GENETICS AND GENOMICS

Genetic parameters of egg quality traits in long-term pedigree recorded Japanese quail

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ABSTRACT This study was conducted to determine the genetic parameters of internal and external quality traits of Japanese quail eggs. Two statistical models were used in the calculation of genetic parameters and variance components. While 286 eggs were used based on model 1, 1,524 eggs were used based on model 2. Genetic parameters of the first eggs were calculated with direct genetic effect included in the analysis as random factors by using model 1. Model 2 was used for all eggs (5 to 6 eggs from each hen for six rearing groups). As different from model 1, their permanent environmental effects were also included in the model 2. Heritability of egg weight, egg length, egg width, shape index, shell weight, shell thickness, and shell ratio among the external quality traits of the eggs was respectively found to be 0.44, 0.53, 0.51, 0.70, 0.19, 0.16, and 0.05, respectively, according to model 1. These values were found to be 0.46, 0.40, 0.74, 0.48, 0.60, 0.28, and 0.21, respectively, according to model 2. Yolk weight, yolk diameter, yolk height, yolk index, yolk ratio, albumen weight, albumen height, albumen ratio, and Haugh unit values among the internal quality traits of the egg were found to be 0.22, 0.32, 0.02, 0.16, 0.19, 0.34, 0.19, 0.17, and 0.17, respectively, according to model 1. These internal quality traits were found to be 0.27, 0.18, 0.38, 0.06, 0.20, 0.41, 0.15, 0.15, and 0.12, respectively, according to model 2. Consequently, in this study, strong genetic correlations were detected between albumen height and Haugh unit, and also between albumen height and albumen weight. Additionally, a high and positive correlation was observed between some yolk traits (yolk weight and diameter) and albumen traits (weight and height). All these genetic correlations can be used to improve egg quality with a selection according to albumen weight.

Key words: Japanese quail, egg quality traits, genetic parameter

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INTRODUCTION

Quail is a species increasingly raised in Turkey. Quails have become important as a model animal in poultry farming since they have a short generation range, promptly show selection effects, and they are suitable for genetic breeding. This importance has created a need for determining internal and external quality traits of both breeding quails' eggs and commercial enterprises' quail eggs, and for investigating the effective factors in these traits (Uluocak et al., 1995; İpek et al., 2003).

Egg quality may be affected by factors such as age, breed, origin, care, nutrition, temperature, diseases, etc,. Additionally, the storing period and temperature of eggs for consumption or incubation may affect internal quality. As the retention period of eggs increases, albumen height and Haugh unit values decrease and this decrease occurs more quickly in eggs stored at high temperature (Silversides and Villeneuve, 1994; Keener et al., 2000). A negative correlation is present between hatchability and albumen height, and the yolk is the main nutrient source for the growth of the embryo in the incubation period. For this reason, the yolk proportion has a positive association with the hatchability (Cavero et al., 2011). Egg weight and shell quality, which are among the external quality traits of the egg, have been reported to have an important effect on hatchability (Altan et al., 1995), incubation period, chick weight (Shanaway, 1987), early chick mortalities (Skewes et al., 1988), and subsequent chick performance (Al – Murrani, 1978). The negative correlation between and egg weight and hatchability was investigated by Cavero et al. (2011). Also, Bennet (1992) reported that hatchability of thin shell eggs was lower compared to standard egg shells. Some of these genetic and phenotypic relationships have been determined among egg quality traits by researchers (Pandev et al., 1984; Uluocak et al., 1995).

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Determination of genetic effects independently from environmental conditions is carried out using various methods. **REML** (Restricted Maximum Likelihood) is the most suitable method to perform this process (Meyer, 1989). This method ensures the estimation of (co)variance components and genetic parameters using the recorded information between relatives in livestock populations (Henderson, 1975; Wei and Van Der Werf, 1995; Nurgiartiningsih et al., 2002; Mielenz et al., 2006). The data used in this study are the result of unique long-term trial and the purpose of this study was to determine the genetic parameters of quail eggs' external and internal quality traits through reliable records obtained from a quail population whose pedigree and yield records were kept for 12 years.

MATERIALS AND METHODS

Birds, Diets and Management

This study was conducted at Kafkas University Training, Research and Practice Farm Quail Unit. Twelve year pedigree records (5,800) of the population used in this study were used in all analyses. Two hundred and eighty-six female quails from 6 successive rearing groups were used. The first laid eggs (286 eggs) at 12 weeks of age were used for the calculation of genetic parameters according to model 1; whereas the first and successive 5 to 6 eggs from each rearing group (1,524 eggs) were measured for use in model 2.

