Selected Traits of Hatched and Unhatched Eggs and Growth Performance of Yellow Japanese Quails

ABSTRACT

This study was carried out to investigate selected traits of hatched and unhatched eggs and chick growth performance of yellow Japanese quails (Coturnix japonica). Eggshell temperature at the time of transfer to the hatcher was higher in hatched eggs (38.09°C) than in unhatched eggs (37.43°C) \( (p=0.000) \), lower in eggs with early embryonic mortality (37.39°C) than those with late embryonic mortality (38.13°C) \( (p=0.000) \), and higher in eggs with female chicks (38.14°C) than those with male chicks (37.95°C). Lower eggshell, yolk, and albumen weights were determined in eggs with embryonic mortality of 17-18 days (0.58 g, 3.13 g and 4.96 g) compared with those with 10-16 days (0.67 g, 3.55 g and 5.58 g) and embryonic mortality of 1-9 days (0.75 g, 3.95 g and 6.19 g) \( (p=0.000) \). Lower egg weight loss was obtained in eggs with embryonic mortality (13.85%) of 1-9 days than those with embryonic mortality of 17-18 days (26.48%) \( (p=0.001) \). Females were heavier at chick weight (8.98 g vs. 8.63 g; \( p=0.033 \)) and at 4 (231.81 g vs. 211.43 g; \( p<0.000 \)) and 5 (260.69 g vs. 231.87 g; \( p<0.000 \)) weeks of age than males, and had longer left shanks (34.39 mm vs. 33.61 mm; \( p=0.004 \)).

INTRODUCTION

Eggshell integrity of hatching egg plays an important role in the development of the embryo on the surface of the egg yolk during the incubation period. Yuan et al. (2013) did not report any differences in egg weight loss and hatchling weight in abnormal striped duck eggs, but determined lower hatchability in eggs with abnormal eggshells compared with those with normal eggshells. Turkey eggs which eggshells presented micro-cracks, low weight, poor pigmentation, and rough surface had higher weight loss throughout the incubation period, higher embryonic mortality rate in the mid and late phases of incubation, and lower hatchability than eggs with intact and normal shells (Mróz et al., 2007). Some literature reports suggest that internal and external egg quality traits, such as the weight of the albumen, yolk and eggshell, and eggshell thickness affect hatchability (Alkan et al., 2008; Lotfi et al., 2011; Caglayan et al., 2014; Alasahan & Copur, 2016; Iqbal et al., 2016; Oleforuh-Okoleh, 2016). Skewes et al. (1988) attributed the higher mortality rate of smaller compared with larger quails to the smaller size of the egg yolk.

Egg weight loss during the incubation period is influenced by eggshell thickness and porosity (Saylam & Sarıca, 1999; Hassan et al., 2013). Bennett (1992) reported higher hatchability in eggs with thick eggshells than in those with thin eggshells, whereas Yamak et al. (2016) indicated that the impact of eggshell thickness on hatchability and hatchling weight was statistically insignificant in partridge eggs.
The yellow feather color of Japanese quails (Coturnix japonica) is determined by an autosomal dominant mutation (Y), which is lethal when homozygous (YY). Quails with heterozygote (Yy1) genes have wheat-straw yellow-colored feathers and abnormal metabolism, including higher levels of abdominal fat (Minvielle et al., 2007).

The present study aimed at determining albumen, yolk, and eggshell traits, egg weight loss during incubation, hatching weight/egg weight ratio, hatching results, and growth performance of male and female yellow Japanese quails.

MATERIAL AND METHODS

This study was carried out at the facilities of the Poultry Unit of Mustafa Kemal University, Samandag Vocational School, Turkey. A total of 319 hatching eggs, collected within a period of three days from 16-week-old yellow Japanese quails (Coturnix japonica)(Figure 1) constituted the material of the study.

Eggs were numbered and individually weighed, placed on trays, and transferred to a setter with temperature set at 37.6°C and relative humidity of 60-65%. On day 14 of embryonic development, eggshell temperature was measured on the outer surface. At the time eggshell temperature measurement, setter room temperature was set at 35.8°C. Eggshell temperature was measured at three parts of the egg, namely, the equator and the sharp and broad ends, without removing the eggs from the setter, and an infrared thermometer (Braun Thermoscan, Kaz Europe SA, Germany). The values measured were used to calculate the average eggshell temperature using the formula given below.

