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RESEARCH ARTICLE

Egg weight estimation and the effect of age and plumage colors on some egg quality traits in Japanese quails (*Coturnix coturnix japonica*)

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ABSTRACT

The aim of this study was to investigate the effect of different age and plumage color on the egg quality traits and cholesterol levels, in addition to which traits can be used for egg weight prediction in Japanese quails. The eggs obtained from 23-week-old original plumage colored Japanese and Jumbo quails, and 39-week-old Jumbo quails; 40, 40, and 20 eggs were used respectively as the research material. The eggs obtained from 23-week-old original plumage colored Japanese and Jumbo quails, and 39-week-old Jumbo quails; 40, 40, and 20 eggs were used respectively as the research material. In terms of plumage color difference, when Japanese quails were compared to Jumbo quails; yolk weight, yolk height, yolk diameter were higher, and likewise the cholesterol level was lower ($P<0.01$). The lowest cholesterol content was found in eggs from 23-week-old Japanese quail ($P<0.01$). Egg width, shape index, yolk height, and shell weight in group 1; albumen weight, yolk diameter, and egg volume in group 2; egg volume and egg length data in group 3 have determined the best fit for estimation of the egg weight. As a result, the plumage color is a factor that affected the egg quality traits and cholesterol level in quails. Furthermore, some egg quality traits may be used to establish the equations for estimation of the egg weight.

Keywords: Age; Egg quality traits; Egg weight estimation; Plumage color; Quail

INTRODUCTION

In the poultry industry, the quail is the smallest type of bird which is considered a farm animal. Among the quails, Japanese quails (Coturnix coturnix japonica), which are a domesticated poultry species indigenous to East Asia, are the most common type and those reared in Asia and Europe for in addition to meat and egg production, they are also bred for hobbies (Lukanov and Pavlova, 2020). Because of resistance to disease, rapid growth, easy management and the opportunity to use a large number of animals in the limited area at the same time, they are a preferred laboratory model animal in biological and genetic studies for poultry (Huss et al., 2008; Morris et al., 2020). At the same time, there is a need for research on many subjects such as selection of lines for high productivity in quail breeding, feeding, care and management, prevention from diseases, processing of eggs and meat (Minvielle, 2004). After the effect of domestication and different selections, quail lines with different plumage colors, which the most common of those are brown, white and yellow have become popular in the world (Lukanov and Pavlova, 2020). It has been noticed that the Japanese quail sub-variety, which is popularly expressed as Jumbo quail, occurs when the ASIP (Agouti Signaling Protein) gene found in mammals is homozygous dominant in quails. This sub-variety is named Jumbo quail (Minvielle et al., 2007; Avşar and Akpınar, 2020). Egg quality is affected by genetic factors and plumage color depends on genetic structure (Alkan et al., 2010). Furthermore, the selection has also affected some eggs quality characteristics as well as plumage color (Altan et al., 1998; Hanusová et al., 2016). Some researchers have investigated egg quality with different plumage colors (Yılmaz et al., 2011; Çelik et al., 2014; Inci et al., 2015; Şimşek et al., 2016; Bai et al., 2019; Eratalar and Okur, 2020; Lan et al., 2021), but there are

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still limited studies on the matter of egg cholesterol levels in quail (Maurice et al., 1994; Nowaczewski et al., 2021).

