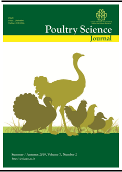

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Egg Production Traits and Egg Quality Characteristics in Black and Brown Plumage Color Lines of Japanese Quail

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Abstract

The present study was conducted to determine egg production traits and egg quality characteristics in black and brown lines of Japanese quail. A total of 500 quails comprising 400 females and 100 males obtained from two breeding centers were raised according to the standard procedure for Japanese quail. They were grouped in according to their plumage colours. Age at first egg-laying has been recorded. Egg production and hen day production (HDP) have also been calculated. Additionally, samples of 240 composite quail eggs, 60 eggs per line, have been randomly selected at the age of 88, 89, and 90 days. Those eggs were used to determine the quality of egg including egg weight, shell thickness, shell weight, shape index, air cavity, albumen index, yolk index, Haugh unit (HU), and yolk color score. Furthermore, the data were analysed using general linear model (GLM) and Tukey's test was performed to evaluate the pairwise differences among quails. The results showed that egg production traits were not different among lines, except age at first egg-laying ($P < 0.0001$). Moreover, brown plumage lines have higher egg weight, shell thickness, shell weight, shape index, yolk index, albumen index, HU, and yolk colour score than black plumage lines ($P < 0.0001$), on the other hand, egg air cavity of black plumage lines were higher than brown plumage lines, 1.71 versus 0.88 mm ($P < 0.0001$). It can be concluded that brown plumage line has better both exterior and interior qualities of egg than black plumage line. These findings may be useful to determine appropriate breeding program for laying quail in the future.

Introduction

Quail, a small domesticated poultry species, is well known as a poultry which is able to produce both egg and meat (Minvielle, 2004). For the past decades, Japanese quail has been popular as an animal model across various purposes in the biological and agricultural fields (Huss *et al.*, 2008; Minvielle, 2004). In Indonesia, Japanese quail (*Coturnix coturnix japonica*) is preferred to be commercially raised due to its high egg production, low feed consumption, and fast growth. Previous studies reported that adult weight of Japanese quail is between 150 and 250 grams (Poynter *et al.*, 2009). In addition, Japanese quail can produce 322 eggs until the age of 69 weeks (Minvielle *et al.*, 2005) and its egg weight is around 11 grams (Kul and Seker, 2004; Minvielle *et al.*, 2005; Alkan *et al.*, 2010).

In general, egg can be classified by evaluating its quality. Egg quality is physically divided into two categories by looking at the exterior and interior qualities itself. These characteristics are usually used as a standard value of egg that may affect to the consumer demand. According to The United States Department of Agriculture/USDA (2000), exterior quality is determined by the color, shape, texture, wholeness, and cleanliness of egg shell whereas interior quality includes the viscosity of egg albumen index, yolk form, and the presence or absence of stains on white or egg yolk. Duman *et al.* (2016) reported that an exterior parameter, shape index, may be used to determine egg weight, albumen index, and Haugh unit. In addition, egg weight was significantly determined by eggshell weight and eggshell thickness (Kul and Seker, 2004). Consumers always pay more attention to eggshell color even though little or no evidence direct relationship between shell color and egg nutritional content is found, however, it can be a strong indicator to evaluate egg freshness and cleanliness directly in the market (Scott and Silversides, 2000). Moreover, egg interior characteristics are often calculated to determine Haugh unit score. It is an appropriate indicator to evaluate the quality of egg (Biswas *et al*., 2010).

Egg production traits and egg quality characteristics are affected by both genetic and environmental factors such as species, line, strain, nutrition, rearing system, and the oviposition time (Ahmadi and Rahimi, 2011; Yang *et al*., 2014). The two Japanese quail lines which are commercially developed to produce egg in Indonesia are black plumage color and brown plumage color lines. Prihtiyantoro *et al*. (2001) reported that plumage color in Japanese quail can be useful to determine the genetic basis for auto sexing of day-old quail (DOQ) and criss-cross inheritance has been identified for brown plumage male and black plumage female mating in this study. Minvielle *et al*. (1999) reported that plumage color did not affect egg production traits in Japanese quail. However, previous studies published that there were differences among plumage color lines for both external and internal quality of Japanese quail egg in Turkey (Yilmaz *et al*., 2011). In addition, Sari *et al*. (2012) reported that egg quality differences among plumage color groups has been investigated for egg weight, shape index, shell weight and ratio, yolk index, albumen index and Haugh unit. The data regarding egg production traits and egg quality characteristics for black and brown lines of Japanese quail in Indonesia is not very well documented. Hence, the present investigation was undertaken to evaluate the egg production traits and egg quality characteristics in black and brown lines of Japanese quail.

