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Effect of Thermal Manipulation During Embryogenesis on Pre and Post-Hatch Performance of Stored Hatching Eggs of Japanese Quails

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ABSTRACT

This research investigated the influence of high incubation temperature on hatching, and post-hatch characteristics of stored hatching eggs of Japanese quails. Hatching eggs of Japanese quails were stored for 7 days and incubated under two temperature conditions. The T1 group (control, 75 eggs) was subjected to a standard incubation temperature (37.5°C) while the T2 group (75 eggs) was exposed to a thermal manipulation protocol (of 38.5°C for 5 hours daily between embryonic days 5-15. The egg weight classification, chick weight, chick length, wing length, weekly body traits, body weight, total feed intake, and stress responses, weight of internal organs, whole carcass, breast, neck, wing, thigh, and neck did not significantly differ ($P<0.05$) between the incubation treatments. Hatchability was higher and early embryonic mortality was lower in T2 than in T1. Late embryonic mortality was lower in T1. Significantly ($P\leq 0.05$) higher pectoral muscle width at hatch and carcass yield/dressing percentage were observed in quails exposed to thermal manipulation protocol during embryogenesis. It was concluded that exposure of stored eggs to thermal manipulation protocol (of 38.5°C for 5 hours between embryonic days, ED 5-15, T2) during embryogenesis could enhance embryonic and growth traits, as well as carcass traits without any negative effect on stress indicators.

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Introduction

The rapidly growing world's population has increased the demand for cheap and affordable chicken meat which has in turn increased the search for the production of other alternative poultry species. The commercial production of Japanese quails (*Coturnix japonica*) as an alternative poultry specie is gaining a significant interest compared to the production other alternative poultry species. The unique flavour of their meat and eggs (Kayang et al., 2004) has been reported to be the cause for the rise in the interest for commercial production of Japanese quails. According to Oguz and Minvielle (2001), Japanese quails have small body sizes with short generation interval, high resistance to diseases and egg production, and low maintenance cost, making these birds suitable for laboratory purposes. Furthermore, Bagh et al. (2016) reported that in India, the Japanese quail is a promising poultry species for rural farmers due to their lower management requirements.

An egg is an important source of nutrients and it was reported that the eggs of Japanese quails are rich in minerals, vitamins, and antioxidants with a 3-4 times nutritional value compare to the eggs of chickens (Lalwani, 2011; Tunsaringkarn et al., 2013). A comparative analysis by Loniță et al. (2008) revealed that compared to meat of broiler chickens and ducks, quail meat has the highest level of protein and the lowest calorie. A different author (Vali, 2008) also reported that quail meat has become a superior economic source of animal protein due to its lower cholesterol and lean nature.

In underdeveloped and developing countries, poultry meat and eggs are the most affordable and cheapest source of protein. This has increased the regional and global demand for poultry meat and eggs leading to the expansion of commercial hatcheries and the number of daily hatched chicks. However, in many countries especially underdeveloped and developing countries, commercial hatcheries have very limited capacities leading to the regular storage of hatching eggs and chicks being hatched in batches. Indeed, Romao et al. (2008) reported that the eggs of quails are collected and normally stored between 1-3 weeks prior to incubation.

For efficient pre and post-hatch performance, it is recommended that hatching eggs should not be stored for more than 7 days or that the optimum egg storage period should be between 5-7 days. According to Whitehead et al. (2002) the optimum storage period for chicken fertilized eggs is 7 days and each extension of this period increases embryonic mortality and decreases hatchability. Fasenko (2007) also reported that the storing eggs before incubation does not adversely affect hatchability when the storage period does not exceed 7 days. In some cases, hatching eggs may be stored beyond the recommended time, which has several negative effects on both pre and post-hatch performance. Eggs stored for longer duration are known to have poor embryonic development, fertility, hatchability, higher embryonic mortality, lower chick weight at hatch and poor-quality hatched chicks. For instance, Garip and Dere (2011) observed an hatchability of 35.4% and 78.4% and for quail eggs stored for 15 d and 5 d at 21°C. Other authors have also reported negative correlation between hatchability and duration of egg storage (Narahari et al., 2002; Fasenko et al., 2001). Naraharim et al. (1988) also observed the highest fertility and hatchability of fertile eggs in hatching egg stored for 1-3 days compared to those stored for longer durations. An increase in the number of storage days' increases embryonic mortality and failed hatch with a reduction in the internal and external egg quality traits of hatching eggs (Ayeni et al., 2020; González-Redondo et al., 2023; Nasri et al., 2020; Carvalho et al., 2023). It has been reported that chicks that hatched from eggs stored for 14 days had the lowest weight at hatch and at 5 weeks during the rearing cycle (El-kazaz and Abo-Samaha, 2018). Furthermore, Mayes and Takeballi (1984) observed a 5% reduction in hatchability per day after 7 days of egg.