Breeding quails were kept in apartment-shaped cages which had dimensions of 110 × 30 × 100 cm (height × depth × width), 5 floors, and 5 sections with dimensions of 20 × 30 × 20 cm on each floor, and 1 female and 1 male quail were kept in each section. In the beginning stage, eggs obtained from breeder quails which had pedigree records and were fed with a ration containing 20% crude protein and 2,900 kcal/kg energy (NRC, 1994) were numbered and placed in the incubator to create the first parent flock, and individual hatchings were obtained with a special compartment. Hatching chicks, with numbered eggs in the isolated compartment, were directly wing tagged and recorded with their parents. Chicks were raised in apartment − shaped cages which had dimensions of 110 × 45 × 100 cm, 5 floors, and separate sections with dimensions of 20 × 45 × 100 cm on each floor. Hatching chicks were fed with a ration containing 24% crude protein and 2,900 kcal/kg energy for a period of 5 weeks, and fed ad libitum with a ration containing 20% crude protein and 2,900 kcal/kg energy from the fifth week until the end of the trial (NRC, 1994). The quails were kept in grower cages for nearly 40 days, and then placed into individual cages with 1 male and 1 female. Necessary measurements were performed on the day, when eggs were collected from 12-week-old quails, in order to make the eggs uniform. A lighting program of 16 hours light/day was applied.

Sample Collection and Analytical Determination

Egg weights were measured using a 0.01 g digital display scale, their widths and lengths were measured using a 0.01 mm digital display calliper, and the shape index was calculated. In order to determine the internal quality traits of the eggs, they were cracked on a flat glass table. Their albumen length, albumen width, albumen height, yolk width, and yolk height were measured by using the calliper, and the eggs' shell thickness and weight were determined. All these proceses were contiued until (six generation) to reach enough data with a genetic structure among the birds.

The following formulas were used to determine external and internal quality traits of the eggs (Yannakopoulos and Tserveni – Gousi, 1986; Altan et al., 1995; Altan et al., 1998).

Egg weight (g): The eggs were weighed individually.
Shell weight (g): Shell weight was determined after cracking the eggs and cleaning the residual albumen left on the shell.
Albumen weight (g): Egg weight − (shell weight + yolk weight)
Shape index (%): (Width/length) × 100
Shell thickness (mm): (Pointed end + waist + blunt end)/3
Yolk index (%): (Yolk height/Yolk diameter) × 100
Haugh unit: $100^{*}\log(\text{Albumen height} + 7.57 - 1.7 \times \text{Egg weight}^{0.37})$
Shell ratio (%): (Shell weight/Egg weight) × 100
Yolk ratio (%): (Yolk weight/Egg weight) × 100
Albumen ratio (%): (Albumen weight/Egg weight) × 100

Statistical Analysis

The Minitab (16.0) program was used to determine descriptive statistics of quality traits of the eggs. The model used to analyse the egg traits was:

$$Y_{ij} = \mu + a_i + e_{ij}$$

μ: is the overall mean
Y_{ij}: external and internal egg quality traits
a_i: rearing group effect (i: 1, 2, 3, 4, 5, 6)
e_{ij}: random residual effect.

The REML method was used to determine the genetic parameters of internal and external quality traits through the software Multiple Trait Derivative Free Restricted Maximum Likelihood (Boldman et al., 1995). While model 1, which included animals' direct additive genetic effects, was used for the first eggs, model 2, which also included the random maternal permanent

Table 1. Mean values of the eggs' external quality traits.

Traits	Rearing group						General
	1 (n = 240)	2 (n = 250)	3 (n = 250)	4 (n = 250)	5 (n = 300)	6 (n = 234)	1,524
Egg weight (g)	12.3	11.8	10.9	12.3	12.4	11.5	11.9
Egg length (cm)	3.3	3.2	3.2	3.4	3.4	3.3	3.3
Egg width (cm)	2.6	2.6	2.5	2.6	2.6	2.6	2.6
Shape index (%)	78.6	80.6	80.3	78.0	77.6	78.7	78.9
Shell weight (g)	1.4	1.4	1.4	1.4	1.3	1.2	1.3
Shell thickness (mm)	0.20	0.19	0.20	0.20	0.21	0.19	0.20
Shell ratio (%)	11.1	11.5	10.5	11.0	10.4	10.6	10.8

Table 2. Mean values of the eggs' internal quality traits.