Eggshell temperature on the day of egg transfer (EST, °C) = (eggshell temperature at equator + eggshell temperature at sharp end + eggshell temperature at broad end) / 3

In the hatcher, eggs were placed in individual hatching baskets. Hatcher temperature and relative humidity were set at 37.2°C and 65-70%, respectively. The following traits were evaluated in the incubated hatching eggs with intact eggshells (from which chicks either hatched or did not hatch) using different formulae and the initial egg weight (WB) values (Rahn & Paganelli, 1988; Rahn & Paganelli, 1989; Sotherland & Rahn, 1987):

Initial eggshell weight (IESW, g) = (0.0524 x (WB) 1.113)
Initial eggshell thickness (IEST, mm) = (0.0546 x (WB) 0.441)
Initial yolk weight (IYW, g) = (0.346 x (WB) 1.02)
Initial egg length (IEL, mm) = (14.7 x (WB) 0.341)
Initial egg width (IEW, mm) = (11.3 x (WB) 0.327)

Egg weight loss (EWL, g) = (0.86 x WB) + (0.082)- (hatching weight)

The other traits investigated using the following formulae and unhatched egg weight (WH):

Eggshell weight at the end of the incubation period (ESWI, g) = (0.0524 x (WH) 1.113)
Eggshell thickness at the end of the incubation period (ESTI, mm) = (0.0546 x (WH) 0.441)
Yolk weight at the end of the incubation period (YWI, g) = (0.346 x (WH) 1.02)
Egg length at the end of the incubation period (ELI, mm) = (14.7 x (WH) 0.341)
Egg width at the end of the incubation period (EWI, mm) = (11.3 x (WH) 0.327)

Egg weight loss (%) was determined for the hatched and unhatched eggs using the initial egg weight values and egg weight values measured on the day of transfer of the eggs.
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Relative egg weight loss of hatched eggs (REWLH, %) = 100 \times \left(\frac{W_0 - W_2}{W_0}\right)

W_0 = Initial egg weight
W_2 = Weight of hatched eggs

Relative egg weight loss of unhatched eggs (REWLU, %) = 100 \times \left(\frac{W_0 - W_1}{W_0}\right)

W_0 = Initial egg weight
W_1 = Weight of unhatched eggs

Furthermore, egg weight loss that occurred during embryonic development was calculated using the following formulae and hatchling weight, initial egg weight and initial eggshell weight values:

Calculated relative egg weight loss (CREWL, %) = 100 \times \left(\frac{W_B - W_1}{W_0}\right)

W_B: Initial egg weight
W_1 = (W_B – (Hatchling weight + Initial eggshell weight))

Unhatched incubated hatching eggs at the end of the incubation period (14+3 days), were broken to determine the number of unfertilized eggs and embryonic mortality. Embryo mortality stage was classified according to guidelines of Aygun et al. (2012) as embryonic mortality of 1-9 days of incubation (black-eye visible and embryo without feathers), embryonic mortality of 10-16 days of incubation(embryo with feathers and embryo with yolk out), and embryonic mortality of 17-18 days of incubation (full-grown embryo dead, with yolk subtracted yolk). Based on these data, the hatching results listed below were calculated.

Fertility rate (FR, %) = \left(\frac{\text{Number of fertilized eggs}}{\text{Number of set eggs}}\right) \times 100

Hatchability of fertile eggs (HRF, %) = \left(\frac{\text{Number of hatched chicks}}{\text{Number of fertilized eggs}}\right) \times 100

Hatchability of set eggs (HR, %) = \left(\frac{\text{Number of hatched chicks}}{\text{Number of set eggs}}\right) \times 100

Embryonic mortality rate (1-9 days, %) = \left(\frac{\text{Number of embryos that die between days 1-9 of the incubation period}}{\text{Number of fertilized eggs}}\right) \times 100

Embryonic mortality rate (10-16 days, %) = \left(\frac{\text{Number of embryos that die between days 10-16 of the incubation period}}{\text{Number of fertilized eggs}}\right) \times 100

Embryonic mortality rate (17-18 days, %) = \left(\frac{\text{Number of embryos that die between days 17-18 of the incubation period}}{\text{Number of fertilized eggs}}\right) \times 100

In total, 230 chicks at hatch were individually weighed and transferred to cages (95x45x25 cm) in six tiers (50 quails/tier) in an environmentally-controlled room. The cages were equipped with nipple drinkers (4 nipple drinkers/tier) and trough feeders.

