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EFFECTS OF LAYER AGE AND EGG WEIGHT ON EGG QUALITY TRAITS OF JAPANESE QUAILS *(Coturnix coturnix japonica)*

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ABSTRACT

The study was carried out to analyze the impact of layer age and egg weight on egg quality characteristics and further assess the correlation between these traits in Japanese quail eggs. In total, 295 quail layers starting from 10 weeks old were used in the experiment and 2,360 eggs were examined for quality evaluation. Bird age was grouped in every four weeks of laying period and eggs were categorized according to their weights (small, medium, large and extra-large). It was shown that eggs were smaller at 10th week of age (11.43 g) and gradually increased in weight till week 26th (11.61 g) and 30th (11.62 g). Quail age influenced all of egg internal characteristics examined ($P<0.001$) while egg weight was significantly associated with most of albumen and yolk traits, except for albumen height, yolk index and yolk color. There existed both negative and positive correlations among these traits as well. The obtained results indicated that advanced age had increasing egg weight but lesser redness in egg yolk color, and larger eggs provided greater values of albumen weight, albumen ratio, yolk height, yolk weight but reduced Haugh unit.

Key words: egg weight, egg quality, Japanese quail, layer age.

INTRODUCTION

It has been observed in poultry breeding that quails were beneficial as much as hens both for their meat and eggs and thus commercial quail breeding has become widespread (Altinel *et al.*, 1996). Egg quality traits including external (egg weight and shell quality) and internal traits (albumen and yolk parameters) are crucial not only for consumers but also essential for the egg product industry (Song *et al.*, 2000; Wolanski *et al.*, 2007). There are many factors that may affect egg quality traits such as genotype, breeding systems, management, nutrition, age and egg weight (Narushin and Romanov, 2002). Among these, age of layer and egg weight are important and taken into consideration by many researchers. Zita *et al.* (2013) found that egg quality traits were significantly affected by the age of females, with the exceptions of egg shape index and yolk color. In the later stage of laying, egg weight, yolk and albumen weight and shell weight increased whereas Haugh unit (HU) and eggshell thickness decreased (Oloyo, 2003; Brand *et al.*, 2004; Rizzi and Chiericato, 2005; Johnston and Gous, 2007). Supportedly, Akyurek and Okur (2009) reported that egg weight, yolk and albumen weight in Japanese quails increased with their age.

In addition, there is an essential need of assessing the quality features of eggs and the age factor affecting them. Not only could age characteristic be the key factor affecting egg weight, but it could also influence other external and internal egg characteristics (Khalil, 2009). Egg weight is one of the key factors for both consumers and egg producers (Genchev, 2012) as it can affect both egg quality and grading (Farooq *et al.*, 2001a), especially it can be evaluated without breaking the egg (Farooq *et al.*, 2001b). Egg weight is represented by the ratios of albumen, egg yolk and eggshell. The percentage of yolk tends to be larger in larger eggs and egg albumen tends to decrease with egg weight (Kaminska *et al.*, 1991). Iposu *et al.* (1994) and Silversides (1994) reported negative correlations between egg weight and albumen height as well as egg weight and HU. Additional conclusions were also reported by Sekeroglu *et al.* (2000) with positive correlations among egg weight and shape index, yolk width, yolk height and albumen index. Despite the current studies on internal and external egg characteristics and their correlation, the researches exploring those features in quails, including phenotypic correlation, remain limited. Therefore, the objectives of the present study were to evaluate the influence of layer age and different egg weight groups on external and internal characteristics and also to determine the correlation among these traits of Japanese quail eggs.

MATERIALS AND METHODS

Quails and egg collection: The study took place in the experimental farm of Tra Vinh Unversity, Vietnam (9° 55′ N, 106° 20′ E) from 2015-2016, where 295 quail layers at 212 ± 17.8 g of body weight and 10 weeks old were used. The birds were individually kept in each cage and feed and water were given *ad libitum.* They were fed with commercial diet containing 20% CP and 2,750 kcal of ME/kg from a feed company and received 16 hours of light per day. All quails were vaccinated against common diseases during the experimental period. Eggs were selected randomly on a given day in weeks of 10th, 14th, 18th, 22nd, 26th, 30th, 34th and 38th for quality assessment. In total, there were 2,360 eggs subjected for quality analysis. Grouping eggs was done based on their weight: group S (up to 10.50 g), group M (10.51-11.50 g), group L (11.51-12.50 g) and group XL (larger than 12.51 g) (Nowaczewski *et al.*, 2010a).

