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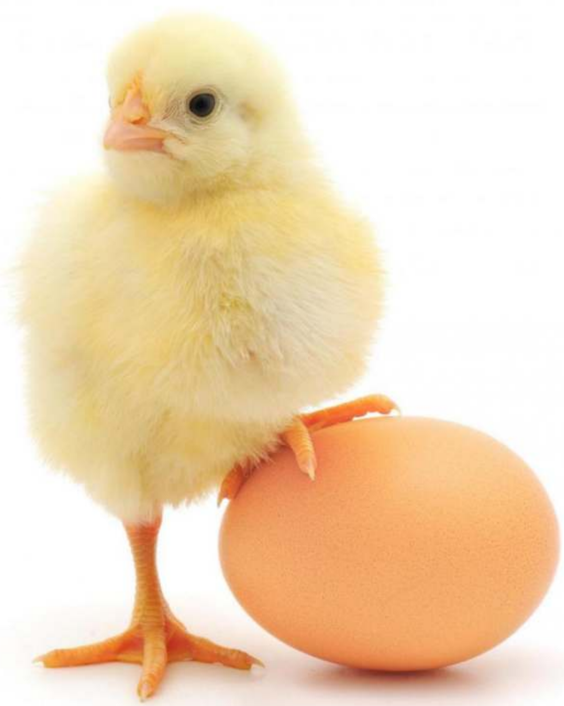

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Phenotypic Correlations Between Some External and Internal Egg Quality Traits in the Japanese Quail (*Coturnix coturnix japonica*)

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Abstract: In this study, it has been aimed to determine the internal and external quality traits of the quail eggs as well as the phenotypic correlation between these traits. Totally 202 Japanese quail eggs collected in three sequential days were used for this study. Eggs were obtained from 90 female quails, all at 20 weeks of age. The birds were housed as 1 male/3 female per cage of 40x30x30 cm at Quail Research unit of the Department of Zootechnia, Faculty of Veterinary Medicine, Firat University. The values related to egg weight, shape index, shell weight, unit surface shell weight, shell ratio and average shell thickness are found respectively as 11.28 g, 74.90%, 0.84 g, 45.98 mg/cm^2, 7.47% and 0.231 mm; and the albumen index, albumen height, albumen weight, albumen ratio, yolk diameter, yolk height, yolk weight, yolk index, yolk ratio and the average values related to the haugh unit are found respectively as 9.37%, 3.80 mm, 6.75 g, 59.83%, 2.57 cm, 0.939 mm, 3.69 g, 36.70%, 32.71% and 85.73%. According to the results obtained in this research, almost all internal quality traits of the egg were changed at the significant levels depending on the change occurred in the egg weight with respect to the external quality traits of the egg. However, the yolk and shell rates changed opposite to the albumen ratio and the albumen index. As a result, it has been considered that it was possible to use the egg weight in determining the eggshell weight, shell thickness and the shell ratio instead of using these traits that are the determinants of the eggshell quality of the quail eggs.

Key words: Quail, egg, quality traits, phenotypic correlation

Introduction

The significance of animal proteins in sufficient and balanced nourishment is considerable for the human health with respect to the physical and mental progress. (Uluocak *et al.,* 1995). Among such animal protein sources, the poultry animals have a significant place due to the numerous advantages contained. In the last years, it has been observed in the poultry breeding that the quails were benefited as much as hens both for their meat and eggs, therefore, commercial quail breeding have become widespread (Altinel *et al.,* 1996).

Although meat production was considered more commonly, the egg breeding became more important in some countries such as China. Besides, the productivity and quality of the breeding eggs have an overall significance for the continuity of the flocks and for an economical breeding (Sogut *et al.,* 2001). Moreover, external and internal quality traits of the eggs are significant in the poultry breeding for their influence on the yield features of the future generations, breeding performances, and quality and growth of the chicks (Altinel *et al.*, 1996, McDaniel *et al.*, 1978).

In numerous research related to the aforementioned subjects, it has been reported that the external and internal quality traits of the eggs in both hens (Hurnik *et al.*, 1978; Nordstrom and Ousterhout, 1982) and quails (Narahari *et al.*, 1988; Peebles and Marks, 1991) had significant effects on the hatchability of incubated and fertile eggs, and weight and development of the laying chicks.

