Effects of genotype and egg weight on hatchability traits and hatching weight in Japanese quail

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Abstract

The effects of genotype and egg weight on hatching weight, fertility, hatchability of fertile eggs and incubated eggs were investigated in Japanese quail. The birds were obtained at an age of 20 weeks from four genetic lines selected for 11 generations for either a high (HL) or a low body weight (LL) at five weeks of age, a randomly bred control line (C) and a layer line (L) selected for egg production over 120 days. Eggs were allocated according to their weight to <10.0 g, 10.1 - 11.0 g, 11.1 - 12.0 g, 12.1 - 13.0 g and >13.1 g groups. There was a significant difference between groups in terms of hatching weight, fertility, hatchability of fertile eggs and hatchability of incubated eggs. The highest hatching weights were recorded in the >13.1 g egg weight group. Genotype affected egg weight significantly, with the highest egg weights recorded in the HL genotype and lowest in the LL genotype. There was a significant positive phenotypic correlation (r = 0.72) between egg weight and hatching weight, and hatching weight increased with an increase in egg weight.

Keywords: *Coturnix coturnix japonica*, egg weight, hatching weight, fertility, hatchability
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Introduction

Hatchability is a function of number of chicks hatched, and is affected by numerous factors such as fertility, egg quality, handling of eggs and management conditions during incubation and hatching. Fertility and egg quality were found to influence hatchability and weight of the day-old chick (Farooq *et al.*, 2000a). Wilson (1991) and Kalita (1994) reported a higher hatchability for intermediate sized eggs compared to too small or too large eggs. Farooq *et al.* (2001a) reported a hatchability of 71.2% in quail on the basis of fertile eggs. Farooq *et al.* (2001b) considered egg and shell weight as the two most important factors affecting hatchability, provided that management is not a limiting factor.

Hatchability, chick weight and subsequent growth performance of chicks are closely related to the weight of the egg. In general, chicks born from excessively small or large eggs exhibit low growth rates (Uluocak *et al.*, 1995). Furthermore, egg weight and weight of one-day old chicks are highly correlated. In the coturnix quail intermediate to large eggs, i.e. those over 8.5 g (Narahari *et al.*, 1988) or 9 g (Insko *et al.*, 1971) displayed the highest fertility and hatchability. Yildirim & Yetisir (1998) investigated the effect of egg weight of Japanese quail on chick weight by grouping eggs in weight classes, *viz.* 11 - 11.9 g, 12.0 - 12.9 g and 13.0 - 13.9 g. Chick weights in the respective groups were 6.98 g, 7.56 g and 8.39 g, and differences were significant with a correlation coefficient of 0.67 (P <0.01) between egg and chick weights. Similarly, Sachdev *et al.* (1985) reported a higher fertility and hatchability in heavy (10.1 - 11.0 g) compared to light (7.01 - 8.9 g) fertile Japanese quail eggs. Sarica & Soley (1995) recorded the highest fertility and hatchability of incubated Japanese quail eggs weighing 11.6 g. However, the highest hatchability of fertile eggs occurred at a weight range of 10.6 - 11.5 g, while the lowest fertility, hatching and hatchability of eggs were observed in eggs weighing 9.5 g and less. Contrary to this, Proudfoot & Hulan (1981) found that egg weight did not affect the fertility and hatchability of fertile eggs.

Egg quality is another factor affecting hatchability. Egg weight, egg shape, shell weight and thickness are external indicators of egg quality. Farooq *et al.* (2001b) and Murad *et al.* (2001) reported lower hatchability of small sized eggs in quail, based on fertile eggs. A reduced hatchability would be observed if embryonic mortality is higher and fertility is lower (Farooq *et al.*, 2001a). Variations in embryonic mortality may be due to eggs of poor quality, imbalanced nutrition of the hen and faults in incubation and hatching equipment. Embryonic mortality as high as 28.8% has been observed in quail (Farooq *et al.*, 2001a).

Kucukyilmaz *et al.* (2001) grouped hatching Japanese quail eggs according to weight groups, *viz.* 9.0 - 9.99 g, 10.0 - 10.99 g, 11.0 - 11.99 g, 12.0 - 12.99 g and >13 g. When stored for nine days embryo mortality was 38.7, 22.0, 21.0, 29.0 and 30.7% in the respective weight groups. Chick weight at hatching as a percentage of initial egg weight was found to be between 62 to 76% (Wilson, 1991), and 68.2% (Murad *et al.*, 2001).

