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Age effect on quality traits of breeder Japanese quail eggs

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ABSTRACT

The experiment explored the effect of age on the quality traits of breeder Japanese quail eggs. 204 eggs were sampled at 68 eggs/week in a Completely Randomised Design that involved 17-, 21- and 25-week-old quails. Data were analyzed with the one-way Analysis of Variance, Pearson Correlation and Best All-subset Regression Analyses in Minitab 18 at 5% significance level. Shell weight was significantly heavier ($p < 0.05$) in the youngest quails than in the older groups. Albumen height and Haugh unit were significantly highest ($p < 0.05$) in the 21-week-old quails. Egg weight associated positively and highly with egg length in the younger quails at weeks 17 and 21 but positively low in the oldest quails. Egg weight related positively and highly with egg width in the younger birds at 17 and 21 weeks. However, egg weight and egg width related moderately and positively in the 25-week-old quails. The overall best predictors of egg weight were egg length, egg width, albumen weight and yolk weight at $R^2 = 95.6\%$ in the 17-week-old birds. Quality traits of breeder eggs and their relationships vary with layers age and quails that are 17 weeks old are most suitable for breeding purposes. However, management of breeder quails that are beyond 17 weeks old must be improved to enhance the quality of their eggs for hatching purposes.

Keywords: Age; breeder eggs; correlation; egg quality; Japanese quail; regression

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Introduction

Long ago, the quail bird had been raised in the East and Southeast Asia for sports, music and decoration (Lukanov & Pavlova, 2020). In recent times, they may be raised as productive or laboratory creatures (Minvielle, 2004; Lukanov *et al*., 2018a; Pavlova *et al*., 2018). Their popularity across the globe nowadays may be chiefly related to the quality of their meat and eggs, which make these products more expensive than chicken products (Ayoola *et al*., 2014). The protein in quail eggs is hypoallergenic (Benichou *et al*., 2014) and so they are considered suitable for people who are allergic to chicken eggs. Meanwhile, to meet the increasing demand for the birds' products and to enhance their inclusion in the poultry business, their biology must be improved to increase the quantity and quality of breeder eggs that they lay; to ensure high hatchability throughout their laying phases. This would warrant enough quail chick production for supply to farmers, and sustainability of the hatchery and quail industries.

Notwithstanding these, it is known that the age of birds affects egg quality traits and their relationships (Rizzi & Marangon, 2012; Shafey *et al*., 2015) and these could in turn affect fertility and hatchability of eggs (Kruenti *et al*., 2022). In this regard, if layers are to improve egg production and hatchability, emphasis must be put on how quality traits of breeder eggs relate and how the associations can be affected by the age of layers. Not only has this been extensively studied in other poultry species (Yousif & Eltayeb, 2011; Bernacki *et al*., 2013; Kgwatalala *et al*., 2016; Ebegbulem & Ayuba, 2017; Markos *et al*., 2017). There is also little knowledge (Kruenti, 2020) on the subject in West Africa and on the Japanese quail (Kul & Seker, 2004) with most of them focusing on table eggs. This study seeks to investigate the effects of age on the quality traits of breeder Japanese quail eggs and their relationships. Breeders will use the knowledge as a guide when selecting quails to improve egg quality for both hatchery operations and consumption.

Materials and Methods

Experimental site and design

The experiment was carried out at the Quail Section of the Animal Research Institute of the Council for Scientific and Industrial Research, located in the Adentan Municipality of Accra, Ghana. The eggs were stored and analysed at the hatchery unit of the institute using the completely randomised design in a single factor experiment that involved Japanese quails that were 17, 21 and 25 weeks old. A total of thirty (30) Japanese quails (20 females and 10 males) were randomly put into two groups at a recommended mating ratio of one male to two females (Woodward & Abplanalp, 1967; Cheng *et al*., 2010). 17 non-cracked eggs were picked from each group at random to make 68 eggs per week and a total of 204 eggs.

Management of birds

The birds were kept as a breeder flock under the same management when they were 9 weeks old until they were separated into the two groups for this experiment. Each group was kept in a labeled slated floor cage – both enclosed in an opened-sided shed to avoid escape. The length and width of the cages excluding the egg collection chamber were 40 cm and 20 cm respectively. The hieghts of the cages were respectively 6.5 cm and 5.5 cm at front and back. Water and a layer diet (17.5% crude protein and 11.5 MJ/g of metabolizable energy) were given *ad libitum*. No vaccinations and medications were administered to the birds before and during the experiment.

Data collection techniques

Egg collection was started seven days after the experiment was setup. The eggs were collected for four days (Monday-Thursday) of each experimental week in the morning (9:00–10:00 am) and evening (4:00–4:30 pm) Greenwich Meridian Time. The eggs were cleaned with a dry cloth and carried on plastic trays to the hatchery within 15 minutes. Sorting was done to discard the cracked eggs. Eggs collected from the two cages on each day were put together and 17 non-cracked ones were picked at random to make 68 eggs per week and a total of 204 eggs. The selected eggs were identified individually by numbering them with a permanent marker and stored together overnight in an air-conditioned room at 17-18.5^{o}C and 73–75% humidity.

The air conditions were measured with a Thermopro TP-50 Digital Hygrometer Indoor Thermometer (Shenzhen Ecare Electronics Company Limited, China).

Eggs collected on each day were analysed individually on the following day but within 24 hours from the time of collection. The eggs were weighed after which their length and width were measured with a Carbon Fibre Composites Digital Calliper with an accuracy of ±0.1 mm/0.01. Each egg was broken into a flat glass prism then the albumen height (AH) was immediately measured with the calliper as the distance between the surface of the glass prism and the albumen (Eyesus, 2018). After noting the yolk colour (YC) with a 14-blade DSM Yolk Colour Fan, the yolk was separated with an egg separator and weighed on a small clean zero-scaled container.