Thermal manipulation during the incubation of non-stored hatching eggs has been reported to enhance embryonic development, and hatchability, decrease incubation time and improve chick quality, post-hatch growth, and welfare performance (Yahav et al., 2004; Piestun et al., 2008; Collin, et al., 2005; Piestun et al., 2009; Al-Zhgoul et al., 2013; Al-Rukibat etal, 2017; Piestun et al., 2011; Piestun et al., 2013; Yalcin et al., 2012).

Therefore, in this research, it was hypothesized thermal manipulation of stored hatching eggs would improve pre and post-hatch performance. To our understanding, this study is one of the few preliminary researches testing the effect of incubation temperature on stored hatching eggs of Japanese quails.

Material and Methods

Experimental Groups and Storage Conditions

In this study, a total of 150 hatching eggs of Japanese quails were used. The eggs were first weighed using an electronic balance with a precision of 0.01g and divided into 2 separate groups (75 eggs per group); control-T1 and the thermal manipulated group-T2. The eggs were then stored with an average temperature and humidity of 18°C and 55% respectively for a week in the storage room. After storage, the eggs were again weighed with an electronic balance and then subjected to a prewarming protocol (26°C, RH 55%) for 5 hours. Moisture (%ML) loss during storage was evaluated using the formulae below.

$$\%ML = \frac{\text{Weight before storage} - \text{Weight after storage}}{\text{Weight before storage}} \times 100$$

Incubation Treatments

The T1-control were subjected to an incubation temperature of 37.5°C throughout the incubation period while the T2 eggs were subjected to a high temperature of 38.5°C for 5 hours between embryonic days (ED) 5-15. On incubation day 15, eggs were transferred to the hatcher.

Evaluation of Hatching Traits

Hatching traits such as embryonic mortality and hatchability were recorded and evaluated. To determine the stage of embryonic mortality, unhatched eggs at the end of the hatching period were cracked. The dead embryos were assessed and the stage of embryonic development was used to determine the stage of embryonic mortality by specialist with vast understanding of embryonic mortality.

$$H = \frac{(\text{The total number of chicks that hatched})}{(\text{The total number of eggs incubated})} \times 100$$

$$E = \frac{(\text{Number of early embryonic deaths})}{(\text{Total number of embryonic deaths in that group})} \times 100$$

$$M = \frac{(\text{Number of mid-embryonic deaths})}{(\text{Total number of embryonic deaths in that group})} \times 100$$

$$L = \frac{(\text{Number of late embryonic deaths})}{(\text{Total number of embryonic deaths in that group})} \times 100$$

H: Hatchability
E: Early embryonic mortality
M: Middle embryonic mortality
L: Late embryonic mortality

Evaluation of Post Hatch Traits and Animals Selected for the Growing Period

At hatch, chick quality traits (chick length, chick weight, and chick pectoral muscle length) in all the chicks that hatched from the respective incubation groups were assessed. The chick weight was measured using scale with a precision of 0.01 g and the chick length was measured using a rule/line gauge attached to a table. The pectoral muscle length was measured using a digital venier caliper. After that, only chicks of high grade quality with no leg problem or having better locomotion abilities were selected for the growing or rearing cycle. Using this criteria, 25 healthy chicks per incubation treatment were reared for 5 weeks.

