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Relationship among productivity and egg traits in the Japanese quail hen

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ABSTRACT

The influence of the 6th week body weight (point of lay) and lay-period on the relationship among egg production and egg quality traits was investigated in *Coturnix coturnix japonica* (Japanese quail) hens. One hundred and eighty quail birds at six weeks were randomized into three body weight groups (123-130, 131-137, and 138-144 g), each consisting of six replicates of 10 birds per replicate. The body weight groupings interacted with three lay periods to give a 3 x 3 factorial treatment design. All replicates were fed common diets from the 6th week to 15th week. Daily feed intake (DFI), average body weight (ABW) average egg weight (AEW), hen day egg production (HDP), feed conversion ratio (FCR), albumen weight (AWT) and yolk weight (YWT) were recorded throughout the experiment by standard experimental procedures. Data were analyzed with the Multiple Linear Regression (MLR) procedures of SAS. Standardized regression analyses revealed significant and positive relationship between DFI/AEW (b=0.819, R^2= 0.615, P=0.001) in the 138-144 body weight group; positive relationship between AWT/AEW, ABW (b=0.671-1.514, d=0.119-0.269, $R^2 \geq 0.671$, P=0.001) in all body weight groups and lay periods; and a negative relationship between HDP/FCR, AEW (b= -0.791 to -1.373, d= -0.222 to -0.624, $R^2 \geq 0.827$, P=0.001) in the last two body weight groups and lay periods respectively. The relationship between daily feed intake and egg weight was positive in mid body weight. Albumen weight/average egg weight and average body weight were positively related, but hen day production/feed conversion ratio, and average egg weight, albumen weight and feed conversion ratio were negatively related._These relationships are of practical importance for management, breeding and improvement of quail production traits.

Keywords: Regression; body weight; lay-period; feed intake; feed conversion

INTRODUCTION

Quail farming requires low investment, less labour, small space requirement due to small size and easy management compared to other poultry types. Quail birds are highly productive, strong and disease-resistant than other poultry birds (Nain *et al.*, 2011). Quail farming is becoming popular in Nigeria due to economic advantages in start-up requirement, excellent nutritional profile of the egg and meat, and affordability to low-income earners (Jesuyon *et al.*, 2021).

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Egg production in poultry is highly influenced by body weight (Ashour *et al.,* 2015) and age-related factors such as physiological age, stage-of-lay or lay-period (Bourin *et al.,* 2022). Since sexual maturity is achieved early in laying quails, the body weight and age at sexual maturity is important for commencement of lay at the earliest possible period. The achievement of the required body size and weight could be influenced by adequate brooding, nutrition and feeding level; optimum environmental condition, body weight uniformity, good genetics, species, season, hormonal secretion level, light duration and intensity (Personal communication). The body weight at sexual maturity age and start of lay significantly influences egg weight (Filho *et al.,* 2016). High and uniform body weight influence flock early and pre-peak egg production, while more uniform flocks exhibit higher egg production than less uniform flocks (Suawa, 2015). To begin egg production at early sexual maturity (ESM), laying quails should attain appropriate and uniform body weight during growth or rearing period (Aviagen, 2020). The body weight of Japanese quail at 6 weeks of age was reported as 168-174 g/bird (Bagh *et al.,* 2016). Body weight uniformity in laying poultry further influences fertility, the magnitude of egg production, uniformity and hatchability of the eggs (Suawa, 2015).

Laying period in poultry refers to phases or stages of the egg production cycle. It exerts an effect different from that of age, and the knowledge of events in the lay periods could point to possible interventions that may be required as egg lay fluctuates during the egg production cycle. After peak egg lay, egg number decreases, but egg weight, egg yolk and feed consumption increase with body weight (Anene *et al.,* 2020). Studies on the effect of lay period on quail productivity is limiting in literature. The purpose or objective of this study was to study specific relationships among daily feed intake, average egg weight, hen-day egg production, FCR to egg, albumen weight and yolk weight; among different weight groups and lay-periods rather than age groups, from sexual maturity point onward. The research hypotheses are that there will be significant relationship between (a) feed intake and egg weight, (b) hen day egg production and feed conversion (c) albumen weight and egg traits.