Each wet shell was weighed and carefully washed to remove the remaining albumen (Hanusová *et al*., 2015). The shells were air dried at room temperature (25-30.2°C) for 24 hours and then re-weighed for their dry weight. The veneer calliper was used to measure the thickness of the dry shells from the broad, middle and narrow culminations and averaged (Sinha *et al*., 2017). The equipment used were washed with distilled water meted out from a wash bottle and dried with tissue paper after analysing each egg. All weights were taken with a 5-bit LCD display 500.0 G (100.00 G/ 200.00 G) Digital Pocket Scale (Srad Technology Limited, China) with an accuracy of 0.1 g. Mathematically, the following derived egg characteristics were computed from the physical measurements examined.

1. ESI (Egg shape index) = $\frac{\text{Egg width}}{\text{Egg length}}$ x 100 (Sinha *et al*., 2017).
2. ST (Shell thickness) = $\frac{\text{Thickness (Broad+middle+narrow (ends))}}{3}$ (Hanusová *et al*., 2015).
3. HU (Haugh unit) = 100 log (H + 7.57 - 1.7$W^{0.37}$); where H = albumen height and W = egg weight (Haugh, 1937).
4. AW (Albumen weight) = Egg weight - (Wet shell weight + yolk weight) (Tůmová *et al*., 2017).

Statistical analysis

Data on the physical egg quality characteristics were analysed with the one-way Analysis of Variance with the age of the quails as the fixed factor. The General Linear Model procedure of Minitab (version 18) was used. Differences in means were separated with the Tukey Comparisons Test Method at a 5% level of significance. Phenotypic correlation between egg quality characteristics and the linear relationship of egg weight (EW), albumen weight (AW) and yolk weight (YW) with other egg traits were determined using the Pearson Correlation and the Best All-subset Regression Analyses in the Minitab statistical software respectively. The model used was:

$Y_{ij} = \mu + A_j + \varepsilon_{ij}$

Where: Y_{ij} = the dependent variable, μ = the general or population mean, A_j = jth observation of age and ε_{ij} = the random error associated with the dependent variable.

Results and Discussion

TABLE 1

The effect of age on the external and internal quality traits of quail eggs

Egg Quality Traits	Age of Quails				
	Week 17	Week 21	Week 25	SEM	*p*-value
Egg Weight (g)	10.63	10.53	10.47	0.114	.610
Wet Shell Weight (g)	1.54	1.50	1.45	0.0318	.054
Dry Shell Weight (g)	0.79^{a}	0.74^{b}	0.74^{b}	0.0148	.020
Shell Thickness (mm)	0.16	0.16	0.16	0.00773	.774
Egg Shape Index (%)	79.78^{ab}	78.53^{b}	80.57^{a}	0.457	.0007
Albumen Height (mm)	4.07^{b}	4.88^{a}	4.64^{a}	0.115	.001
Haugh Unit	87.61^{b}	92.14^{a}	91.0^{a}	0.626	.001
Albumen Weight (g)	5.67	5.48	5.63	0.0770	.201
Yolk Weight (g)	3.43	3.54	3.40	0.0549	.145
Yolk Colour	2.90^{b}	5.65^{a}	5.26^{a}	0.138	.001

Means with different superscripts are significantly different; g: grams; mm: millimetre; %: percentage; SEM: Standard error of means; P-Value: probability value ($p < .05$)

The results in Table 1 show that age had no significant effect on the weight and shell thickness (ST) of the eggs. Whereas the weight of the eggs decreased slightly as the birds aged from 17 (10.63 g) to 21 (10.53 g) and to 25 (10.47 g) weeks, the thickness of the eggshell was approximately 0.16 mm across the ages. While shell weight (SW) was significantly higher in eggs from the youngest quails (0.79 g) than in those from the older groups (0.74 g), egg shape index (ESI) was irregular at 79.78, 78.53 and 80.57% respectively for weeks 17, 21 and 25. AW and YW changed marginally and irregularly at the various ages of the quails (Table 1). AH and HU were similar in weeks 21 and 25 but significantly higher than that recorded for week 17. AH was similar in weeks 21 (4.88 mm) and 25 (4.64 mm) but significantly higher than that recorded for week 17 (4.07). In the same way, HU was similar in weeks 21 (92.4) and 25 (91.0) but significantly higher than that recorded for week 17 (87.61). YC was significantly lowest (2.90) in the youngest quail group compared with the older groups whose YC were similar (Table 1).

Age is an important factor considered when selecting layers for breed improvement because it does not only affect growth and product quality of layers, but also the relationships that exist between their quality traits (Kgwatalala *et al*., 2016; Ebegbulem & Ayuba, 2017). From this study, it can be deduced that the age of quails did not significantly influence the weight of their hatching eggs but the trait may decrease slightly as the birds grow. Similarly, Kruenti *et al*. (2022) found an insignificant decrease in the weight of Japanese quail eggs from week 43 (11.3 g) to week 46 (11.2 g). Though the reduction in EW was consistent as the birds aged in this study, the results of Kruenti *et al*. (2022) did not show any change in the parameter between 40 and 43 weeks.

Therefore, the lower EW (10.195 g) reported for a 12-week-old brown Japanese quails as reported by Okon *et al*. (2020) could be attributed to genetics, the management or an underdeveloped reproductive system at that age; though some quails kept in northern Ghana started laying at week 8 (Omane *et al*., 2020). Meanwhile, the mean EW (10.47–10.63 g) recorded in the present study falls within the 10–12 g reported for some hatching quail eggs collected at other ages (Redoy *et al*., 2017). The decrease in EW detected in this work as the birds aged is against the notion that as quails advance in age, their eggs become heavier (Omane *et al*., 2020). As the birds grow, they may produce lighter but more fertile eggs if other conditions are adequate. Similarly, Alkan *et al*. (2008) and Kruenti *et al*. (2022) have reported higher fertility rates in lighter quail eggs. The reduction in EW with age could render eggs from older quails non-suitable for incubation. This is because Kruenti *et al*. (2022) and Ng'ambi *et al*. (2013) have reported higher hatchability on heavier breeder eggs than their smaller counterparts though Ayeni *et al*. (2018) had reported an opposite result.