Egg measurements: Eggs were weighed using an electronic scale with the accuracy of 0.01 g. After breaking and separating egg components, eggshells were weighed and the percentages were calculated in relation to egg weight and the result was multiplied by 100. For internal egg quality characteristics, a caliper was used to measure the length and width of albumen and yolk. The yolk weight was recorded to an accuracy of 0.01g and the proportion of this parameter was expressed in percentage corresponding to egg weight. Yolk color was determined using the La Roche scale scoring from 1-15. Albumen weight was calculated by subtracting the yolk and the shell weight from the whole egg weight. In addition, indexes of albumen, yolk and HU were calculated as followed: albumen index (%) = (albumen height, mm/average of albumen length, mm and albumen width, mm) x 100; yolk index (%) = (yolk height, mm/yolk diameter, mm) x100 and Haugh unit = 100 x log(AH + 7.57 – 1.7 x $EW^{0.37}$), where AH = albumen height (mm) and EW = egg weight (g) (Nasr *et al.*, 2015; Sari *et al.*, 2012). All measurements were done at laboratories of Department of Animal Sciences, College of Agriculture and Applied Biology, Can Tho University, Vietnam.

Statistical analysis: Data were analyzed using General Linear Model (GLM) procedure of the Minitab version 16.1 using the following model: $Y_{ijk} = \mu + A_i + W_j + (A + W)_{ij} + e_{ijk}$, where: Y_{ijk} is the phenotypic value of the traits (egg weight, shell weight, shell ratio, albumen height, albumen weight, albumen ratio, albumen index, yolk height, yolk diameter, yolk weight, yolk ratio, yolk color and HU); μ is the overall mean; A_i is the effect of bird age (10, 14, 18, 22, 26, 30, 34, and 38 week); W_j is the effect of the egg weight group (S, M, L and XL); $(AW)_{ij}$ is the interaction between bird age and egg weight and e_{ijk} is the random error. The differences and their significance among weeks of age and egg weight group were done by using Tukey's test at levels of P<0.05, 0.01 and 0.001 and data are presented as least square mean. Additionally, Pearson correlation was applied to determine the relationship between internal egg quality traits.

RESULTS

Table 1 shows the effects of bird age and egg weight group on external parameters of Japanese quail eggs. In the first stage of laying (10 weeks of age), eggs were small (11.43 g) and gradually increased in weight till the 26th (11.61 g) and 30th (11.62 g) weeks of age and then slightly reduced but no significant difference was found in the later stages of laying. Similar trends were also found for eggshell weight and eggshell ratio with highest values from eggs obtained in the 26th week (1.62 g and 14.06%, respectively). In addition, egg weight was statistically different according to the four groups that eggs were divided into. Eggshell weight was also the heaviest in largest egg weight group (1.66 g) (P≤0.001); however, the percentage of eggshell was shown to be higher in S and M group (14.07 and 13.72%, respectively). Moreover, there were significant interactions between layer age and egg weight group for all external traits examined.

Table 1. Effects of layer age and egg weight on external characteristics of Japanese quail eggs

Parameters	External traits		
	Egg weight (g)	Shell weight (g)	Shell ratio (%)
Layer age (week, n=295)			
10	11.43^{b}	1.50^{d}	13.14^{b}
14	11.52^{ab}	1.52^{bcd}	13.19^{b}
18	11.57^{a}	1.53^{bcd}	13.27^{b}
22	11.54^{a}	1.54^{bcd}	13.40^{b}
26	11.61^{a}	1.62^{a}	14.06^{a}
30	11.62^{a}	1.58^{ab}	13.60^{ab}
34	11.58^{a}	1.56^{abc}	13.52^{b}
38	11.56^{a}	1.55^{abcd}	13.48^{b}
Week 10-38	11.55	1.55	13.46
SEM	0.225	0.013	0.110
p-value	000	0.000	0.000
Egg weight group (n=2360)			
S (n=167)	10.16^{d}	1.43^{d}	14.07^{a}
M (n=733)	11.06^{c}	1.52^{c}	13.72^{a}
L (n=920)	11.96^{b}	1.59^{b}	13.27^{b}
XL (n=540)	13.03^{a}	1.66^{a}	12.77^{c}
SEM	0.016	0.008	0.072
p-value	0.000	0.000	0.000
p-value (layer age* egg weight group)	0.012	0.000	0.000