Birds were fed a starter feed containing 22% crude protein and 3100 kcal metabolizable energy/kg. Feed and water were provided ad libitum. Birds were sexed at 3 weeks of age based on the color of the thoracic feathers: those with black spotted feathers were considered female, and those with spotless feathers were considered male.

For the determination of growth performance, the sexed chicks were identified with individual wing numbers and weighed to determine their initial body weights at the beginning of the growth period. For this purpose, 135 three-week-old male and female chicks were randomly distributed into four replicate cages. Their body weights were measured at 3, 4 and 5 weeks of age. The length of their right and left legs was measured at 5 weeks of with the aid of a caliper.

The results were analyzed using the SPSS 22.0 software. In the present study, while descriptive statistics were used for the analysis of the data related to the general characteristics of the eggs, the two-sample t-test was used for the analysis of the data related to the growth performance of the male and female chicks post-hatch. One-way analysis of variance (ANOVA) was used for the analysis of certain traits of the hatched and unhatched eggs. Duncan’s multiple comparison test was used to determine differences among groups in the event of the detection of statistically significant differences by ANOVA.

RESULTS

Some traits of the eggs loaded in the setter are presented in Table 1. Average egg weight, average eggshell weight, average albumen weight, average yolk weight, and average eggshell thickness were 12.23 g, 0.85 g, 6.93 g, 4.45 g, and 0.164 mm, respectively. Average eggshell temperature on day 14 of the incubation period (day of egg transfer) was 37.91°C.

Table 1 – Some traits of the eggs placed in the incubator (n=319)

| Traits | Mean ± SE |
|--------|-----------|
| Egg weight (g) | 12.23 ± 0.07 |
| Eggshell thickness (mm) | 0.164 ± 0.00 |
| Eggshell weight (g) | 0.85 ± 0.01 |
| Eggshell ratio (%) | 6.95 ± 0.01 |
| Yolk weight (g) | 4.45 ± 0.03 |
| Yolk ratio (%) | 36.37 ± 0.01 |
| Albumen weight (g) | 6.93 ± 0.04 |
| Albumen ratio (%) | 56.68 ± 0.01 |
| Egg length (mm) | 34.47 ± 0.08 |
| Egg width (mm) | 25.58 ± 0.06 |
| Shape index (%) | 74.23 ± 0.01 |
| Eggshell temperature on the day of egg transfer (°C) | 37.91 ± 0.04 |
Some traits of the hatched and unhatched eggs are presented in Table 2. Eggshell temperature on the day of egg transfer to the hatcher was higher in the hatched eggs in comparison with the unhatched eggs ($p<0.001$). It was observed that, for several of the traits investigated, the unhatched eggs displayed higher values than the hatched eggs ($p>0.05$).

### Table 2 – Some traits of hatched and unhatched eggs (unfertilized + embryonic mortality)

| Traits                      | Hatched eggs | Unhatched eggs | t     | p-value |
|-----------------------------|--------------|----------------|-------|---------|
| Initial egg weight (g)      | 12.15 ± 0.08 | 12.42 ± 0.16   | -1.612| 0.108   |
| Initial eggshell thickness (mm) | 0.164 ± 0.00 | 0.166 ± 0.00   | -1.497| 0.135   |
| Eggshell temperature on the day of egg transfer (°C) | 38.09 ± 0.04 | 37.43 ± 0.07   | -8.885| 0.000   |
| Initial egg length (mm)     | 34.40 ± 0.10 | 34.66 ± 0.15   | -1.434| 0.153   |
| Initial egg width (mm)      | 25.53 ± 0.07 | 25.72 ± 0.11   | -1.428| 0.154   |
| Shape index (%)             | 74.24 ± 0.01 | 74.21 ± 0.01   | 1.325 | 0.186   |
| Eggshell weight (g)         | 0.85 ± 0.01  | 0.87 ± 0.01    | -1.606| 0.109   |
| Yolk weight (g)             | 4.42 ± 0.47  | 4.52 ± 0.55    | -1.618| 0.107   |
| Yolk ratio (%)              | 36.37 ± 0.11 | 36.38 ± 0.09   | -1.327| 0.186   |
| Eggshell ratio (%)          | 6.94 ± 0.01  | 6.96 ± 0.01    | -1.333| 0.183   |
| Albumen weight (g)          | 6.89 ± 0.71  | 7.04 ± 0.09    | -1.598| 0.111   |
| Albumen ratio (%)           | 56.69 ± 0.11 | 56.66 ± 0.02   | 1.332 | 0.184   |

