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RESEARCH ARTICLE

Effects of Selection for Body Weight and Egg Production on Egg Quality Traits in Japanese Quails *(Coturnix coturnix japonica)* of Different Lines and Relationships between These Traits [1]

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Summary

This research was conducted to investigate the effects of selection on egg weight, shell thickness, shell weight, shape index, albumen index, yolk index and Haugh Unit in 11 generations selected Japanese quails (Coturnix coturnix japonica). The material used in this research was selected for 11 generations from high (HL) or low (LL) body weight Japanese quail lines according to 5-week body weights and their random bred control line (C) and layer line (L) for 120 d egg production. There were found significant differences among the lines in terms of all egg traits (P<0.01). The egg weights were determined in HL, LL, L and C lines as 14.14±0.17 g, 9.23±0.07, 10.49±0.10 and 11.43±0.13 g respectively. Besides there were significant (P<0.01) differences among the lines for the shell weight, and highest and lowest values were determined as 1.15±0.02 g and 0.84±0.02 g in HL and LL lines. Once again, there were found significant (P<0.05) differences among the lines in point of Haugh Unit. The highest positive correlation (P<0.01) was found between egg weight and egg width (0.938), and the highest negative correlation (P<0.01) was found between shape index and egg length (-0.531). Almost all of the internal quality traits of the egg changes depending on external quality traits of the egg.

Keywords: *Japanese quail, Selection, Egg quality*

Canlı Ağırlık ve Yumurta Verimine Göre Yapılan Seleksiyonun Farklı Hatlardaki Japon Bıldırcınlarının *(Coturnix coturnix japonica)* Yumurta Kalitesi Özelliklerine Etkileri ve Bu Özellikler Arasındaki İlişkiler

Özet

Bu çalışma, 11 generasyon boyunca seleksiyon uygulanmış Japon bıldırcınlarında (Coturnix coturnix japonica) seleksiyonun yumurta ağırlığı, kabuk kalınlığı, kabuk ağırlığı, şekil indeksi, albumen indeksi, sarı indeksi ve Haugh Birimi üzerine olan etkilerinin belirlenmesi amacıyla yapılmıştır. Materyal olarak yüksek canlı ağırlık, düşük canlı ağırlık (5. hafta canlı ağırlığına göre) ve yumurta verimi (120 günlük) yönünde seleksiyon uygulanan hatlar ile kontrol hattı kullanılmıştır. Bütün yumurta özellikleri bakımından gruplar arasında önemli farklılıklar bulunmuştur (P<0.01). Yumurta ağırlıkları yüksek canlı ağırlık, düşük canlı ağırlık, yumurtacı ve kontrol grubu için sırasıyla 14.14±0.17 g, 9.23±0.07, 10.49±0.10 ve 11.43±0.13 g olarak belirlenmiştir. Ayrıca, hatlar arasında yumurta kabuk ağırlığı bakımından da önemli (P<0.01) farklar bulunmuş olup en yüksek ve en düşük değerler HL (1.15±0.02 g) ve LL (0.84±0.02 g) hatlarında saptanmıştır. Benzer şekilde Haugh Birimi bakımından da hatlar arasında önemli (P<0.01) farklılıklar ortaya çıkmıştır. En yüksek pozitif korelasyonun (P<0.01) yumurta ağırlığı ile yumurta eni arasında (0.938), en yüksek negatif korelasyonun (P<0.01) ise şekil indeksi ile yumurta boyu arasında (-0.531) olduğu belirlenmiştir. Neredeyse yumurtanın bütün iç kalite özellikleri yumurtanın dış kalite özelliklerine bağlı olarak değişmektedir.