Material and Methods

Quail population and management

The quail population was obtained from two quail breeding centers consisting two lines in accordance to their plumage colors, i.e. black plumage and brown plumage lines. A total of 500 Japanese quails consisting of 400 females and 100 males have been raised in this study. This population was constructed by two breeding centers i.e. quail breeding center 1 (QBC1) and quail breeding center 2 (QBC2). Every breeding center has two different Japanese quail lines based on their plumage colors, hence two black plumage lines and two brown plumage lines have been raised to produce eggs. Each line was composed by four colony cages for female quail and a cage for male quail, and each cage was inhabited by 25 heads of quail. The number of cages represented replication.

The birds were fed using a commercial feed for laying quail containing 2700 kcal ME/kg, 18% crude protein, 3% calcium, and 0.9% phosphor. Each quail offered around 25 g of feed whereas water was available ad libitum. A lighting was applied for 12 hours/day. All quails were reared under the same environmental and management condition based on standard procedure for raising Japanese quail (Randall and Bolla, 2008).

Observation of egg production traits

Egg production traits, age at first egg-laying, total number of eggs, and hen day egg production (HDP), have been observed. Age at first egg-laying has been recorded as the first quail spawn in the colony cage. The total number of eggs was calculated as total egg production in every cage started from first egg-laying until 12 weeks of age before quails were moved to mating cage. In addition, HDP was determined according to average of total number of eggs produced during the age of 88, 89, and 90 days compared to the total number of hen-days in the same period. Hen day egg production is expressed in percentage (%).

Measurement of egg quality characteristics

A total of 240 eggs have been collected for both exterior and interior characteristic of quail eggs analyses. They were obtained from four colony cages for each line. Five composite eggs were collected at the age of 88, 89, and 90 days for every cage. Furthermore, egg quality characteristics including egg weight, shape index, shell weight, shell thickness, air cavity, yolk index, albumen index, Haugh unit, and yolk colour have been analyzed to evaluate the egg quality traits in this population. Egg and shell weights were individually recorded using a digital weighing with 0.01 g accuracy and yolk color was measured by Roche yolk color (RYC) fan (Lokaewmanee *et al*., 2009). A digital display caliper was used for width, length, yolk diameter, albumen length and width of the egg measurements. A table with a glass cover on it was used on which the eggs are broken. Heights of yolk and albumen, shell thickness, and air cavity were calculated using a depth micrometer. Dried shells were weighted together with the shell membrane. Those data were used to evaluate egg quality traits by following these formulas (Nazligul *et al*., 2001).

- Shape index (%) = (Width (mm)/Length (mm)) × 100
- Yolk index (%) = (Yolk height (mm)/Yolk diameter (mm)) ×100
- Albumen index (%) = (Albumen height (mm)/{(Albumen length (mm) + Albumen width (mm))/2}) × 100
- Haugh unit = 100 log (Albumen height (mm) + 7.57 – 1.7 × Egg weight (g)$^{0.37}$)

Statistical analyses

Data collected were subjected to be analized with analysis of variance (ANOVA) using general linear model (GLM) and correlation among traits was carried out (MINITAB version 14.0). The following mathematic model was used to determine the effect of quail line on observed traits.

$$Y_{ijkl} = \mu + F_i + L_{j(i)} + C_{k(ij)} + \varepsilon_{ijk(l)}$$

where, Y_{ijkl} is the phenotype of the l^{th} quail, μ is population mean, F_i is the fixed effect of quail breeding center (farm), $L_{j(i)}$ is the random effect of the i^{th} farm nested within the j^{th} line, $C_{k(ij)}$ is the random effect of the k^{th} cage nested within the j^{th} line and i^{th} farm, and $\varepsilon_{ijk(l)}$ is the residual error associated with the l^{th} bird. The level of alpha was set at $P < 0.05$. Pairwise differences among quail lines were evaluated by using Tukey's test.

Results

Evaluation of egg production traits and egg quality characteristics in black and brown lines of Japanese quail has been conducted in the present study. Analysis of variance proved that age at the first egg-laying was significantly different among lines. Black plumage line from QBC2 was two days older than other lines at the first egg-laying, on the other hand, total number of egg and hen day egg production were not different among quail lines (Table 1). The significant effect of quail breeding center was found in this study. Quail breeding center 2 (QBC2) produced more eggs and higher hen day egg production than QBC1, however the age at first egg-laying of quail population from QBC2 was slower one to two days than quail from QBC1.

