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ORIGINAL ARTICLE

Early heat acclimation during incubation improves Japanese quail performance under summer conditions

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Abstract

Effects of exposing quail eggs to high temperature on the heat tolerance ability and productivity of birds were investigated. Four groups of 600 fertile eggs were randomly selected; the first group was incubated under 37.5 °C and the hatched chicks were reared under a gradual decrease in temperature from 35 to 24 °C (Control). The second group was exposed to 39.1 °C for 2 h/day during 4–14 days of embryogenesis and the hatched chicks were reared under a gradual decrease in temperature from 35 to 24 °C. The third group was incubated under 37.5 °C and the hatched chicks were exposed to 39 ± 1 °C for 2 h/day during 4–14 days of age. The fourth group was exposed to 39 ± 1 °C for 2 h during 4–14 days of embryogenesis and the hatched chicks were exposed to 39 ± 1 °C for 2 h/day during 4–14 days of age. The temperature applied changed ($P < 0.01$) embryo weight and incubation period. Birds exposed to high temperature during brooding had superior growth performance, dressed carcass, body temperature and health traits. Birds subjected to 39 ± 1 °C during brooding exhibited decreased feed consumption and body weight gain. Finally, this work suggests that thermal acclimation during embryogenesis might offer a practical method for easing heat stress.

Keywords Growth performance · Incubation · Thermal adaptation · Quail

Introduction

High ambient temperature generates stress and evokes a combination of productive, immunological and physiological changes in animals (Rizk et al. 2019; Awad et al. 2021; Farghly et al. 2021). Environmental factors such as temperature influence the development of the chick embryo (Sgavioli et al. 2016). One of the effective methods to sustain thermal tolerance and avoid the deleterious impact of heat stress is acclimation (Khalil et al. 2008; Wasti et al. 2020).

The premature lifetime (prenatal, neonatal and post-hatching) has been reported to be very critical in shaping poultry responses throughout its lifetime (Dixon et al. 2016). Early embryogenesis is a vital view of feeling to the environment, and environmentally stimulated alterations can be transferred through development by following cell splits (David et al. 2019). The literature suggests that conditions through incubation could have substantial impacts on poultry performance and well-being (Farghly et al. 2015; Dixon et al. 2016). Incubation temperature is one of the environmental elements that can induce epigenetic adaptation of different physiological control systems (Sardary et al. 2015). Stress restraints could be impacted by early thermal exposure (Yahav 2009). Temperatures higher than recommended have been used to broilers in the embryonic duration in order to conquer thermal fatigue (Fernandes et al. 2016). High temperature during incubation enhances embryo metabolism, boosts oxygen consumption and carbon dioxide production (Sgavioli et al. 2016). Temperature rising during mid-term embryogenesis boosts myoblast proliferation, thus increasing myogenic progeny reservoir in the muscle, resulting in confirmed muscle development in the embryo and post-hatching (Piestun et al. 2015).

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The possibility to motivate amended thermotolerance in poultry is of great prominence. Early age thermal acclimation has been proposed as a technique to reinforce resistance of poultry breeds to heat stress, especially, post-hatching performance (Walstra et al. 2010; Alkan et al. 2013; Elsayed 2016). Thermal acclimation during the first week of age has been shown to considerably enhance the ability of chicks to deal with high temperature (El Azim 2012). Our objective was to determine the effects of early thermal acclimation during incubation and/or at early age of life on the heat tolerance ability and productivity of Japanese quails during summer season.

Materials and methods

This trial was conducted at the research farm of Poultry Production Department, Agriculture College, Asyut University, Asyut, Egypt, during summer season (June to September). All the experimental procedures were carried out following the Local Experimental Animal Care Panel and permitted by the animal ethics board of Poultry Production Department, Asyut University (AUN-IACUC/3/F/96/2018).

A total of 600 eggs of Japanese quail (*Coturnix japonica*) were utilized. Eggs were randomly divided into four groups (5 replicates); the first group (control) was incubated under 37.5 °C during incubation period and the hatched chicks were reared under gradual decrease in temperature from 35 °C at hatching to 24 °C at 6-weeks old (Farghly et al. 2015). The second group was exposed to 39 ± 1 °C for 2 h/day during 4–14 days of embryogenic age and the hatched chicks were kept under gradual decrease in temperature from 35 °C at hatching to 24 °C at 6-weeks old (T1). The third group was incubated under 37.5 °C and the hatched chicks were exposed to 39 ± 1 °C for 2 h/day during 4–14 days of age (T2). The fourth group was exposed to 39 ± 1 °C for 2 h through 4–14 of embryogenic age and the hatched chicks were exposed to 39 ± 1 °C for 2 h/day during 4–14 days of age (T3). Temperature during hatching was 37.0 °C for all groups. Relative humidity during incubation was 50% and during hatching was 60%.

Before incubation, eggs were individually weighed (to 0.01 g) to determine initial egg weight and re-weighed at 14 days of incubation to determine egg weight loss as a percentage of initial egg weight. Time of setting eggs into the incubator was recorded for the experiment to get the hatch time exactly in hours and considered as zero time of experiment.

Embryonic development Thirty eggs from each group were taken randomly at setting and weighed individually. These eggs (having normal embryos) were taken at 6, 10 and 14 days of setting and examined for embryonic development. The eggs were broken gently and embryos were separated as described by Asmar et al. (1972). The embryo was weighed and placed in a forced-air draft oven at 70 °C until the constant weight was reached and recorded to the nearest 0.1 mg. Embryo length was measured from the tip of the beak to the end of the middle toe with the chick's dorsal surface extended over a ruler.