An egg is expressed as a complex structure with protein, water, carbohydrates, fat, ash, and cholesterol content which consists of albumen, yolk, and shell (Campbell et al., 2003). The dry matter of the egg yolk is 66% and it contains 80% lipids, out of which 25% are phospholipids and 5% cholesterol in the total egg yolk content. Egg yolk is the one part of the egg as source of nutrition (Vieira, 2007). Albumen contains approximately 88% water. Furthermore, it is an important source of protein for both human nutrition and embryo development. Choi et al. (2001) examined cholesterol levels in different poultry species and reported that quail eggs were lower than other poultry. However, there have been many studies on egg quality and content in the literature. The lack of sufficient studies examining different age and plumage color groups on cholesterol levels motivated this study. Egg weight is one of the most concerned trait for both consumers and producers to determine the egg prices (Genchev, 2012). Studies made on the prediction of egg weight have been popular in the last two decades. Some researchers have revealed modelling equations by using egg quality traits (Khurshıd et al., 2003; Dere et al., 2009; Dudusola et al., 2019; Okon et al., 2020; Portillo-Salgado et al., 2020; Portillo-Salgado et al., 2021). This study investigates the effects of different ages and feather colors on Japanese quail eggs' internal and external quality characteristics and cholesterol value. Because egg quality is crucial for both human nutrition and the incubation sector, this study aims to determine which characteristics can be used to predict egg weight, which has economic importance.

MATERIAL AND METHODS

Animal husbandry

This study was carried out in Prof. Dr. Hümeyra Özgen Research and Application Farm (38.037594313909835, 32.5052012168554) belongs to Selcuk University. The material of the study was obtained from 75 original and light-yellow plumage color Japanese quails at 23-week-old, and 40 light yellow plumage color quails at 39-week-old (it is also known as Jumbo). The eggs were collected as daily. The flocks used in the study had a male/female ratio of 1: 4 and were bred under the same care and feeding conditions. The quails were bred in animal breeding rooms dimension of which 4 × 4 m in cages 94 × 44 × 21 cm dimensions and were provided at least 120 cm^2 area for each animal. Chicks were allowed access to water and food *ad libitum*. The lighting method was 16 L:8 D. Temperature and humidity were maintained at 20-22°C and 40-50% respectively by radiant heater and ventilation. Temperature and humidity conditions in the rearing rooms were checked at regular intervals twice a day with a digital temperature and humidity meter. Basal diet of the quails was given in Table 1.

Egg quality and cholesterol measuring

In the study, egg and yolk weights were weighed with a digital scale (KERN PFB 1200, 0.01 g sensitivity) while egg width and length, yolk height and yolk diameter were measured with a digital caliper (Kanon EMS-150, 0.01 mm sensitivity). After the removal of internal egg components, eggshell was washed and left to dry for 24 hours and then dried eggshell weights and shell thicknesses were measured. Egg cholesterol levels were measured in a medical laboratory by GC-MS analysis and using seven eggs from each group. The cholesterol analysis of the study was used to standard (COI/T.20/Doc.No.10/Rev.1.2001) methods. The data were used to calculate, rely on the equations given below (Haugh, 1937; Alkan et al., 2015):

Haugh unit: 100 x Log [Albumen height – (1.7 × Egg weight $^{0.37}$) + 7.57].

Shape index: (Egg width/Egg length) x 100
Albumen weight (g): Egg Weight – (Yolk weight + Shell weight)
Albumen ratio (%): (Albumen weight/Egg weight) × 100
Yolk ratio (%): (Yolk weight/Egg weight) × 100
Shell ratio (%): (Shell weight/Egg weight) x 100

Egg weight estimation and statistical analysis

One-way ANOVA test was used to compare the means of more than two groups, and the differences between groups were detected with Duncan's multiple comparison test. Stepwise method was used in the construct of regression models and equations for each group were performed with following equation below (Okon et al., 2020):

$$EW = a + b_1X_1 + e$$

Table 1: Basal diet contents of the study (Dry matter basis)

Crude Protein (%)	20.0
Crude Fiber (%)	2.2
Crude Fat (%)	5.2
Crude Ash (%)	5.0
Ca (%)	0.7
P (%)	0.6
Na (%)	0.2
Lysine (%)	1.2
Methionine (%)	0.5
Vit A (IU/kg)	13500
Vit D3 (IU/kg)	3500
Vit E (mg/kg	80

IU: International Unit

Where:
EW = Egg weight
a = constant
b_1 = regression coefficient of the i^{th} independent variable
X_1 = the value of the independent variable
e = error term

IBM SPSS Version 25.0 package program was used for statistical analysis, results were evaluated at 95% confidence interval and statistical significance at P<0.05 level.