$t$ = Independent Samples “t” test, $p$-value = significance level ($\alpha = 0.05$)

Some traits of the unhatched eggs, which were either unfertilized or presented with early, intermediate, or late embryonic mortality, are given in Table 3. Eggshell temperature on the day of egg transfer was higher in the eggs presenting with late embryonic mortality than in unfertilized eggs and those eggs presenting early and intermediate embryonic mortality ($p<0.000$). For all the other investigated traits, the values of the eggs presenting with late embryonic mortality were lower than those of the unfertilized eggs and of the eggs presenting early and intermediate embryonic mortality ($p>0.05$).

### Table 3 – Some parameters of unfertilized eggs and eggs with embryonic mortality

| Traits                      | Hatched eggs | Unfertilized eggs | Embryonic mortality of fertile eggs (%) | General | F     | p     |
|-----------------------------|--------------|-------------------|----------------------------------------|---------|-------|-------|
| W (g)                       | 12.15 ± 0.08 | 12.44 ± 0.29      | 12.63 ± 0.19 12.27 ± 0.34 11.85 ± 0.46 | 12.23 ± 0.07 | 1.280 | 0.278 |
| EST (°C)                    | 38.09 ± 0.04 | 37.35 ± 0.10      | 37.39 ± 0.10 37.34 ± 0.16 38.13 ± 0.14 | 37.91 ± 0.04 | 23.617 | 0.000 |
| IEST (mm)                   | 0.164 ± 0.00 | 0.166 ± 0.00      | 0.167 ± 0.00 0.165 ± 0.00 0.162 ± 0.00 | 0.164 ± 0.00 | 1.124 | 0.345 |
| IESW (g)                    | 0.85 ± 0.01  | 0.87 ± 0.02       | 0.88 ± 0.02 0.86 ± 0.03 0.82 ± 0.04 | 0.85 ± 0.01 | 1.279 | 0.278 |
| IESWR (%)                   | 6.94 ± 0.01  | 6.96 ± 0.02       | 6.98 ± 0.01 6.95 ± 0.02 6.93 ± 0.03 | 6.95 ± 0.01 | 0.890 | 0.470 |
| IYW (g)                     | 4.42 ± 0.03  | 4.53 ± 0.11       | 4.60 ± 0.07 4.46 ± 0.13 4.31 ± 0.17 | 4.45 ± 0.03 | 1.287 | 0.275 |
| IYWR (%)                    | 36.37 ± 0.01 | 36.38 ± 0.02      | 36.40 ± 0.01 36.38 ± 0.02 36.35 ± 0.03 | 36.37 ± 0.01 | 0.877 | 0.478 |
| IAW (g)                     | 6.89 ± 0.05  | 7.04 ± 0.16       | 7.15 ± 0.11 6.95 ± 0.18 6.72 ± 0.25 | 6.93 ± 0.04 | 1.267 | 0.283 |
| IAWR (%)                    | 56.69 ± 0.04 | 56.66 ± 0.04      | 56.63 ± 0.02 56.67 ± 0.04 56.72 ± 0.06 | 56.68 ± 0.01 | 0.861 | 0.488 |
| IEL (mm)                    | 34.40 ± 0.10 | 34.64 ± 0.28      | 34.88 ± 0.18 34.53 ± 0.33 34.12 ± 0.45 | 34.47 ± 0.00 | 2.138 | 0.397 |
| IEW (mm)                    | 25.53 ± 0.07 | 25.71 ± 0.20      | 25.88 ± 0.13 25.63 ± 0.23 25.33 ± 0.32 | 25.59 ± 0.06 | 1.086 | 0.401 |
| ISI (%)                     | 74.24 ± 0.01 | 74.22 ± 0.03      | 74.19 ± 0.02 74.22 ± 0.03 74.26 ± 0.04 | 74.23 ± 0.01 | 0.018 | 0.506 |

$W = $ Initial egg weight $EST = $Eggshell temperature on day 14, $IEST = $Initial eggshell thickness, $ESW = $Initial eggshell weight, $IESWR = $Initial eggshell weight ratio, $IYW = $Initial yolk weight, $IYWR = $Initial yolk weight ratio, $IAW = $Initial albumen weight, $IAWR = $Initial albumen weight ratio, $IEL= $Initial egg length, $IEW = $Initial egg width, $ISI = $Initial egg shape index