Eggs collected at all ages in this experiment weighed less than 11 g and may be least considered for hatching according to Kruenti *et al*. (2022). Whereas heavy eggs from the younger quails will develop into heavier chicks, chick mortality may increase as the birds get older and their eggs decrease in weight (Kruenti *et al*., 2022). This is because heavier eggs contain more nutrients (Ulmer-Franco *et al*., 2010; Williams, 1994) to nourish the embryo during development, and have more yolk accessory (Hassan *et al*., 2005; Woanski *et al*., 2006) on which newly hatched chicks feed. Nevertheless, other researchers have reported greater chick mortality for heftier eggs (Ng'ambi *et al*., 2013; Woanski *et al*., 2006). That notwithstanding, the heavier eggs from the younger quails during week 17 should be the prime choice – in that heavier eggs mean high prices for farmers; higher hatchability and chick quality for hatchery operators.

The similarity of ST of the eggs at all ages of the quails show that irrespective of age, ST of quail eggs would not change. Thinner shelled-eggs have however been found in older bird species (Rodriguez-Navarro *et al*., 2002; Butcher & Miles, 2003a). Hatchery operators must therefore ensure that eggs with the best ST are selected for hatching, while poultry breeders must use appropriate breeds and feed to enhance or maintain the shell quality of quail eggs. Meanwhile, for manufacturers of products that need egg shells, eggs or hatchery waste from younger quails at week 17 should be the topmost choice. Hatchability of Japanese quail eggs may vary with age regarding egg shape but quail eggs collected at week 21 would hatch best because of the low ESI recoreded at that age (Cavero & Schmutz, 2009; Icken *et al*., 2009; Blanco *et al*., 2014). However, the shape of the eggs collected at all ages in this work is above the 74% standard ESI proposed for the domestic chicken (North & Bell, 2000) and so the eggs may not be too good for hatchery use. Poor internal quality of hatching eggs would affect their hatchability, chicks' quality and survivability. Per the current findings, bigger eggs (Ulmer-Franco *et al*., 2010; Kruenti *et al*., 2022) from the younger quails will provide more yolk attachments (Hassan *et al*., 2005; Woanski *et al*., 2006) and probably more nutrients for chick nourishment at hatch. If an egg's hatchability depends on its freshness, then eggs from older quails must be the target for hatcheries even though eggs collected at week 21 revealed the best traits for egg freshness (AH and HU). In relation to consumers' acceptability of yolk colour, eggs from older quails are more suitable. It must be noted that most quality traits of eggs cannot be obtained without destroying eggs. However, simple regression equations and information on how egg quality traits relate are provided in this article and other works of literature. Stakeholders are advised to rely on such publications in order to make informed decisions in relation to egg selection for their respective activities

TABLE 2

The effects of age on the phenotypic correlation coefficient (r) of external and internal quality traits of quail eggs

Age of Quails	Egg Traits	EW r	EL r	EWD r	ESI r	AH r	HU r	AW r	YW r
Week 17	EL	0.72*							
	EWD	0.82*	0.56*						
	ESI	0.01	-0.55*	0.38*					
	AH	0.18	0.14	0.25*	0.09				
	HU	0.03	0.05	0.12	0.07	0.98*			
	AW	0.79*	0.53*	0.58*	-0.01	0.22	0.09		
	YW	0.66*	0.55*	0.62*	0.01	0.09	-0.00	0.13	
	ST	0.06	-0.02	0.12	0.15	-0.25*	-0.27*	0.06	-0.01
Week 21	EL	0.83*							
	EWD	0.85*	0.67*						
	ESI	-0.19	-0.61*	0.17					
	AH	0.18	0.23*	0.11	-0.19				
	HU	0.04	0.12	-0.01	-0.17	0.98*			
	AW	0.80*	0.65*	0.62*	-0.19	0.21	0.09		
	YW	0.67*	0.59*	0.53*	-0.21	0.09	0.01	0.35*	
	ST	0.10	0.17	0.01	-0.20	-0.02	-0.03	0.03	0.01
Week 25	EL	0.37*							
	EWD	0.58*	0.44*						
	ESI	-0.05	0.15	0.13					
	AH	-0.01	0.00	0.18	-0.04				
	HU	-0.13	-0.05	0.09	-0.02	0.98*			
	AW	0.78*	0.22	0.50*	0.01	0.06	-0.04		
	YW	0.80*	0.37*	0.46*	-0.08	-0.03	-0.12	0.40*	
	ST	0.03	0.03	0.13	0.04	-0.06	-0.06	-0.01	0.01

EW: egg weight; EL: egg length; EWD: egg width; ESI: egg shape index; AH: albumen height; HU: Haugh unit; AW: albumen weight; YW: yolk weight; ST: shell thickness; *: P-Value ($p < .05$ significant)

Results presented in Table 2 show the effect of age on the coefficients of correlation (*r*) of external and internal quality traits of the quails' eggs. The association between EW and EL (egg length) was high and positive in the younger quails at week 17 (*r* = 0.72) and week 21 (*r* = 0.83), but positively low in the oldest quails at week 25 (*r* = 0.37). EW related positively and highly with EWD (egg width) in the younger birds at (*r* = 0.82) and 0.85, respectively, but moderately positive (*r* = 0.58) in the oldest group. EW related lowly with ESI across the ages; but while the direction was positive in the 17-week quails, it was negative for eggs collected from the older birds (Table 2). EW correlated highly and positively with AW and YW but related positively low with ST across the ages. The relationship of EW with AH and HU was positive but low for eggs laid by the younger quails at weeks 17 (*r* = 0.18, 0.03), and 21 (*r* = 0.18, 0.04), but negatively low for eggs collected from the oldest quails (*r* = -0.1, -0.13) in order of the egg quality parameters (Table 2).