RESULTS

Effect of plumage color on egg quality traits and cholesterol levels

Effect of plumage color on external and internal quality traits were given in Table 2.

Egg weight, egg width and egg length were affected by plumage color (P<0.001). Similarly, plumage color affected the shell weight (P<0.01). Those traits were found to be higher for Japanese quails than Jumbo quails. On the other hand, shape index, shell ratio and eggshell thickness did not significantly affect by plumage color.

Egg internal quality traits and cholesterol levels were also presented in Table 2. In terms of plumage color groups, there was no significant affect was determined in Haugh unit, yolk ratio and albumen ratio. Yolk weight and diameter values were determined the highest in original plumage-coloured Japanese quails (P<0.01). In contrast to other quality traits, cholesterol level of eggs was measured the highest in Jumbo quails (P<0.001).

Effect of age on egg quality traits and cholesterol levels

The effect of age on egg quality traits and cholesterol levels were presented in Table 3. Egg weight and egg width were affected by the age of quails and showed an increase with the age increase (P<0.05). Similarly, with the increasing of age eggshell thickness increased (P<0.001).

In terms of internal quality traits Haugh unit, albumen weight and albumen ratio did not affect significantly by the age groups. Yolk weight was determined the most affected internal quality trait by age groups (P<0.001). The highest yolk weight was observed in elderly Jumbo quails. Moreover, age showed significant effect on yolk ratio and yolk diameter (P<0.05). The yolk height, which is another internal quality trait, was also significantly affected by age and was determined higher in elderly Jumbo quails (P<0.01). Cholesterol levels of eggs were found lower in younger quails while higher in elderly Jumbo quails (P<0.05).

Egg weight estimation

Regression analysis of some egg quality traits and the regression equations were given respectively in Table 4 and Table 5. Egg width, shape index, yolk height and shell weight in group 1; albumen weight, yolk diameter and egg volume in group 2; egg volume and egg length data in group 3 were determined the best fit for estimation of the egg weight with high R^2_{adj} values.

DISCUSSION

Plumage color

Egg weight is an important quality parameter both consumer and egg producers (Genchev, 2012). In this study,

Table 2: Effect of plumage colors on egg external and internal quality traits

Traits	Group-1 n = 40	Group-2 n = 40	$\bar{X} \pm SEM$ n = 80	P Value
External traits				
Egg weight (g)	12.49±0.16[a]	11.35±0.18[b]	11.92±0.14	***
Egg width (mm)	26.06±0.11[a]	25.35±0.15[b]	25.71±0.10	***
Egg length (mm)	33.96±0.21[a]	32.57±0.30[b]	33.27±0.20	***
Shell weight (g)	1.10±0.02[a]	0.96±0.03[b]	1.03±0.02	**
Shape index (%)	76.83±0.41	78.04±0.75	77.44±0.43	-
Shell ratio (%)	8.77±0.16	8.53±0.30	8.65±0.17	-
Eggshell thickness (mm)	0.20±0.00	0.21±0.00	0.21±0.00	-
Internal traits				
Haugh unit	93,67±0,53	92,32±0,61	93.00±0.41	-
Yolk weight (g)	4,08±0,08[a]	3,57±0,10[b]	3.83±0.07	***
Yolk ratio (%)	32,59±0,40	31,49±0,71	32.04±0.41	-
Yolk height (mm)	11,08±0,17[a]	10,39±0,16[b]	10.74±0.13	**
Yolk diameter (mm)	24,79±0,29[a]	23,51±0,24[b]	24.15±0.20	***
Albumen weight (g)	7,32±0,09[a]	6,82±0,14[b]	7.07±0.09	**
Albumen ratio (%)	58,64±0,44	59,98±0,73	59.31±0.41	-
Cholesterol levels of eggs (mg/100g)	464,59±1,59[b]	508,89±2,69[a]	486.74±2.93	***

Group-1: Japanese quail; Group-2: Jumbo quail.
[a,b]Means along the same row with different superscripts are significantly (**: *P*<0.01; ***: *P*<0.001) different.