Housing Facility during the Rearing Cycle

The poultry housing facility at Çukurova University Farm was used in this study. The quails were reared in cages with dimensions 28cm×92cm×44cm (height, length, and width respectively). There were 3 replicates per experimental group. The number of birds and replicates used in the current experiment are given in Table 1.

Table 1. The number of experimental birds and replicates used in the study

Treatments	T1R1	T1R2	T1R3	Total
T1	8	8	9	25
T2	T2R1 8	T2R2 8	T2R3 9	25

T1; Treatment 1, T2; Treatment 2, R1; Replicate 1, R2; Replicate 2, R3; Replicate 3

Experimental Diet

A broiler chick diet containing 3000 kcal/kg ME and 24% crude protein were given to chicks between 0-2 weeks of the experiment. From the 3-5 weeks of the experiment, a diet containing 3000 kcal/kg ME and 22% crude protein were provided for the grower quails.

Measurements/Evaluation of Feed Intake and Body Weight

Using an electronic balance with a precision of 0.01 g, feed intake and body weight were recorded weekly. The formulae below were used in evaluating the weekly feed intake.

$$(\mathrm{FG} - \mathrm{FL})$$

FG: Feed given at the beginning of a particular week
FL: feed left at the end of that week

Measurement of Body Traits During the Rearing Period

All the quails (25 quails per incubation treatment) were assessed for body traits such as chick length, wing length, and length and width of the pectoral muscle on weekly basis throughout the production period using a digital Venier calliper.

Measurement of Stress

The rectal temperature and leg composite asymmetry were used as the measure of stress in this study.

- ***Rectal Temperature Measurements***

The rectal temperature of the 25 quails per experimental treatment was recorded by inserting a digital thermometer 3cm inside the cloaca (Kursun et al., 2024).

- ***Measurements of Fluctuating Asymmetry of Leg***

The leg fluctuating asymmetry (FA) was recorded using a digital calliper (Archer et al., 2009) after slaughter in all the slaughtered quails (25 quails per incubation treatment). FA was evaluated using the formula below.

- $\mathrm{FA}=\frac{\mathrm{ML(L-R)+MW(L-R)+MTL(L-R)}}{3}$

R (Right); L (Left); ML (Metatarsal length); MTL (Middle Toe length); MW (Metatarsal width)

Evaluation of Carcass Traits

All the experimental birds were slaughtered (25 quails per incubation treatment), the whole carcass was measured and each part of the carcass (neck, wings, breast, and thigh) were measured separately. The measurements were done using an electronic balance with a precision of 0.01 g. The formula below was used to evaluated the carcass yield or dressing percentage;

$$\mathrm{DP}=\frac{(\text{Carcass weight})}{(\text{Live weight})}\times 100$$

DP: Dressing percentage/Carcass yield

Measurement of Immune and Other Internal Organs

The immune organ (spleen) weight, weight of proventriculus, heart, gizzard (ventriculus), liver, and intestines were all measured using an electronic balance with a precision of 0.01 g.

Statistical Analysis

Using SPSS version 26, test of normality was conducted using the Shapiro-Wilk. After confirming the normality of the data, independent sample t-test analysis was then used to evaluate the statistical mean difference of the various incubation treatments for all the measured data except for hatching traits. The hatching traits were analysed by diving the occurrence of a particular trait by the total number of all the traits and expressed in percentages.

Results

The weight of the eggs before and after storage as well as during transfer to the hatcher is presented in Table 2. The weight of the egg before and after storage as well as during transfer to the hatcher was not statistically ($P \geq 0.05$) different between the control and the thermal manipulated group.

The results of incubation treatments on the hatching traits of stored eggs are given in Table 3. The T2 group had higher hatchability than the T1 group. The percentage of early embryonic mortality was higher in T1, however, the T2 group had the higher percentage of late embryonic mortality.

Table 2. The weight (g) of the eggs before and after storage and during transfer to the hatcher

Experimental Treatment	Classifications of Egg Weight		
	Weight Before Storage	Weight After Storage	Weight Before Transfer to Hatcher
T1 (Control)	12.67 ± 0.11	12.55 ± 0.11	11.30 ± 0.15
T2	12.89 ± 0.10	12.72 ± 0.10	11.24 ± 0.16
P Value*	0.139	0.262	0.263

*T1: Treatment 1 (control, stored eggs exposed to normal incubation temperature). T2: Treatment 2 (Stored eggs exposed to thermal manipulation).