Traits	Rearing group						General
	1 (n = 240)	2 (n = 250)	3 (n = 250)	4 (n = 250)	5 (n = 300)	6 (n = 234)	1,524
Yolk weight (g)	4.0	3.8	3.5	4.1	4.2	3.9	3.9
Yolk diameter (cm)	2.5	2.4	2.3	2.4	2.4	2.5	2.4
Yolk height (cm)	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Yolk index (%)	43.0	45.0	43.8	44.5	44.0	44.7	44.2
Yolk ratio (%)	33.0	31.9	31.6	33.0	33.7	35.5	33.1
Albumen weight (g)	6.9	6.6	6.3	6.9	6.9	6.2	6.7
Albumen height (mm)	5.5	6.0	5.9	6.2	5.9	5.5	5.9
Albumen ratio (%)	55.9	56.6	57.9	56.1	55.9	54.0	56.1
Haugh unit	94.3	96.8	97.1	97.5	96.3	94.9	96.2

environmental effects of quails, was used for all eggs. According to these models:

Model 1 (For the first eggs): $Y_{ij} = \mu + a_i + b_j + e_{ij}$
Model 2 (For all eggs): $Y_{ijk} = \mu + a_i + b_j + c_k + e_{ijk}$
μ: is the overall mean
$Y_{ij(k)}$: any trait (external and internal egg quality)
a_i: rearing group effect,
b_j: random direct additive genetic effect,
c_k: random maternal permanent environmental effect,
$e_{ij(k)}$: random residual effect.

The phenotypic correlation values related to the external and internal quality traits of the eggs were determined by the Pearson correlation analysis (SPSS 16.0).

RESULTS

Table 1 illustrates mean values of external quality traits of the eggs according to the rearing groups. The mean values of egg weight, egg length, egg width, egg shape index, shell weight, shell thickness, and shell ratio were respectively 11.9 g, 3.3 cm, 2.6 cm, 78.9%, 1.3 g, 0.20 mm, and 10.8%.

Table 2 illustrates mean values of internal quality traits of the eggs according to the breeding groups. The mean values of yolk weight, yolk diameter, yolk height, yolk index, and yolk ratio were respectively 3.9 g, 2.4 cm, 1.1 cm, 44.2, and 33.1%. The mean values of albumen weight, albumen height, albumen ratio, and Haugh unit were respectively 6.7 g, 5.9 cm, 56.1%, and 96.2.

Table 3 illustrates the genetic parameters of external quality traits of the eggs according to model 1 and model 2. While the highest heritability was observed in shape index (0.70) according to model 1, the highest heritability was found in egg width (0.74) according to model 2. The lowest heritability was obtained in shell ratio (0.05 and 0.21) according to model 1 and model 2. Heritability of external quality traits was generally high according to model 2.

Table 3. Genetic parameters of the eggs' external quality traits according to model 1 and model 2.

Traits	h^2		PE^2
	Model 1	Model 2	Model 2
Egg weight	0.44	0.46	0.29
Egg length	0.53	0.40	0.26
Egg width	0.51	0.74	0.49E-05
Shape index	0.70	0.48	0.15
Shell weight	0.19	0.60	0.10E-04
Shell thickness	0.16	0.28	0.20E-03
Shell ratio	0.05	0.21	0.25

h^2 = heritability; PE^2 = permanent environmental effect associated with animal, which is related animal itself apart from genetic structure.

Table 4 illustrates the genetic parameters of internal quality traits of the eggs according to model 1 and model 2. Heritability of internal quality traits calculated with model 1 and model 2 was generally low and moderate. While the highest heritability was found in albumen weight and yolk diameter according to model 1, the highest heritability was determined in albumen weight and yolk height according to model 2.

Table 5 illustrates the phenotypic correlations between external and internal quality traits of the eggs. The phenotypic correlations of egg weight with egg length, egg width, and shell weight were calculated to be high and positive. High levels of positive phenotypic correlations were found between yolk weight and yolk diameter, between yolk diameter and yolk ratio,

Table 4. Genetic parameters of the eggs' internal quality traits according to model 1 and model 2.

