	EWT	8.95^{ab}	8.83^{a}	9.30^{b}	0.124	0.24	8.65^{a}	9.24^{b}	9.19^{b}	0.051	*0.10*	*0.047*	*0.004*	*0.603*
Egg	EHT	29.04^{a}	29.68^{a}	40.72^{b}	1.857	1.68	29.95^{ab}	30.83^{b}	29.17^{a}	1.578	3.09	*0.039*	*0.003*	*0.005*
Quality	EDM	23.60	23.88	23.67	0.137	0.27	23.34^{a}	23.59^{ab}	23.80^{b}	0.139	0.27	*0.210*	*0.028*	0.460
	ESI	81.33^{b}	80.55^{b}	77.39^{a}	0.670	1.31	81.03	80.84	80.92	4.264	8.36	*0.019*	*0.155*	*0.100*
	ESA	20.63^{a}	20.45^{a}	21.16^{b}	0.213	0.42	20.17^{a}	21.07^{b}	20.99^{b}	0.288	0.56	0.050	0.050	0.049
	SWT	0.84	0.85	0.84	0.015	0.03	0.90^{c}	0.83^{b}	0.80^{a}	0.006	0.01	*0.474*	*0.001*	*0.925*
	SPT	9.37	9.21	9.12	0.147	0.29	10.28^{c}	9.02^{b}	8.78^{a}	0.491	0.96	0.486	0.001	0.295

*DFI=average daily feed intake (g), ABW=average body weight (g), ABG=average body weight gain (g), FCR=feed conversion ratio (to egg), FCE=feed conversion efficiency (to egg, %), AEN=average egg number per week, HDP=hen day egg production per week (%), EWT=average egg weight per week (g), EWG=average egg weight gain per week (g), EHT=egg height (mm), EDM=egg diameter (mm), ESI=egg shape index (%), ESA=egg surface area (cm^2), SWT=shell weight (g), SPT=shell percentage (%), SEM=standard error of the means, BWT=body weight, LP=lay period, *P-values*=probability, *B x L*=interaction of body weight and egg lay-period

Within a column means followed by different alphabets differ significantly thickness and strength (Yan *et al.*, 2020). The observed improvements in Haugh unit values across interaction levels indicate better hen-day production, superior egg quality, and enhanced preservation potential up to 15 weeks of age (Table 1). These findings contrast with those of Samiullah *et al.* (2014), who reported a decline in Haugh unit scores with advancing flock age. However, the current study focused on eggs produced during the early production life (6-15 weeks), where all eggs were classified as "very good" to "excellent" on the Haugh unit scale. Commercial eggs with Haugh unit scores below 60% are deemed "unfit for consumption" (Nematinia and Mehdizadeh, 2018). The slight decline in AQI and HUT values observed in the 131-137 g and 138-144 g body weight classes during the mid-lay period (9-11 weeks) could be attributed to egg production stress as birds approached peak laying capacity. The findings of this interaction study suggest that quail breeding and management strategies should focus on achieving an optimum sexual maturity body weight of 131-137 g at six weeks of age to maximize egg performance and quality. This performance advantage persisted up to the 15th week, with these birds outperforming their lighter counterparts (123-130 g) in all traits. The lower weight group exhibited reduced productivity and lower economic efficiency. Overall, the general improvement in traits within higher body weight classes highlights the positive effects of body weight and lay-period on egg productivity. Commercially important traits such as ESA, AQI, yolk quality index, and Haugh unit play a crucial role in determining egg quality. A fresh table egg with a large surface area, high egg weight, and excellent Haugh unit scores is likely to command a premium price in the consumer market.