EL and EWD correlated positively across the study periods but the association was stronger in eggs from the 21-week-old birds (*r* = 0.67) than in those collected at weeks 17 (*r* = 0.56) and 25 (*r* = 0.44). Although EL correlated negatively and weakly with ST in the quails during week 17 (*r* = -0.02), the parameters related positively but lowly during the 21st (*r* = 0.17) and 25th (*r* = 0.03) weeks. EL associated positively with AW and YW at all the ages but at different magnitudes (Table 2). Across the ages, EWD recorded a positive but low relationship with ST. The *r* values of the link between EWD and AW, and between EWD and YW were 0.58, 0.62, 0.50 and 0.62, 0.53, 0.46 accordingly at the ages. There was a positive but low correlation between AW and YW in the younger quails during weeks 17 (*r* = 0.13) and 21 (*r* = 0.35), but the duo had a moderately positive association during the 25th week (*r* = 0.40).

Generally, ESI mostly correlated lowly and negatively with the other egg variables across the ages while the correlation between AH and HU was high and positive throughout the weeks (Table 2). Phenotypic traits of eggs and their relationships are very useful for breeding layers, hence they must be studied and the information made available. A positive correlation between two variables means that the selection or otherwise of any traits tend to improve the other trait proportionately. A negative correlation on the other hand will result in an improvement in the favoured trait against the other. Selecting highly correlated traits would make breed development faster and more economical, so traits that correlate significantly low should not be considered for selection (Blanco *et al*., 2014).

With regards to these, the positive association of EW with EL and EWD across the ages means that improving EW for bigger quail eggs will improve EL and EWD as well to make the eggs well-shaped (elongated) for increased hatchability when quails are selected at all the ages. Such selection should however not be encouraged in quails that are more than 21 weeks old. The high and positive correlation of EW with EL and EWD at weeks 17 and 21 is consistent with Kul & Seker (2004) who also reported a high and positive association (*r* = 0.76 and 0.80) between the pairs accordingly in the same bird species despite the positively low and medium correlation recorded between them respectively during week 25 in this work. For heavy or large quail eggs that will fit well into crates to avoid breakages during storage or transport (Ebegbulem & Ayuba, 2017), selecting 17-week-old quails in favour of ESI would be appropriate though the process would be slow. Meanwhile, when ESI is favoured in older quails, smaller eggs may be produced to the disadvantage of farmers and hatchery operators.

On the other hand, EW can be improved as quails grow older to make the eggs slightly oval for higher hatchability (Icken *et al*., 2006; Cavero & Schmutz, 2009; Blanco *et al*., 2014). Similarly, negative and positively low correlations have been reported between EW and ESI at *r* = -0.25, -0.07, -0.31, 0.39 and 0.14, at weeks 28, 40, 52, 64 and 72, respectively (Padhi *et al*., 2013). AW and YW are vital sources of nutrients for embryo development and chick nourishment at hatch, and both traits are directly proportional to EW. The current correlation results show that, the weight/content of albumen and yolk of breeder quail eggs can be largely improved alongside EW when any of the two or EW is favoured for improvement irrespective of the birds' age. However, the improvement will be faster between EW and AW when younger quails are selected.

Meanwhile, between EW and YW, selecting older quails may produce quicker results. The highly positive correlation detected between EW and AW at the various ages is similar to those (*r* = 0.995, 0.996 and 0.868) found in a meat-type breeder hens during weeks 32, 45 and 59 according to (Shafey *et al*., 2015) though the magnitudes are lower in this work. The high and positive relationship found between EW and YW across the ages almost disagrees with the different *r* values found between them in Vanaraja male line (PD1) chicken eggs that were 40 weeks old (*r* = 0.60) (Padhi *et al*., 2013). Selecting thicker-shelled eggs in quails will simultaneously improve EW when quails are selected for breeding at each of the current ages but not at any fast rate. Padhi *et al*. (2013) have also revealed a positively low correlation between EW and ST at weeks 28 (*r* = 0.02), 40 (*r* = 0.25) and 52 (*r* = 0.27). Generally, EW correlated positively with most of the egg characteristics and so can be improved side by side with them.

The relationship between EL and EWD defines the shape of an egg (Cavero & Schmutz, 2009) which in turn affects eggs' ability to break or hatch (Alsobayel & Albadry, 2011). Lengthier eggs are more elongated and suitable for hatching because they can fit well into setter trays while poor hatchability and fragility have been linked to wider (round) eggs (Icken *et al*., 2006; Cavero & Schmutz, 2009; Alsobayel & Albadry, 2011; Blanco *et al*., 2014). Consequently, the positive *r* (0.35) as was reported by Kul & Seker (2004) though higher between the pair across the ages of this investigation means that EL and EWD can be enhanced rapidly together to produce well-shaped quail eggs that will hatch well but such selections should not be encouraged in the bird after 21 weeks of growth. Selecting quails that are 17 weeks of age in favour of EL will enhance egg elongation but produce thin-shelled eggs. However, selecting in favour of EL in older quails will improve egg shape and ST as well but the improvement will be quicker when the selection is done in 21-week than 25-week old quails.