* means followed by different superscripts in the same row are statistically different

The results of the traits evaluated in unhatched eggs, expressed as a percentage of unhatched (unfertilized eggs and eggs presenting with embryonic mortality) egg weight, are shown in Table 4. For all traits investigated, the values obtained in unfertilized eggs were lower than in those presenting early, intermediate, and late embryonic mortality ($p<0.001$). Considering only the eggs presenting embryonic mortality, the eggs with early embryonic mortality presented the highest values and those with late embryonic mortality presented the lowest values for the evaluated traits ($p<0.001$).
Relative egg weight loss, which occurs during embryonic development, is shown in Table 5. Relative hatched egg weight loss, calculated as the percentage of egg weight on the day of egg transfer relative to egg weight at setting, was 21.24%, whilst the calculated weight loss was determined to be 15.36%. The relative weight loss differences determined in unhatched eggs were statistically significant \( (p<0.001) \) and were determined as 29.54%, 29.54%, 26.48%, 20.38%, and 13.85% for unfertilized eggs, eggs with late, intermediate, and early embryonic mortality, respectively. The relative weight loss of the eggs presenting early embryonic mortality was significantly lower than those presenting with late embryonic mortality \( (p<0.05) \).

**Table 4 – Some traits of the unhatched eggs**

| Traits | Unfertilized eggs | Embryonic mortality of fertile eggs (%) | General embryonic mortality of fertile eggs (%) |
|--------|-------------------|----------------------------------------|-----------------------------------------------|
|        | 1-9 d | 10-16 d | 17-18 d | 1-9 d | 10-16 d | 17-18 d | 1-9 d | 10-16 d | 17-18 d |
| Post-incubation egg weight (g) | 8.61±0.41 | 10.89±0.21 | 9.80±0.58 | 8.67±0.53 | 9.56±0.24 | 8.167 | 0.000 |
| Post-incubation eggshell thickness (mm) | 0.139±0.00 | 0.156±0.00 | 0.149±0.00 | 0.141±0.00 | 0.147±0.00 | 8.235 | 0.000 |
| Post-incubation eggshell weight (g) | 0.58±0.03 | 0.75±0.02 | 0.67±0.04 | 0.58±0.04 | 0.65±0.02 | 7.718 | 0.000 |
| Post-incubation eggshell ratio (%) | 6.65±0.04 | 6.86±0.02 | 6.77±0.05 | 6.68±0.05 | 6.74±0.02 | 8.099 | 0.000 |
| Post-incubation yolk weight (g) | 3.11±0.15 | 3.95±0.08 | 3.55±0.21 | 3.13±0.20 | 3.46±0.09 | 8.146 | 0.000 |
| Post-incubation yolk ratio (%) | 36.09±0.04 | 36.29±0.01 | 36.21±0.05 | 36.12±0.05 | 36.18±0.02 | 7.821 | 0.000 |
| Post-incubation albumen weight (g) | 4.92±0.23 | 6.19±0.12 | 5.58±0.32 | 4.96±0.30 | 5.45±0.13 | 8.168 | 0.000 |
| Post-incubation albumen ratio (%) | 57.26±0.08 | 56.85±0.03 | 57.03±0.09 | 57.20±0.09 | 57.08±0.04 | 7.865 | 0.000 |
| Post-incubation egg length (mm) | 30.30±0.52 | 33.15±0.22 | 31.90±0.66 | 30.62±0.66 | 31.53±0.30 | 7.960 | 0.000 |
| Post-incubation egg width (mm) | 22.61±0.38 | 24.64±0.16 | 23.75±0.47 | 22.84±0.47 | 23.48±0.21 | 7.959 | 0.000 |
| Post-incubation egg shape index (%) | 74.64±0.06 | 74.35±0.02 | 74.47±0.06 | 74.59±0.07 | 74.51±0.03 | 7.782 | 0.000 |

\( ^4 \)Means followed by different superscripts in the same row are statistically different

The hatching results are presented in Table 6. Hatchability, fertility, and hatchability of fertile eggs were determined as 72.10%, 87.15%, and 82.73%, respectively. The general embryonic mortality rate was 17.27%, and early and late embryonic mortality were determined as 11.15% and 2.53%, respectively.

Eggshell, albumen, and yolk weights, egg length and width, egg weight loss, and eggshell temperature results of eggs of male and female hatchlings are given in Table 7. The values of all traits investigated, except for egg weight loss, were numerically, but not statistically different compared with the eggs of male hatchlings.