The significance of the egg as a protein source for the nourishment of humans led the consumers to demand for some qualities in this nutrient (Uluocak *et al.*, 1995). Approximately 7-8 % of the total amount of the eggs is broken throughout the transfer of the eggs from the breeders to the consumers. Thus, especially the amount of cracked and broken eggs results in a serious economical problem both for the breeders and the dealers (Hamilton, 1982). Moreover, some of the egg quality traits have significant and direct effects on the prices of especially commercial flocks. In the egg processing enterprises, the weight of eggshell, albumen and the yolk that form the egg as well as their rates affect the amount and price of the product (Altan *et al.*, 1998). During the investigations made on the quality traits of the egg, the researches had focused on the studies related to the increasing of the stiffness of the eggshell, because the quality of the eggshell has a vital importance for the laying force, embryo growth and the chick quality (Altan *et al.*, 1995).

There are various methods used in the assignment of eggshell quality. The most commonly used methods are specific gravity, shell deformation, shell thickness and the shell rate of the total egg (Thompson and Hamilton, 1982). While determining the qualities such as shell thickness, shell weight and the shell stiffness, either the compulsory of breaking of the egg or the need for the construction of some special mechanisms should be considered. Due to the said reasons, some other methods are said to be applied for determining the shell stiffness (Poyraz, 1989).

In some other researches, the egg weight is said to have a direct relation with the eggshell quality which has a positive correlation with the shell thickness (Choi *et al*., 1983; Stadelman, 1986) and the shell weight (Choi *et al*., 1983; Poyraz, 1989). It is also mentioned by some other researchers that the shell thickness has an effect on the shell stiffness (Buss, 1982; Thompson *et al*., 1981).

Although the internal and external quality traits, especially in the eggs of hens, as well as the correlation between these traits were studied in a number of researches in previous years (Poggepel, 1986; Narahari *et al*., 1988), the number of researches covering such qualities in the quails, especially the phenotypic correlation among these traits were relatively less (Hamilton, 1982).

In Turkey, especially in the recent years, the increasing number of quail breeding activities led the need for examining some issues such as internal and external quality traits of the quail eggs; determining the phenotypic and genetic correlation related to these traits; and determining some environmental factors that affect on these traits.

In this research, it has been aimed to determine the internal and external quality traits of the quail eggs as well as the phenotypic correlation between these traits.

Materials and Methods

Materials: Totally 202 Japanese quail eggs collected in three sequential days were used for this study. Eggs were obtained from 90 female quails, all at 20 weeks of age. The birds were housed as 1 male/3 female per cage of 40x30x30 cm at Quail Research unit of the Department of Zootechnia, Faculty of Veterinary Medicine, Firat University. The Japanese quails were raised in floor pens and fed conventional starter and grower diets until they reached 6 wk of age. The quails were given quail diet "*ad libitum*" containing 21% protein and 3000 kcal ME/kg energy in the first 6 weeks period, and later 17% protein and 2750 kcal ME/kg energy. A lighting schedule of 16 h light/day was applied.

During the research, 0.001 gr. sensitive electronic scale was used for weighing the eggs; a compass sensitive to 0.01 mm was used for measuring the length, width, yolk diameter, albumen length and width of the eggs; a table with a flat glass on it was used on which the eggs are broken; a 3-legged micrometer sensitive to 0.01 mm was used for measuring the height of yolk and albumen; and a micrometer sensitive to 0.01 mm was used for measuring the shell thickness.

Methods: The collected eggs to be used in the research were numerated at first. Then they were balanced in order to determine their weights. Later, the width and length of the eggs were measured. After this process, the eggs were broken on a table with a glass cover in order to measure the yolk height, yolk diameter, albumen length and the albumen height. The yolk departed from the albumen part was weighed together with the membrane and the yolk weight was obtained. The shells were washed under slightly flowing water so that the albumen remains are removed. The washed shells were left to dry in the open air for 24 hours. Then, they were balanced together with the shell membrane. Finally samples taken from sharp, blunt and equatorial parts were measured, and the average shell thickness was obtained from the average values of these three parts (Tyler, 1961).