This study was carried out to determine the effects of egg weight on different parameters of fertility in Japanese quail selected to differ distinctly in genotype.

Materials and Methods

Twenty-week old Japanese quail hens were selected from four genotypes. The lines were: a high body weight line (HL) and a low body weight line (LL), based on 5-week body weights (these lines were developed over 11 generations), a randomly bred control line (C) and a layer line (L) selected for egg production over 120 days. The hens were bred at the Akdeniz University Faculty of Agriculture in Turkey. The hens were raised individually in cages. They received a quail diet *ad libitum*, containing 240 g protein/kg and 11.9 MJ ME/kg feed for the first six weeks, and then a diet containing 210 g protein/kg and 11.7 MJ ME/kg feed. A lighting schedule of 16 h light/day was applied. Eggs were collected daily for seven days and weighed on the day of lay on an electronic scale with the sensitivity of 0.01 g. Based on their weights the eggs were classified to <10.0 g, 10.1 - 11.0 g, 11.1 - 12.0 g, 12.1 - 13.0 g or >13.1 g weight groups.

The collected eggs were numbered according to genotype and kept for the seven days in a storeroom at 15 - 20 °C with a relative humidity of 75 - 80%. The eggs were incubated for 14 days at a temperature of 37.8 °C and a relative humidity of 55%. The eggs were individually transferred to hatcher trays in an incubator that was maintained at 37.2 °C and at a relative humidity of 75% until hatching. During incubation the eggs were turned automatically every hour. At the end of the incubation period all unhatched eggs were checked for fertility. Fertility, hatchability of incubated eggs and hatchability of fertile eggs were calculated as follows:

(%) Fertility = (number of fertilized eggs/ total number of eggs placed into incubator) x 100;
(%) Hatchability of incubated eggs = (number of released chicks/total number of eggs placed in incubator) x 100;
(%) Hatchability of fertile eggs = (number of released chicks/number of fertilized eggs placed in incubator) x 100.

In addition, at the end of the incubation eggs that did not hatch were cracked to determine the cause that included infertile eggs, and early (0 - 6 d), middle (7 - 14 d) or late embryonic mortalities (15 - 17 d). The percentage of each condition was calculated within each genotype.

The following model was used to determine the effect of genotype on egg weight:

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

Y_{ij} - represents the egg weight;
G_i - the effect of the i^{th} genotype on egg weight;
e_{ij} - is the error term, $\sim N(0, \sigma_e^2)$.

A similar model was used for predicting other traits (fertility, hatchability of fertile eggs, hatchability of incubated eggs, hatching weight and hatching weight of initial egg weight). For example:

$$Y_{ijk}=\mu+G_i+YA_j+e_{ijk}$$

Y_{ijk} - represents the observation on hatching weight;
G_i - the effect of i^{th} genotype on hatching weight;
YA_j - the effect of j^{th} egg weight group on hatching weight;
e_{ijk} - is the error term, $\sim N(0, \sigma_e^2)$.

To measure the distribution of traits, SAS (1997) was used, and the SPSS (Anonymous, 2001) programme was used for analysis of variance. The Duncan multiple comparison test was applied when a factor affected a trait significantly.

Results and Discussion

The mean body weights at 12 weeks of age of the HL, LL, L and C genotypes were 316 ± 3.5 g, 150 ± 1.4 g, 191 ± 2.1 g and 209 ± 3.6 g, respectively. Genotype had a significant (P <0.01) effect on egg weight. The highest and lowest egg weights were recorded in the HL (12.69 ± 0.063 g) and LL (10.17 ± 0.034 g) genotypes, respectively (Table 1).