Effect of 6th week body weight on egg productivity, internal, and external egg traits

Table 2 highlights the significant influence of 6th-week (42 days) body weight on daily feed intake (DFI), average body gain (ABG), feed conversion efficiency (FCE), and egg weight (EWT) (*p = 0.019-0.050; 95% CI: 2.16, 7.45, 11.66, 0.24*). ABG decreased as body weight increased, whereas DFI, FCE, and EWT (Fig. 1) reached their minimum values in the mid-weight class (131-137 g). The 6th-week body weight also significantly affected external egg traits, including egg weight (EWT), eggshell thickness (EHT), and egg surface area (ESA). These traits exhibited their lowest values at the mid-weight class (131-137 g) (*p = 0.019-0.050; 95% CI: 0.24, 1.68, 0.42*). In contrast, the eggshell index (ESI) decreased to its lowest value in the highest body weight group (138-144 g) (*p < 0.05, 95% CI: 1.31*). Table 3 further illustrates the influence of body weight on yolk height (YHT) and yolk quality index (YQI), which peaked in the 138-144 g weight class. In contrast, Haugh unit

Table 3. Effect of 6th-week body weight and lay-period on internal egg quality of *Coturnix coturnix japonica* hens in Ikole Nigeria

	Body weight (g)					Lay-period (wks)					*P*-values		
Trait	123-130	131-137	138-144	SEM	95% CI	6-8	9-11	12-15	SEM	95% CI	BWT	LP	B x L
AWT*	4.79	4.94	5.03	0.086	0.17	4.70^{a}	4.94^{b}	4.75^{ab}	0.094	0.18	*0.239*	*0.005*	*0.101*
AHT	4.13	4.10	4.26	0.083	0.16	3.79^{a}	4.02^{b}	4.71^{c}	0.089	0.17	*0.374*	*0.001*	*0.605*
APT	52.89	53.56	54.59	0.609	1.19	53.27^{b}	53.39^{b}	52.61^{a}	0.638	1.25	*0.072*	*0.050*	*0.397*
AQI	87.41	84.37	86.29	2.058	4.03	81.95^{a}	82.39^{a}	86.18^{b}	2.238	4.39	*0.707*	*0.001*	*0.050*
YCL	3.94	3.97	3.50	0.297	0.58	3.65	3.70	3.90	0.262	0.51	*0.658*	*0.599*	*0.666*
YWT	2.92	3.04	2.76	0.189	0.37	2.59	3.20	2.93	0.206	0.40	*0.708*	*0.092*	*0.953*
YHT	8.28^{ab}	8.52^{b}	8.03^{a}	0.092	0.18	8.02^{a}	8.08^{a}	8.84^{b}	0.100	0.20	*0.050*	*0.001*	*0.455*
YDM	21.93	22.04	21.99	0.139	0.27	21.99^{b}	22.69^{c}	21.20^{a}	0.218	0.43	*0.877*	*0.001*	*0.403*
YPT	32.65	32.89	30.09	1.920	3.76	29.60	34.36	31.68	2.092	4.10	*0.711*	*0.226*	*0.961*
YQI	37.45^{ab}	38.68^{b}	36.44^{a}	0.703	1.38	36.80^{a}	35.80^{a}	42.34^{b}	0.764	1.50	*0.050*	*0.001*	*0.050*
YAP	61.88	63.72	55.80	3.625	7.11	56.86	63.74	60.80	4.044	7.93	*0.514*	*0.453*	*0.901*
HUT	89.57^{a}	90.39^{b}	90.04^{b}	0.194	0.38	87.98^{a}	88.76^{a}	92.52^{b}	1.144	2.24	*0.050*	*0.050*	*0.050*

*AWT=albumen weight (g), AHT=albumen height (mm), APT=albumen percentage (%), AQI=albumen quality index (%), YCL=yolk colour, YWT=yolk weight (g), YHT=yolk height (mm), YDM=yolk diameter (mm), YPT=yolk percentage (%), YQI= yolk quality index (%), YAP=yolk albumen percent (%), HUT=Haugh unit (%), SEM=standard error of the means, BWT=body weight, LP=lay period, *P-values*=probability, *B x L*=interaction of body weight and egg lay-period
Within a column means followed by different alphabets differ significantly