Some internal and external quality traits of the egg were estimated using following formulae on the basis of the aforementioned measures (Tyler, 1961; Marks and Kiney, 1964; Nesheim *et al*., 1979; Csuka and Ledec, 1981; Stadelman, 1986; Yannakopoulos and Tserveni-Gousi, 1986; Yalcin *et al*., 1990; Altan *et al*.,1995).

$S=3.9782\ W^{0.75056}$

S = Egg surface area (cm^2),

W = Egg weight (mg)

Unit surface shell weight (mg/cm^2) = Egg weight (mg) / Egg surface area (cm^2)

Shape index (%) = [Width (cm) / Height (cm)] x 100

Shell ratio (%) = (Shell weight / Egg Weight) x 100

Albumen index (%) = Albumen height (mm)/[(Albumen length (mm) + Albumen width (mm)]/2) x 100

Albumen ratio (%) = (Albumen weight / Egg weight) x 100

Yolk index (%) = (Yolk height / Yolk diameter) x 100

Yolk ratio (%) = (Yolk weight / Egg weight) x 100

Albumen weight (g) = Egg weight - (Yolk weight + Shell weight)

Haugh unit (HU) = $100 \log (H + 7.57 - 1.7\ W^{0.37})$.

H= Albumen height (mm), W= Egg weight (g)

The phenotypic correlation values related to the internal and external quality traits of the egg are determined by the Pearson Correlation Analysis (Snedecor and Cochran, 1980). The estimations are made by using SPSS (SPSS for Windows, 1999).

Results

The descriptive statistics related to the quality traits of the examined egg in the research are shown in Table 1. The values related to egg weight, shape index, shell weight, unit surface shell weight, shell ratio and average shell thickness are found respectively as 11.28 g, 74.90%, 0.84 g, 45.98 mg/cm^2, 7.47% and 0.231 mm; and the albumen index, albumen height, albumen weight, albumen ratio, yolk diameter, yolk height, yolk weight, yolk index, yolk ratio and the average values related to the haugh unit are found respectively as 9.37%, 3.80 mm, 6.75 g, 59.83%, 2.57 cm, 0.939 mm, 3.69 g, 36.70%, 32.71% and 85.73%.

Table 1: Descriptive statistics of egg quality characteristics

Traits (n=202) External egg quality traits	$X \pm S_x$	Minimum	Maximum	Coefficient of Variation (%)
Egg weight (g)	11.28± 0.06	9.10	13.50	7.43
Egg width (cm)	2.50±0.01	2.34	2.67	2.84
Egg length (cm)	3.34±0.01	2.97	3.70	4.19
Shape index (%)	74.90±0.22	67.42	83.28	4.17
Average shell thickness (mm)	0.231±0.001	0.192	0.282	6.41
Shell thickness (blunt region) (mm)	0.224±0.001	0.195	0.310	8.57
Shell thickness (sharp region) (mm)	0.245±0.001	0.200	0.320	8.24
Shell thickness (equatorial region) (mm)	0.225±0.001	0.180	0.265	7.82
Unit surface shell weight (mg/cm^2)	45.98±0.06	43.61	48.11	1.86
Shell weight (g)	0.84±0.01	0.61	1.06	9.69
Shell ratio (%)	7.47±0.04	5.44	8.96	7.99
Internal egg quality traits				
Albumen length (cm)	4.63±0.04	3.50	5.82	11.12
Albumen width (cm)	3.58±0.03	2.60	4.80	13.52
Albumen height (mm)	3.80±0.03	2.76	4.69	9.84
Albumen index (%)	9.37± 0.10	6.81	12.72	14.91
Albumen weight (g)	6.75±0.04	5.43	8.18	8.77
Albumen ratio (%)	59.83±0.14	55.53	66.64	3.21
Haugh Unit	85.73±0.15	78.99	91.09	2.43
Yolk diameter (cm)	2.57±0.01	2.21	2.78	4.20
Yolk height (cm)	0.939±0.01	0.725	1.110	9.04
Yolk weight (g)	3.69±0.02	2.75	4.40	8.13
Yolk index (%)	36.70±0.28	26.36	46.25	1.10
Yolk ratio (%)	32.71±0.12	25.98	36.27	5.27

On the other hand, the phenotypic correlation values related to the internal and external quality traits of the egg are shown in Table 2, 3 and 4.