Table 3. Influence of incubation treatments on embryonic mortality (%) and hatchability (%)

Experimental Treatment	Number of Hatched Chicks (*N*)	Hatchability (%)	Embryonic Mortality (%)		
			Early Embryonic Mortality (%)	Middle Embryonic Mortality (%)	Late Embryonic Mortality (%)
T1	29	38.67	85.71	-	14.29
T2	33	44.00	66.67	-	33.33

T1: Treatment 1 (control, stored eggs exposed to normal incubation temperature). T2: Treatment 2 (Stored eggs exposed to thermal manipulation).

Table 4. Influence of incubation treatments on chick body traits at hatch

Experimental Treatment	Chick Body Traits at Hatch			
	Chick Weight (g)	Chick Length (cm)	Pectoral Muscle Width (mm)	Wing Length (mm)
T1	9.22 ± 0.15	11.08 ± 0.10	13.68 ± 0.27	21.83 ± 0.31
T2	8.94 ± 0.12	10.98 ± 0.14	14.74 ± 0.26	22.08 ± 0.46
P values	0.148	0.547	0.006	0.642

T1: Treatment 1 (control, stored eggs exposed to normal incubation temperature). T2: Treatment 2 (Stored eggs exposed to thermal manipulation).

Table 5. Effect of incubation treatments on chick body traits during the rearing period

Body Traits	Treatments	Weeks of Production			
		1	2	4	5
Chick Length (cm)	T1	15.84 ± 0.14	20.88 ± 0.24	27.22 ± 0.28	27.92 ± 0.84
	T2	16.20 ± 0.17	21.12 ± 0.23	26.73 ± 0.35	37.89 ± 9.65
P value		0.113	0.478	0.281	0.309
Pectoral Muscle Width (mm)	T1	21.38 ± 0.49	26.21 ± 0.42	41. 30 ± 1.40	43.36 ± 0.85
	T2	21.37 ± 0.45	26.32 ± 0.41	41.08 ± 0.88	42.56 ± 0.72
P value		0.986	0.850	0.899	0.483
Pectoral Muscle Length (mm)	T1	46.83 ± 0.66	53.14 ± 1.01	60.18 ± 1.32	67.14 ± 1.06
	T2	48.03 ± 0.83	52.83 ± 1.10	59.71 ± 1.15	66.68 ± 1.28
P value		0.267	0.841	0.789	0.787
Wing Length (mm)	T1	43.75 ± 0.72	66.00 ± 1.79	87.93 ± 1.92	96.83 ± 0.96
	T2	45.61± 1.27	67.47 ± 1.45	89.70 ± 1.40	96.89 ± 1.26
P value		0.220	0.525	0.458	0.972

T1: Treatment 1 (control, stored eggs exposed to normal incubation temperature). T2: Treatment 2 (Stored eggs exposed to thermal manipulation).

Table 6. Effect of incubation treatments on total feed intake and average weekly body weight

Experimental Treatments	Body Weight (g) /Week					Total Feed Intake (g)
	1	2	3	4	5	
T1	33. 16 ± 0.85	84.96 ± 1.89	155.63 ± 3.82	212.46 ± 5.57	253.45 ± 7.80	4229.28 ±750.47
T2	33.44 ± 1.02	81.87 ± 2.66	149.55 ± 5.56	210.92 ± 7.41	257.38 ± 9.93	4302.32 ± 791.73
P Values	0.832	0.355	0.380	0.869	0.757	0.948

T1: Treatment 1 (control, stored eggs exposed to normal incubation temperature). T2: Treatment 2 (Stored eggs exposed to thermal manipulation).

Table 7. Influence of incubation treatments on cloacal/rectal temperature and fluctuating asymmetry of the leg.

Experimental Treatments	Stress Responses	
	Rectal/Cloacal Temperature (^{0}C)	Fluctuating Asymmetry
T1	41.94 ± 0.10	0.79 ± 0.12
T2	42.04 ±0.11	1.00 ± 0.19
P Values	0.492	0.357

T1: Treatment 1 (control, stored eggs exposed to normal incubation temperature). T2: Treatment 2 (Stored eggs exposed to thermal manipulation).