MATERIALS AND METHODS

The Experimental Site

The experimental site was the Teaching and Research Farm of the Federal University Oye-Ekiti, Ikole Campus located on GPS coordinates: latitude 07°48.338´ N, longitude 05°29.922´ E; Global Positioning System, GARMIN GPS 72H, with mean daily temperature, humidity ranges, rainfall and altitude of 21.7–31.1°C, 72–78%, 177.8 cm/annum and 460 MSL.

Quail Management

Two hundred and fifty-two (252), 3-week-old, mixed-sexed *Coturnix Coturnix Japonica* **(**quail) birds, sourced from the National Veterinary Research Institute, Vom, Ikire Out-station, Osun State, Nigeria, were used for the experiment. Prior to stocking, the house and cages were cleaned and disinfected, and cages laid with wood shavings as bedding-material which was replaced weekly.

On arrival of chicks, glucose in water (15g/litre) was administered orally to birds for replenishment of energy. Chicks were housed initially at 15 birds/cage (size = 75 × 48 × 45 cm^3). Birds were adjusted to the new environment till 6th week of age. Breast plumage colouration was used at 6th week to cull the males from the flock. Quail birds were subsequently weighed with the digital sensitive balance (Model: Emperors_EK5350, Camry, Zhongshan, China, 500 g capacity, 0.1 g sensitivity), grouped into three weight classes (123-130g, 131-137g, 138-144g) to improve their body weight uniformity, and randomly assigned to six replicates within body weight group with 10 birds per replicate. The aforementioned weight groups thus interacted with lay periods (6-8, 9-11, 12-15 weeks) as they advanced in egg production to give a 3 x 3 factorial treatment structure.

From weeks 3 to 6, birds were placed on a high-profile chicks' starter diet with standard energy, dietary protein, fat, calcium, lysine, methionine and available phosphorus of 2664.5 kcal/kg ME; 24.0, 5.06, 1.5, 1.06, 0.55, 0.48 (%) respectively. Routine management practices of feeding, provision of water, cleaning and egg collection were conducted uniformly in all replicates from the 6^{th} to 15^{th} week of age. From the sixth week onward, all birds were fed a compounded layer mash diet which provided 2864.5 kcal/kg ME, 18, 7.21, 3.13, 0.96, 0.45 and 0.42 (%) for stated nutrients respectively. Birds were offered feed at 30g/bird during the laying period.

Traits Measured

Production data collected on each replicate weekly were daily feed intake (g), average body weight (ABW, g), average egg weight (AEW, g), hen day egg production (HDP, %), FCR to egg (FCR_{egg}), albumen weight (ALW, g) and yolk weight (YWT, g). The equipment and tools used were digital weighing balance (500 g capacity, 0.1 g sensitivity, Model: Emperors_EK5350, Camry, Zhongshan, China), digital Venir calliper (0.01 mm sensitivity, Bombay Pvt Ltd., India) and micrometre screw gauge for measurement of egg traits.

Experimental Design

Quails were assigned to uniform weight groups at the beginning of sixth week (early sexual maturity age) to study effect of body weight groups on egg production. 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 relationships between production and egg traits in quails. The completely randomized design (CRD) in a 3 x 3 factorial treatment was adopted for the experiment.

Statistical Analysis

The regression model adopted 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 or lay-period or dependent trait of interest (daily feed intake, g, hen-day egg production, % and albumen weight, g), a = intercept or constant, while b, c, d = power or coefficients of traits of interest (or predictor traits), $X_{1\text{-}3}$, = predictor traits of interest (egg weight, g, FCR, average body weight, g, egg number, yolk weight, g) of the dependent trait Y.