Results and Discussion

In this study, the average values that are determined related to the external quality traits of the egg indicated similarities with the findings of most researches (Yannakopoulos and Tserveni-Gousi, 1986, Uluocak *et al.*, 1995; Altan *et al.*, 1998; Nazligul *et al.*, 2001; Ozcelik 2002), whereas, they indicated differences for some other traits (Altan *et al.*, 1998, Nazligul *et al.*, 2001).

In this study, the average values that are determined related to the internal quality traits of the egg were found similar to the results of most researches (Yannakopoulos and Tserveni-Gousi, 1986; Uluocak *et al.*, 1995; Altan *et al.*, 1998; Nazligul *et al.*, 2001; Özcelik 2002), whereas, they indicated differences with the results of some other researches (Nagarajan *et al.*, 1991; Uluocak *et al.*, 1995; Nazligul *et al.*, 2001). It was considered that the differences between the results of this research and the results of the other researches might have resulted from the genetic structure, health condition, flock age, use of different content diets in feeding, and the differences in the care and management conditions of the quails.

In the study, the statistically significant but negative phenotypic correlation value (-0.22) determined between the egg weight and the egg shape index were determined in conformity with the phenotypic correlation values obtained by Iscan and Akcan (1995) in the hen eggs and by Ozcelik (2002) in the quail eggs respectively as -0.26 and -0.10 with the same traits. In this study, statistically significant phenotypic correlation was obtained between the egg weight and the shell weight, and the average shell thickness. The egg weight has an indirect relation with the shell quality of the egg. Thus, it has been stated by most of the researchers that the shell thickness (Choi *et al.*, 1983; Stadelman, 1986) that has a direct relation with the egg weight has positively significant correlations with the shell weight (Choi *et al.*, 1983; Poyraz, 1989). One of these researchers, Stadelman (1986) has mentioned a positive correlation value of 0.26 between the egg weight and the shell thickness. In this research, the shell ratio in the total egg was said to have an opposite correlation with the increase of the egg weight; that is to say, it decreased. This case was most probably resulted from the fact that the increase depending on the egg weight at the shell weight and the shell thickness was less than the increase of the other components that formed the egg. This result was supported by the research results of Ozcelik (2002).

It has been considered that the eggshell quality would be determined by using the egg weight values due to the positive and significant correlation determined between

Table 2: The phenotypic correlations between external egg quality traits

External egg quality traits	Egg width	Egg length	Shape index	Average shell thickness	Shell weight	Shell ratio
Egg weight	0.80**	0.76**	-0.22**	0.21*	0.60**	-0.22**
Egg width		0.35**	0.34**	0.18**	0.42**	-0.25**
Egg length			-0.77**	0.15*	0.53**	-0.08
Shape index				-0.03	-0.25**	-0.10
Average shell thickness					0.67**	0.62**
Shell weight						0.65**

*: P<0.05, **: P<0.01

Table 3: The phenotypic correlations between internal egg quality traits

Internal egg quality traits	Albumen index	Albumen weight	Albumen ratio	Haugh Unit	Yolk diameter	Yolk height	Yolk weight	Yolk index	Yolk ratio
Albumen height	0.67**	0.45**	0.31**	0.95**	0.07	0.30**	0.20**	0.23**	-0.27**
Albumen index		0.14*	0.10	0.68**	-0.04	0.20**	0.08	0.01	-0.05
Albumen weight			0.57**	0.18**	0.40**	0.25**	0.53**	0.05	-0.52**
Albumen ratio				0.26**	-0.08	-0.03	-0.37**	0.01	-0.95**
Haugh Unit					-0.09	0.23**	-0.04	0.23**	-0.22**
Yolk diameter						-0.30**	0.55**	-0.63**	0.15*
Yolk height							0.30**	0.93**	0.03
Yolk weight								0.03	0.45**
Yolk index									-0.03

*: P<0.05, **: P<0.01

the egg weight and the shell thickness, and the shell weight. Similarly, Ozcelik (2002), in his study, has reported that the egg weight values would be used instead for determining the shell quality, because the shell thickness and shell weight would be measured after the breaking of the egg, and it took time to make such measurements.