The results of incubation managements on chick body traits at hatch is presented in Table 4. The incubation treatments had no statistical effect (P≥0.05) on wing length, chick length and chick weight at hatch between the two experimental treatments however, the T2 group had significantly (P≤0.05) higher pectoral muscle width at hatch than the T1 group.

The effect of incubation treatments on weekly body traits during the production/rearing phase is presented in Table 5. The weekly body traits were not statistically (P≥0.05) different between the two incubation treatments. The experimenters (students) that measured the body traits data on week 3 were inexperienced thereby recording wrong values for that week. Therefore, the body trait data for week 3 was excluded/ discarded from the research.

The influence of the incubation treatments on total feed intake and weekly body weight is given in Table 6. The incubation treatments did not have any statistical influence (P≥0.05) on the total feed intake and weekly body weight evaluated in this study.

The influence of incubation treatments on responses to stress is presented in Table 7. No significant (P≥0.05) effect of the incubation treatment was observed on the measured stress parameters (fluctuating asymmetry of the leg rectal/cloacal temperature and).

The influence of the incubation treatments on carcass trait is given in Table 8. The weight of the whole carcass, breast, wings, thigh, and neck did not differ significantly between the incubation treatments (P≥0.05). However, the T2 group had statistically (P≤0.05) higher dressing percentage compared to the compared to T1 group. Furthermore, the weight of the heart, liver, gizzard, proventriculus, and intestines did not statistically (P≥0.05) differ between the two incubation treatments.

Table 8. Influence of incubation treatments on carcass parameters

Weight of Carcass and Internal Organs (g)	Treatments		P Values
	T1	T2	
Whole carcass	173.35 ± 6.29	185.02 ± 6.92	0.218
Breast	87.16 ± 17.94	89.33 ± 19.23	0.682
Wing	12.32 ± 0.41	12.67 ± 0.52	0.60
Thigh	37.54 ± 1.35	40.19 ± 1.64	0.220
Neck	6.87 ± 0.26	6.89 ± 0.27	0.958
Dressing Percentage (%)	68.22 ± 0.82	72.12 ± 1.02	0.004
Heart	2.36 ± 0.16	2.17 ± 0.10	0.311
Liver	6.21 ± 0.33	6.93 ± 0.37	0.150
Gizzard	5.06 ± 0.24	4.87± 0.24	0.588
Proventriculus	0.92 ± 0.06	1.03± 0.06	0.214
Intestines	9.77 ± 2.93	9.44 ± 2.35	0.668

T1: Treatment 1 (control, stored eggs exposed to normal incubation temperature). T2: Treatment 2 (Stored eggs exposed to thermal manipulation).

Discussion

In terms of egg weight before and after storage, no statistical difference between the experimental treatments were observed. The eggs from the two experimental treatments were from the same breeder parents, similar average egg weight, and similar storage conditions and this reason may have accounted for the lack of significant different in terms of egg weight before and after storage between the experimental groups. Furthermore, egg weight loss before transfer to the hatcher was not significantly different between the incubation treatments however, it was numerically higher in T2 compared to T1. In line with our observations, other authors (Abdelfattah, 2019; Kamanli et al., 2021; Lin et al., 2017; Farghly et al., 2022) have reported higher egg weight loss in non-stored eggs exposed to high incubation temperature (38.1°C, 38.5°C, 39±1°C or 41°C) compared to those exposed to low or standard incubation temperature. Another author also reported that the exposure of non-stored eggs to a temperature of 39°C decreased egg weight (Sgavioli et al. 2016). The exchange of gas between the egg and its surrounding is regulated by the eggshell conductance and this has been reported to regulate metabolic heat and water loss (Campos and Santos, 2003; Hamidu et al., 2007). The greater loss of egg weight in the T2 group observed in the present experiment could probably be due to the high evaporation of water from the developing embryos (Shafey, 2002). Contrary to our results higher egg weight loss in stored eggs exposed to normal incubation temperature than in stored eggs exposed to thermal manipulation during embryogenesis was observed (Alkıs, 2021).