RESULTS

Relationship of Daily Feed Intake with Egg Weight

Table 1 shows the standardized regression equations of DFI on egg weight. Several traits were tested but only egg weight (possessed the required strong variability or had a p-level less than 0.05) was statistically qualified to enter into the regression equations. For body weight classes, the intercepts were 69.96, 19.85, 0.13g, in the lowest, medium and upper body weight classes of 123-130, 131-137, 138-144 g respectively. The coefficient, b, of egg weight revealed a reverse trend, to that of the intercept by increasing from -0.47, 0.17 to 0.82 unit in the lowest, medium and upper body weight classes respectively. The equations for the lowest and upper weight classes, 123-130, and 138-144, g, were significant ($P<0.05$) but only the upper body weight class produced practically important and strong relationship between DFI and EWT ($R^2 = 0.62$, SEE= 7.30).

The equation for lay-periods showed a different trend from above. The mean value of intercept, a, increased, peaked and declined from 18.99, 83.31 to 69.55g to produce a near ogive shape between consecutive periods. The coefficients of egg weight however declined from 0.11, -0.59, to -0.49 respectively, between lay periods. The equation for the early lay period of 9-11 and 12-15 weeks were highly significant ($P<0.05$) and produced the higher SEE (10.56, 12.09 and 17.70) with stable VIF at 1.00 and but higher DW statistics ranging from 1.04 to 2.23.

Relationship of Hen Day Egg Production with Feed Conversion Ratio, Body Weight, and Egg Weight

Table 2 reveals the standardized regression of HDP on FCR_{egg} and ABW (or AEW). The intercepts display a normal bell-shape pattern for basal or average HDP (-86.72, 193.37, 93.23, units) for the weight classes, and increasing feed efficiency (decreasing FCR= -0.39, -1.37, -0.99) with lowest middle value, as body weight increased. Also, average HDP (-62.45, 181.55 and 143.49) produced similar ogive shape, while feed efficiency increased (decreased FCR_{egg} -0.39, -0.77, -0.84:) with successive lay-period. This brought about slight improvement of AEW from mid lay-period (-0.29 to -0.22 g) onward. Within both factors, increased egg weight contributed to HDP from mid body weight and mid lay-period onward. The VIF was stable (1.1-1.0), while R^2 improved from 0.31 to 0.83 at the late lay period.

Relationship of Albumen Weight with Egg, Yolk and Body Weights

Table 3 shows the standardized regression equations of albumen weight on egg weight, yolk weight, body weight (or FCR). From low to high body weight class, basal AWT decreased to a minimum at mid body weight and then increased (-3.43, -7.48, -1.06), AEW decreased while ABW of quails increased (0.12 - 0.27). Similarly, successive lay-period revealed lowest mid-value for basal AWT (-0.96, -1.29, -0.38), as the YWT decreased in values (-0.27, -0.32, -0.78); but AEW increased (0.87, 1.03, 1.51) from early to late lay-period. The late lay-period (12-15-week) also revealed a complementary improvement in feed efficiency (decreased in FCR). All equations were significant (P <0.05, R^2 >0.67 - 0.85, VIF >1.0, DW =1.2 - 2.76).

Table 1: Standardized regression equations for daily feed intake on egg weight in *coturnix coturnix japonica* hens raised in Ikole Nigeria

Regression model: $Y = \alpha + bX_1 + \mathcal{E}$

Y=DFI (g), a=class/period constant, b= egg weight coefficient, X_1=egg weight (EWT, g), $\mathcal{E}$= Standard error of estimate

Model Parameters			*A*	*b*	*SEE*	*T*	*Sig*	*VIF*	*SEE*	*Adj. R^2*	*P-value*	*DW*
DFI, g	BWT class	123-130 g	69.961	-0.471	10.020	12.69	0.001	1.00	10.020	0.212	0.001	0.613
		131-137 g	19.851	0.170	3.440	7.07	0.522	1.00	3.440	-0.037	0.522	1.236
		138-144 g	0.126	0.819	7.268	3.51	0.013	1.00	7.270	0.615	0.013	1.451
DFI, g	Period of Lay	6–8 wks	18.998	0.110	10.560	2.580	0.569	1.00	10.560	-0.025	0.569	1.203
		9–11 wks	83.308	-0.590	12.096	5.374	0.001	1.00	12.096	0.336	0.001	1.041
		12-15wks	69.548	-0.485	17.705	7.190	0.009	1.00	17.700	0.205	0.009	1.712