**Table 5 – Post-incubation egg weight loss.**

| Hatched Eggs | From Day 0 to post-incubation | Weight loss (g) | Relative weight loss (%) | Calculated egg weight loss (g) | Calculated relative egg weight loss (%) |
|--------------|-------------------------------|-----------------|--------------------------|-----------------------------|--------------------------------------|
| Unfertilized eggs | 2.65±0.03 | 21.24±0.25 | 1.87±0.03 | 15.36±0.25 |
| Embryonic mortality of fertile eggs (%) | 1-9 d | 1.74±0.11 | 13.89±0.86 | 2.47±0.41 | 20.38±3.57 | 3.17±0.58 | 26.48±4.53 |
| 10-16 d | 2.47±0.41 | 20.38±3.57 | |
| 17-18 d | 3.17±0.58 | 26.48±4.53 | |
| Total | 2.88±0.25 | 22.65±1.80 | |

Due to the unavailability of chick body weights at hatch, it was not possible to calculate egg weight loss.

\( ^4 \)Means followed by different superscripts in the same column are statistically different

**Table 6 – Hatching results.**

| Traits | Values (%) |
|--------|------------|
| Hatchability | 72.10 |
| Fertility | 87.15 |
| Hatchability of fertile eggs | 82.73 |
| Embryonic mortality rate (1-9 d) | 11.15 |
| Embryonic mortality rate (10-16 d) | 3.60 |
| Embryonic mortality rate (17-18 d) | 2.53 |
| General embryonic mortality rate | 17.28 |

Hatchling weight and body weight at 3, 4 and 5 weeks of age, body weight gain, and daily body weight gain of male and female quails are presented in Table 8. Females presented higher body weight at
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Table 7 – Some traits of eggs from which male and female chicks hatched

| Traits                              | Female (60) | Male (75) | t    | p    |
|-------------------------------------|-------------|-----------|------|------|
| Initial egg weight (g)              | 0.87 ± 0.01 | 0.84 ± 0.01 | 1.775 | 0.078|
| Initial eggshell percentage (%)     | 6.97 ± 0.01 | 6.96 ± 0.01 | 1.663 | 0.099|
| Initial eggshell thickness (mm)     | 0.166 ± 0.00| 0.164 ± 0.00| 1.768 | 0.079|
| Initial yolk mass (g)               | 4.54 ± 0.06 | 4.41 ± 0.05 | 1.774 | 0.078|
| Initial yolk percentage (%)         | 36.39 ± 0.01| 36.37 ± 0.01| 1.667 | 0.098|
| Initial albumen weight (g)          | 7.07 ± 0.09 | 6.68 ± 0.07 | 1.770 | 0.079|
| Initial albumen percentage (%)      | 56.65 ± 0.02| 56.69 ± 0.02| -1.678| 0.096|
| Initial egg length (mm)             | 34.73 ± 0.15| 34.40 ± 0.12| 1.711 | 0.088|
| Initial egg width (mm)              | 25.77 ± 0.11| 25.54 ± 0.08 | 1.714 | 0.089|
| Initial shape index (%)             | 74.21 ± 0.01| 74.23 ± 0.01 | -1.654| 0.101|
| Initial egg weight (g)              | 12.48 ± 0.16| 12.13 ± 0.12 | 1.771 | 0.079|
| Egg weight loss (g)                 | 2.63 ± 0.06 | 2.67 ± 0.08 | -0.435| 0.664|
| Egg weight loss (%)                 | 21.14 ± 0.41| 21.97 ± 0.56 | -1.126| 0.262|
| Calculated egg weight loss (g)      | 1.84 ± 0.05 | 1.92 ± 0.07 | -0.913| 0.363|
| Calculated egg weight loss (%)      | 14.77 ± 0.41| 15.76 ± 0.51 | -1.454| 0.148|
| Eggshell temperature on the day of egg transfer | 38.14 ± 0.07 | 37.95 ± 0.07 | 1.866 | 0.064|