a,b,c Within each column for layer age and egg weight group, values with different superscripts are different at P<0.05. S, M, L, XL: egg weight groups with S (up to 10.50 g), M (10.51-11.50 g), L (11.51-12.50 g) and XL (larger than 12.51 g).

The age of birds had certain effects on albumen height and albumen index and most of yolk parameters, with the exception of yolk weight and yolk ratio (Table 2). Greater albumen and yolk indexes were found in the later laying stage. However, the darkness of yolk color gradually reduced from the 10th to the 38th weeks of age ($P<0.001$) while HU value was of about 1.5 unit improvement from the beginning to the end of laying period (87.49-88.97). Table 2 also indicates significant effects of egg weight group on albumen and yolk parameters with greater values found in heavier egg groups excepting for albumen index, yolk ratio and HU.

The correlation coefficients of external and internal egg quality traits are shown in Table 3. Shell weight was negatively correlated with albumen ratio (r = -0.390) but positively correlated with yolk height (r = 0.275). In addition, negative correlations were found between shell proportion and albumen weight (r = -0.496) and albumen ratio (r = -0.589). Within internal egg quality traits, yolk ratio was negatively related to albumen weight (r = -0.604) and albumen ratio (r = -0.900). Moreover, HU showed a positive relationship with albumen height (r = 0.941) and albumen index (r = 0.741). All of the above scores were statistically significant at $P\leq0.001$.

Table 2. Effects of layer age and egg weight on internal quality characteristics of Japanese quail eggs.

Parameters	**Internal traits**										
	Albumen height (mm)	**Albumen weight (g)**	**Albumen ratio (%)**	**Albumen index (%)**	**Yolk height (mm)**	**Yolk width (mm)**	**Yolk Weight (g)**	**Yolk ratio (%)**	**Yolk Index (%)**	**Yolk color**	**Haugh unit**
Layer age (week, n=295)											
10	4.13^{c}	6.27^{bc}	54.84^{a}	9.26^{c}	10.14^{e}	25.77^{a}	3.66^{b}	32.02^{ab}	39.59^{e}	5.73^{b}	87.49^{b}
14	4.32^{ab}	6.35^{ab}	55.14^{a}	10.33^{b}	10.83^{bcd}	23.47^{b}	3.65^{b}	31.67^{bc}	46.38^{abc}	5.84^{b}	88.72^{a}
18	4.04^{c}	6.39^{ab}	55.23^{a}	9.22^{c}	10.75^{cd}	23.76^{b}	3.64^{b}	31.50^{bc}	45.39^{bcd}	6.02^{a}	86.95^{b}
22	4.12^{c}	6.35^{abc}	54.95^{a}	9.43^{c}	10.62^{d}	23.89^{b}	3.65^{b}	31.66^{bc}	44.62^{d}	5.88^{ab}	87.52^{b}
26	4.16^{bc}	6.20^{c}	52.94^{b}	9.59^{c}	11.23^{a}	23.94^{b}	3.80^{a}	33.00^{a}	47.14^{ab}	4.72^{cd}	87.24^{b}
30	4.35^{ab}	6.43^{a}	55.32^{a}	10.80^{ab}	11.07^{ab}	23.28^{b}	3.62^{b}	31.08^{c}	47.78^{a}	4.92^{c}	88.83^{a}
34	4.36^{a}	6.41^{a}	55.31^{a}	11.15^{a}	10.93^{abc}	23.55^{b}	3.61^{b}	31.17^{c}	46.66^{abc}	4.77^{cd}	88.88^{a}
38	4.37^{a}	6.37^{ab}	55.10^{a}	11.13^{a}	10.76^{bcd}	23.88^{b}	3.63^{b}	31.42^{bc}	45.17^{cd}	4.69^{d}	88.97^{a}
SEM	0.039	0.032	0.238	0.145	0.064	0.128^{b}	0.025	0.203	0.365	0.044	0.232
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
Egg weight group (n=2360)											
S (n=167)	4.16	5.47^{d}	53.79^{c}	10.67^{a}	10.42^{d}	22.91^{d}	3.27^{d}	32.15^{a}	45.70	5.33	88.63^{a}
M (n=733)	4.23	6.00^{c}	54.21^{c}	10.19^{b}	10.71^{c}	23.79^{c}	3.55^{c}	32.08^{a}	45.30	5.30	88.39^{a}
L (n=920)	4.25	6.61^{b}	55.22^{b}	9.86^{c}	10.92^{b}	24.35^{b}	3.77^{b}	31.51^{a}	45.11	5.35	87.88^{b}
XL (n=540)	4.28	7.32^{a}	56.20^{a}	9.72^{c}	11.11^{a}	24.72^{a}	4.04^{a}	31.03^{b}	45.25	5.31	87.40^{c}
SEM	0.026	0.021	0.155	0.095	0.045	0.084	0.015	0.133	0.240	0.029	0.152
p-value	0.079	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.554	0.292	0.000
p-value (layer age* egg weight group)	0.000	0.000	0.000	0.035	0.001	0.000	0.000	0.000	0.000	0.206	0.000