The T2 group had higher hatchability than the T1 group in the current study. The findings of this experiment are in agreement with the results of other studies (Farghly et al., 2022; Abdelfattah, 2019; Lin et al., 2017) which also observed that non-stored eggs subjected to higher temperature during incubation had higher hatchability than those subjected to standard incubation temperature. The higher hatchability in the group subjected to high temperature during incubation could be related to an excessive reduction in the number of early embryo mortality in the present study. Contrary to our findings, others (Shah and Özkan, 2022; El-Shater et al., 2020; El-Shater et al., 2021; Abuoghaba et al., 2021) observed higher hatchability in embryos exposed to standard incubation temperature (37.7°C or 37.5°C) than those subjected to thermal manipulation protocols (41°C or 39.5°C). The diversity in the various scientific reports might be related to the differences in the thermal manipulation protocol used by the different authors.

Early embryonic mortality was higher in the T1 than in T2. Eggs exposed to storage have been reported to have a lower number of embryonic cells due to apoptotic death of cells which has a huge influence on embryonic mortality after standard incubation conditions (temperature and humidity) are restored. It could be possible that thermal manipulation of the T2 group increased the proliferation of embryonic cells resulting in an adequate number of cells for initial embryonic development. Our observation is supported by the findings of other researches (Shah and Özkan 2022) who also reported a lower percentage of early embryonic mortality in eggs exposed to thermal manipulation. The higher number of late mortality among the T2 group could be due to excessive dehydration of the embryo due to evaporation caused by higher heat exposure. Contrary to our observations several authors (Abdelfattah, 2019; Vitorino Carvalho et al., 2020; Abuoghaba et al., 2021) have observed a higher number of late and early embryonic mortality in non-stored eggs exposed to higher incubation temperature. The differences between the findings of the present experiment and other experiments in terms of early embryonic mortality might be related to the storage effect which was part of the current study or the thermal manipulation protocol used.

In the present study, in terms of chick body traits, significantly ($P \leq 0.05$) higher pectoral muscle width/diameter at hatch was observed in the T2 group compared to the T1 group. Other authors also reported that the exposure of non-stored eggs to thermal manipulation increased breast muscle hypertrophy (El-Shater et al., 2021). In non-stored eggs, thermal manipulation has been reported to enhance proliferative activity, increase the number of muscle cells in embryonic and post-hatch chicks as well as IGF-I which is known to stimulate the proliferation and differentiation of satellite cells and increase myofiber hypertrophy (Paul and Rosenthal, 2002;

Adams and McCue 1998; Piestun, et al., 2009; Adams et al., 2000). Again, it was reported that exposure of embryos to thermal manipulation protocols increased muscle development and the diameter of myofiber (Piestun et al., 2009). This reason may account for the higher pectoral muscle width in T2 than in T1 observed in the current study. Other chick body traits (wing length, chick weight, and chick length) at hatch were not statistically different from one another between the experimental groups. In line with our reports, other authors have also reported that thermal manipulation had no statistical effect of on chick weight and chick length at hatch (Farghly, et al. 2022; Shah and Özkan, 2022). Although not statistically different, numerically higher chick weight and length in T1 compared to T2 were observed at hatch. Higher chick weight and chick length at hatch or day-old in non-stored and stored eggs exposed to normal incubation temperature than those exposed to high incubation temperature have been reported by several authors (Abdelfattah, 2019; Alkıs, 2021; Sgavioli et al., 2016; Abuoghaba et al., 2021; El-Shater et al., 2021; Amjadian and Shahir. 2020; Kamanli et al., 2021). The lower chick weight and chick length traits at hatch or day old reported in the group subjected to thermal manipulation might be related to the reduction in the utilization of yolk causing a subsequent reduction in the availability of nutrients for embryonic development (Willemsen et al., 2010). However, Alkıs (2021) observed higher chick weight in stored eggs subjected to high temperature during embryogenesis.