Table 1. Egg production and egg quality traits in black and brown lines of Japanese quail

No	Variable	QBC1 (Mean±*SEM*)		QBC2 (Mean±*SEM*)		*P*-Value
		L	B	L	B	
1	Age at first egg-laying (day)	$38.75±0.11^a$	$38.75±0.06^a$	$39.75±0.17^b$	$41.00±0.09^c$	<0.0001
2	Egg production	791.3±12.2	794.8±31.4	720.0±16.6	736.8±22.2	0.860
3	Hen day egg production (%)	73.00±3.16	72.33±4.33	84.67±2.99	81.33±3.20	0.787
4	Egg weight (g)	$9.30±0.07^a$	$10.86±0.07^b$	$9.08±0.10^a$	$10.67±0.10^b$	<0.0001
5	Shell thickness (mm)	$0.35±0.01^a$	$0.53±0.02^c$	$0.30±0.01^a$	$0.42±0.02^b$	<0.0001
6	Shell weight (g)	$1.37±0.02^a$	$1.68±0.06^b$	$1.41±0.03^a$	$1.59±0.04^b$	<0.0001
7	Shape index (%)	$74.44±0.43^a$	$82.02±0.28^d$	$77.36±0.41^b$	$79.70±0.38^c$	<0.0001
8	Air cavities (mm)	$2.00±0.07^d$	$0.63±0.05^a$	$1.42±0.07^c$	$1.13±0.09^b$	<0.0001
9	Albumen index (%)	$10.54±0.10^a$	$12.72±0.21^c$	$10.73±0.20^a$	$11.53±0.16^b$	<0.0001
10	Yolk index (%)	$38.51±0.27^a$	$41.62±0.19^c$	$38.03±0.34^a$	$39.52±0.22^b$	<0.0001
11	Haugh unit (HU)	$67.30±0.47^a$	$74.41±0.23^c$	$69.33±0.79^b$	$70.77±0.25^b$	<0.0001
12	Yolk colour score	$6.77±0.06^a$	$8.03±0.08^c$	$7.28±0.06^b$	$7.50±0.07^b$	<0.0001

Note: ^{a,b,c,d} Means in the same row with different superscript indicate significantly differences.
QBC1 is quail breeding center 1; QBC2 is quail breeding center 2; L is black plumage line; B is brown plumage line; SEM is standard error of measurement.

Table 2. Person correlation among phenotypic traits in black and brown lines of Japanese quail

Traits	Age at first egg-laying (AFE)	EP	HDP	EW	ST	SW	SI	AC	AI	YI	HU
Egg Production	-0.380ns										
Hen day egg production (%)	0.303^*	0.023^{ns}									
Egg weight (EW)	0.135^*	0.063^{ns}	0.079^{ns}								
Shell thickness (ST)	-0.098^{ns}	-0.022^{ns}	-0.332^*	0.445^{**}							
Shell weight (SW)	0.038^{ns}	-0.133^{ns}	-0.033^{ns}	0.311^{**}	0.085^{ns}						
Shape index (SI)	0.045^{ns}	-0.018^{ns}	-0.179^{ns}	0.491^{**}	0.312^{**}	0.302^{**}					
Air cavity (AC)	-0.069^{ns}	0.249^{ns}	0.101^{ns}	-0.467^{**}	-0.275^{**}	-0.358^{**}	-0.538^{**}				
Albumen index (AI)	-0.011^{ns}	-0.115^{ns}	-0.002^{ns}	0.418^{**}	0.305^{**}	0.264^{**}	0.339^{**}	-0.449^{**}			
Yolk index (YI)	-0.057^{ns}	-0.058^{ns}	-0.214^{ns}	0.320^{**}	0.342^{**}	0.298^{**}	0.325^{**}	-0.396^{**}	0.372^{**}		
Haugh unit (HU)	-0.028^{ns}	-0.276^{ns}	-0.092^{ns}	0.437^{**}	0.244^{**}	0.257^{**}	0.361^{**}	-0.536^{**}	0.475^{**}	0.339^{**}	
Yolk colour (YC)	0.022^{ns}	0.066^{ns}	0.050^{ns}	0.422^{**}	0.309^{**}	0.258^{**}	0.491^{**}	-0.487^{**}	0.344^{**}	0.323^{**}	0.450^{**}

Note: The values in the table represent Pearson correlation. *represents significant correlation among traits ($P < 0.05$); **represents highly significant correlation among traits ($P < 0.01$); ^{ns} represents no significant correlation among traits.

This study found that egg weight, shell thickness, albumen and yolk indexes were significantly different among quail lines ($P < 0.0001$). Egg weight, shell thickness, albumen and yolk indexes which are produced by laying quail from QBC1 were higher than egg produced by laying quail from QBC2 (Table 1). Moreover, all of observed egg quality traits were significantly different among lines ($P < 0.0001$). Two brown plumage quail lines were completely better than two black plumage quail lines for both exterior and interior characteristics of egg. Egg weight, shell thickness, shell weight, shape index, yolk index, albumen index, Haugh unit, and yolk colour score of brown quail were higher than black quail. In addition, egg air cavity of brown plumage quail lines was lower than black plumage quail lines (Table 1).