^{a,b,c} *Within each column for layer age and egg weight group, values with different superscripts are different at P<0.05*

Table 3. Correlation coefficients among external and internal egg quality traits.

Traits	Shell ratio (%)	Alb. weight (g)	Alb. height (mm)	Alb. ratio (%)	Alb. index (%)	Yolk height (mm)	Yolk diameter (mm)	Yolk weight (g)	Yolk ratio (%)	Yolk index (%)	Yolk color	Haugh unit
Shell weight (g)	0.763 ***	0.099 ***	0.094 ***	-0.390 ***	0.047 *	0.275 ***	0.153 ***	0.366 ***	0.062 **	0.100 ***	-0.088 ***	-0.027
Shell ratio (%)		-0.496 ***	0.047 *	-0.589 ***	0.111 ***	0.089 ***	0.028	-0.039	0.177 ***	0.044 *	-0.011	0.060 **
Alb. weight (g)			0.077 ***	0.716 ***	-0.056 **	0.144 ***	-0.026	0.130 ***	-0.604 ***	0.126 ***	-0.120 ***	-0.059 **
Alb. height (mm)				0.055 **	0.742 ***	0.176 ***	-0.035	-0.020	-0.093 ***	0.152 ***	-0.094 ***	0.941 ***
Alb. ratio (%)					0.018	-0.112	-0.295	-0.549	-0.900	0.112	-0.059	0.068

	***	***	***	***	***	**	**
Alb. index (%)	0.153***	-0.152***	-0.128	-0.083***	0.212***	-0.121***	0.741***
Yolk height (mm)		-0.078***	0.281***	0.088***	0.760***	-0.089***	0.103***
Yolk diameter (mm)			0.416***	0.345***	-0.690***	0.050*	-0.105***
Yolk weight (g)				0.690***	-0.064	-0.018	-0.186***
Yolk ratio (%)					-0.160***	0.078***	-0.116***
Yolk index (%)						-0.096***	0.143***
Yolk color							-0.080***

****: P<0.001; **: P<0.01; *: P<0.05; Alb.: Albumen.*

DISCUSSION

Effect of layer age and egg weight on egg external traits: In the present study, both quail age and egg weight significantly affected egg quality characteristics including eggshell weight and eggshell ratio. The average value of egg weight (11.55 g) during the 10th to the 38th weeks of age was similar to the results obtained by Sari *et al.* (2012), Zita *et al.* (2013) and Hrnčár *et al.* (2014), higher than those reported by Kul and Seker (2004), Vali *et al.* (2006) and Nowaczewski *et al.* (2010a) and smaller than those published by Baylan *et al*. (2011), Dukic Stojcic *et al.* (2012) and Nasr *et al.* (2015).