Although a negative correlation was determined between the egg shape index and the shell weight, any correlation was not found at the significant level between the average shell thickness and the shell rate referring to the traits that determined the shape index and the shell quality. Statistically significant, respectively positive and negative correlation was obtained between the shape index and the width and height of the egg. Such results were similarly determined in a previous research (Ozcelik, 2002). However, in this study, the result that the shape index might give an idea about the shell weight due to the significant negative correlation value between the shape index and the shell weight indicated differences with the results of some researchers (Poyraz, 1989; Ozcelik, 2002). Thus, these researchers did not determine a significant relation between the shape index and the shell weight. Furthermore, the finding obtained between the egg shape index and the shell thickness was in consistent with the research results of Poyraz (1989). However, the shape index was not referred to be a good estimator for the shell thickness and the shell ratio. On the contrary, Yannakopoulos and Tserveni-Gousi (1986) reported that the egg shape index would be used as a criterion for determining the stiffness of eggshell.

In this study, statistically significant negative correlation was found between the albumen height and the yolk ratio among the internal quality traits of the egg, whereas, statistically significant (P<0.01) positive phenotypic correlation was found between the inner quality traits except yolk diameter.

Statistically significant negative correlation (P<0.01) was obtained between the albumen weight and the yolk rate, whereas, statistically significant (P<0.05, P<0.01) positive correlation was obtained between the other traits except the yolk index. Statistically significant negative correlation (P<0.01) was determined between the haugh unit and the yolk rate, whereas, statistically significant positive phenotypic correlation was determined between the other traits except for the yolk diameter and yolk weight. Statistically important positive correlation (P<0.05, P<0.01) was found between the albumen index and the albumen height, albumen weight, haugh unit and the yolk height. Statistically important positive correlation was determined between the albumen rate and the albumen height, albumen weight and the haugh unit, whereas, negative phenotypic correlation was determined between the yolk weight and the yolk rate. These results indicated that as the yolk weight, height and diameter increased, the albumen height also increased and the albumen quality got better.

The improvement of the albumen index, albumen weight and the albumen ratio in addition to the albumen height, which are the parameters (Ozcelik, 2002) presenting an idea about the dense albumen quality as well as being used for the estimation of the haugh unit which is one of

Table 4: The phenotypic correlations between external and internal quality traits of eggs

Internal quality traits	External egg quality traits						
	Egg weight	Egg width	Egg length	Shape index	Average shell thickness	Shell weight	Shell ratio
Albumen index	0.12	0.06	-0.01	0.05	-0.12	-0.04	-0.17*
Albumen height	0.41**	0.32**	0.27**	-0.04	-0.14*	0.14*	-0.23**
Albumen weight	0.94**	0.77**	0.70**	-0.18**	0.04	0.45**	-0.34**
Albumen ratio	0.26**	0.25**	0.15*	0.02	-0.39**	-0.17*	-0.46**
Haugh Unit	0.11	0.08	0.04	0.02	-0.23**	-0.05	-0.18*
Yolk diameter	0.51**	0.46**	0.45**	-0.13	0.03	0.25**	-0.17*
Yolk height	0.30**	0.18**	0.20**	-0.08	0.12	0.23**	-0.01
Yolk weight	0.78**	0.61**	0.60**	-0.19**	0.33**	0.51**	-0.10
Yolk ratio	-0.21**	-0.20**	-0.14*	0.01	0.22**	-0.04	0.17*

*: P<0.05, ** :P<0.01

the internal quality traits of the egg, and an important criterion for determining the internal quality of the egg, indicated that the value of the haugh unit increased as well. Similar to the results obtained in this study, Akbas *et al.*, (1996) have found statistically significant phenotypic correlation between the yolk height and the albumen height (0.48) and haugh unit (0.52), and between the albumen height and the haugh unit (0.97), and Ozcelik (2002) has found statistically significant phenotypic correlation between albumen height and the haugh unit (0.97), the yolk rate (-0.28), yolk height (0.49), between the albumen ratio and the haugh unit (0.22), yolk height (0.24), and between the haugh unit and the yolk height (0.43).