Table 8 – Growth performance of the male and female quails

| Traits                              | Female (n=60) | Male (n=75) | t    | p    |
|-------------------------------------|---------------|-------------|------|------|
| Hatching weight of the chicks (g)   | 8.98 ± 0.13   | 8.63 ± 0.10 | 2.151| 0.033|
| Week 3 (g)                          | 116.21 ± 1.93 | 115.14 ± 1.25| 0.481| 0.631|
| Week 4 (g)                          | 231.81 ± 3.87 | 211.43 ± 2.50| 0.481| 0.631|
| Week 5 (g)                          | 260.69 ± 3.86 | 231.87 ± 2.85| 6.133| 0.000|
| Length of the right leg at week 5 (mm) | 34.70 ± 0.21 | 34.27 ± 0.17 | 1.645| 0.102|
| Length of the left leg at week 5 (mm) | 34.39 ± 0.21 | 33.61 ± 0.17 | 2.905| 0.004|
| Body weight gain between days 0-21 (g) | 107.23 ± 1.93 | 106.51 ± 1.23 | 0.329| 0.743|
| Body weight gain between weeks 3-4 (g) | 115.60 ± 2.58 | 96.29 ± 1.77 | 6.351| 0.000|
| Body weight gain between weeks 4-5 (g) | 28.88 ± 2.20 | 20.44 ± 1.04 | 3.699| 0.000|
| Body weight gain between weeks 0-5 (g) | 251.71 ± 3.81 | 232.24 ± 2.83 | 6.122| 0.000|
| Daily body weight gain between days 0-21 (g/day) | 5.11 ± 0.09 | 5.07 ± 0.06 | 0.325| 0.746|
| Daily body weight gain between weeks 3-4 (g/day) | 16.51 ± 0.07 | 13.74 ± 0.25 | 6.350| 0.000|
| Daily body weight gain between weeks 4-5 (g/day) | 4.13 ± 0.31 | 2.92 ± 0.15 | 3.697| 0.000|
| Daily body weight gain between weeks 0-5 (g/day) | 7.19 ± 0.11 | 6.38 ± 0.08 | 6.122| 0.000|
| Chick weight/Initial egg weight      | 71.89 ± 0.41  | 71.18 ± 0.61 | 0.921| 0.359|

DISCUSSION

In the present study, the average egg weight of the yellow Japanese quail (Coturnix japonica) was determined 12.23 g. The following weight values were previously reported: 11.28 g by Kul & Seker (2004); 11.06 g by Sezer (2007); 11.43 g by Alkan et al. (2010); 11.14-12.84 g by Ozdemir & Inci, (2012); 11.52-12.30 g by Stojčić et al. (2012); 8.19 g by Ojedapo (2013); 13.06 g and 11.48 g for meat and layer types, respectively, by Hrncar et al. (2014); 12.70 g by Alasahan et al. (2015); and 12.20-13.26 g by Hanusová et al. (2016). Average eggshell weight was determined as 0.85 g in the present study, which was previously reported as 0.84 g by Kul & Seker (2004), 0.96 g by Sezer (2007), 1.00 (0.84-1.15 g) by Alkanet al. (2010), 1.73-1.80 g by Stojčić et al. (2012), 0.94 g by Ojedapo (2013), 1.09 g by Alasahan et al. (2015), and 1.12-1.21 g by Hanusová et al. (2016). In the present study, albumen and yolk weights were determined as 6.93 g and 4.45 g, respectively, and previously reported as 6.75 g and 3.69 g by Kul & Seker (2004), 6.07-7.08 g and 3.42-3.72 g by Stojčić et al. (2012), 6.35-7.44 g and 3.86-4.54 g by Ozdemir & Inci (2012), 4.95 g.
and 2.29 g by Ojedapo (2013), 7.76 g and 3.98 g by Alasahan et al. (2015), and 7.38-8.16 g and 3.68-3.89 by Hanusová et al. (2016), respectively. The differences between the obtained egg trait results with those reported in literature may be attributed to differences in the calculation of the traits and by the fact that yellow Japanese quail (Coturnix japonica) eggs were used in the present study.

In the present study, average eggshell temperature on the day of egg transfer was 37.91°C on average, with 38.09°C in hatched eggs and 37.43°C in unhatched eggs (Tables 1 and 2). Lourens (2001) reported that the average eggshell temperature of chick is 37.8°C, on average, which may present deviations above 4°C, depending on the position of the egg in the setter and the age of the embryo. In their study on Japanese quail eggs, Alasahan et al. (2016) reported an eggshell temperature on the day of egg transfer of 37.44°C, on average, with 37.62°C in hatched eggs and 37.14°C in unhatched eggs. While the eggshell temperatures determined in the present study were higher than those reported by Alasahan et al. (2016), it was observed that the average value and the values of the hatched and unhatched eggs showed similar alterations and were lowest in unhatched eggs. Internal egg temperature of changes as the embryo grows during the incubation period as metabolic heat production increases (French 2009).