On the other hand, EWD can be enhanced to produce thicker-shelled eggs at all the ages of quails but at a slow pace. At all ages, quails can be selected to enhance EL and EWD vis-à-vis AW and YW for good-shaped eggs as well as high albumen and yolk contents for bigger embryo size, better embryo development as well as chick nourishment at hatch using limited resources – but doing so as the birds grow older may retard progress. The possibility of albumen and yolk weights (contents) to improve together if either of them is favoured when quails are selected at any of the three ages exist. The association can be utilised to develop quail breeds that would lay eggs with bigger albumen and yolks (larger eggs) to enhance egg hatchability in the bird (Hegab & Hanafy, 2019) – and such development will be more rapid as the birds grow. It must be noted that selecting in favour of ESI in quails irrespective of their age, could affect most of the other traits negatively; thus, such selection must be guided by research findings.

TABLE 3

Regression analysis for egg weight from external and internal egg quality traits as influenced by the age of quails

Age of Quails (Weeks)	Prediction Models/ Equations	Adj. R^2 (%)
17	EW = -2.98 + 0.0532 EL + 0.1489 EWD + 0.8781 AW + 0.9436 YW	95.6
	EW = -1.715 + 0.1455 EWD + 0.9232 AW + 1.0110 YW	95.4
	EW = -0.204 + 0.0495 EL + 0.9753 AW + 1.0939 YW	95.0
21	EW = -10.40 + 0.1773 EL + 0.4351 EWD + 0.5235 AW + 0.4732 YW	93.1
	EW = -8.00 + 0.5121 EWD + 0.6524 AW + 0.6368 YW	91.0
	EW = -12.89 + 0.2582 EL + 0.5109 EWD + 0.4759 AW	90.2
25	EW = 0.593 + 0.0432 EWD + 0.8722 AW + 1.1499 YW	89.8
	EW = 1.326 + 0.9090 AW + 1.1878 YW	89.7
	EW = 0.907 + 0.0175 EL + 0.9036 AW + 1.1614 YW	89.7
Pooled Data	EW = -2.406 + 0.0432 EL + 0.1501 EWD + 0.8419 AW + 0.9135 YW	90.8
	EW = -1.751 + 0.1677 EWD + 0.8616 AW + 0.9570 YW	90.6
	EW = -0.153 + 0.0641 EL + 0.9286 AW + 1.0123 YW	89.6

EW: egg weight; EL: egg length; EWD: egg width; AW: albumen weight; YW: yolk weight; Adj. R^2: adjusted coefficient of determination; %: percentage

Table 3 shows the stepwise regression for egg weight with the best three (3) prediction equations (models) using EL, EWD, AW and YW as the predictors. The best predictors of egg weight during the 17th week were EL, EWD, AW and YW with a precision or coefficient of determination (R^2) of 95.6%. At 21-week, EL, EWD, AW and YW best predicted egg weight at an accuracy of 93.1%. At 25-week, the best predictors of egg weight were EL, EWD, AW and YW at R^2 = 89.8%. However, from the pooled data, EL, EWD, AW and YW were the best predictors of egg weight at 90.8% precision. Meanwhile, the overall best predictors of egg weight (EL, EWD, AW and YW) were obtained when the birds were 17 weeks old (Table 3).

The hatchery is the main source of birds (day-old chicks) for commercial poultry production. Nonetheless, the businesses in developing countries are faced with inefficiencies including the inability to meet the demands of farmers. Due to this, most farmers in these countries resort to foreign sources for day-old chicks to the detriment of the local economies. This gap can be closed if local layers are improved to lay quality hatching eggs that must be selected from birds at the appropriate age(s) for hatching purposes. Meanwhile, breeding for quality eggs can be expensive and time-consuming relative to the number of traits involved and how the traits relate.

Prediction and selection of quality eggs for incubation can be difficult at the farm and hatchery due to inadequate machinery. Simple linear models or equations can be used directly to project the quality of eggs for selection and development of breeding models to select birds for improvement. This however will depend on the number of variables in the models and the degree of accuracy (coefficient of determination) according to Sarstedt & Mooi (2014). In this regard, results from the current regression analyses indicate that predicting egg weight or developing breeding models to enhance egg weight using EL, EWD, AW and YW will produce the best results with an accuracy of 95.6% when selecting quails that are 17 weeks old. Nonetheless, when EWD, AW and YW are used in a breeding model for quails at the age, breeding may be more economical due to the fewer traits involved but the results will be 0.2% slower. EL, EWD, AW and YW will be most useful in a selection model for quails that are 21 weeks old to enhance egg weight at the rate of 93.1%. Meanwhile when quails are 25 weeks old, the best variables to use in the selection model are EWD, AW and YW. However, though AW and YW will be more economical, the results may be slower at 0.1% if egg weight is the target, while, EL, EWD, AW and YW will give the overall best prediction of egg weight for quails at week 17 and so be recommended.

In the past, Ebegbulem & Ayuba (2017) reported that EWD, EL and ST are the best predictors of egg weight in three guinea fowl ecotypes at R^2 = 74.7, 28.1 and 74.9%, when both external and internal parameters were used – but when they used only the external egg parameters, the best estimators of the trait were EWD and EL (R^2 = 86.4%), ST (R^2 = 74.9%) and ST (R^2 = 28.1%), respectively, for the chicken ecotypes.