Anahtar sözcükler: *Japon bıldırcını, Seleksiyon, Yumurta kalitesi*

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INTRODUCTION

Egg weight, shell weight, shell thickness, weight of egg yolk and albumen are the important egg traits influencing egg quality, chick weight and hatching performance if other management conditions and fertility are not the limiting factors [1]. Egg weight is easily predictable from egg length and width as positive association among these traits exists [2]. Information on egg weight along with egg width and length further opens the domain for trying out various prediction equations in order to predict eggshell weight and shell thickness. Positive correlations between egg weight, shell weight and shell thickness have also been reported by Farooq et al.[2]. It was reported that in quail eggshell thickness, albumen index, yolk index and Haugh Unit varied between 0.20-0.30 mm, 5.77-6.68%, 43.15-48.82%, and 82.75-85.53%, respectively [3-5]. Effects of selection for egg number on egg weight and on some egg quality traits were first studied by Wilhelmson [6], who measured shape index, shell thickness, albumen and yolk heights after 4 generations in lines I_1 and I_2 (index selection on egg number and albumen height), selection on egg number, selection on albumen height and control. He only found a response in line I_2 for albumen height, which increased consistently. However, associated effects on egg components were somewhat different between selection experiments [7]. Baumgartner and Simeonovova [8] did not find a difference in the yolk percentage between eggs from heavy and light lines. Altan et al.[9] studied various egg quality traits in their line selected from body weight of 4-week and in the control line, and they found only transient differences for yolk, albumen and shell percentages which later disappeared. Ansah et al.[10] found a significant decrease in egg weight in all three selected generations in the low yolk cholesterol line in comparison with unselected control but no changes in yolk weight.

This study was designed to determine the effects of selection for body weight and egg production on internal and external quality traits of the eggs and relationships between these traits in Japanese quails of different lines.

MATERIAL and METHODS

The lines used in this research was selected 11 generations from four lines: High body weight line (HL), low body weight line (LL) of 5-week body weight, a random bred control line (C) and layer line (L) of egg production for 120 days of Japanese quails which were bred in the Akdeniz University Faculty of Agriculture in Turkey. The lines were established by applying individual selection with 10% and 40% selection intensity for males and females, respectively. Mating was random to minimize inbreeding. The research has been done in the spring season in May. The lines started to laying in March. The temperature and humidity values were determined as 14.90±0.840°C, 77.69±3.383%; 17.15±0.821°C, 79.81±3.305% and 21.00±0.755°C, 73.17±3.041% in March, April and May respectively. Mean body weights in the egg collected period were determined as 335.28±6.40 g; 161.81±1.46 g; 201.80±1.88 g; 220.84±3.11 g in HL, LL, L and C lines, respectively.

Quails were housed individually in 20x20x29 cm cages in quail house with windows at both sides, exposed to 16 h of light and 8 h of darkness. One-to three mating rate was applied. During the experiment, the quails were fed with a diet consisting of 2800 kcal/kg metabolic energy and 21% g crude protein/kg as ad libitium and unlimited water was supplied during the experiment. A total of 60 eggs (3 eggs per each quail) were obtained from 20 female quails per line, all at 16 weeks of age. The eggs were collected three sequential days in the morning hours. The eggs were examined for egg weight (g), egg length (mm), egg width (mm), shell thickness (mm), shell weight (g), albumen index (%), yolk index (%), Haugh Unit (HU) and egg shape index. Egg weights were measured by digital balance to the nearest 0.1 g. Egg width, egg length, yolk width, albumen length, and albumen width are measured by digital compass to the nearest 0.01 mm. Shell thickness measurements of the dried shells with the membrane still intact were obtained from two sides in the equatorial region, as well as on the blunt and the pointed edges with a micrometer to the nearest 0.01 mm. Also, yolk and albumen heights were measured by micrometer to the nearest 0.01 mm.

Egg quality traits were calculated by using formulations [11,12], which follow below.

Shape Index (%): (egg width (mm)/egg length (mm) x 100

Yolk Index (%): yolk height (mm)/yolk width (mm) x 100

Haugh Unit: 100 log (albumen height (mm) + 7.57 - 1.7 x egg weight $^{0.37}$ (g)

Albumen Index: Albumen height (mm)/[(Average albumen length (mm) + width (mm) /2] x100

Following model was used for determination of the effect of line on egg quality traits of quails.

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

Y_{ij}: Represents the egg quality traits

L_i: Effect of the i^{th} line

e_{ij}: Error term

Data were analyzed using one-way ANOVA procedure of SPSS [13] for all egg quality traits except egg shape index, yolk index and albumen index, and significant differences among the means were tested by Duncan's Multiple Range Test. Egg shape index, yolk index and albumen index values did not show normal distribution. So, Kruskal-Wallis was used to analyze these three indexes, and Mann-Whitney U was used to test significant differences. Also, the Pearson's correlations were calculated among the traits [14].

RESULTS

The means of internal and external egg quality traits were given in *Table 1*. It clearly shows that lines had significant effect on egg quality traits.