In this study, as a result of phenotypic correlation determined between the internal and external quality traits of the egg, it was understood that there was an increase in the weight of the egg and a decrease in the yolk ratio, and there was statistically significant increase in the other traits (P<0.01) except for the albumen index and the haugh unit. These results were found in conformity with the research findings of Ozcelik (2002). Statistically important positive correlation was obtained in the eggshell weight and the internal quality traits, e.g. between the albumen height, albumen weight, yolk diameter, yolk height and the yolk weight, whereas, negative correlation value was obtained between the shell weight and the albumen rate.

As far as the eggshell ratio increased, statistically significant decreases occurred in all internal quality traits (except for the yolk ratio) studied so far, however, the decreases in the yolk weight and the yolk height were not considered statistically significant. These results are also supported by the research results of Ozcelik (2002).

According to the results obtained in this research, almost all internal quality traits of the egg were changed at the significant levels depending on the change occurred in the egg weight with respect to the external quality traits of the egg. However, the yolk and shell rates changed opposite to the albumen ratio and the albumen index. This case was found to be in conformity with the findings of some researchers (Iscan and Akcan, 1995).

The shape index was found in a significant negative correlation with the albumen weight and the yolk weight; however, no significant correlation was determined with the other internal quality traits. Statistically significant phenotypic correlation value was obtained between the internal quality traits except for the egg width, egg height and the haugh unit, whereas, the correlation only with the yolk ratio among these traits was found negative. The correlation with the internal quality traits of the egg width was determined somewhat higher than the internal quality traits of the egg height except for the yolk height. This result has shown that the egg width might indicate rather better results than the egg height in the estimation of the internal quality traits. Similar result was obtained in another research as well (Ozcelik, 2002).

Conclusion: As a result, it has been considered that it was possible to use the egg weight in determining the eggshell weight, shell thickness and the shell ratio instead of using these traits that are the determinants of the eggshell quality of the quail eggs. In addition, it was determined that the internal quality traits of the egg changed at statistically significant levels, except for the haugh unit, according to the changes in the egg weight, egg width and the egg height, and that the other external quality traits had effects on the changes occurred in some internal quality traits. We hope that the results obtained in this study that contain numerous external and internal quality traits of the quail eggs would contribute in the studies of other researchers who will study on these traits as well as the activities of the breeders who deal with the quail eggs breeding and improvement.

References

Akbas, Y., O. Altan and C. Kocak, 1996. Effects of hen's age on external and internal egg quality characteristics. Turk. J. Vet. Anim. Sci., 20: 455-460.

Altan, O., I. Oguz and P. Settar, 1995. Japon bildircinlarinda yumurta agirligi ile ozgul agirliginin kulucka ozelliklerine etkileri. Turk. J. of Agri. Foresty, 19: 219-222.

Altan, O., I. Oguz and Y. Akbas, 1998. Effects of selection for high body weight and age of hen on egg characteristics in Japanese Quail (*Coturnix coturnix japonica*). Turk. J. Vet. Anim. Sci., 22: 67-473.

Altinel, A., H. Güneþ, T. Kirmizibayrak, S.G Corekci and T. Bilal, 1996. The studies on egg quality characteristics of Japanese quails. J. Fac. Vet. Univ. Istanbul, 22: 1: 203-213.

Buss, E.G., 1982. Genetic differences in avian egg shell formation. Poult. Sci., 61: 2048-2055.

Choi, J.H., W.J. Kang, D.H. Baik and H.S. Park, 1983. A study on some characteristics of fractions and shell quality of the chicken egg. Korean J. Anim. Sci., 25: 651-655.

Csuka, J. and M. Ledec, 1981. Egg quality evaluation by selected physical markers. Rocz. Nauk Zoot T., 8: 45-58.

Hamilton, R.M.G., 1982. Methods and factors that affect the measurement of egg shell quality. Poult. Sci., 61: 2022-2039.

Hurnik, G.G., B.S. Renhart and J.F. Hurnik, 1978. Relationship between albumen quality and hatchability in fresh and stored hatching eggs. Poult. Sci., 57: 854-857.

Iscan, K.M. and A. Akcan, 1995. Broyler parent yumurtalarinda yumurta agirligi, yumurta ozgul agirligi ve bazi yumurta kisimlari arasindaki iliskiler. J. Central Anim. Res. Inst., 5: 49-52.

Marks, H.L. and T.B. Kiney, 1964. Measures of egg shell quality. Poult. Sci., 43: 269-271.