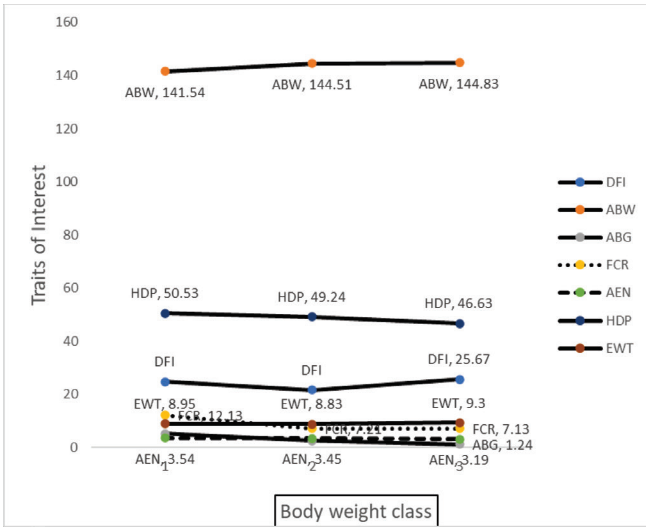

Fig. 1. Graphical representation of production traits of Quail raised in Ikole, Nigeria by body weight classes

Keys: average body weight (ABW), hen day production (HDP), daily feed intake (DFI), egg weight (EWT), feed conversion ratio (FCR), Average body gain (ABG) and average weekly egg number (AEN)

(HUT) values demonstrated a linear increase across weight classes, rising progressively from the lowest to the highest body weight group (*$p < 0.05$, 95% CI: 1.19, 0.58*).

The observed increases in daily feed intake (DFI), feed conversion efficiency (FCE), egg weight (EWT), egg weight gain (EWG), eggshell thickness (EHT), egg surface area (ESA), and albumen percentage (APT) with increasing body weight in quails indicate that the birds were provided with adequate nutrition and received progressively larger feed quantities to support their higher productivity. These increases also suggest efficient feed conversion, as the birds effectively utilized the consumed feed to improve egg production, egg weight, and egg shape and quality (Edeh *et al.*, 2020; Ekinci *et al.*, 2023). The enhanced ESA could positively influence egg quality and hatchability, contributing to better egg management for incubation in hatcheries. Additionally, the improvement in albumen percentage has implications for egg quality and its nutritional value. To maximize these gains, adjustments to feed intake, especially an upward adjustment to counteract the decline in hen-day production (HDP) at mid-body weight (131-137 g), are essential to optimize productivity and profitability. The linear decline in body weight gain and egg shape index (ESI) observed in the results reflects a gradual reduction in the growth rate of birds and egg production efficiency, with ESI values shifting toward a "sharper" shape as 6th-week body weight increased. A reduction in egg shape index below the normal range could negatively impact hatchability and market value (Duman *et al.*, 2016). Quails experiencing a linear decline in weight gain may employ compensatory mechanisms to sustain production and reproduction. These mechanisms could include alterations in egg shape, decreased energy expenditure, increased appetite, and changes in nutrient metabolism (Coutinho *et al.*, 2018). However, these adaptive strategies might result in trade-offs in egg quality. For instance, a reduction in ESI may reflect a strategic energy allocation shift to prioritize survival over egg production, possibly compromising certain quality traits (Ross *et al.*, 2021).