NOTES: DFI=average daily feed intake (g), *SEEp=standard error of parameter, t=T-statistics, Sig.=significance of parameters in equation, VIF=variance inflation factor, $\mathcal{E}$=SEE=standard error of estimate, Adj. R^2=adjusted R-squared, P-value=significance of equation, DW=Durbin-watson statistics.*

Table 2: Standardized equations by stepwise method for hen day egg production in *coturnix coturnix japonica* hens raised in Ikole Nigeria

Model: $Y = \alpha + bX_1 + cX_2 + \mathcal{E}$

Y=HDP (%), α=class/period constant, b=coefficient of FCR to egg, c= coefficient of ABW/AEW (g), X_1=FCR to egg number, X_2=ABW/AEW (g),

Model Parameters			a	b	c	CSE	T	Sig	VIF	SEE	Adj. R^2	P-value	DW
HDP, %	BWT class	123-130 g	-86.718	-0.385	0.374 (ABW)	32.532	4.409	0.001	1.155	15.361	0.382	0.001	1.543
		131-137 g	193.374	-1.373	-0.624 (AEW)	30.343	-9.566	0.001	2.955	5.353	0.867	0.001	1.105
		138-144 g	93.228	-0.986	-	3.757	-14.572	0.001	1.000	1.322	0.968	0.001	1.938
HDP, %	Period of Lay	6 – 8 wks	-62.451	-0.391	0.328 (ABW)	42.505	-2.920	0.006	1.124	16.942	0.314	0.001	2.496
		9 – 11 wks	181.548	-0.791	-0.294 (AEW)	15.391	-15.397	0.001	1.144	3.839	0.873	0.001	1.530
		12-15 wks	143.487	-0.843	-0.222 (AEW)	22.093	-10.276	0.001	1.048	4.255	0.827	0.001	1.856

NOTES: HDP=hen day production (%), BWT=body weight, ABW=average body weight (g), AEW=average egg weight (g), FCR=feed conversion to egg number, α=overall mean, CSE=cumulative standard error of parameters, t=T-statistics, Sig.=significance of parameters in equation, VIF=variance inflation factor, Ɛ=SEE=standard error of equation, Adj. R^2=adjusted R-squared, P-value=significance of equation, DW=Durbin-watson statistics.

Table 3: Standardized regression equations of albumen weight on egg and body weight or feed conversion ratio in *coturnix coturnix japonica* hens raised in Ikole Nigeria

Regression model: $Y = \alpha + bX_1 + cX_2 + dX_3 + \mathcal{E}$

Y= AWT (g), α= class/period constant, b, c, d =coefficients of parameters, X_1= Average egg weight (AEW, g), X_2=yolk weight (YWT, g), X_3=average body weight (ABW, g) / Feed conversion ratio (FCR)

Model Parameters			a	b	c	d	CSE	T	Sig	VIF	SEE	Adj. R^2	P-value	DW
AWT, g	BWT	123-130 g	-3.435	1.056	-0.427	0.119 (ABW)	1.398	-6.142	0.001	1.660	0.343	0.747	0.001	2.266
	class	131-137 g	-7.475	0.911	-	0.269 (ABW)	0.756	9.020	0.001	1.008	0.288	0.838	0.001	1.837
		138-144 g	-1.06	0.671	-	-	1.411	4.954	0.003	1.000	0.399	0.771	0.003	1.167
AWT, g	Period	6-8 wks	-0.961	0.872	-0.272	-	1.175	7.693	0.001	1.094	0.436	0.671	0.001	1.358
	of Lay	9-11 wks	-1.292	1.029	-0.319	-	0.698	12.577	0.001	1.546	0.348	0.762	0.001	1.838
		12-15wks	-0.383	1.514	-0.778	-0.183 (FCR)	0.742	10.194	0.001	4.175	0.247	0.852	0.001	2.759

NOTES: AWT=albumen weight (g), BWT= body weight, ABW=average body weight (g), AEW=average egg weight (g), YWT=yolk weight (g), FCR=feed conversion to egg, CSE=cumulative standard error of parameters, t=T-statistics, Sig.=significance of parameters in equation, VIF=variance inflation factor, Ɛ=SEE=standard error of estimate, Adj. R^2=adjusted R-squared, P-value=significance of equation, DW=Durbin-watson statistics.