Age of bird is one of many factors affecting egg size (Asuquo and Okon, 1993). The changes of egg weight during the laying period in the present work supported the above statement and this is in accordance with the report of Zita *et al.* (2013), who showed similar trend of laying in Japanese quails and laying hens. Previously, it was reported by many researchers that egg weight increased with the quail age and reached a plateau by the end of productive cycle (Altan *et al.*, 1998; Danilov, 2000; Nazligül *et al.*, 2001; Orhan *et al.*, 2001). One of the explanations for this might be that egg weight is positively correlated with quail age, thus its content can be associated with the advance of parental age (Fletcher *et al.*, 1983).

Together with egg weight, eggshell was also positively correlated with many internal egg quality traits (Nasr *et al.*, 2015), thus an improvement of these two parameters would improve most of the egg quality traits. In the present work, the eggshell weight was found to increase with age. These were comparable to data given by Nasr *et al.* (2015) and were approximately 0.2-0.4 g and 2-4.5% greater than those in the reports of Hrnčár *et al.* (2014), Alaşahan *et al.* (2015) and Hanusova *et al.* (2016). An increase of shell weight over laying period may reflect its attribution to the increase of egg weight as the duration of staying in the reproductive tract is longer for eggs of greater weight (Akram *et al.*, 2014).

Effect of layer age and egg weight on egg internal characteristics: Egahi *et al.* (2011) reported that weight; length and width as well as HU, yolk, albumen weight and height of the eggs could be significantly affected by the age of birds. Considering the effects of layer age on egg quality traits, it can be seen that when the age of quails increased, an increase of external (weight, length, and width) and internal parameters (HU, yolk, albumen weight and height) was correspondingly obtained. Similar findings were also indicated (Akpa *et al.*, 2006; Egahi *et al.*, 2011). Previously, it was reported that albumen height in quail eggs increased together with age (Dańczak *et al.*, 1997; Dikmen and Ipek, 2006; Wilkanowska and Kokoszyński, 2012). In comparison with albumen height of Pharaoh quail (5.06 mm), that of Japanese quail in this study was about 0.8 mm thinner (4.23 mm), yet it was comparable with that in the study of Nasr *et al.* (2015).

In addition, the weight of albumen was found of highest value in older quails (Wilkanowska and Kokoszyński, 2012). Our data partly supported that finding as there was a slight increase of albumen weight (0.1 g) in the 10th and 38th weeks of age but fluctuations were found in the middle stage of laying period. In another study of Zita *et al.* (2013), the albumen weight slowly increased until the 25th age week, followed by a decline in value until the laying period was over. Irrespective of certain differences of albumen weight, the albumen ratio was almost similar during laying period with the exception at the 26th week old. The lowest and highest albumen percentages were found in the eggs of from 18- and 23-week-old quails, respectively (Wilkanowska and Kokoszyński, 2012). The varied percentages of albumen weight among publications might come from the genetic make-up of the birds, nutrition and management and laying period (Hussain *et al.*, 2016).

In relation to yolk parameters, Sari *et al.* (2012) concluded that as the quail age increased, yolk weight increased whereas yolk index and HU decreased. In this study, the yolk weight remained stable during the laying period, excluding the 26th week where yolk weight was higher. Previously, it was indicated that as yolk weight increased, the albumen height also increased and thus better albumen quality could be achieved (Kul and Seker, 2004). The positive correlation between these two values confirmed the above statement. Additionally, for yolk ratio and yolk index, the present results were in partial agreement with those given by Zita *et al.* (2012), which pointed out that as the age of quails increased, yolk index and yolk ratio also increased. In fact, there was a great change in yolk index (about 5.5%) at the beginning and the end of laying period at 38 weeks of age. In contrast, Orhan *et al.* (2001) found that the yolk index decreased with age.