The reduced mid-weight values for daily feed intake (DFI), feed conversion efficiency (FCE), and egg weight (EWT) may be attributed to a slight reduction of approximately 3.16 g in feed consumption within this body weight class. This phenomenon could also result from production-related stresses. The observed reduction in hen-day production (HDP), albumen energy (AEN), egg shape index (ESI), yolk height (YHT), and yolk quality index (YQI) at higher body weights likely reflects a shift in energy and nutrient allocation toward maintenance, body reserves, and enhanced performance of traits such as EWT, eggshell thickness (EHT), egg surface area (ESA), albumen percentage (APT), and Haugh unit (HUT), facilitated by improved FCE. Interestingly, the maximum YHT and YQI values observed at mid-body weight (131-137 g) suggest this range as an optimal body weight for egg production. In contrast, the body weight of 123-130 g at 6 weeks associated with early sexual maturity (ESM) in this study is lower than the 140 g reported at 42 days by Filho *et al.* (2016). However, the age of sexual maturity aligns with the 36-42 days reported for Japanese quails (Camci *et al.*, 2002) and the 5-6 week period observed for quails receiving *in-ovo* injections of plant extracts (Al-Shammari *et al.*, 2019). Body size or weight has been shown to positively influence egg number, egg weight, and feed conversion ratio per gram of egg (FCR) (Jatoi *et al.*, 2013). Additionally, it is positively correlated with egg length (r = 0.77) but negatively correlated with albumen height (r = -0.003) and egg shape index (r = -0.73) in Japanese quails (Ojo *et al.*, 2011).

Effect of lay period on egg productivity, internal, and external egg traits

Lay-period had significant and varied effects on egg productivity traits, except for daily feed intake (DFI) and egg shape index (ESI) (*p = 0.001–0.050*) (Table 2). Average body weight (ABW) increased, while feed conversion ratio (FCR) and egg weight gain (EWG) decreased linearly across successive lay-periods (*95% CI: 1.27, 12.71, 1.22*). Average body weight gain (ABG) reached its lowest value at mid lay-period (*95% CI: 2.98*), whereas feed conversion efficiency (FCE), albumen energy (AEN), hen-day production (HDP), and egg weight (EWT) showed their highest values at mid lay-period (*95% CI: 26.59, 0.60, 3.22, 0.09*). Table 2 further reveals that lay-period had its most pronounced effects on external egg traits, with EWT, eggshell thickness (EHT), and egg surface area (ESA) peaking during the late lay-period (9-11 weeks, *95% CI: 0.10, 3.09, 0.56*). An increasing linear trend was observed for egg density mass (EDM) (*$p < 0.028$, 95% CI: 0.27*), while shell weight (SWT) and shell protein thickness (SPT) exhibited a decreasing linear trend with successive lay-periods (*$p = 0.001$-0.050; 95% CI: 0.01, 0.96*). Table 3 shows that albumen percentage (APT) and yolk dry matter (YDM) achieved maximum values during the mid lay-period (9-11 weeks, *$p < 0.050$, 95% CI: 1.25, 0.43*). However, yolk quality index (YQI) was at its lowest during the same period (*9-11 weeks, $p < 0.001$, 95% CI: 1.38*). Successive lay-periods resulted in increasing values for albumen weight (AWT), albumen height (AHT), albumen quality index (AQI), yolk height (YHT), and Haugh unit (HUT) (*$p < 0.050$, 95% CI: 0.18, 0.17, 4.39, 0.20, 2.24*).

The effect of lay-period on quail productivity is underexplored in the literature, likely due to limited research in this area. However, findings indicate that successive lay-periods contribute positively to the productivity of laying quails, improving body weight and both external and internal egg traits up to 15 weeks of age. The observed linear increases in average body weight (ABW), egg diameter mass (EDM), egg surface area (ESA), albumen height (AHT), albumen quality index (AQI), yolk height (YHT), and Haugh unit (HUT) suggest significant improvements in quail productivity, with possible positive impacts on farm profitability (Muhammad-Lawal *et al.*, 2017). The progressive increase in body weight could be linked to early high hen-day production (HDP), larger egg weights, and better bird health and welfare, all of which enhance farm profitability. The improved egg diameter and surface area are indicative of superior egg quality, which may enhance consumer acceptance (Rath *et al.*, 2015) and increase the market value of eggs. A larger egg surface area also reduces the risk of egg contamination and enhances hatchability (Kostaman and Sopiyana, 2021). Moreover, the upward trends in Haugh unit values, albumen height, and albumen quality index reflect higher egg quality, further reducing contamination risks and possibly improving egg hatchability rates. Similarly, the increasing yolk quality index not only enhances the nutritional value of eggs but also boosts consumer acceptance (Asare *et al.*, 2024).