Table 3: Effect of age on egg external and internal quality traits

Traits	Group-2	Group-3	$\bar{X} \pm SEM$	P Value
	n = 40	n = 20	n = 60	
External traits				
Egg weight (g)	11.35±0.18[b]	12.25±0.37[a]	11.65±0.18	*
Egg width (mm)	25.35±0.15[b]	25.99±0.28[a]	25.57±0.14	*
Egg length (mm)	32.57±0.30	33.08±0.41	32.74±0.24	-
Shell weight (g)	0.96±0.03	0.95±0.04	0.96±0.03	-
Shape index (%)	78.04±0.75	78.68±0.77	78.26±0.56	-
Shell ratio (%)	8.53±0.30	7.74±0.25	8.27±0.22	-
Eggshell thickness (mm)	0.21±0.00[b]	0.24±0.00[a]	0.22±0.00	***
Internal traits				
Haugh unit	92.32±0.61	90.55±0.85	91.73±0.51	-
Yolk weight (g)	3.57±0.10[b]	4.26±0.14	3.80±0.09	***
Yolk ratio (%)	31.49±0.71[b]	35.38±1.63[a]	32.78±0.75	*
Yolk height (mm)	10.39±0.16[b]	11.12±0.21[a]	10.63±0.14	**
Yolk diameter (mm)	23.51±0.24[b]	24.59±0.46[a]	23.87±0.23	*
Albumen weight (g)	6.82±0.14	7.04±0.35	6.89±0.15	-
Albumen ratio (%)	59.98±0.73	56.89±1.69	58.95±0.76	-
Cholesterol levels of eggs (mg/100g)	508.89±2.69[a]	530.60±12.72	516.13±4.73	*

Group-2: Jumbo quail; Group-3: Elderly Jumbo
[a,b]Means along the same row with different superscripts are significantly (*: $P<0.05$; **: $P<0.01$; ***: $P<0.001$) different.

Table 4: Regression analyzes of some egg quality traits

Group/Model		B	$s_{\bar{x}}$	Beta	t	P Value
Group-I	Constant	-10.765	1.390		-7.746	0.000
	Egg width	1.247	0.052	0.911	23.783	0.000
	Shape index	-0.143	0.012	-0.375	-11.723	0.000
	Yolk height	0.104	0.030	0.115	3.477	0.001
	Shell weight	0.571	0.249	0.086	2.290	0.028
Group-II	Constant	-2.147	0.993		-2.162	0.037
	Albumen weight	0.744	0.083	0.583	8.959	0.000
	Yolk diameter	0.208	0.052	0.272	4.028	0.000
	Egg volume	0.301	0.077	0.304	3.915	0.000
Group-III	Constant	2.382	1.077		2.212	0.040
	Egg volume	1.076	0.051	1.095	21.218	0.000
	Egg length	-0.110	0.048	-0.119	-2.316	0.033

Table 5: Regression equations of the experimental groups

Group	Equation	R2adj	MSE
I	$EW = -10.765 + 1.247\ EWT - 0.143\ SI + 0.104\ YH + 0.571\ SW$	0.961	0.19543
II	$EW = 2.147 + 0.744\ AW + 0.208\ YD + 0.301\ EV$	0.887	0.38656
III	$EW = 2.382 + 1.076\ EV - 0.110\ EL$	0.985	0.20309

$R^2_{adj.}$ Adjusted coefficient of determination; MSE: Mean Square Error; Egg weight (EW, g); Egg width (EWT, mm); Shape index (SI, %); Yolk height (YH, mm); Shell weight (SW, g); Albumen weight (AW, g); Yolk diameter (YD, mm); Egg volume (EV, cm^3); Egg length (EL, mm).