DISCUSSION

Among all the variables considered for the relationship of DFI on egg weight, only "egg weight" had a significant impact on DFI (α=0.05). This implies that "egg weight" is a useful predictor of DFI, and its inclusion in the model equation could help explain the variation in the response variable, DFI. The model attempts to quantify the contribution of egg weight to the variability in daily feed consumption, or vice versa, of the quail birds. Among body weight classes, only the upper weight class was important for practice (R^2 =0.61), where a 2.5unit change in DFI was needed to bring about a 1unit change in the egg weight. While the model reveals a genetic or innate decline in the body requirement for feed consumption at higher body weight (decreasing intercept), the hens also displayed increased feed consumption (-41.99, 1.96 and 20.91g) for an egg of similar weight (8.5g) probably principally for maintenance and egg production, from the low to highest weight classes. It is important to raise quails to a high body weight before point of lay to reap the benefit of high egg weight in lay. To produce heavier eggs, apart from genetics, breed or strain, managers should target high body weight for quail pullets at mature body weight (131-137g and 6 weeks) to guarantee mature body frame and the right body composition. A monitored increase in feed intake after mature body has been reached, provision of extra methionine in feed during peak egg-lay for increased egg weight and possibly high linoleic acid supplementation (soyabean) without increasing energy content of feed are management techniques being employed to promote higher egg weight in birds (Mavromichalis, 2013). Offering a balance diet, providing calcium supplementation for strong eggshell and reproductive health, and reduction of stress also contribute to large egg size in birds (Phoenix, 2022).

In contrast, a one-unit change in egg weight produced 0.11, -0.59 to -0.49 units change in average DFI from early, to mid and late lay-periods respectively. But the body requirement for feed (intercept) increased rapidly to a peak at mid-lay period and declined in the late lay-period. Although this is in line with egg production characteristic, it might also be due to increased egg mass production (egg number and weight) from early to late-lay period, as the body compensates lower egg production after peak egg production with high egg weight. The model also revealed that actual feed consumption was high in the early but decreased with successive period to late lay (0.94, -5,19 and -4.12g for an egg of 8.5g). This scenario pictures an increasing feed conversion to egg weight with successive lay-period. This high feed conversion efficiency to egg weight could also be attributed to increasing age, good body frame development, adequate nutrition, breed, climate and housing, vaccination schedules and disease control measures (Thiele, 2025). The regression model thus revealed a direct relationship between daily feed intake and egg weight and the importance of adequate feeding level and management for optimum egg weight in laying quails.

At the lower and mid-weight (123-130, 131-137g) feed intake, growth, body frame development, body composition changes, increasing egg production rate, maintenance, heat increment activity were at high rate, thus making higher demand on the nutrient supply, but these physiological changes declined after peak egg lay, from mid- to late-lay period, and with age. The decreased physiological needs give room for higher feed conversion in the late lay-period with time. Thus, the need for adequate and controlled feed management to prevent excess fat deposition which could impede egg lay. This management practice also matches egg productivity with feed offered for economic gains.

The effect of body weight on the equation of HDP on FCR_{egg} and ABW or AEW reveals that high feed conversion ratio to egg and body weight were important at lower body weight and at early stage of egg production (6-8 weeks) for onset and sustainability of egg-laying, but egg weight becomes important at mid-body weight and mid-lay period onwards. This reveals a positive relationship between HDP and ABW at early production stage (Ashour *et al.,* 2015), but the contribution of ABW to HDP decreased while the contribution of AEW to HDP increased with increasing body weight. The coefficients of FCR_{egg} revealed an ogive pattern signalling improvement in feed conversion efficiency to egg from low to mid-body weight which began to decrease at late body weight. The effect of lay-period produced an ogive genetic pattern similar to that of the egg production curve, but FCR_{egg} decreased relatively. The hen weight was important for on-set of egg lay (early lay period), but the egg weight became important for sustainability of egg production and probably persistency from the mid-lay period onward. The high innate ability (intercept) for egg production and high feed efficiency displayed by hens at mid-body weight and mid lay period could have been the cause of the observed increases in HDP onward which ensured high and optimum egg-lay intensity in birds. This high HDP could be sustained for a period with high density energy-feeds at appropriate level, to cope with physiological and nutrient demand for egg laying, body repair and maintenance (Bain, *et al*., 2016). Because HDP was initially influenced by average body weight at ESM point (0.37 unit), the fulfilment of the requirement for optimum body weight and high body-weight uniformity is vital to optimize HDP and egg-weight (Abbas *et al.,* 2010). Subsequent hen-laying ability from mid-body weight and mid lay-period onward was dictated by increases in egg weight.