The peak values of feed conversion efficiency (FCE), albumen energy (AEN), hen-day production (HDP), egg weight (EWT), eggshell thickness (EHT), albumen percentage (APT), and yolk dry matter (YDM) observed

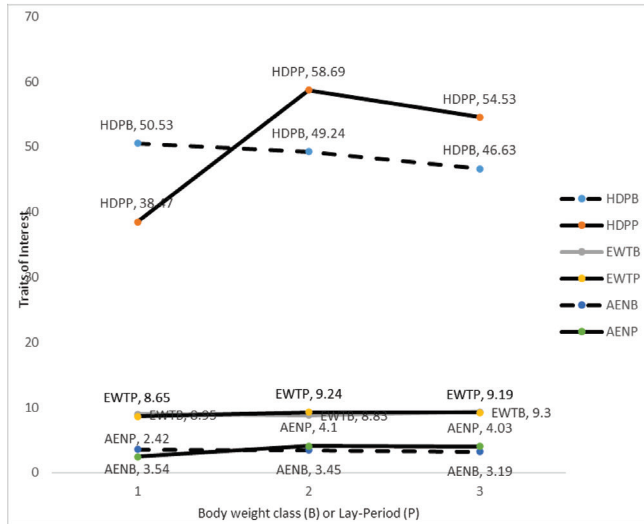

Fig. 2. Comparative effects of body weight class and lay-period on production traits of quails in Ikole, Nigeria

Keys: hen day production (HDP), egg weight (EWT), and average weekly egg number (AEN).
The fourth letter in each code indicates weight class (B) or lay-period (P).

during the mid-lay period (9-11 weeks) highlight this phase as the optimal period for performance across these traits. These findings reflect the characteristic growth (ogive) curve observed in avian species, where trait performance initially rises and plateaus as the lay period progresses (Fig. 2). The upward trend in the early period indicates a steady improvement in nearly all investigated traits, while the decline in shell percentage thickness (SPT) from the late period suggests the need for calcium supplementation starting from period 2 to support eggshell formation. The sustained improvement in FCE over successive lay periods highlights the efficient utilization of nutrients from feed, facilitating the development of key productivity traits such as average body weight (ABW), average body gain (ABG), AEN, HDP, EWT, egg diameter mass (EDM), egg surface area (ESA), albumen height (AHT), albumen quality index (AQI), yolk height (YHT), yolk quality index (YQI), and Haugh unit (HUT). These traits are crucial for enhancing egg quality, productivity, and ultimately, profitability for farmers.

The optimal values for feed conversion efficiency (FCE), egg weight (EWG), and yolk diameter (YDM) observed at 9-11 weeks align with the typical growth curve of intensive egg-producing hens. This curve is characterized by a peak in these traits during mid-lay, followed by a period of stabilization before a subsequent decline (Fig. 2). The reduction in egg weight, shell thickness (SWT), and shell percentage thickness (SPT) with advancing lay periods may be attributed to genetic factors, an increasing yolk-to-albumen ratio, and reduced nutrient mobilization. Additionally, factors such as low bone resorption, linked to calcium and bone metabolism adaptations for egg production, and the physiological stress associated with aging and egg production may contribute to these declines (Everts *et al.*, 2022). The 6-8 week period marks the onset of egg production, characterized by the lowest values for these traits, followed by improvements in feed efficiency and trait values. The observed increase in productivity traits across successive lay periods could be attributed to the enhanced daily feed intake (DFI), body weight, and feed conversion, which contribute to energy accretion and better overall performance as birds approach peak production. Furthermore, layers nearing full sexual maturity continue to grow, leading to increases in body weight, egg weight, egg diameter, hen-day production (HDP), and egg number, driven by greater feed intake and conversion during early lay periods (Davies, 2020). The final period (12-15 weeks), which coincides with the post-peak phase of egg production, was associated with a deceleration in HDP.