This study has also investigated the correlation among phenotypic traits. The results indicated that there was significant correlation between age at firs egg-laying with egg production, hen day egg production, and egg weight. Negative significant correlation was also found between total number of egg and hen day egg production traits with shell thickness. Moreover, tightly positive relationship among egg quality characteristics in this population has been investigated, except for shell thickness and shell weight (Table 2). A negative correlation between air cavity and other egg characteristics were also found in this study.

Discussion

Since Japanese quail is introduced to surrounding Southeast Asian countries, it becomes very popular among small holder farmers especially in Indonesia. It is raised to produce both egg and meat as a source of important nutrients for human body (Poynter *et al*., 2009). The differences of some phenotypic traits of quail from QBC1 and QBC2 have been investigated in this study. Age at the first egg-laying, egg production traits, and some egg quality characteristics i.e. egg weight, shell thickness, albumen and yolk indexes. The QBC2 was completely better in egg production traits compared than QBC1. However, QBC1 produced heavier egg weight, thicker shell, and higher albumen and yolk indexes than QBC2. It may due to existence of genetic differences between lines developed by the farmers (Minvielle and Oguz, 2002; Hanusová *et al*., 2015). The average of age at first egg-laying in this study was around 38 to 41 days. It was much faster than the study reported by Dauda *et al*. (2014) that the age at first egg-laying of Japanese quail in Egypt was 54 days. This trait is affected by feeding and management practices. Early age at first egg-laying may lead to produce more small eggs, however, early age at first egg-laying followed by improvement of body weight could be very advantageous for commercial reason. The hen day egg production in this study was around 72 to 84%. It was moderate to high hen day egg production. This finding suggested effectiveness to produce egg has been shown in this study (Dauda *et al*., 2014).

The plumage colors were strongly affecting age at first egg-laying and egg quality traits in this population. The differences between similar plumage color lines was also identified for shell thickness, shape index, air cavity, albumen index, yolk index, Haugh unit, and yolk color score. However, the value of these traits for brown plumage quail lines was consistently higher than black plumage quail lines. This trend was also applied for egg and shell weights. These findings were very similar with previous study reported by Chimezie *et al.* (2017) that egg weight and shape index of brown plumage quail line was higher than black plumage line. Yilmaz (2011) reported that shape index, albumen index and Haugh unit of brown plumage line was higher than black plumage line, on the other hand, egg weight of black plumage line was higher than brown plumage line. No differences between brown and black line was found for shell weight, shell thickness, and yolk index. In addition, albumen and yolk indexes of brown plumage line were significantly higher than black line (Sari *et al*., 2012). The value of egg quality traits in the current study is relatively lower than previous studies, however, the trend that brown plumage line has better in egg qualities than black plumage line is the same (Yilmaz *et al*., 2011; Sari *et al*., 2012; Chimezie et al., 2017). In addition, the study of egg air cavity in the present study may be the first report. The height of air cavity in population of black plumage line was higher than population of brown plumage line. The results regarding egg quality traits on quail are generally consistent with the findings of this study that use eggs from different plumage color line of Japanese quail. The plumage color differences may bring different genetic variation that play important role to egg production on quail (Minvielle and Oguz, 2002; Mignon-Grasteau and Minvielle, 2003; Kul and Seker, 2004; Minvielle *et al*., 2005; Huss *et al*., 2008; Yilmaz *et al*., 2011). The phenotypic correlations among egg quality traits has previously been reported (Kul and Seker, 2004; Yilmaz *et al*., 2011; Sari *et al*., 2012; Duman *et al*., 2016). This study mentioned that all of egg quality traits observed was positively correlated each other, except air cavity. A study found certain correlations between the shape index with shell thickness, and egg yolk colour (Sekeroğlu *et al*., 2000). On the other hand, Alkan *et al*. (2010) have determined a significant negative correlation between the egg shape index and shell thickness. Egg shell quality depends on egg size and egg weight. Shell strength and thickness were highly correlated to each other. Shape index has a significant effect on the proportion of crushing strength variation (Anderson *et al*., 2004). Regarding correlation among internal egg quality traits, the improvement of the albumen and yolk indexes that indicate the density and quality of albumen and yolk represent internal quality of egg. Higher albumen height which is indicated by denser albumen directly increase the value of Haugh unit since it is used in the formula to estimate its value. Haugh unit is widely known as an important criteria reflecting an idea about internal quality of egg over the world (Kul and Seker, 2004). Regarding the negative correlation between the height of air cavity and other egg quality parameters in this study, no previous study was reported.

Conclusion

This research found that brown plumage of Japanese quail lines were slower at first age of egg-laying and better qualities of both interior and exterior of egg than black plumage line. It may be useful to determine appropriate breeding program for laying quail in small holder farmers in Indonesia.

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