The Pearson correlations among egg quality traits were given in *Table 2*. As it was seen in *Table 2,* there were significant correlations among the almost of egg quality traits.

Table 1. *Means of the egg quality traits in Japanese quails (Mean±SEM)*
Tablo 1. *Japon bıldırcınlarında yumurta kalite özelliklerine ait ortalamalar (Ortalama±SH)*

Traits	HL	LL	L	C
Egg weight (g)	14.14±0.17 a	9.23±0.07 d	10.49±0.10 c	11.43±0.13 b
Egg width (mm)	27.13±0.11 a	23.56±0.06 d	24.93±0.10 c	25.65±0.08 b
Egg length (mm)	34.71±0.18 a	30.02±0.16 d	31.24±0.16 c	33.41±0.11 b
Yolk height (mm)	12.03±0.08 a	10.51±0.07 c	10.71±0.09 c	11.09±0.10 b
Yolk width (mm)	27.01±0.19 a	21.99±0.12 d	24.41±0.14 c	25.34±0.12 b
Albumen length (mm)	51.15±0.57 a	40.80±0.55 c	48.07±0.45 b	49.50±0.52 ab
Albumen Width (mm)	38.92±0.60 a	31.54±0.34 b	37.49±0.48 a	38.56±0.42 a
Albumen height (mm)	4.58±0.10 a	3.90±0.06 bc	3.78±0.08 c	4.10±0.07 b
Shell thickness (mm)	0.231±0.00 ab	0.226±0.00 ab	0.225±0.00 b	0.234±0.00 a
Shell weight (g)	1.15±0.02 a	0.84±0.02 d	0.91±0.01 c	1.00±0.01 b
Haugh Unit	87.96±0.57 a	88.28±0.34 a	86.07±0.50 b	87.01±0.48 ab
Egg shape index (%)	78.23±0.38 b	78.62±0.37 ab	79.88±0.44 a	76.80±0.26 c
Yolk index (%)	44.57±0.36 b	47.33±0.34 a	43.28±0.42 b	43.67±0.41 b
Albumen index (%)	10.08±0.28 ab	10.67±0.25 a	9.40±0.25 bc	9.33±0.18 c

a,b,c,d: *Means in a row with no common superscript differ significantly (P<0.01)*
HL: *High Line,* ***LL:*** *Low Line,* ***L:*** *Layer,* ***C:*** *Control*

Table 2. *Pearson's correlation coefficients among the egg quality traits in Japanese quails*
Tablo 2. *Japon bıldırcınlarında yumurta kalite özellikleri arasındaki Pearson korelasyon katsayıları*

Traits #	EWi	EL	YH	YW	AH	AW	AL	SW	SI	ST	HU	YI	AI
EWe	0.938**	0.889**	0.727**	0.870**	0.402**	0.548**	0.636**	0.752**	-0.170**	0.132*	-0.018	-0.216**	-0.072
EWi		0.821**	0.676**	0.877**	0.368**	0.567**	0.657**	0.698**	0.044	0.149*	-0.038	-0.270**	-0.101
EL			0.597**	0.806**	0.339**	0.533**	0.641**	0.734**	-0.531**	0.219**	-0.072	-0.242**	-0.127*
YH				0.552**	0.498**	0.271**	0.369**	0.530**	-0.047	0.049	0.207**	0.341**	0.162*
YW					0.239**	0.653**	0.686**	0.661**	-0.114	0.124	-0.163*	-0.507**	-0.228**
AH						-0.065	0.044	0.270**	-0.048	-0.077	0.813**	0.234**	0.673**
AW							0.763**	0.393**	-0.094	0.103	-0.366**	-0.456**	-0.523**
AL								0.432**	-0.148*	0.063	-0.248**	-0.382**	-0.460**
SW									-0.240**	0.347**	-0.076	-0.127*	-0.068
SI										-0.156*	0.073	0.027	0.067
ST											-0.159*	-0.020	-0.080
HU												0.392**	0.766**
YI													0.422**

 # EWe: *Egg weight,* ***EWi:*** *Egg width,* ***EL:*** *Egg length,* ***YH:*** *Yolk height,* ***YW:*** *Yolk width,* ***AH:*** *Albumen height,* ***AW:*** *Albumen width,* ***AL:*** *Albumen length,* ***SW:*** *Shell weight,* ***SI:*** *Shape index,* ***ST:*** *Shell thickness,* ***HU:*** *Haugh unit,* ***YI:*** *Yolk index,* ***AI:*** *Albumen index*
******* *P<0.01,* ******* *P<0.05*