Traits	h^2		PE^2
	Model 1	Model 2	Model 2
Yolk weight	0.22	0.27	0.33
Yolk diameter	0.32	0.18	0.31
Yolk height	0.02	0.38	0.34E-5
Yolk index	0.16	0.06	0.25
Yolk ratio	0.19	0.20	0.18
Albumen weight	0.34	0.41	0.24
Albumen height	0.19	0.15	0.11
Albumen ratio	0.17	0.15	0.20
Haugh unit	0.17	0.12	0.10

h^2 = heritability; PE^2 = permanent environmental effect associated with animal, which is related animal itself apart from genetic structure.

between yolk height and yolk index, between albumen weight and albumen ratio, and between albumen height and Haugh unit.

Tables 6 and 7 illustrate the genetic correlations of external and internal quality traits of the eggs according to model 1 and model 2, respectively. The genetic correlations of external and internal traits between themselves were generally high. High and positive genetic correlations were determined between egg weight and egg length, and between egg width and shell weight according to model 1 and model 2. High and positive genetic correlations were found between yolk weight and yolk diameter, between albumen height and albumen ratio, between albumen height and Haugh unit, and between albumen ratio and Haugh unit according to model 2.

DISCUSSION

Mean egg weight, egg length and egg width values of the study were similar to those reported by Saatci et al. (2006). Shape index, which is important for both good hatchability and desirable commercial table eggs, was determined as 78.9% in this study and showed similarity with those reported by Icken et al. (2006), Sezer (2007) and Nowaczewski et al. (2010). Additional information was given by Cavero et al. (2011) and they stated that round eggs often had lower hatchability and longer eggs tended to hatch better. Shell weight and shell ratio obtained in this study were higher than those reported by Yilmaz et al. (2011) for gray group quails and those reported by Kul and Seker (2004), and shell thickness was found to be similar to those reported in both studies.

Traits related to yolk are a significant factor in quality of hatching and edible eggs. Values of yolk weight, yolk diameter, yolk height, and yolk ratio were found to be similar to those reported by Kul and Seker (2004). Yolk index and yolk ratio were similar to the values reported by Yilmaz et al. (2011) for gray quails. However, yolk index was lower than the value reported by Gonzalez (1995) for 12-week-old quails. Albumen weight, albumen height, albumen ratio, and Haugh unit in the study were higher than those reported by Nazligul et al. (2001) for the albumen weight and Haugh unit of 12-week-old-quails; whereas, the albumen ratio was lower compared to the same study. These differences between quails in terms of internal and external quality traits of eggs may be associated with their characteristics such as breed/origin, age, care, and nutrition etc.

The heritability of egg weight determined in this study according to model 1 and model 2 was lower than the value reported by Sezer (2007), higher than those reported by Baumgartner (1994) and Daikwo et al. (2013), and similar to those reported by Minvielle et al. (1997), Minvielle (1998) and Lotfi et al. (2012). According to model 2, heritability of egg length and egg width was found to be higher than the values reported by Saatci et al. (2006) and Daikwo et al. (2013). According to model 1 and model 2, shape index heritability in this study was higher than the values reported by Baumgartner (1994), Lotfi et al. (2012), and Daikwo et al. (2013). While the heritability of the shape index calculated according to model 1 was higher than the value reported by Sezer (2007), the value calculated according to model 2 was low. Heritability of shell weight and shell thickness according to model 1 was similar to those by Lotfi et al. (2012). Heritability of the shell ratio determined according to model 1 and model 2 in this study was lower than the value determined by Daikwo et al. (2013). Heritability of shell weight according to model 2 was high; whereas, heritability of shell thickness and shell ratio was moderate. Heritability of shell traits according to model 1 was low. The low heritability was associated with the fact that environmental factors such as feed, management and temperature may have more effect than the additive genetic effect.

Heritability of the eggs' internal quality traits was generally low and moderate in both models. Heritability of internal quality traits was lower than all values reported by Sezer (2008). This may be associated with the different method used by Sezer (2008) as well as some factors such as breed, care, and nutrition. Heritability of albumen height according to model 1 in this study was similar to the heritability reported by Lotfi et al. (2012) and lower than those reported by Singh et al. (2011) and Daikwo et al. (2013). Heritability of albumen weight specified in this study was higher than the value reported by Lotfi et al. (2012), and lower than the value reported by Singh et al. (2011). Heritability of albumen weight according to model 1 was similar to the heritability reported by Baumgartner (1994), and heritability of albumen weight according to model 2 was calculated to be higher than the value reported by Baumgartner (1994). Heritability of yolk weight determined in this study was lower than heritability reported by Baumgartner (1994), Singh et al. (2011), and Lotfi et al. (2012). Similarly, heritability of yolk weight and Haugh unit in this study was lower than heritability reported by Daikwo et al. (2013). The fact that these values of the eggs' internal quality traits were different from the values determined in the other studies may be associated with breed, origin, age, care, nutrition, measurement errors, and the use of different methods.