Quail farmers should focus on managing body weight, feed intake, and nutrition, with the goal of achieving high feed conversion efficiency (low FCR) to optimize albumen content in quail eggs. For optimal albumen weight development, farmers should aim for high hen weight at early sexual maturity (ESM) and prioritize high feed efficiency during the late lay-period (≥12 weeks). The findings of this study can guide quail farmers in optimizing their nutrition, feeding strategies, and management practices to enhance overall performance, egg production, and quality. Additionally, these insights can help farmers identify potential issues in flock management and make informed decisions based on performance records to optimize their operations.

CONCLUSION

In conclusion, the findings from the current study provide valuable insights that can help quail farmers optimize resource allocation by focusing on factors that significantly impact quail performance, egg production, and profitability. The interaction of 138-144 g body weight and lay-periods resulted in the best values for ABW, ESA, AQI, and HUT, while 131-137 g body weight by lay-periods produced the optimal EHT and YQI values. Both 6th-week body weight and lay-period independently contributed to improvements in feed conversion efficiency (FCE), egg weight (EWT), egg surface area (ESA), yolk quality index (YQI), and Haugh unit (HUT). Increases in body weight positively influenced daily feed intake (DFI), egg height (EHT), and yolk height (YHT), though it led to reductions in egg shape index (ESI) and albumen grade (ABG). Successive lay-periods generally resulted in improvements in body weight (ABW), albumen grade (ABG), albumen energy number (AEN), egg diameter (EDM), albumen weight (AWT), albumen height (AHT), and albumen quality index (AQI), while negatively impacting shell percentage (SPT) and albumen percentage (APT). The mid-lay period had a significant impact on the best values of hen-day production (HDP), egg weight (EWG), shell weight (SWT), and yolk diameter (YDM). Future research should explore lay-periods beyond week 15 to provide a more comprehensive understanding of quail production, which will further guide farmers in improving their practices for higher productivity and profitability.

Authors' contribution

Conceptualization and designing of the research work (JOMA); Execution of field/lab experiments and data collection (JOMA); Analysis of data and interpretation (JOMA); Preparation of manuscript (JOMA); Proof-reading of manuscript (AKL, OSO), Editing of manuscript (JOMA, AKL).

Conflicts of interest

The authors declare that they have no conflicts of interest, whether financial, personal, or otherwise, related to any individuals or organizations involved with the material discussed in this manuscript.

Acknowledgements

No financial support was received for this project. The authors acknowledge the valuable contributions of Miss Grace Falade, who meticulously recorded all experimental data.

LITERATURE CITED

Al-Shammari K, Batkowska J, Drabik K and Gryzinska K 2019. Time of sexual maturity and early egg quality of Japanese quails affected by *in ovo* injection of medicinal plants. *Arch Anim Breed* **62**: 423-30. https://doi.org/10.5194/aab-62-423-2019

Anene D, Akter Y, Thomson P, Groves P and O'Shea C 2020. Variation and association of hen performance and egg quality traits in individual early-laying ISA brown hens. *Animals* (Basel) **10**(9): 1601. https://dx.doi.org/10.3390/ani10091601

Asare B K, Achaglinkaime M A, Sam F E, Atuna R A and Amagloh F K 2024. Yellowness of egg yolk influences consumer preference for eggs in Ghana. *Int Food Res J* **31**(2): 486-95.

Ashour A, Badwi Y and Abd El-karim R 2015. Effect of selection for body weight on egg production, egg quality, fertility and hatchability traits in El-Salam chicken strain in Egypt. *J Animal Poultry Prod* **6**(12): 781-96.