DISCUSSION

There were significant differences among the lines for egg weight, egg length, and egg width. HL line had heavier egg weight, egg length, and egg width than the other lines (P<0.01). Camcı et al.[15] reported a 12 g average egg weight for the quails. This value was the same as our control line, and was lower than HL line, but higher than L and LL lines. Altan et al.[9] determined egg weight as 11.86 g and 11.40 g in selected and control lines, respectively, and the difference was found significant. Also, these values were similar to our control line, and lower than HL line, but higher than the L and LL lines. Türkmut et al.[16] found egg weight as 10.70 g for the selected line. This value was lower than our HL and C lines, but higher than LL and L lines. Also, egg weight of HL line was higher than those reported by Yannakopoulos and Tserveni-Gousi [12], Tserveni-Gousi [17] and Uluocak et al.[4], but egg weight of L line was lower than those reported by Yannakopoulus and Tserveni-Gousi [12] and Tserveni-Gousi [17]. Egg weight, egg length and egg width values increase significantly with selection in HL line, but decrease significantly in LL line. So, egg weight, egg length and egg width was affected significantly by selection in respect of 5th week body weight. Depending on body weight increased, egg weight increased. Similar result was reported by Altan et al [9].

Yolk index values in this study were in agreement with data reported for yolk index in quail in the literature [3,5-18]. These researches reported that yolk index value was ranged from 43.15% to 49.28%. Also, yolk index was affected by selection. There was found significant difference the LL and other lines in respect of yolk index. Depending on body weight decreased, the yolk index increased in this study. Altan et al.[9] reported that yolk weight was found higher for selection group that those of control group. But, Marion et al.[19] reported that yolk ratio in larger eggs was lower than small eggs.

In the same way there were significant differences among the lines for egg shape index, and highest egg shape index value was calculated in L line. Altan et al.[9] reported egg shape index as 78.97% and 78.63% in selected and control lines, respectively, and the difference was found no significant. Generally, depending on body weight increased, egg shape index decreased. Egg shape index values in this study were in agreement with data reported for egg shape index values of between 75.6% and 80.45% in quail in literature [4,5,12,20]. Similarly, decreased shape index with increasing egg weight was supported by Reddy et al.[21].

There were significant differences among the lines for eggshell weight. Since egg weight increases with selection for high body weight, the eggshell weight increases in HL line, and in the same way eggshell weight decreases in L line. Altan et al.[9] reported that eggshell weight was found higher for selection group (0.946 g) than control (0.920 g) group (P<0.05). But, Strong and Nestor [22] reported that differences between selection and control groups in terms of eggshell weight were found no significant in turkeys. Also, significant differences were determined among the lines in respect to albumen traits as length, width and height. Depending on body weight increased, albumen traits increased in HL line.

There were significant differences among the lines for eggshell thickness. The eggshell thickness values in this research were somewhat higher than those reported as 0.206-0.220 mm by Altan et al.[9] and Orhan et al.[18]. The same amount of shell material to the wound as a result of larger egg shell thickness is expected to decrease slightly. But, in this study, there was no significant difference between control and selection groups (HL and LL lines) for 5-week body weight. But, the difference between the control and L groups was found significant. Altan et al.[9] reported that there was no significant difference between the control and selection groups in respect to eggshell thickness.

There was determined significant difference among the lines for the Haugh Unit. The Haugh Unit values in this study were in agreement with data reported for Haugh Unit such as 85.53-95.21 in quail in literature [3,9,16].

In this research, significant but negative phenotypic correlation value (-0.170) determined between the egg weight and the egg shape index was found in conformity with the phenotypic correlation values obtained by İşcan and Akcan [23] in the hen eggs and by Özçelik [24] in quail eggs respectively as -0.26 and -0.10 with the same traits. Also, in this research, significant positive phenotypic correlation was obtained between the egg weight and the eggshell weight (0.752) and the average eggshell thickness (0.132). The egg weight has an indirect relation with the eggshell quality of the egg. So, it has been stated by most of the researchers that the eggshell thickness [25,26] that has direct relation with the egg weight has positively significant correlations with the eggshell weight [25,27]. Stadelman [26] has mentioned a positive correlation value of 0.26 between the egg weight and the eggshell thickness.