Table 5. Phenotypic correlations between the eggs' external and internal quality traits and their significance levels.

	Egg weight	Egg length	Egg width	Shape index	Shell weight	Shell thickness	Yolk weight	Yolk diameter	Yolk height	Yolk index	Yolk ratio	Albumen weight	Albumen height	Albumen ratio
Egg length	0.80^{***}													
Egg width	0.86^{***}	0.53^{***}												
Shape index	-0.26^{***}	-0.75^{***}	0.15^{***}											
Shell weight	0.50^{***}	0.36^{***}	0.45^{***}	-0.07^{***}										
Shell thickness	0.16^{***}	0.11^{***}	0.13^{***}	-0.03^{-}	0.10^{***}									
Shell ratio	-0.15^{***}	-0.17^{***}	-0.12^{***}	0.10^{***}	0.78^{***}	-0.01^{-}								
Yolk weight	0.75^{***}	0.66^{***}	0.65^{***}	-0.27^{***}	0.29^{***}	0.11^{***}								
Yolk diameter	0.53^{***}	0.44^{***}	0.50^{***}	-0.13^{***}	0.23^{***}	-0.03^{-}	0.65^{***}							
Yolk height	0.26^{***}	0.25^{***}	0.24^{***}	-0.10^{***}	0.17^{***}	-0.05^{-}	0.29^{***}	0.25^{***}						
Yolk index	-0.11^{***}	-0.06^{*}	-0.11^{***}	-0.01^{-}	-0.00^{-}	-0.02^{-}	-0.16^{***}	-0.42^{***}	0.77^{***}					
Yolk ratio	0.01^{-}	0.11^{***}	0.02^{-}	-0.12^{***}	-0.11^{***}	-0.02^{-}	0.67^{***}	0.40^{***}	0.16^{***}	-0.11^{***}				
Albumen weight	0.88^{***}	0.67^{***}	0.75^{***}	-0.19^{***}	0.31^{***}	0.14^{***}	0.38^{***}	0.30^{***}	0.15^{***}	-0.06^{*}	-0.40^{***}			
Albumen height	0.19^{***}	0.15^{***}	0.20^{***}	-0.02^{-}	0.08^{**}	0.07^{**}	0.04^{-}	0.03^{-}	0.16^{***}	0.13^{***}	-0.15^{***}	0.24^{***}		
Albumen ratio	0.06^{*}	-0.03^{-}	0.02^{-}	0.07^{**}	-0.26^{***}	0.03^{-}	-0.54^{***}	-0.32^{***}	-0.15^{***}	0.07^{**}	-0.89^{***}	0.52^{***}	0.17^{***}	
Haugh unit	-0.06^{*}	-0.05^{*}	-0.02^{-}	0.05^{-}	-0.05^{-}	0.03^{-}	-0.14^{***}	-0.10^{***}	0.10^{***}	0.15^{***}	-0.15^{***}	0.02^{-}	0.97^{***}	0.16^{***}

−: $P > 0.05$; *: $P < 0.05$; **: $P < 0.01$; ***: $P < 0.001$.

The egg weight, shape index, shell weight, yolk height, and albumen weight, whose heritability is moderate or high, could be improved by selection.

Phenotypic correlations of the eggs' external traits between themselves in this study were generally similar to the values reported by Ozcelik (2002) and Sezer (2007). The phenotypic correlations between yolk height and yolk diameter, yolk index and yolk ratio; between albumen height and albumen ratio and Haugh unit; between albumen weight and albumen ratio and Haugh unit; and between albumen ratio and Haugh unit were generally similar to those reported by Sezer (2008).

Both egg length and width showed positive genetic correlations with egg weight according to model 1 and model 2 in this study. Similar situations were also reported by Saatci et al. (2006), Sezer (2007) and Alkan et al. (2010). Negative genetic correlations were found between egg weight and shape index, and the same situation was also reported by Daikwo et al. (2013) and Narinc et al. (2015). High and positive genetic correlations were found between egg weight and shell weight according to model 1 and model 2, and a similar situation was also determined by Narinc et al. (2015). Heavier egg weight is related with thicker and heavier egg shell; this condition is also associated with the hatchability as well as defensive barrier against bacterial penetration (Sauter and Petersen, 1974; Liao et al., 2013). Bennet (1992) found that eggs with thin shell had lower hatchability rates at the rate of 3% to 9% compared to eggs with thick shell. Low and negative genetic correlations were found between egg weight and shell ratio according to model 1 and model 2, and similar situation was also reported by Sezer (2007), Alkan et al. (2010) and Narinc et al. (2015).