The scenario requires a balance of nutrition and feeding level to match-up with egg production level for optimization. The decreased VIF and DW values signified that multicollinearity among regressors and autocorrelation among residuals decreased at higher body weights and with successive lay-periods. Thus, predictability and efficiency of HDP equations improved (R^2 =0.31-0.97) with higher body weight and successive lay-period, than at early body weight and lay-period.

The effect of body weight and lay-period on the relationship of albumen weight to egg weight, yolk weight, body weight and feed conversion to egg, depicted an interesting and complex dynamics. As body weight increased, the genetic ability for average albumen weight decreased to a minimum at mid body-weight and at mid-lay period and increased subsequently. While the contribution of AEW to ALW decreased from low to high body weight, its contribution to ALW increased from early lay to late lay period. This meant that at constant body weight, between periods, average egg weight increases, but the yolk weight decreases with attendant high feed conversion to egg at late period. The contribution of the yolk weight to albumen weight differs, while yolk weight contributes little to albumen weight between body weight groups, it decreases contribution to albumen weight between lay-periods. The body weight of quail hen contributes highly to the variability for high albumen weight from low to high body weight, but only feed conversion ratio influenced albumen weight at late lay-period. The low innate values (intercept) for albumen weight at mid-body weight and mid-lay period could be due to production and nutritional stresses resulting from high demand on dietary protein for albumen formation, maintenance and heat increment, (Moran, 1987) and especially the dietary amino acid isoleucine which could be limiting in supply through the feed due to the high nutritional stress or due to poor quality feed supply; but the use of natural plant products in feed has been found to improve albumen quality and its ovomucin content (Obianwuna *et al.,* 2022). Other factors affecting albumen weight include nutrition, age in lay, body weight and breed (Peebles *et al*., 2000, Congjiao *et al*., 2019; Kirikci *et al*., 2007, Bekele *et al*., 2022). The improved innate ability (intercept), AEW and FCR_{egg} combined positively to influence AWT at the third lay-period in quail. The relationship between AWT and AEW was positively influenced at the late lay-period by the improvement in feed efficiency (low FCR). It thus appeared that adequate body weight, high egg weight and feed conversion efficiency are important factors for improving albumen weight in quails. Findings also show that egg weight decreased relative to improving hen weight but increased between successive lay-periods while feed efficiency improved (FCRegg decreased). The low ranges of SEE and high R^2 meant that regressed equations were highly efficient in describing the relationship among investigated traits. Thus, improvement in albumen weight could be obtained through targeting high body and egg weight at ESM age and high feed efficiency at late lay-period. Egg size is influenced by management during rearing, dietary protein, methionine, linoleic acid content in early diet (Davies, 2020). Biological factors such as genetics, age in lay (physiological) and body weight contribute to development and maintenance of optimum egg traits in quails. For optimum albumen weight development, high hen weight at ESM and high feed efficiency at late lay-period (≥12 weeks) are required.

CONCLUSION

The relationship between daily feed intake and egg weight was positive in mid body weight, also albumen weight/average egg weight and average body weight were positively related; but hen day production/feed conversion ratio, and average egg weight, albumen weight and feed conversion $ratio_{egg}$ were negatively related.

Managers and farmers should offer adequate quantity and quality of feed for improved egg weight; and implement management techniques that improve feed conversion ratio for a positive influence on hen day production of laying quails. Techniques to improve yolk weight, pullet weight and feed conversion could greatly improve the albumen weight.

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