It has been regarded that the eggshell quality will be determined by using the egg weight values due to the positive and significant correlation determined between the egg weight and the eggshell thickness, and the eggshell weight. Similarly, Özçelik [24] reported that the egg weight values may be used for determining the

eggshell quality. Because the eggshell thickness and eggshell weight will be measured after the breaking of the egg, it took time to make such measurements.

Although a significant negative correlation was determined between the egg shape index and egg length (-0.531), the positive correlation between the egg shape index and egg width was not found significant (0.044) in this research. Such results were similarly determined in a previous research [24,28]. However, in this research, the result that the shape index might give an information about the eggshell weight due to the significant negative correlation value (-0.240) between the shape index and the eggshell weight indicated similarity with the results reported by Kul and Şeker [28]. But, Poyraz [27] and Özçelik [24] did not found significant relation between the egg shape index and the eggshell weight. There was found significant relation between the egg shape index and the eggshell thickness (-0.156) in this research. Therefore, the shape index was referred to be a good estimator for the eggshell thickness. Similarly, Yannakopoulos and Tserveni-Gousi [12] reported that the egg shape index would be used as a criterion for determining the stiffness of eggshell.

There was found high significant positive correlation (0.673) between the albumen height and albumen index. Also, significant positive correlation was determined between the Haugh Unit and the albumen index (0.766) and yolk index (0.392). Except egg shape index, the yolk height had effected significantly other egg quality traits ($P<0.01$, 0.05). Thus, yolk height increased, the albumen height also increased and the albumen quality had better.

The improvement of the albumen weight and the albumen ratio in addition to the albumen height, which are the parameters [24] presenting an information about the dense albumen quality as well as being used for the estimation of the Haugh Unit which is one of 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. Similarly to the results of obtained in this research, Akbaş et al.[29] have determined 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). Özçelik [24] has found significant phenotypic correlation between albumen height and the Haugh Unit (0.97), yolk height (0.49), and between the Haugh Unit and the yolk height (0.43). Again, Kul and Şeker [28] has found significant phenotypic correlation albumen height and the Haugh Unit (0.95), yolk height (0.30), and between the Haugh Unit and the yolk height (0.23).

According to the results obtained in this research, almost all internal quality traits of the egg change occurred in the egg weight with respect to the external quality traits of the egg. It has been considered that it was possible to use the egg weight in determining the eggshell weight and eggshell thickness instead of using these traits that are determinants of the eggshell quality of the quail eggs. In addition, it was determined that in the HL line which was selected for high body weight, egg weight, egg length, egg width, yolk height, yolk width, albumen height and eggshell weight increased. But, albumen length, albumen width, eggshell thickness and Haugh unit had no changed significantly. The egg qualities are affected by many factors as genetic structure of population, nutrition, health, age, maintenance, storage condition of eggs and storage period. Therefore, new selection studies should be done in different regions, and various production traits could be considered in the divergent selected quail lines. Also, should be given more attention for quail breeding and selection programs.

REFERENCES

1. Khurshid A, Froog M, Durrani FR, Sarbiland K, Chand N: Predicting egg weight, shell weight, shell thickness and hatching weight of japanese quail using various egg traits as regressors. *Int J Poult Sci,* 2, 164-167, 2003.

2. Farooq M, Aneela K, Durrani F, Mugarrab AK, Chand N, Khurshid A: Egg and shell weight, hatching and production performance of japanese broiler quail. *Sarhad J Agr,* 17, 289-293, 2001.

3. Vogt H: Untersuchungen über die Zusammensetzung von Ei und Fleisch bei der japanischen Wachteln. *DGS,* 17, 320-321, 1968.

4. Uluocak N, Okan F, Efe E, Nacar H: Bıldırcın yumurtalarında bazı iç ve dış kalite özellikleri ile bunların yaşa göre değişimi. *Turk J Vet Anim Sci,* 19, 181-185, 1995.

5. Erensayın C, Camcı O: Effects of the oviposion time on egg quality in quails. *Arch Geflügelkd,* 66, 283-284, 2002.

6. Wilhelmson M: Breeding experiments with Japanese quail *(Coturnix coturnix japonica)* II. Comparison between index selection and specialized selection followed by crossing. *Acta Agr Scand A-An,* 30, 373-387, 1980.

7. Minvielle F, Oğuz Y: Effects of genetics and breeding on egg quality of Japanese quail. *World Poult Sci J,* 58, 291-295, 2002.