TABLE 4

Regression analysis for albumen weight from external quality traits as influenced by the age of quails

Age of Quails (Weeks)	Prediction Models/ Equations	Adj. R^2 (%)
17	AW = 8.71 + 0.748 EW - 0.205 EL - 0.0569 ESI	63.6
	AW = 49.2 + 0.730 EW - 1.49 EL + 1.64 EWD - 0.570 ESI	63.6
	AW = 2.55 + 0.6818 EW - 0.165 EWD	63.5
21	AW = 3.19 + 0.6868 EW - 0.199 EWD	66.0
	AW = 4.54 + 0.758 EW - 0.0559 EL - 0.213 EWD	65.9
	AW = 2.75 + 0.757 EW + 0.0225 ESI - 0.283 EWD	65.9
25	AW = 0.571 + 0.4658 EW - 0.0310 EL + 0.0457 EWD	61.2
	AW = 0.625 + 0.4774 EW	61.1
	AW = 1.146 + 0.4963 EW - 0.0234 EL	61.1
Pooled Data	AW = 0.819 + 0.5740 EW - 0.0409 EL	62.9
	AW = 1.226 + 0.5918 EW - 0.0385 EL - 0.0270 EWD	62.8
	AW = 0.543 + 0.5732 EW - 0.0393 EL + 0.00294 ESI	62.7

AW: albumen weight; EW: egg weight; EL: egg length; EWD: egg width; ESI: egg shape index; Adj. R^2: adjusted coefficient of determination; %: percentage

Table 4 shows the linear relationship between albumen weight and the external egg quality traits at the various ages of the quails. EW, EL and ESI best predicted albumen weight with an accuracy of 63.6% in eggs from the 17-week-old quails. In the 21-week-old birds, the best predictors of albumen weight were EW and EWD at R^2 = 66.0%. Eggs laid at week 25 had EW, EL and EWD as the best predictors of albumen weight at a 62.9% precision level. Whereas the overall best predictors of albumen weight (EW and EWD) were detected when the birds were 21 weeks old, EW and EL were the best predictors from the pooled data with an accuracy (R^2) of 62.9% (Table 4).

Albumen and yolk of eggs are usually considered for consumption but these are vital for hatching eggs too. While more albumen content would mean bigger and heavier chicks; adequate yolk content would ensure enough nutrient reserve for chick nourishment at hatch (Hassan *et al*., 2005; Woanski *et al*., 2006). For non-destructive prediction of albumen and yolk contents (weights), simple regression models as presented in tables 4 and 5 can be used on-farm and at the hatchery to ensure that quality breeder quail eggs with adequate albumen and yolk contents are selected for hatching purposes at the various ages.

The regression results in Table 4 show that at 17 weeks of age, EW, EL and ESI will best predict albumen weight. However, to develop selection models for quail breeding, EW and EWD could be used instead to minimise resources though the precision rate may decrease by 0.1%. To predict albumen weight of eggs from breeder quails at week 21 for hatching and or for selection models, EW and EWD will give the most precise and fastest results with an accuracy of 66.0%. The best predictors of albumen weight that should be used to develop breeding models for 25-week-old quails are EW, EL and EWD (R^2 = 61.2%) but it would be prudent to use only EW to make breeding time and cost-effective but at a reduced rate of 0.1%. Generally, EW and EWD will give the overall best prediction for the albumen weight of breeder quail eggs laid during the 21st week of their growth. This indicates that to improve albumen content for bigger and heavier chicks, quails that are 21 weeks old should be selected using selection models involving EW and EWD while non-destructive prediction of albumen weight should be done onto the duo.

TABLE 5

Regression analysis for yolk weight from external egg quality traits as influenced by the age of quails

Age of Quails (Weeks)	Prediction Models/ Equations	Adj. R^2 (%)
17	YW = -7.62 + 0.1679 EW + 0.1789 EL + 0.0456 ESI	44.8
	YW = -41.5 + 0.1829 EW + 1.25 EL - 1.37 EWD + 0.476 ESI	44.8
	YW = -3.91 + 0.1710 EW + 0.0645 EL + 0.1393 EWD	44.7
21	YW = 0.317 + 0.3066 EW	44.5
	YW = 1.66 + 0.2989 EW - 0.0161 ESI	44.4
	YW = 1.80 + 0.3670 EW - 0.0854 EWD	44.4
25	YW = -1.173 + 0.3763 EW + 0.0204 EL	64.1
	YW = -0.716 + 0.3928 EW	63.9
	YW = -0.835 + 0.3723 EW + 0.0234 EL - 0.00481 ESI	63.9
Pooled Data	YW = -0.813 + 0.3032 EW + 0.0343 EL	48.6
	YW = -0.289 + 0.3048 EW + 0.0312 EL - 0.00558 ESI	48.6
	YW = -0.755 + 0.3058 EW + 0.0347 EL - 0.0039 EWD	48.4

YW: yolk weight; EW: egg weight; EL: egg length; EWD: egg width; ESI: egg shape index; Adj. R^2: adjusted coefficient of determination; %: percentage

Table 5 shows the linear relationship between YW and the external egg quality traits at various ages. EW, EL and ESI gave the best prediction rate (44.8%) for yolk weight on eggs collected from the quails when they were 17 weeks old. At week 21, EW was the best predictor of yolk weight at R^2 = 44.5% but at week 25, EW and EL were the best predictors of yolk weight (R^2 = 64.1%). The best predictors of yolk weight for the pooled data were EW and EL (R^2 = 48.6%) which also gave the overall best prediction for the parameter at the 25th week of raising the birds (Table 5).

Variation in yolk weight of Japanese quail eggs is best explained by EW, EL and ESI; EW; EW and EL at 44.8, 44.5 and 64.1% of accuracy during the respective ages. However, generally, EW and EL will give the overall best prediction for yolk weight of eggs from quails that are 25 weeks old; and are therefore recommended for developing breeding or selection models if quails are to be improved for increased yolk content for enhanced chick nourishment (Hassan *et al*., 2005; Woanski *et al*., 2006), and survivability at hatch. The parameters should also be considered most for non-destructive prediction of yolk weight in quails. In a previous investigation, EL, EWD, ST and SW best explained the variation in the yolk weight of some quail eggs at 81.0% precision (Okon *et al*., 2020). Nevertheless, the age effect on the linear relationship between various egg components as observed in this work has been reported by Shafey *et al*. (2015).