Mean hatching weights and egg weights as affected by genotypes and egg weight groups are presented in Tables 1 and 2. Hatching weights of the different egg weight groups differed (P <0.01). Hatching weight means were 6.37 ± 0.049 g, 7.11 ± 0.038 g, 7.64 ± 0.056 g, 8.44 ± 0.102 g and 9.32 ± 0.117 g for the <10.0 g, 10.1 - 11.0 g, 11.1 - 12.0 g, 12.1 - 13.0 g and >13.1 g egg weight groups, respectively. These results correspond with those of Yannakopoulos & Tserveni-Gousi (1987), Farooq *et al.* (2001c) and Seker *et al.* (2004). Uddin *et al.* (1994) grouped Japanese quail eggs in weight groups of 8.59 g, 9.52 g and 10.56 g and recorded a positive correlation between egg weight and hatching weight. They concluded that eggs in the middle weight (9.1 - 10.0 g) group would ensure a successful incubation. In the present study, genotype had a significant (P <0.01) effect on hatching weight. The highest and lowest hatching weights were found in the HL (8.45 ± 0.097 g) and LL (6.32 ± 0.049 g) genotypes, respectively. Hatching weight was positively (P <0.01) correlated with egg weight (r = 0.7199). In this study, mean fertility rates were 46 ± 0.02%, 50 ± 0.02%, 46 ± 0.02%, 36 ± 0.03% and 39 ± 0.03% in egg weight groups <10.0 g, 10.1 - 11.0 g, 11.1 - 12.0 g, 12.1 - 13.0 g and >13.1 g, respectively. Fertility was the highest (P <0.01) in the 10.1 - 11.0 g egg weight group and the lowest in the 12.1 - 13.0 g egg weight group. Furthermore, genotype had a significant effect on fertility, with the highest level in the C genotype (56 ± 0.02%) and the lowest in the HL genotype (34 ± 0.02%). Seker *et al.* (2004) obtained fertility rates of 61.7%, 58.8% and 78.8% in egg weights groups 9.5 - 10.5 g, 10.51 - 11.50 g and 11.51 - 12.5 g, respectively, with differences being significant (P <0.01). Similarly, Sarica & Soley (1995) recorded the highest fertility in Japanese quail eggs in a weight group of 11.6 g. Lower fertility in this study was attributed to the rearing of breeding quail in cages because cage rearing did not ensure effective mating as is the case in floor rearing (Khurshid *et al.*, 2004).

In the present study hatchability of incubated eggs were 43 ± 0.02%, 44 ± 0.02%, 40 ± 0.02%, 29 ± 0.03% and 30 ± 0.03% in the egg weight groups <10.0 g, 10.1 - 11.0 g, 11.1 - 12.0 g, 12.1 - 13.0 g and >13.1 g, respectively. Differences were significant (P <0.01). The highest hatchability of incubated eggs occurred in the egg weight group 10.1 - 11.0 g, and the lowest in the egg weight group 12.1 - 13.0 g. Hatchability of incubated eggs decreased as egg weights increased to 12.1 g, suggesting that egg weights of 10.0 to12.0 g were best suited for incubation. Seker *et al.* (2004) reported significant differences in the hatchability of incubated eggs, ranging from 46.4%, 58.3% to 67.9% in their egg weight groups, 9.5 - 10.5 g, 10.51 - 11.50 g and 11.51 - 12.5 g, respectively. These results differ from the results reported by Prabkaran *et al.* (1984), Sergeeva (1984) and Altan *et al.* (1995). Egg quality and storage conditions might have caused these differences, because these researchers indicated that the hatchability of incubated eggs was higher in heavy than in light eggs. Saylam (1999) reported that differences between the egg weight groups in respect of the hatchability of incubated eggs in Japanese quail were not significant.

In the present study differences (P <0.01) were observed between egg weight groups and hatchability of fertile eggs. The hatchability of fertile eggs was 93 ± 0.02%, 88 ± 0.02%, 86 ± 0.02%, 79 ± 0.04% and 78 ± 0.05% for the <10.0 g, 10.1-11.0 g, 11.1-12.0 g, 12.1-13.0 g and >13.1 g egg weight groups, respectively. The curvilinear relationship between egg weight and hatchability was investigated by Shatokhina (1975) in fowls. He observed that the hatchability of eggs weighing between 46 and 50 g as well as those weighing between 66 and 74 g was between 8 and 10.5% lower than for eggs weighing between 50 and 66 g. Similar results were obtained by Nordskog & Hassan (1969) who found that hatchability was maximal at an egg weight of about 50 g. A 10 g increase in egg weight above this optimum lowered hatchability by 10.7%. Our results support these conclusions, indicating that the hatchability of fertile eggs was low in the heavy egg group, in accordance with results reported by Sachdev *et al.* (1985), Sarica & Soley (1995) and Saylam

Table 1 The effects of genotype on hatching weight, hatching weight of initial egg weight, hatchability of incubated eggs, fertility, egg weight and hatchability of fertile eggs (means ± standard errors)