The current experiment is one of the first to evaluate the influence of thermal manipulation on chick body traits from hatch till slaughter age. Although several authors have reported the long-lasting and immediate effect of thermal manipulation from hatch till slaughter age (Piestun et al., 2009; Vitorino Carvalho, et al., 2020), The measured body traits from the first week of age till slaughter were not significantly different between the experimental groups.

The experimental groups in the present study did not differ statistically in terms of weekly body weight gain. Vitorino Carvalho et al. (2020) also observed no statistical influence of high incubation temperature on the body weight of quails at 35 days of age. Contrary to our findings other authors reported higher post-hatch (5 weeks) body weight in quails that hatched from eggs exposed to thermal manipulation during incubation (41°C for 3h/day at ED 6-8) (Alkan, et al., 2013; El-Shater et al., 2021). It was reported that at 8 weeks of age, chickens that hatched from eggs subjected to thermal manipulation during incubation (39 ± 1°C for 2 h during ED 4–14) had higher live weight (Farghly et al., 2022). Other authors also reported lower body weight in quails exposed to higher incubation temperature than those incubated with standard incubation temperature at 5 weeks and 25 days of age (Vitorino Carvalho et al., 2020; Abuoghaba et al., 2021). The differences in results could be related to the thermal manipulation protocol used or the quail breeder genotype from which eggs were obtained.

The total feed intake throughout the production period was not statistically different between the incubation treatments in the current study. İn agreement with our results, several authors have reported no statistical effect of thermal manipulation during embryogenesis on total feed intake (Farghly et al., 2022; Amjadian, and Shahir, 2020). Contrary to our results, significantly lower total feed intake in quails exposed to thermal manipulation during incubation have been reported (Abuoghaba et al., 2021).

Furthermore, the physical stress parameters (rectal temperature and fluctuation asymmetry of the leg) measured in the present study did not significantly between the experimental groups. In line with the current study, several authors (Amjadian, and Shahir, 2020; Yalçin, et al., 2006; Sgavioli et al., 2016) have reported no significant effect of thermal manipulation during embryogenesis on cloacal temperature. It is possible that the thermal manipulation protocol employed during embryogenesis did not have any significant effect on the mechanism that influences the acquisition of thermoregulation or thermotolerance leading to the subsequent lack of significant effect on the cloacal temperature of the birds. However, some authors (Abdelfattah, 2019; Abuoghaba, 2016) observed higher rectal temperature at hatch in quails that hatched from eggs subjected to high incubation temperature and others (Al-Zghoul et al., 2015; Shah, 2021; Al- Al-Zghoul, 2018; Al-Rukibat, et al., 2017; Zghoul, et al., 2019) also reported that thermal manipulation during embryogenesis decreased post hatch rectal/cloacal temperature at normal rearing temperature or during post-hatch heat challenge. The variations in results are probably due to the timing of the thermal manipulation, incubation temperature, and the duration of thermal manipulation.

The T2 group had statistically higher carcass yield/ dressing percentage than the T1 group in the present study. This is a reflection of the higher carcass weight and live body that was observed in the T2 group weight at the end of the experiment. Contrary to our findings, no significant effect of thermal manipulation on dressing percentage has been reported (Farghly et al., 2022). No significant effect of the incubation treatments on the weight of the full carcass, breast, thigh, wing, neck, heart, liver, gizzard, proventriculus, and intestines was observed in the present study. In line with our reports, other researchers (Abuoghaba, et al., 2021; Lin, et al., 2017; Farghly et al., 2022) also reported no statistical influence of thermal manipulation on carcass percentage, liver heart, gizzard, and intestines. Contrary to our results, higher percentages of breast, heart, and gizzard at hatch and slaughter age in chicks that hatched from non-stored eggs exposed to normal incubation temperature than those exposed to thermal manipulation have been reported (Abdelfattah, 2019; Lin, et al., 2017; Abuoghaba, et al., 2021).

Conclusion

Our preliminary research revealed that thermal manipulation of stored eggs could decrease early embryonic mortality as well as improve live body weight, feed intake, and carcass traits without any negative effect on production and welfare performance.

Declarations

Ethical of approval

The ethics committee of Cukurova University granted the approval/ethic report (approval number: 28.03.2024/2) for this study.

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