McDaniel, G.R., D.A. Roland and M.A. Coleman, 1978. The effect of egg shell quality on hatchability embryonic mortality. Poult. Sci., 58: 10-13.

Nagarajan, S., D. Narahari, I.A. Jayaprasad and D. Thyagarajan, 1991. Influence of stocking density and layer age on production traits egg quality in japanese quail. Br. Poult. Sci., 32: 243-248.

Narahari, D., K. Abdul-Mujev, A. Thangavel, N. Ramamurty, S. Visunathan, B. Mohan, B. Murgananda and V. Sunrararosu, 1988. Traits influencing the hatching performance of japanese quail eggs. Br. Poult. Sci., 29: 101-112.

Nazligul, A., H.E. Bardakcioglu, N.K. Turkyilmaz and D.C. Oral, 2001a. The effect of cage density on egg weight, egg prodcution and feed consumpstion in Japanese quails. J. Fac. Vet. Med. Univ. Istanbul, 27: 2: 429-438.

Nazligul, A., K. Turkyilmaz and H.E. Bardakcioglu, 2001b. A study on some production traits and egg quality characteristics of Japanese quail. Turk. J. Vet. Anim. Sci., 25: 1007-1013.

Nesheim, M.C., R.E. Austic and L.E. Card, 1979. Poultry production. Twelfth edition, Lea & Febiger, Philadelphia. U.S.A.

Nordstrom, J.O. and L.E. Ousterhout, 1982. Estimating of shell weight and shell thickness from egg specific gravity and egg weight. Poult. Sci., 61: 1991-1995.

Ozcelik, M., 2002. The phenotypic correlations among some external and internal quality characteristics in Japanese quail eggs. Vet. J. Ankara Univ., 49: 67-72.

Peebles, E.D. and H.L. Marks, 1991. Effects of selection for growth and selection diet on egg shell quality and embryonic development in Japanese quail. Poult. Sci., 70: 1471-1480.

Poggepel, D.G., 1986. Correlated responce in shell and albumen quality with selection for increased egg production. Poult. Sci., 65: 1633-1641.

Poyraz, O., 1989. Kabuk kalitesi ile ilgili yumurta ozellikleri arasindaki fenotipik korelasyonlar. J. Lalahan Livest. Res. Inst., 29: 66-79.

Snedecor, G.W. and W.G. Cochran, 1980. Statistical method. Seventh edition. The Iowa State University Press, Ames, Iowa, U.S.A.

Sogut, B., M. Sarý, O. Kalpak, H. Inci and E. Babacanoglu, 2001. 1. Dogu Anadolu kanatli yetistiriciligi sempozyumu, 21-24 Mayis, Yuzuncu Yil Universitesi, Van., 197-203.

SPSS for Windows, 1999. Release 9.0. Standard version. Copyright SPSS Inc.

Stadelman, W.J., 1986. The preservation of quality in shell eggs. In W.J. Stadelman. O.J. Cotteril (Eds), Egg science and technology. Avi Puplishing Com Inc Westport, Connecticut, U.S.A.

Thompson, B.K., R.M.G. Hamilton and P.W. Voisey, 1981. Relationships among various egg traits relating to shell strength among and within five avian species. Poult. Sci., 60: 2388-2394.

Thompson, R. and R.M.G. Hamilton, 1982. Comparision of precison and accurarcy of the flotation and archimedes' methods for measuring the specific gravity of eggs. Poult. Sci., 61: 1599-1605.

Tyler, C., 1961. Shell strength. Its measurement and its relationship to other factors. Br. Poult. Sci., 2: 3-19.

Uluocak, A.N., F. Okan, E. Efe and H. Nacar, 1995. Bildircin yumurtalarinda bazi dis ve ic kalite ozellikleri ve bunlarin yasa gore degisimi. Turk. J. Vet. Anim. Sci., 19: 181-185.

Yalcin, S., A Ergun, I. Coplan and A. Sehu, 1990. Yumurta tavugu rasyonlarinda findik ici kabugunun kullanilma olanaklarinin arastirilmasi. Vet. J. Ankara Univ.,3: 485-498.

Yannakopoulos, A.L. and A.S. Tserveni-Gousi, 1986. Quality characteristics of quail eggs. Br.. Poult. Sci., 27: 171-176.