Aviagen 2020. Flock management tips for breeders: Uniformity of sexual maturity. The Poultry Site. www.thepoultrysite.com/articles/flock-management

Bagh J, Panigrahi B, Panda N, Pradhan C, Malik B, Majhi B and Rout S 2016. Body weight, egg production and egg quality traits of gray, brown and white varieties of Japanese quail *(Coturnic coturnix japonica)* in coastal climatic condition of Odisha. *Vet World* **9**(8): 832-36. https://dx.doi.org/10.14202/vetworld.2016.832-836

Bourin M, Travel A, Souchet C, Bernard J, Ledru E, Bernardet N, Jimenez J, Chesse M, Rehault-Godbert S and Guyot N 2022. Effects of lengthening the laying period of laying hens on egg quality. Abstracts, 26th World Poultry Congress, Aug 7-11, 2022, Paris, France.

Camci O, Erensayin C and Aktan S 2002. Relations between age at sexual maturity and some production characteristics in quails. *Archiv Geflug* **66**(6): 280-82.

Chang A 2021. The importance of nutrition on egg shell quality. The Poultry Site. https://www.thepoultrysite.com/the-importance-of-nutrition-on-egg-shell-quality-in-broiler-breeders-1

Coutinho S R, With E, Rehfeld JF, Kulseng B, Truby H and Martins C 2018. The impact of rate of weight loss on body composition and compensatory mechanisms during weight reduction: A randomized control trial. *Clin Nutr* https://dx.doi.org/10.1016/j.clnu.2017.04.008

Davies J 2020. Four key management factors influencing egg size. Farmers Weekly. 18th March, 2020. https://fwi.co.uk/livestock/livestock-feed-nutrition/4-key-poultry-management-factors-influencing-egg-size (accessed October 2022).

DSM (Dutch State Mines/Roche) 2022. DSM egg quality manual. https://www.dsm.com/content/dam/dsm/anh/en/documents/dsm-egg-quality-manual.pdf

Duman M, Sekeroglu A, Yildirim A, Eleroglu H and Camci O 2016. Relation between egg shape index and egg quality characteristics. *Eur Poult Sci* 80. https://dx.doi.org/10.1399/eps.2016.117

Dumoulin P G 2019. The importance of body weight management. Hendrix genetics, https://layinghens.hendrix-genetics.com/en/articles/importance-body-weight-management/

Edeh H O, Osita C O, Nwoga C C, Ani A O and Okwor J 2020. The effect of bodyweight variation on laying performances of Shaver brown hen in humid tropical environment. *Nig J Anim Sci* **22**(1): 83-90.

Ekinci O, Esenbuga N and Dagdemir V 2023. The effects of body weight and age on performance, egg quality, blood parameters and economic production of laying hens. *J Hell Vet Medical Soc* **74**(2): 5799-5806. https://dx.doi.org/10.12681/jhvms.30324

El-Tarabany M 2016. Effect of thermal stress on fertility and egg quality of Japanese quail. *J Therm Biol* https://dx.dor.org/10:1016/j.jtherbio.2016.08.004

Everts V, Jansen I and de Vries T 2022. Mechanisms of bone resorption. *Bone* **163**: 1-7. https://dx.doi.org/10.1016/j.bone.2022.116499

Filho J, Garcia E, Molino A, Antonio dos Santos T, Paz I and Baldo G 2016. Productivity of Japanese quails in relation to body weight at the end of the rearing phase. *Maringa* **38**(2): 212-17. https://dx.doi.org/10.4025/actascianimsci.v38i2.29858

Hyline 2024. Optimuzing egg size. Hyline Technical Update. https://www.hyline.com-body-weight-and-flock-uniformity-is-important

Jatoi A, Sahota A, Akram M, Javed K, Jaspal M, Hussain J, Mirani A and Mehmood S 2013. Effect of different body weight categories on the productive performance of four close-bred flocks of Japanese quails (*Coturnix coturnix japonica*). *JAPS* **23**(1): 7-13.