Conclusion and Recommendation

Quality traits of breeder quail eggs and their relationships can vary as quails grow, and so when selecting the birds for breeding or selecting their eggs for hatching, their age must be considered. The total weight, shell weight, albumen weight and yolk weight of the eggs were highest in the 17-week-old quails. Egg shape, albumen height, the Haugh unit and yolk colour were best in the 21-week-old group. Therefore, quails that are 17 weeks old should be considered most for breeding purposes followed by those that are 21 and then 25 weeks old. This means that management of breeder quails that are beyond 17 weeks old should be improved to enhance the quality of their eggs for hatching purposes. Most quality traits of hatching eggs cannot be detected prior to incubation because fertile eggs may be lost. Nevertheless, knowledge of the correlation of egg traits, and simple regression equations provided in this work can be used.

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REFERENCES

Alabi, O.J., Ng'ambi, J., Norris, D. & Mabelebele, M. (2012b) Effect of egg weight on Hatchability and subsequent performance of Potchefstroom Koekoek chicks. *Asian Journal of Animal and Veterinary Advances*, **7**(8), 718–725.

Alkan, S., Karabag, K., Galic, A. & Balcioglu, M.S. (2008) Effects of genotype and egg weight on hatchability traits and hatching weight in Japanese quail. *South African Journal of Animal Science*, **38**(3), 231–237.

Alsobayel, A.A. & Albadry, M.A. (2011) Effect of storage period and strain of layer on Internal and external quality characteristics of eggs marketed in Riyadh area. *Journal of the Saudi Society of Agricultural Sciences*, **10**(1), 41–45.

Ayeni, A.O., Agbede, J.O., Igbasan, F.A., Onibi, G.E.O. & Adegbenro, A. (2018) Effect of egg sizes on egg qualities, hatchability and initial weight of the hatched-chicks. *International Journal of Environment, Agriculture and Biotechnology*, **3**(3), 987–993.

Ayoola, A.A., Adeyemi, O.A., Egbeyale, L.T., Sogunle, O.M. & Ekunseitan, D.A. (2014) Effects of sex and stocking density on growth performance and some physiological traits of Japanese quails (*Coturnix coturnix japonica*). *Malaysian Society of Animal Production*, **17**(2), 43–53.

Benichou, A.C., Armanet, M., Bussière, A., Chevreau, N., Cardot, J.M. & Tétard, J.A. (2014) Proprietary blend of quail egg for the attenuation of nasal provocation with a standardized allergenic challenge: A randomized, double-blind, placebo-controlled study. *Food Science and Nutrition*, **2**(6), 655–63.

Bernacki, Z., Kokoszynski, D. & Bawej, M. (2013) Laying performance, egg quality and hatching results in two guinea fowl genotypes. *Achieve Geflügelk*, **77**(2) 109–115.

Blanco, A.E., Icken, W., Ould-Ali, D., Cavero, D. & Schmutz, M. (2014) Genetic parameters of egg quality traits on different pedigree layers with special focus on dynamic stiffness. *Poultry Science*, **93**(10), 2457–2463.

Butcher, G.D. & Miles, R.D. (2003a) Concepts of eggshell quality. University of Florida. Available at http://edis.ifas.ufl.edu/pdffiles/VM/VM01300.pdf. on 17 June 2019.

Cavero, D. & Schmutz, M. (2009) Relationship between egg quality traits and hatchability in pure-line white layer strains. Paper presented at the World Poultry Science Association of the European Poultry Symposium on quality of poultry meat, and quality of eggs and egg production (Vol. 7), Turku, Finland.

Cheng, K.M.T., Bennet, D.C. & Mills, A.D. (2010) The Japanese quail. In: Hubrecht R, Kirkwood J, editors. The UFAW handbook on the care and management of laboratory and other animals. 5th Ed, Wiley Blackwell Publishing, Chichester West Sussex, 655–674.

Ebegbulem, V.N. & Ayuba, D. (2017) Phenotypic correlations and regression among some external and internal egg quality parameters of Nigerian guinea fowl (*Numida meleagris*) genotypes. *Journal of Scientific and Engineering Research*, **4**(5) 220–229.

Eyesus, T.W. (2018) Performance of farmer managed Bovans brown layers fed on different locally available rations. MSc thesis, Mekelle University, Ethiopia. Available at https://cgspace.cgiar.org/bitstream/handle/10568/97029/thesis_eyesus_2018.df?sequence=1&isAllowed=y on 26 April 2022.

Hanusová, E., Hrnčár, C., Hanus, A. & Oravcová, M. (2015) Effect of breed on some parameters of egg quality in laying hens. *Acta fytotechnology zootechnology*, **18**(1), 20–24.

Hassan, S.M., Siam, A.A., Mady, M.F. & Cartwright, A.L. (2005) Eggs storage, period and weight effects on hatchability of ostrich (*Struthio camelus*) eggs. *Poultry Science*, **84**(12), 1908–1912.

Haugh, H. (1937) The Haugh unit for measuring egg quality. *The U.S. Egg & Poultry Magazine*, **43**(1), 552–555, 572–573.

Hegab, I.M. & Hanafy, A.M. (2019) Effect of egg weight on external and internal qualities, physiological and hatching success of Japanese quail eggs (*Coturnix coturnix japonica*). *Brazilian Journal of Poultry Science*, **21**(3), 1–8.

Icken, W., Schmutz, M. & Preisinger, R. (2006) Dynamic stiffness measurements with the “crack detector”: a new method to improve egg shell strength. *Lohmann Information*, **41**(1), 13–19.

Kgwatalala, P.M., Molapisi, M., Thutwa, K., Sekgopi, B., Selemoge, T.P. & Nsoso, S.J. (2016) Egg quality characteristics and phenotypic correlations among egg quality traits in the naked neck, normal and dwarf strains of Tswana chickens raised under intensive management system. *International Journal of Environmental and Agriculture Research*, **2**(8) 96–105.

