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

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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 in 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 (Y/Y). Quails with heterozygote (Y/y1) 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, hatchling 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.

Figure 1 – Female yellow Japanese quail (*Coturnix japonica*)

Figure 2 – Male yellow Japanese quail (*Coturnix japonica*)

Eggs were numbered and individually weighed, placed on trays, and transferred to a setter with temperature set at 37.6ºC 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 35.8ºC. 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, ºC) = (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 37.2ºC 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 (W_B) values (Rahn & Paganelli, 1988; Rahn & Paganelli, 1989; Sotherland & Rahn, 1987):

Initial eggshell weight (IESW, g) = $(0.0524 \times (W_B)^{1.113})$

Initial eggshell thickness (IEST, mm) = $(0.0546 \times (W_B)^{0.441})$

Initial yolk weight (IYW, g) = $(0.346 \times (W_B)^{1.02})$

Initial egg length (IEL, mm) = $(14.7 \times (W_B)^{0.341})$

Initial egg width (IEW, mm) = $(11.3 \times (W_B)^{0.327})$

Egg weight loss (EWL, g) = $(0.86 \times W_B)+(0.082)-$(hatchling weight)

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

Eggshell weight at the end of the incubation period (ESWI, g) = $(0.0524 \times (W_H)^{1.113})$

Eggshell thickness at the end of the incubation period (ESTI, mm) = $(0.0546 \times (W_H)^{0.441})$

Yolk weight at the end of the incubation period (YWI, g) = $(0.346 \times (W_H)^{1.02})$

Egg length at the end of the incubation period (ELI, mm) = $(14.7 \times (W_H)^{0.341})$

Egg width at the end of the incubation period (EWI, mm) = $(11.3 \times (W_H)^{0.327})$

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.

Relative egg weight loss of hatched eggs (REWLH, %) = 100 x $((W_0 - W_2) / W_0)$

W_0 = Initial egg weight

W_2 = Weight of hatched eggs

Relative egg weight loss of unhatched eggs (REWLU, %) = 100 x $((W_0 – W_1) / W_0)$

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 x $((W_B - W_1) / W_0)$

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, %) = (Number of fertilized eggs/ Number of set eggs) x100

Hatchability of fertile eggs (HRF, %) = (Number of hatched chicks/Number of fertilized eggs) x 100

Hatchability of set eggs (HR, %) = (Number of hatched chicks/Number of set eggs) x 100

Embryonic mortality rate (1-9 days, %) = (Number of embryos that die between days 1-9 of the incubation period/Number of fertilized eggs) x 100)

Embryonic mortality rate (10-16 days, %) = (Number of embryos that die between days 10-16of the incubation period/Number of fertilized eggs) x 100

Embryonic mortality rate (17-18 days, %) = (Number of embryos that die between days 17-18of the incubation period/Number of fertilized eggs) x 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 n = 231	Unhatched eggs n = 88	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*
			1 to 9 d	10-16 d	17-18 d			
W_B (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^A ± 0.04	37.35^B ± 0.10	37.39^B ± 0.10	37.34^B ± 0.16	38.13^A ± 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 ± 0.01	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

$W_{B=}$ 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

$^{A-B}$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 ($p<0.001$).

Table 4 – Some traits of the unhatched eggs

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

A-B means followed by different superscripts in the same row are statistically different

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 be15.36%. 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 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 (%)
		2.65±0.03	21.24 ± 0.25	1.87 ± 0.03	15.36 ± 0.25
				Unhatched Eggs	
Unfertilized eggs		$3.83^{A} \pm 0.49$	$29.54^{A} \pm 3.39$		
Embryonic mortality of fertile eggs (%)	1-9 d	$1.74^{B} \pm 0.11$	$13.85^{B} \pm 0.86$	Due to the unavailability of chick body weights at hatch, it was not possible to calculate egg weight loss.	
	10-16 d	$2.47^{AB} \pm 0.41$	$20.38^{AB} \pm 3.57$		
	17-18 d	$3.17^{AB} \pm 0.58$	$26.48^{AB} \pm 4.53$		
Total		2.88 ± 0.25	22.65 ± 1.80		
F		5.544	6.197		
p		0.002	0.001		

A-B means followed by different superscripts in the same column 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 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

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	6.88 ± 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	1.717	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

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

hatch and at 4 and 5 weeks of age, weekly (weeks 3-4, 4-5) and total body weight gain (weeks 0-5), and daily body weight gain (between weeks 3-4, 4-5 and 0-5) compared with males, and the differences between the sexes were statistically significant ($p<0.05$, $p<0.01$, $p<0.001$). The lengths of the right and left legs at 5 weeks of age were significantly greater in females than in males ($p<0.01$), when compared to the males.