8. Baumgartner J, Simeonovova J: Bred or line differences of cholesterol content in quail eggs. *XIX World's Poultry Congress,* September 20-24, 1992, Amsterdam. Proc Book, 3, 265-267, 1992.

9. Altan Ö, Oğuz İ, Akbaş Y: Japon bıldırcınlarında *(Coturnix coturnix japonica)* canlı ağırlık yönünde yapılan seleksiyonun ve yaşın yumurta özelliklerine etkisi. *Turk J Vet Anim Sci,* 22, 467-473, 1998.

10. Ansah GA, Chan CW, Touchburn SP, Buckland RB: Selection for low cholesterol in Leghorn-type chickens. *Poult*

Sci, 64, 1-5, 1985.

11. Haugh R: The Haugh unit for measuring egg quality. *US Egg Poult Mag,* 43, 552-555, 572-573, 1937.

12. Yannakopoulos AL, Tserveni-Gousi AS: Quality characteristics of quail eggs. *Brit Poult Sci,* 27, 171-176, 1986.

13. Anonymous: SPSS for Windows, Release 11.0, SPSS Inc., 2001.

14. Snedecor GW, Cochran WG: Statistical Methods. 6th ed., The Iowa State University Press, Iowa, 1967.

15. Camcı O, Erensayın C, Aktan S: Relations between age at sexual maturity and some production characteristics in quail. *Arch Geflügelkd,* 66, 280-282, 2002.

16. Türkmut L, Altan Ö, Oğuz İ, Yalçın S: Japon bıldırcınlarında canlı ağırlık için yapılan seleksiyonun üreme performansı üzerine etkileri. *Turk J Vet Anim Sci,* 23, 229-234, 1999.

17. Tserveni-Gousi AS: Relationship between parental age, egg weight and hatching weight of Japanese quail. *Br Poult Sci,* 28, 749-752, 1987.

18. Orhan H, Erensayın C, Aktan S: Japon bıldırcınlarında *(coturnix coturnix japonica)* farklı yaş gruplarında yumurta kalite özelliklerinin belirlenmesi. *Hayv Üretim Derg,* 42, 44-49, 2001.

19. Marion JE, Woodart JG, Tindell D: Physical and chemical properties of eggs as affected by breeding and age of hens. *Poult Sci,* 45, 1189-1195, 1966.

20. Türkyılmaz KM, Dereli E, Şahin T: Effects of shell thickness, shell porosity, shape index and egg weight loss on hatchability in Japanese quail *(Coturnix coturnix japonica). Kafkas Univ Vet Fak Derg,* 11 (2): 147-150, 2005.

21. Reddy PM, Reddy VR, Reddy CV, Rap PSP: Egg weight, shape index and hatchability in Khaki Campbell duck egg. *Ind J Poult Sci,* 14, 26-31, 1979.

22. Strong Jr CF, Nestor KE: Egg quality and reproduction in turkeys: 5. Relationships among traits in medium and large bodies lines. *Poult Sci,* 59, 417-423, 1980.

23. İşcan KM, Akcan A: Broyler parent yumurtalarında yumurta ağırlığı, yumurta özgül ağırlığı ve bazı yumurta kısımları arasındaki ilişkiler. *J Central Anim Res Inst,* 5, 49-52, 1995.

24. Özçelik M: The phenotypic correlations among some external and internal quality characteristics in Japanese quail eggs. *Ankara Univ Vet Fak Derg,* 49, 67-72, 2002.

25. Choi JH, Kang WJ, Baik DH, Park HS: A study on some characteristics of the fractions and shell quality of the chicken egg. *Korean J Anim Sci,* 25, 651-655, 1983.

26. Stadelman WJ: The preversation of quality in shell eggs. **In,** Stadelman WJ, Cotteril OJ (Eds): Egg Science and Technology. 3rd ed. pp. 63-73, Avi Publishing Inc., Westport, Connecticut, 1986.

27. Poyraz Ö: Kabuk kalitesi ile ilgili yumurta özellikleri arasındaki fenotipik korelasyonlar. *Lalahan Hayv Arş Enst Derg,* 29, 66-79, 1989.

28. Kul S, Şeker I: Phenotypic correlations between some external and internal egg quality traits in the Japanase quail *(coturnix coturnix japonica). Int J Poult Sci,* 3 (6): 400-405, 2004.

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