Genotype	N	Hatching weight (g)	Egg weight: hatching weight	N	Hatchability of incubated eggs	Fertility	Egg weights (g)	N	Hatchability of fertile eggs
C	419	7.74[c] ± 0.047	0.70[c] ± 0.004	859	0.49[c] ± 0.017	0.56[c] ± 0.017	11.13[c] ± 0.034	477	0.88[ab] ± 0.015
L	275	6.84[b] ± 0.044	0.66[b] ± 0.004	642	0.43[c] ± 0.020	0.46[b] ± 0.020	10.43[b] ± 0.030	293	0.94[b] ± 0.015
HL	122	8.45[d] ± 0.097	0.68[b] ± 0.005	453	0.27[a] ± 0.021	0.34[a] ± 0.022	12.69[d] ± 0.063	152	0.80[a] ± 0.032
LL	229	6.32[a] ± 0.049	0.63[a] ± 0.004	658	0.35[b] ± 0.019	0.42[b] ± 0.019	10.17[a] ± 0.034	276	0.83[a] ± 0.023

[a,b,c] P <0.01. Means in a column with no common superscript differ significantly.
C – control; L – layers; HL - high body weight; LL - low body weight lines.

Table 2 The effects of egg weight groups on hatching weight, hatching weight of initial egg weight, hatchability of incubated eggs, fertility and hatchability of fertile eggs (means ± standard errors)

Egg weight groups	N	Hatching weight (g)	Egg weight: hatching weight (g)	N	Hatchability of incubated eggs	Fertility	N	Hatchability of fertile eggs
≤10.0	262	6.37[a] ± 0.049	0.67 ± 0.005	614	0.43[b] ± 0.020	0.46[bc] ± 0.020	283	0.93[a] ± 0.016
10.1 - 11.0	404	7.11[b] ± 0.038	0.67 ± 0.003	921	0.44[b] ± 0.016	0.50[c] ± 0.016	458	0.88[ab] ± 0.015
11.1 - 12.0	240	7.64[c] ± 0.056	0.67 ± 0.008	605	0.40[b] ± 0.020	0.46[bc] ± 0.020	280	0.86[ab] ± 0.021
12.1 - 13.0	75	8.44[d] ± 0.102	0.67 ± 0.008	262	0.29[a] ± 0.028	0.36[a] ± 0.030	95	0.79[b] ± 0.042
>13.0	64	9.32[e] ± 0.117	0.67 ± 0.008	210	0.30[a] ± 0.032	0.39[ab] ± 0.034	82	0.78[b] ± 0.046

[a,b,c,d,e] P <0.01. Means in a column with no common superscript differ significantly.

(1999). Szczerbinska & Zubrecki (1999) also determined that the hatchability of fertile eggs was lower in heavy than in lighter quail eggs. Seker *et al.* (2004) recorded the hatchability of fertile eggs to be 75.2%, 99.2% and 86.2% in egg weight groups of 9.5 - 10.5 g, 10.51 - 11.50 g and 11.51 - 12.5 g, respectively. The highest hatchability of fertile eggs was found in the middle egg weight group, 10.51 - 11.50 g.

Embryo mortality in early, middle and late stages of incubation were 2.11%, 0.97% and 0.32% for the <10.0 g egg group; 3.47%, 0.97%, 1.41% for the 10.1 - 11.0 g egg group; 3.63%, 1.32%, 1.65% for the 11.1 - 12.0 g egg group; 3.43%, 3.05%, 1.14% for the 12.1 - 13.0 g egg group and 5.23%, 1.42%, 1.90% for the >13.1 g egg group, respectively. In all egg weight groups the highest embryo mortality rates were found in the early stage of incubation. Sergeyeva (1976) found that the percentage of dead embryos was higher in heavier than in lighter eggs. Findings of the present study suggested that an increase in egg weight would result in an increase in early mortality. However, Seker *et al.* (2004) reported that in Japanese quail, embryo mortality was higher in the low than in the heavy egg weight group. Compared to our results, Farooq *et al.* (2001a) reported higher early (20.3%) and lower late embryonic mortality (3.6%) in Japanese quail.

Hatching weights were 70.0 ± 0.004%, 66.0 ± 0.004%, 68.0 ± 0.05% and 63.0 ± 0.04% of the egg weight set for hatching in the C, L, HL and LL genotype (Table 1). The genotype had a significant ($P < 0.01$) effect on egg weight : hatching weight, but there was no significant difference among the egg weight groups in terms of egg weight : hatching weight set for hatching (Table 2). The weight of the chick as a percent of egg weight is fairly constant across species, e.g. numerous studies in chickens have shown the relationship between egg weight and chick weight. A rather broad range of egg weight : chick weight ratios (58 - 79%) have been reported for the Japanese quail (Marks, 1975; Shanawany, 1987; Tserveni-Gousi, 1987). A similar wide range of 51 to 72% has been reported for egg weight : chick weight ratios in the bobwhite quail (Mahmoud, 1971; Skewes *et al.*, 1988). Wilson (1991) reported that hatching weight was 62 to 76% of the initial egg weight set in the incubator, while Murad *et al.* (2001) and Khurshid *et al.* (2004) found this proportion to be 67.3% and 68.2%, respectively.