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	4.581	0.000
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 ± 1.88	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	223.24 ± 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

t = Independest Samples "t" test, *p*=value-significance level ($\alpha = 0.05$)

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 Alkan*et 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 1.12-1.21g 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 of37.44°C, on average, with 37.62°C in hatched eggs and 37.14°Cin 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.

REFERENCES

Alasahan S, Copur AG. Hatching characteristics and growth performance of eggs with different egg shapes. Brazilian Journal of Poultry Science 2016;18:1-8.

Alasahan S, Copur Akpinar G, Canogulları S, Baylan M. Determination of some external and internal quality traits of Japanese quail (*Coturnix coturnix japonica*) eggs on the basis of eggshell colour and spot colour. Eurasian Journal of Veterinary Sciences 2015;31:235-241.

Alkan S, Karabag K, Galic A, Balcioglu MS. Effects of genotype and egg weight on hatchability traits and hatching weight in japanese quail. South African Journal of Animal Science 2008;38:231-237.

Alkan S, Karabag K, Galic A, Karsli T, Balcıoglu MS. Effects of selection for body weight and egg production on egg quality traits in Japanese quail (*Coturnix coturnix japonica*) of different lines and relationships between these traits. Journal of The Faculty of Veterinary Medicine, Kafkas University 2010;16:239-244.

Aygun A, Sert D, Copur G. Effects of propolis on eggshell microbial activity, hatchability, and chick performance in Japanese quail (Coturnix coturnix japonica) eggs. Poultry Science 2012;91:1018–1025.

Baylan M, Canogullari S, Sahinler S, Uluocak AN, Copur G. Effects of divergent selection methods based on body weights of quail on improvement of broiler quail parents. Journal of Animal and Veterinary Advances 2009;8:962-970.

Bennett CD. The influence of shell thickness on hatchability in commercial broiler breeder flocks. The Journal of Applied Poultry Research 1992;1:61-65.

Caglayan T, Kirikci K, Aygun A. Comparison of hatchability and some egg quality characteristics in spotted and unspotted partridge (Alectoris chukar) eggs. The Journal of Applied Poultry Research 2014;23:1-8.

Daikwo SI, Dim NI, Momoh MO. Hatching characteristics of japanese quail eggs in a tropical environment. International Journal of Poultry Science 2011;10:876-878.

Farghly MFA, Mahrose KhMA, Abou-Kassem DE. Pre and post hatch performance of different Japanese quail egg colors incubated under photostimulation. Asian Journal of Poultry Science 2015;9:19-30.

French NA. The critical importance of incubation temperature. Avian Biology Research 2009;2:55-59.

Gambo D, Momoh OM, Dim NI, Kosshak AS. Body parameters and prediction of body weight from linear body measurements in coturnix quail. Livestock Research for Rural Development 2014;26(6).

Genchev A. Influence of hatching eggs storage period upon the incubation parameters in Japanese quails. Journal Central European Agriculture 2009;10:167-174.

Hanusová E, Hrnčár C, Hanus H, Oravcová M. Egg traits in japanese quails. Acta Fytotechnica et Zootechnica 2016;19:62-67.

Hassan HA, El-Nesr SS, Osman AMR, Arram GA. Ultrastructure of eggshell, egg weight loss and hatching traits of japanese quail varying in eggshell color and pattern using image analysis. Egyptian Poultry Science 2013;34:1-17.

Hrncar C, Hanusova E, Hanus A, Bujko J. Effect of genotype on egg quality characteristics of Japanese quail (*Coturnix japonica*). Slovak Journal of Animal Science 2014;47:6-11.

Iqbal J, Khan SH, Mukhtar N, Ahmed T, Pasha RA. Effects of egg size (weight) and age on hatching performance and chick quality of broiler breeder. Journal of Applied Animal Research 2016;44:54–64.

Kosshak AS, Dim NI, Momoh OM, Gambo D. Effect of sex on carcass characteristics and correlation of body weight and blood component in japanese quails. IOSR Journal of Agriculture and Veterinary Science 2014;7:72-76.

Kul S, Seker I. Phenotypic correlations between some external and internal egg quality traits in the Japanese quail (*Coturnix coturnix japonica*). International Journal of Poultry Science 2004;3:400-405.

Lotfi A, Shadryar HA, Maheri-Sis N, Abedi AS, Nahand MK. Hatching characterizes of Japanese quail (*Coturnix coturnix japonica*) eggs with different egg shape indexes. American-Eurasian Journal Agricultural & Environmental Sciences 2011;10:475-477.

Lourens A. The importance of air velocity in incubation. World Poultry 2001;17:29-30.

Minvielle, F, Gourichon,D, Ito, S, Inoue-Murayama M, Riviere S. Effects of the dominant lethal yellow mutation on reproduction, growth, feed consumption, body temperature, and body composition of the japanese quail. Poultry Science 2007;86:1646–1650.