egg weight was significantly affected by plumage color ($P<0.001$, Table 2). Moreover, yellow-colored (Jumbo) quails age of which 23-week-old had lower egg weight among the groups. This is similar to findings of Lan et al. (2021) that yellow plumage-colored quail lines lay lower egg weight than brown ones. Also, this result is compatible with similar to other studies for plumage color (Yılmaz et al., 2011; Sarı et al., 2012; Inci et al., 2015; Begum et al., 2016; Bai et al., 2019; Cahyadi et al., 2019; Eratalar and Okur, 2020). However, Bagh et al. (2016); Şimşek et al. (2016); Hassan et al. (2017) noticed that there was no difference in egg weight in different plumage-colored quails. Those results can be explicable with plumage color is determined not by environmental factors but genetic structure.

In this study, it was determined that the difference between the plumage color groups in terms of egg length and width values was significant (P<0.001). These results were found to be similar to Yılmaz et al. (2011); Bai et al. (2019). On the other hand, plumage color did not any significant effect on the shape index (Table 2). Although, our result in agreement with Bagh et al. (2016); Hassan et al. (2017), almost in all studies, plumage color effect on shape index determined as significant (Yılmaz et al., 2011; Genchev, 2012; Sarı et al., 2012; Begum et al., 2016; Bai et al., 2019). However, the differences between the studies are varied, in fact the shape of the egg is formed in the oviduct.

Eggshell quality affects the consumers preference and embryo development, therefore it is a versatile external quality feature with economic value for the poultry industry (Zita et al., 2013). Eggshell quality shows wide variation depending on many genetic and environmental factors. In this study, among the shell quality traits, plumage color affected only the shell weight(Cahyadi et al., 2019). Except the shell weight, findings of Hassan et al. (2017) supported other shell quality traits. Similarly, Chimezie et al. (2017); Al-Kafajy et al. (2018) determined a differences between the shell weights of the black, white and brown plumage colored quails. Opposite to our results, Yılmaz et al. (2011) reported that there was no differences in shell weight of brown, gray and white plumage-colored quails. Moreover, contrary to present study results', Sarı et al. (2012) determined that there are significant differences between shell ratio in brown, white, golden and gray plumage-colored quails. Meanwhile, Inci et al. (2015); Bagh et al. (2016); Chimezie et al. (2017) reported that eggshell thickness did not significantly affect by plumage color similar to the current study. Observation of differences in shell quality characteristics in studies may be due to basal diet contents of the quails or genetic structure.

Haugh unit as known one of the most take attention quality parameter of the eggs by consumers. In the present study, among the plumage color groups, there was no significant effect was observed. When the study results are evaluated, it can be advised that both original and light yellow quail eggs can be eaten in terms of the quality without no concern supported by some studies that used different plumage-colored quails (Inci et al., 2015; Bagh et al., 2016; Chimezie et al., 2017).

Yılmaz et al. (2011), examining egg quality in different plumage colors, reported that these four parameters are affected by plumage color differences. Yolk ratio and albumen ratio were not affected, while yolk weight and albumen weight, the internal quality characteristics of eggs, were significantly affected by plumage color differences. Maiorano et al. (2009) reported that this difference in yolk weight and egg albumen weight might affect the amount of cholesterol.

The present study concluded that cholesterol was significantly affected by the difference in plumage color, in accordance with hypothesis of them.

Quail age

In the present study, egg weight also affected by quail age (P<0.05, Table 3). This result is similar to some studies reporting that the effect of age on egg weight is significant (Sarı et al., 2012; Wilkanowska and Kokoszyński, 2012; Zita et al., 2013; Nhan et al., 2018; Udoh et al., 2020). The present study also showed that elderly quails produce more heavier egg but the increase of the egg weight proceed till a certain age. That finding in line with the findings of Abanikannda et al. (2007); Zita et al. (2013); Udo=(2020) but not agreement with results of Santos et al. (2015); Nowaczewski et al. (2021). That may be related with the rearing management or age of the quails used in the studies are varied.