Conclusions

Because large adult hens produced large eggs, it follows that large eggs will be expected to produce large birds, at least at the adult stage. That is, an increase in egg weight will result in an increase in weight of the new-born chick. Therefore, the heavy eggs can be used by the quail industry to increase commercial quail meat. However, in general, an increase in egg weight resulted in a decrease in hatchability traits. Many researchers have established a relationship between egg weight and hatchability traits. Many agree that it is preferable to have eggs of average weight to achieve good hatchability (Wilson, 1991; Brah *et al.*, 1999; Gonzales *et al.*, 1999). Romanoff & Romanoff (1949) and Tsarenko (1988) suggested that hatchability is not well estimated by considering egg weight alone, but also, by taking into account the ratio of egg weight to shell surface area. Large eggs tend to have relatively less shell surface, and that can be an obstacle for normal gas exchange for the embryo. Fertile eggs have the highest probability of hatching successfully when their physical characteristics are average.

Egg weight groups affected hatchability traits significantly. Average-sized eggs resulted in a better hatchability of fertile eggs, hatchability of incubated eggs and fertility as compared to large-sized eggs. That is, hatchability traits decrease with increased egg weight (over 12 g). Thus, the egg weight should be selected carefully for good incubation, and optimum numbers of selection must be determined to reach maximum hatchability. Meanwhile, it should be kept in mind that the economic cost of hatchability must be evaluated while consideration of the beneficial effects in mind. Additionally, if the eggs can be sorted by weight we can produce uniform size quail to meet specific markets demands. The integrated quail operation might find it advantageous to sort hatching eggs by weight, with consideration for flocks by egg weight to obtain more uniform quail at market age with improved efficiency.

Acknowledgement

This study was financially supported by the Scientific Research Projects Unit of Akdeniz University under the project number of 2005.01.0104.007.

References

Altan, O., Oguz, I. & Settar, P., 1995. Effects of egg weight and specific gravity on hatchability and chick weight in Japanese quail. Turk. J. Agric. For. 19, 219-222.

Anonymous, 2001. SPSS for Windows. Release 11.0.0, SPSS Inc.

Brah, G.S., Chaudhary, M.L. & Sandhu, J.S., 1999. Analysis of relation of egg weight with embryonic mortality, hatching time, chick weight and embryonic efficiency in chickens. Ind. J. Poult. Sci. 34, 308-312.

Farooq, M., Aneela, K., Durrani, F.R., Muqarrab, A.K., Chand, C., & Khurshid, A., 2001a. Egg and shell weight, hatching and production performance of Japanese broiler quails. Sarhad J. Agric. 17 (3), 289-293.

Farooq, M., Mian, M.A., Murad, A., Durrani, F.R., Asghar, A., & Muqarrab, A.K., 2001b. Egg traits of Fayumi birds under subtropical conditions. Sarhad J. Agric. 17 (2), 141-145.

Farooq, M., Durrani, F.R., Aleem, M., Chand, N. & Muqarrab, A.K., 2001c. Egg traits and hatching performance of Desi, Fayumi and Rhode Island Red chicken. Pakistan J. Biol. Sci., 4 (7), 909-911.

Gonzales, A., Satterlee, D.G., Moharer, F. & Cadd, G.G., 1999. Factors affecting ostrich egg hatchability.Poult. Sci. 78, 1257-1262.

Insko Jr, W.M., Maclaury, D.W., Begin, J.J. & Johnson, T.H., 1971. The relationship of egg weight to hatchability of coturnix eggs. Poult. Sci. 50, 297-298.

Kalita, N., 1994. Effect of egg weight, storage period and position of egg on hatchability. Ind. J. Poult. Sci. 29 (3), 281-283.

Kucukyilmaz, K., Baser, E., Erensayin, C., Orhan, C. & Arat, E., 2001. Effect of egg weight on the hatchability, fattening performance and egg yield traits of Japanese quail. J. Cent. Anim. Res. Ins., 11, 6-12.

Mahmoud, T.H., 1971. The interrelatioship between dam weights, egg weights and one-day chick weights for Bobwhite quail. Agric. Res. Rev. 49, 103-107.