Moraes TGV, Romao JM, Teixeira RSC, Cardoso WM. Effects of egg position in artificial incubation of Japanese quail eggs (*Coturnix japonica*). Animal Reproduction Science 2008;5:50-54.

Mróz E, Michalak K, Orłowska A. Embryo mortality and poult quality depend on the shell structure of turkey hatching eggs. Animal Science Papers and Reports 2007;25:161-172.

Nowaczewski S, Witkiewicz K, Kontecka H, Krystianiak S, Rosińs A. Eggs weight of Japanese quail vs. eggs quality after storage time and hatchability results. Archiv Tierzucht 2010;53:720-730.

Nowaczewski S, Kontecka H, Rosiński A. Effect of Japanese quail eggs location in the setter on their weight loss and eggshell temperature during incubation as well as hatchability results. Archiv für Geflügelkunde 2012;76:168-175.

Ojedapo LO. Phenotypic correlation between the external and internal egg quality traits of pharaoh quail reared in derived savanna zone of Nigeria. Journal of Biology, Agriculture and Healthcare 2013;3:80-83.

Ojedapo LO, Amao SR. Sexual dimorphism on carcass characteristics of japanese quail (*coturnix coturnix japonica*) reared in derived savanna zone of Nigeria. International Journal of Science, Environment and Technology 2014;3:250-257.

Ojo V, Fayeye TR, Ayorinde KL, Olojede H. Relationship between body weight and linear body measurements in japanese quail (*Coturnix coturnix japonica*). Journal of Scientific Research 2014;6:175-183.

Oleforuh-Okoleh VU. Hatchability prediction in chickens using some external egg quality traits. Asian Journal of Animal Sciences 2016;10:159-164.

Ozdemir G, Inci H. The effect of live weight of japan quails (*Coturnix coturnix japonica*) on the characteristics of interior and exterior quality of eggs. Journal of Animal and Veterinary Advances 2012;11:1666-1668.

Rahn H, Paganelli CV. Length, breadth, and elongation of avian eggs from the tables of Schoenwetter. Journal für Ornithologie 1988;129:366-369.

Rahn H, Paganelli CV. Shell mass, thickness and density of avian eggs derived from the tables of Schoenwetter. Journal für Ornithologie 1989;130:59-68.

Raji AO, Girgiri AY, Alade NK, Jauro SA. Characteristics and proximate composition of japanese quail *(coturnix japonica*) carcass in a semi arid area of Nigeria. Trakia Journal of Sciences 2015;2:159-165.

Romao JM, Moraes TGV, Teixeira RSC, Cardoso WM, Buxade CC. Effect of egg storage length on hatchability and weight loss in incubation of egg and meat type japanese quails. Brazilian Journal of Poultry Science 2008;10:143-147.

Saylam SK, Sarica M. Effects of shell thickness, shell pores and egg weight loss on hatchability on japanese quail eggs. Turkish Journal of Veterinary and Animal Sciences 1999;23:41-46.

Seker I, Kul S, Bayraktar M. Effects of storage period and egg weight of Japanese quail eggs on hatching results (short communication). Archiv Tierzucht 2005;48:518-526.

Sezer M. Heritability of exterior egg quality traits in Japanese quail. Journal of Applied Biological Sciences 2007;1:37-40.

Skewes PA, Wilson HR, Mather FB. Correlation among egg weight, chick weight, and yolk sac weight in bobwhite quail (Colinus virginianus). Florida Scientist 1988;51:159-162.

Sotherland PR, Rahn H. On the composition of bird eggs. The Condor 1987;89:48-65.

Soliman FNK, Rizk RE, Brake J. Relationship between shell porosity, shell thickness, egg weight loss, and embryonic development in japanese quail eggs. Poultry Science 1994;73:1607-1611.

Stojčić MD, Milošević N, Perić L. Determining some exterior and interior quality traits of japanese quail eggs (*Coturnix japonica*). Agroznanje 2012;13:667-672.

Turkyılmaz MK, Dereli E, Sahin T. Effects of shell thickness, shell porosity, shape index and egg weight loss on hatchability in Japanese quail (*Coturnix coturnix japonica*). Journal of The Faculty of Veterinary Medicine, Kafkas University 2005;11:147-150.

Yamak US, Sarica M, Boz MA, Ucar A. The effect of eggshell thickness on hatching traits of partridges. Brazilian Journal of Poultry Science 2016;18:13-18.

Yuan J, Wang B, Huang Z, Fan Y, Huang C, Hou Z. Comparisons of egg quality traits, egg weight loss and hatchability between striped and normal duck eggs. British Poultry Science 2013;54:265-269.

Wilkanowska A, Kokoszyński D, Cieślińska J. Body conformation and morphometry of some internal organs of pharaoh quail of different ages. Journal of Central European Agriculture 2013;14:836-846.