While, egg width affected by quail age, egg length not and that finding in agreement with Eratalar and Okur (2020). On the other hand, the effect of age on shape index did not significant supported by the results of Zita et al. (2013); Lan et al. (2021). These differences may be due to age and care-feeding. In the current study, among the shell quality traits, age of the quail affected only the eggshell thickness.

Likewise, also age of the quails did not affect significantly Haugh unit of the eggs, and it can be concluded that both quail eggs obtained from 23 and 39 week of age can be eaten without no concern in terms of quality. Quiet similar result was reported in a study concluded that Haugh unit of quail eggs did not affected by age Santos et al. (2015). However, Zita et al. (2013) reported that albumen weight and albumen ratio decreased with the Haugh unit, but the yolk weight and yolk ratio increased. In this study, it was determined that age did not affect the albumen ratio and albumen weight, but the yolk weight and yolk ratio increased (Table.3). This difference may be due to nutritional differences or genotypes.

Nowaczewski et al. (2021) reported that cholesterol level increases with age, found the lowest amount of cholesterol in quail eggs at 23 weeks of age. In the present study, the amount of cholesterol in the eggs of young animals was lower than in the elderly, and this result was found to be compatible with the literature.

Egg weight estimation

Egg weight is a trait closely related to egg production (Okon et al., 2020) and it could predict by using some

egg internal and external quality traits (Dudusola et al., 2019). In the current study, egg weights for each group were predicted with multiple linear regression (stepwise method) and the equations were established. The equations in each group for the estimation of egg weight were given in Table 5. In the present study, it was observed that for the 1st group, the egg weight was dependent on the effect of four variables, and therefore it can be said that it has a more complex structure. On the other hand, it was determined that a more superficial evaluation could be made in the 3rd group, in which the egg weight was explained with the least variable. Egg quality and weight can be evaluated more comprehensively by detailing the effect of the variables (egg width, shape index, yolk height and shell weight) that are important in determining and examining the egg weight in the group 1, which is more affected by the variables. Additionally, the presence of more variables in the equation established to predict egg weight in group 1 may be of genetic origin, especially plumage color. As seen in Table 5, egg length can use as a variable for the prediction of the egg weight. As in our results, Khurshıd et al. (2003); Okon et al. (2020) reported the egg weight could be predict with using egg width and length as regressors. In multiple linear regression which variables are necessary to prediction of the egg weight was determined. In summary, it can be said that by using only those variables may be enough to egg weight prediction.

CONCLUSION

In conclusion, the plumage color is a factor affecting the egg quality traits and cholesterol level in quails. The results demonstrated that Japanese quails are more suitable than Jumbo quails because of producing more heavier eggs with low cholesterol levels. In terms of Haugh unit, eggs of obtained light yellow quails until 39 week of age and both original and light-yellow plumage-colored quails and can be eaten by consumers without no concern. On the other hand, egg width and length can be used as regressors for the estimation of the egg weight in Japanese quails. The presented study showed that it can provide some practical and commercial benefits to layer and breeder farms. Furthermore, some egg quality traits may be used to establish the equations for estimation of the egg weight.

AVAILABILITY OF DATA AND MATERIALS

The authors declare that data supporting the study findings are also available to the corresponding author.

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CONFLICT OF INTEREST

The authors declared that there is no conflict of interest.

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ETHICAL STATEMENT

This study was approved by the Selcuk University Experimental Research and Application Center, Animal Experiments Ethics Committee (Approval no: 2021/13).

AUTHORS' CONTRIBUTIONS

Conception and Drafting the Manuscript: Emre Arslan, Serdar Güler. Analysis and interpretation of data: Emre Arslan, Serdar Güler. Collected data: Muhammet Mücahit Sarı. Critical revision of the manuscript for important intellectual content and supervising the work: Orhan Çetin. Statistical analysis: Harun Yonar. All authors read and approved the final manuscript.

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