Marks, H.L., 1975. Relationship of embryonic development to egg weight, hatch weight and growth in Japanese quail. Poult. Sci. 54, 1257-1262.

Murad, A., Farooq, M., Mian, M.A. & Muqarrab, A.K., 2001. Hatching performance of Fayumi eggs. Sarhad J. Agric. 17 (1), 1-6.

Narahari, D., Abdul Mujeeri, K., Thangavel, A., Ramamurthy, N., Viswanathan, S., Mohan, B., Muraganandan, B. & Sundararasu, V., 1988. Traits influencing the hatching performance of Japanese quail eggs. Br. Poult. Sci. 29, 101-112.

Nordskog, A.W. & Hassan, G.M., 1971. Direct and maternal effects of egg size genes on hatchability. Genetics 67, 267-278.

Prabkaran, R., Narahari, D., Ramamurthy, N., Parivalal, A.V. & Musser, K.A., 1984. Influence of egg size and shell color on hatchability. Poult. Abst. 10, 1644.

Proudfoot, F.G. & Hulan, H.W., 1981. Influence of hatching egg size on the subsequent performance of broiler chickens. Poult. Sci. 60, 2167-2170.

Romanoff, A.L. & Romanoff, A.J., 1949. The Avian Egg. John Wiley & Sons Inc., New York, USA.

Sachdev, A.K., Ahuja, S.D., Thomas, P.C. & Agrawal, S.K., 1985. Effect of egg weight and duration storage on the weight loss, fertility and hatchability traits in Japanese quail. Ind. J. Poult. Sci. 20, 19-22.

Sarica, M. & Soley, F., 1995. The effect of hatching egg weight on the hatchability, growing and egg production traits of Japanese quail (Coturnix coturnix japonica). J. Agric. Fac. Ondokuz Mayis Univ. 10, 19-30.

SAS, 1997. Statistical Analysis Systems user's guide, JMP. Version 3.2.2. SAS Institute, Inc., Cary, North Carolina. USA.

Saylam, S.K., 1999. The effects of egg weight and storage time on egg weight loss and hatchability traits in Japanese quail. Turk. J. Vet. Anim. Sci. 23, 367-372.

Seker, I., Kul, S. & Bayraktar, M., 2004. Effects of parental age and hatching egg weight of Japanese quails on hatchability and chick weight. Int. J. Poult. Sci. 3 (4), 159-265.

Sergeeva, A., 1984. The incubation of eggs of different weight classes. Poult. Abst. 10, 542.

Shanawany, M.M., 1987. Hatching weight in relation to egg weight in domestic birds. World Poult. Sci. J. 43, 107-115.

Shatokhina, S.T., 1975. Relationship of morphological traits of eggs with embryonic and post-embryonic development of different lines of laying hens. Thesis of Candidate of Agricultural Sciences, Kuban Agricultural University, Krasnodar, Russia.

Skewes, P.A., Wilson, H.R. & Mather, F.B., 1988. Correlation among egg weight, chick weight, and yolk sac weight in Bobwhite quail (Colinus virginianus). Florida Scientist 51, 159-162.

Szczerbinska, D. & Zubrecki, A., 1999. The quail egg weight and their storage period vs. hatching success and rearing performance. Adv. Agric. Sci. 6, 91-100.

Tsarenko, P.P., 1988. Increasing the quality of poultry products. Table and Hatching Eggs. Agropromizdat, Leningrad, Russia.

Tserveni-Gousi, A.S., 1987. Relationship between parental age, egg weight and hatching weight of Japanese quail. Br. Poult. Sci. 28, 749-752.

Uddin, M.S., Paul, D.C. & Huque, Q.M.E., 1994. Effect of egg weight and pre-incubation holding periods on hatchability of Japanese quail eggs in different seasons. Asian Austral. J. Anim. 7, 499-503.

Uluocak, A.N., Okan, F., Efe, E. & Nacar, H., 1995. Exterior and interior quality characteristics and their variation according to age in Japanese quail. Turk. J. Vet. Anim. Sci. 19, 181-187.

Wilson, H.R., 1991. Interrelationships of egg size, chick size, post-hatching growth and hatchability. World Poult. Sci. J. 47, 5-20.

Yildirim, I. & Yetisir, R., 1998. Effects of hatching egg weight and parental age on the hatching weight and 6^{th} week live weight in Japanese quail (Coturnix coturnix japonica). Turk. J. Vet. Anim. Sci. 22, 315-319.