Kruenti, F. (2020) Relationship between external and internal egg quality traits of chicken layers as influenced by genetic and non-genetic factors. (Unpublished master's thesis). University of Cape Coast, Cape Coast, Ghana. https://ir.ucc.edu.gh/xmlui/bitstream/handle/123456789/7264/KRUENTI%2c%202020.pdf?sequence=1&isAllowed=y.

Kruenti, F., Lamptey, K.V., Okai, A.M., Adu-Aboagye, G., Oduro, O.A.D., Bebanaayele, F. & Suurbesig B. (2022) The influence of flock age and egg size on egg shape index, hatchability and growth of Japanese quail chicks. *Journal of Innovative Agriculture*, **9**(1), 8–16.

Kul, S. & Seker, I. (2004) Phenotypic correlation between some external and internal egg quality traits in the Japanese quail (*Coturnix coturnix japonica*). *International Journal of Poultry Science*, **3**(6), 400–405.

Lukanov, H. & Pavlova, I. (2004) Domestication changes in Japanese quail (*Coturnixjaponica*): A review. *World's Poultry Science Journal*, **76**(4), 787–801.

Lukanov, H., Genchev, A. & Kolev, P. (2018) Comparative investigation of egg production in WG, GG and GL Japanese quail populations. *Trakia Journal of Sciences*, **16**(4), 334–343.

Markos, S., Belay, B. & Astatkie, T. (2017) Evaluation of egg quality traits of three indigenous chicken ecotypes kept under farmers' management conditions. *International Journal of Poultry Science*, **16**(5) 180–188.

Minvielle, F. (2004) The Future of Japanese quail for research and production. *World's PoultryScience Journal*, **60**(4), 500–507.

Ng'ambi, J.W., Thamaga, M.W., Norris, D., Mabelebele, M.A. & Olushola, J. (2013) Effects of egg weight on hatchability, chick hatch-weight and subsequent productivity of indigenous Venda chickens in Polokwane. *South African Journal of Animal Science*, **43**(Issue 5, Supplement 1), S70–S74.

North, M.O. & Bell, D.D. (2002) Commercial chicken production manual. **4th** Ed, *Springer,* New York.

Okon, B., Ibom, L.A., Ayuba, D. & Ebegbulem, V.N. (2020) Egg quality traits, phenotypic correlations, egg and yolk weights prediction using external and internal egg quality traits of Japanese quails reared in Calabar, Nigeria. *International Journal of Molecular Biology Open*, **5**(1), 21–26.

Omane, O.K., Aikins, T.K. & Imoro, A.Z. (2020) Reproductive potential and egg laying performance of quail in savannah ecological zone of Ghana. *UDS International Journal of Development*, **7**(1), 246–255.

Padhi, M.K., Chatterjee, R.N., Haunshi, S. & Rajkumar, U. (2013) Effect of age on egg quality in chicken. *Indian Journal of Poultry Science*, **48**(1), 122–125.

Pavlova, I., Lukanov, H., Ivanov, V., Petrova, Y. & Genchev, A. (2018) Simultaneous administration of Silymarin and Doxycycline in Japanese quail suggests probable herb-drug interaction. *Bulgarian Journal of Agricultural Science*, **24**(1), 126–131.

Redoy, Md., R.A., Shuvo, A.A. S. & Al-Mamu, M. (2017) A review on present status, problems and prospects of quail farming in Bangladesh. *Bangladesh Journal of Animal Science*, **46**(2), 109–120.

Rizzi, C. & Marangon, A. (2012) Quality of organic eggs of hybrid and Italian breed hens. *Poultry Science*, **91**(9), 2330–2340.

Rodriguez-Navarro, A., Kalin, O., Nys, Y. & Garcia-Ruiz, J.M. (2002) Influence of the microstructure on the shell strength of eggs laid by hens of different ages. *British Poultry Science*, **43**(3), 395–403.

Sarstedt, M. & Mooi, E. (2014) *A concise guide to market research*. Berlin, Heidelberg: *Springer*.

Shafey, T.M., Hussein, E.O.S., Mahmoud, A.H., Abouheif, M.A. & Al-Batshan, H.A. (2015) Managing collinearity in modelling the effect of age in the prediction of egg components of laying hens using stepwise and ridge regression analysis. *Brazilian Journal of Poultry Science*, **17**(4), 473–482.

Sinha, B., Mandal, K.G. & Kumari, R. (2017) Effect of egg weight on egg quality traits of laying hens. *International Journal of Pure and Applied Bioscience*, **5**(3), 293–300.

Tůmová, E., Vlčková, J. & Chodová, D. (2017) Differences in oviposition and egg quality of various genotypes of laying hens. *Czech Journal of Animal Science*, **62**(9), 377–383.

Ulmer-Franco, A.M., Fasenko, G.M. & O'Dea, C.E. (2010) Hatching egg characteristics, chick quality, and broiler performance at 2 breeder flock ages and from 3 egg weights. *Poultry Science*, **89**(12), 2735–2742.

Williams, T.D. (1994) Intraspecific variation in egg size and egg composition in birds: effect on offspring fitness. *Biological Reviews*, **69**(1), 35–59.

Woanski, N.J., Renema, R.A., Robinson, F.E., Carney, V.L. & Fancher, B.I. (2006) Relationship between chick conformation and quality measures with early growth traits in males of eight selected pure or commercial breeder strains. *Poultry Science*, **85**(8), 1490–1497.

Woodward, A.E. & Abplanalp, H. (1967) The effects of mating ratio and age on fertility and hatchability in Japanese quail. *Poultry Science*, **46**(2), 383–388.

Yousif, I.A. & Eltayeb, N.M.N. (2011) Performance of Sudanese native dwarf and bare neck chicken raised under improved traditional production. *Agriculture and Biology Journal of North America*, **2**(5), 860–866.