Jesuyon OMA, Aganga A, Orunmuyi M and Falade G 2021. Effect of dietary protein level on egg production and egg-quality characteristics of Japanese quail (*Coturnix coturnix japonica*) in the tropical environment. Special Issue. *Anim Prod Sci* https://doi.org/10.1071/AN20399

Kostaman T and Sopiyana S 2012. The weight and hatchability of quail egg viewed from the weight, index and surface area of the egg. 3rd International Conference of Animal Science and Technology. IOP Conference Series: Earth and environmental Science **788**: 012128. https://doi.org/10.1088/1755-1315/788/1/012128

Muhammad-Lawal A, Amolegbe K B and Abdulsalam O A 2017. Economics of quail production in Ilorin, Kwara State, Nigeria. *J Agric Ext* **21**(2): 44-53.

Nematinia E and Mehdizadeh S 2018. Assessment of egg freshness by prediction of Haugh unit and albumen pH using an artificial neural network. *Food Measure* **12**: 1449-59. https://doi.org/10.1007/s11694-018-9760-1

Noble N 2022. Five key areas that can optimize feed efficiency in layer flocks. Farmers Weekly Magazine, https://fwi.co.uk/livestock/poultry/5-areas-that-optimise-feed-efficiency-in-layer-flocks (accessed in October 2022).

Ojo V, Ayorinde K and Fatoki H 2011. Relationship between body weight and some egg production traits in the Japanese quail (*Coturnix coturnix japonica*). *Nig Soc Exp Biol* **11**(1): 89-94.

Onunkwo D and Okoro I 2015. Predicting egg quality and egg production traits using egg weight and body weight respectively in three varieties of helmeted guinea fowls in humid tropics. *Int J Livest Res* **5**(3): 111-21.

Paganelli C, Olszowska A and Ar A 1974. The avian egg: Surface area, volume, and density. *The Condor* **76**: 319-25.

Rath P K, Mishra K P, Mallick B K and Behura N C 2015. Evaluation of different egg quality traits and interpretation of their mode of inheritance in White Leghorns. *Vet World* **8**(4): 449-52. https://dx.doi.org/10.14202/vetworld.2015.449-452

Ross J G B, Newman C, Buesching C D, Connoly E, Nakagawa S and Macdonald D W 2021. A fat chance of survival: Body condition provides life-history dependent buffering of environmental change in a wild mammal population. *Climate Change Ecol* **2**: https://doi.org/10.1016/j.ecochg.2021.100022

Samiullah J, Roberts R and Chousalkar K 2014. Effect of production system and flock age on egg quality and total bacterial load in commercial laying hens. *J Appl Poult Res* **23**: 59-70. http://dx.doi.org/10.3382/japr.2013-00805

SAS/STAT 2013. Statistical Analytical Systems software® v 9.4, SAS Institute Inc., N.C., USA.

Singh A and Kim W 2021. Effects of dietary fiber on nutrient utilization and gut health of poultry: A review of challenges and opportunities. *Animals* (Basel) **11**(1): 181. https://dx.dor.org/10.3390/ani11010181

Suawa E 2015 Body weight, flock uniformity, production performance and egg quality over the laying period of brown egg-laying hens. PhD Thesis. https://hdl.handle.net/1959.11/21655

Viswanathan K, Priyadharshini M, Nirmala K, Raman M and Raj G 2016. Bacteriocidal paper trays doped with silver nano-properties for egg storing applications. *Bull Mats Sci* **39**(3): 819-27. https://dx.dor.org/10.1007/s12034-016-1202-2

Wang G, Kim W K, Cline M A and Gilbert E R 2017. Factors affecting adipose tissue development in chicken: A Review. *Poult Sci* **96**: 3687-99. https://dx.doi.org/10.3382/ps/pex184

Yan H, Nova P, Adrizal A and Mahata M 2020. The response of laying hens fed fermented pineapple peel waste by indigenous microorganism from bamboo sprout. RBSPA **21**(1-8), e2121372020, https://doi.org/10.1590/S1519-99402121372020