High and positive genetic correlations were specified between albumen height and Haugh unit according to model 1 and model 2 in this study. A similar situation was also reported by Sezer (2008) and Daikwo et al. (2013). High and positive genetic correlations were found between yolk diameter and yolk weight, between albumen height and Haugh unit, and between albumen weight and albumen ratio according to model 1 and model 2. Similarly, low and negative genetic correlations were found between yolk diameter and albumen ratio, and between yolk weight and albumen ratio; whereas, high and negative genetic correlations were found between yolk ratio and albumen ratio, and similar situations were also reported by Sezer (2008). The albumen height is considered the most important trait of internal egg quality. The Haugh unit measures the egg protein quality based on albumen height of the egg. Higher albumen height in the eggs might be attributed to higher Haugh units, which is a very important trait for consumers. However, optimal storage conditions and minimum storage times are crucial to obtain the best quality at the consumer's level. Silversides and Scott (2001) reported that when the eggs were laid, albumen height of eggs was the highest and decreased with increasing storage time.

Table 6. Genetic correlations of the eggs' external quality traits according to model 1 and model 2.*

	Egg weight	Egg length	Egg width	Shape index	Shell weight	Shell ratio
Egg weight		0.82	0.87	−0.06	0.85	−0.16
Egg length	0.73		0.15	−0.78	0.76	−0.03
Egg width	1.00	1.00		0.48	0.66	−0.44
Shape index	−0.08	−0.71	1.00		−0.10	−0.18
Shell weight	0.70	1.00	1.00	0.14		0.41
Shell ratio	−0.02	−0.82	−0.02	0.21	0.71	

*Genetic correlations of the eggs' according to model 1 are above and model 2 below the diagonal.

Table 7. Genetic correlations of the eggs' internal quality traits according to model 1 and model 2.*

	Yolk weight	Yolk diameter	Yolk index	Yolk ratio	Albumen weight	Albumen height	Albumen ratio	Haugh unit
Yolk weight		0.65	−1.00	1.00	0.63	1.00	−0.18	−0.14
Yolk diameter	1.00		1.00	1.00	0.44	1.00	−0.14	1.00
Yolk index	−0.23	1.00		−1.00	−1.00	1.00	1.00	1.00
Yolk ratio	0.30	1.00	−0.86		−0.53	−0.44	−1.00	−0.33
Albumen weight	1.00	0.98	−0.29	−1.00		0.54	0.62	0.27
Albumen height	0.30	1.00	1.00	−0.41	0.70		0.41	0.94
Albumen ratio	−0.17	−0.17	1.00	−0.85	0.59	1.00		0.29
Haugh unit	−0.05	0.25	1.00	−0.34	0.18	1.00	1.00	

*Genetic correlations of the eggs' according to model 1 are above and model 2 below the diagonal.

Quail records have been kept for approximately 15 years until today. In this period, 94 generations and 11,000 wing tags have been reached, and pedigree and yield records of 8,500 quails have been regularly and still kept. It is inevitable that the studies conducted depending on the reliability of these records have more accurate results. Although there are many studies in the literature related to model 1 for the examined traits in poultry, this is not the case for model 2. Genetic and permanent environmental effects on egg quality among quails were revealed by this study. Determination of permanent environmental effects related to quails is important in terms of arranging care and nutrition conditions.

Haugh unit is a criterion to evaluate egg quality. Strong genetic correlation between this trait and albumen height was determined in this study. Additionally, correlation between albumen height and albumen weight, which has high heritability, was also strong. All these genetic relations can be used to improve egg quality with a selection according to albumen weight. On the other hand, a selection made according to yolk height might be employed to develop egg quality traits, as it had a high and positive correlation with yolk traits (yolk weight and diameter) and albumen traits (weight and height). Furthermore, a simultaneous selection on yolk weight and egg weight occurs by making selection on yolk ratio since yolk ratio is a proportion of yolk weight and egg weight.

Methods used in this study were familiar with many livestock studies. But in this study, those methods were applied to eggs' internal and external traits with the support of pedigree file. This application showed that estimated genotypic and phenotypic parameters of egg traits could be used in the desired selection in Japanese quail.

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