It is well known that the HU is used to calculate the egg protein quality in relation to the albumen height of the egg (Kondaiah *et al.*, 1983) and the higher the HU, the better the egg quality. The higher HU might be because of the higher value of albumen height resulted from higher viscosity of albumen (Akram *et al.*, 2014). This is an important characteristic of egg that may attract consumers (Spada *et al.*, 2012) and it also contributes to the shelf life of an egg (Caner and Cansiz, 2008). According to Oliveira *et al.* (2007) and Nickolova and Penkov (2010), HU can range between 87.08 and 103.1. With respect to this range, the score in this study was in between and there was about 1 unit difference among different laying weeks. However, the conclusions on the HU were controversial. While Altan *et al.* (1998), Nazligül *et al.* (2001) and Orhan *et al.* (2001) stated that with the advanced age of quails, the HU score may decrease or remain unchanged, Hanusova *et al.* (2016) concluded that younger birds (13 weeks of age) had higher value of HU. It is worth mentioning that the higher HU and yolk index are, the more desirable egg interior quality becomes (Adeogun and Amole, 2004). As stated by Ihekoronye and Ngoddy (1985), eggs of high quality usually have HU of 70 or above, thus the values in the present study suggest that the birds from which the eggs were obtained are desirable.

In terms of egg weight influences on internal quality traits, all values but albumen index, yolk ratio and HU, improved with the increased weight of egg. The present work was in agreement with the conclusion that albumen and yolk height increased with increasing egg size (Şekeroğlu and Altuntaş, 2009). Also, smaller egg weight was reported to result in smaller weight and ratio of yolk of quails in the first stage of laying. On the other hand, Nowaczewski *et al.* (2010b) found smallest yolk weight and its proportion in egg mass in week 25 of laying and these authors proved that the quality of Japanese quail eggs decreased with their age. Moreover, eggs from group L had higher HU value as compared with group XL (Nowaczewski *et al.*, 2010a), which was in line with the result from this study.

Correlation among external and internal egg quality traits: The correlation among external and internal egg quality traits in quails has been reported by numerous authors; for example, Kul and Seker (2004) and Alkan *et al.* (2010) found that shell weight and albumen height, yolk height and yolk weight were positively correlated. In the present study, shell weight was shown to correlate with most of the internal egg quality traits and confirmed the findings of many researches that shell weight has a positive correlation with albumen height, yolk height and yolk weight (Alkan *et al.*, 2010; Kul and Seker, 2004; Zita *et al.*, 2013). Due to the positive relationship between egg weight and eggshell weight and most of external and internal egg traits, Nasr *et al.* (2015) also recommended using them as important parameters to improve most of quality traits. However, it should be noted that there was a negative correlation between albumen ratio and shell weight and shell ratio as well.

In this study, the albumen index was increasing with the advancement of quail age. The range of albumen index was from 9.22 to 11.15%, which was in agreement with the statement that this index in fresh quail eggs ranges between 10-15% (González, 1995; Waheda *et al.*, 1999). It was noticed that an improvement of the albumen index will result in an improvement in albumen weight and the albumen ratio (Ozcelik, 2002); however, the present data did not support this point of view as the correlation coefficients between these values were very weak; instead, the albumen index was more related to albumen height ($r = 0.742$).

According to Kul and Seker (2004), yolk height developed as quails age and can range from 9.8 mm to 11.1 mm. Similar results were also found in this study, of which the yolk height seemed to affect other egg quality traits since it was found to have a positive relationship with yolk and albumen traits and shell weight. Moreover, being one of the internal quality features of eggs, the HU also serves as an important indicator to determine eggs internal quality traits. Thus, HU can also be affected by albumen improvement (Ihekoronye and Ngoddy, 1985). In fact, in the present work, HU was highly correlated with albumen height and albumen index and the results confirmed the finding of Zita *et al.* (2013). Similarly, in chicken, Silversides and Scott (2001) also found that HU and albumen height had significant positive phenotypic correlation. Moreover, Ayorinde (1987), Isikwenu *et al.* (1999) and Copur Akpinar *et al.* (2015) pointed out that HU and yolk index are considered the most important internal egg quality traits since they are best indicators of egg quality and the higher the values, the better the egg quality is obtained.

Conclusion: In conclusion, the results of this study indicated that advanced age was associated with increasing egg weight but lesser egg color redness and heavier eggs were of greater values of albumen weight, albumen ratio, yolk height and yolk weight but lower in Haugh unit score. The findings may be useful for researchers and breeders in selection and improving egg quality traits of interest in Japanese quails.

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