Egg weight loss, which occurs during embryonic development, is an important parameter that affects hatching results. In the hatched eggs, while the relative weight loss obtained by measurements was 21.24%, the calculated relative weight loss was 15.36% (Table 5). In previous research studies, relative weight loss was reported as 8.27% in the eggs of meat-type quails by Romao et al. (2008); 10.05% by Genchev (2009); 9.9% in eggs weighing 11.51-12.50 g by Nowaczewski et al. (2010); 9.07%, 8.94% and 8.98% in eggs placed at the upper, mid, and lower levels of the setter, respectively, by Nowaczewski et al. (2012); 15.42% in spotted brown eggs by Farghly et al. (2015); and 10.48% in hatched eggs by Alasahan et al. (2016). In the present study, among the eggs displaying embryonic mortality, weight loss was greatest in those with late embryonic mortality (26.48%) and smallest in those with early embryonic mortality (13.85%). These findings are different from those reported by Soliman et al. (1994), which suggested that the weight loss of Japanese quail (Coturnix japonica) eggs was greater in the eggs presenting early embryonic mortality, in comparison with those presenting late embryonic mortality. In a previous study conducted by Turkyilmaz et al. (2005) on quail eggs, the weight loss determined in the early phase of embryonic development, between days 0-5, 5-10 and 10-15, was smaller compared with the late phase of embryonic development.

In the present study, total embryonic mortality rate was 17.27%, with early, intermediate, and late embryonic mortality rates of 11.15%, 3.60%, and 2.60%, respectively (Table 6). These results are different from those reported by Seker et al. (2005) for early (15.13%), intermediate (5.04%), and late (14.29%) embryonic mortality rates. The early embryonic mortality rate (12.0%) determined by Moraes et al. (2008) for normally-positioned eggs (placed vertically with the sharp end up) is similar to that determined in the present study, but the late embryonic mortality rate reported by those researchers (24.0%) is higher than that found in the present study. In a study on the eggs of Japanese quails (Coturnix japonica) raised in a tropical environment, Daikwo et al. (2011) reported early and late embryonic mortality rates of 18.59% and 9.89%, respectively. The early (12.39%) and late (4.29%) embryonic mortality rates reported by Farghly et al. (2015) for brown spotted eggs are similar to those determined in the present study. In the studies conducted by Alasahan & Copur (2016) and Alasahan et al. (2015) on the influence of egg shape index and eggshell color and spot are a on hatching results, respectively, early embryonic mortality rates were much higher than the late embryonic mortality rates.

In the present study, the length of the right and left legs at 5 weeks of age were 34.70 mm and 34.39 mm, respectively, in females, and 34.27 mm and 33.61 mm, respectively, in males (Table 8). In their study on Japanese quails (Coturnix japonica), Ojo et al. (2014) reported 2.96 cm and 2.95 cm leg lengths in 4-week-old females and males, respectively, and indicated that leg length increased to 3.00 cm at 6 weeks of age in both sexes. Wilkanowska et al. (2013) reported equal leg length (3.7 cm) in 35-day-old and 45-day-old female and male quails, whereas Gambo et al. (2014) determined and average leg length of 3.21 cm in 5-week-old quails.

In the present study, females were heavier than males at hatch (8.98 g vs. 8.63 g), as shown in Table 8. This sex-related difference continued when quails were 3, 4, and 5 weeks old. The body weight of 5-week-old females (260.69 g) was higher than that of males (231.87 g), which was expected and in agreement with the findings of Baylan et al. (2009), Kosshak et al. (2014), Ojedapo & Amao (2014), Raji et al. (2015), and Alasahan & Copur (2016).
CONCLUSIONS

Eggshell temperature of eggs presenting late embryonic mortality was higher than those presenting early and intermediate embryonic mortality. Eggshell weight, yolk weight, and albumen weight of the embryonic mortality eggs of 17-18 days were lower than those with embryonic mortalities of 1-9 days and of 10-16 days. Eggs with embryonic mortality of 1-9 days lost less weight than those with embryonic mortality of 17-18 days. Females were heavier at hatch and at 4 and 5 weeks of age, and presented longer shanks that males. Eggshell temperature at the time of transfer to the hatcher of eggs with female chicks was higher than those with male chicks.

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