Hatching performance At hatch, all live chicks were recorded and un-hatched eggs were opened to verify embryonic mortality. Hatching time and chick body weight at hatch was monitored every four hours after the hatch of the first chicks (chicks were considered hatched when they completely emerged and were free from the shell). Hatchability percent, the number of hatched eggs out of the total number of fertile eggs × 100, was calculated for each group.

Chick quality Hatched chicks were removed, wing-banded, weighed to the nearest 0.1 g and recorded as chick body weight at hatch then placed again in the incubator after recording the time of hatch. Chick weight loss % was calculated as:

(Chick weight at hatch—Chick weight at pull out)/Chick weight at hatch × 100.

Body temperature of hatched chicks was measured with a digital thermometer. Chick sex (female/male) was recorded and was determined by detecting the internal ovaries or testes. Chick quality was measured at hatch, all the hatched chicks were examined macroscopically in order to identify the different characteristics. The chick quality scores were using a scale from 1(poor quality) to 5 (good quality).

All chicks were kept in brooding area, fed the same diet and weighed individually until 8 weeks of age. The trial diet (Table 1) was elicited to recognize the nutrient demands of Japanese quails as indicated by NRC (1994). All chicks were reared in pens in 4 groups, according to the incubation treatment, with 3 replicates (20 birds in a replicate/ 50 × 60 cm). All management procedures were executed as described by Farghly et al. (2015). The newly hatched chicks were exposed to continuous lighting for 24 h/day during the first 3 days of age. Thereafter, the photoperiod was decreased gradually (one h/wk) until 12 h/day with light intensities of 10 and 20 Lux. Daily body weight gain was calculated at biweekly intervals depending on the difference between the recorded initial and final body weight then divided by number of days. Feed conversion ratio (FCR, g feed/g gain) was calculated at biweekly intervals by dividing the total feed consumed (g) in a replicate by the total body weight gain (g/d) of its birds. Mortality was recorded when it occurred and expressed as percentage (mortality rate, %) during the experimental period. Indoor averages of temperature and humidity through the trial period are given in Table 2.

Table 1 Ingredients and nutrient composition of the diet

Item	(%)
Ingredients composition (g/k; as –fed basis)	
Maize	525
Soybean meal	382
Maize gluten meal 60%	43.0
Vegetable oil	16.0
Di-calcium phosphate	16.0
Limestone	9.0
NaCl	3.0
Premix [(1)]	3.0
L-lysine	0.3
DL methionine	0.7
Choline chloride	2.0
Chemical composition (g/kg) [(2)]	
CP	241.5
ME MJ/kg	12.15
Lysine	13.1
Methionine	5.0
Methionine + Cystine	8.2

[(1)]Vitamin and mineral premix; each kg contains: Vit A 12,000, 000 IU; Vit D_3, 2000, 000 IU; Vit. E. 10 g; Vit k_3 2 g; Vit B_1, 1000 mg; Vit B_2, 49 g; Vit B_6, 105 g; Vit B_{12}, 10 mg; Pantothenic acid, 10 g; Niacin, 20 g, Folic acid, 1000 mg; Biotin, 50 g; Choline Chloride, 500 mg, Fe, 30 g; Mn, 40 g; Cu, 3 g; Co, 200 mg; Si, 100 mg and Zn, 45 g

[(2)] Calculated according to NRC (1994)

At 8-weeks old, 10 birds/ group (2/replicate; one of each sex) were chosen at random and slaughtered according to Abou-Kassem et al. (2015). The internal organs (heart, liver, empty gizzard, spleen and pancreas), abdominal fat, testes and ovaries were removed, weighed and calculated as percentages of carcass weight. Dressing percentage was calculated by dividing carcass and giblet weights/ the pre-slaughter live body weight. Blood samples were collected at slaughter in heparinized tubes. Plasma was separated by centrifugation at 3000 rpm for 20 min and kept at -20 °C until analyzed. Plasma total protein, albumin, glucose, cholesterol and transaminase enzymes activities (aspartate aminotransferase; AST and alanine aminotransferase; ALT) were specified calorimetrically by diagnostic kits of Diamond Biodiagnostic (Cairo, Egypt).

Data obtained were normally distributed and were analysed using the General Linear Model (GLM) Procedure of SAS software. Differences between means of different groups and the level of significance were set at $P < 0.05$ using Tukey test. Before analysis, all percentages were submitted to arcsine transformation to approximate normal distribution.

Results

Embryo weight (g) and embryo length (cm) did not differ significantly ($P > 0.05$) due to early heat adaptations, except for embryo weight (%) at 14^{th} day of incubation (Table 3). Eggs in T3 and T1 had the heaviest (P = 0.0074) weight of embryos, at 14 days of incubation, when compared to the control and T2 groups (Table 3). Hatchability (%) of Japanese quail did not differ significantly ($P > 0.05$) between the tested groups. Eggs in groups T1 and T3 had the shortest (404.3 and 405.5 h, respectively; P = 0.0037) incubation periods when compared with the other groups (Table 3). Chick traits and quality were not changed significantly ($P > 0.05$) due to early heat acclimation. Chick traits and its quality were not changed due to early heat acclimation (Table 4). Birds hatched from eggs of groups T3 and T2 had superior growth performance, in terms of body weight, daily body weight gain, feed consumption and feed conversion ratio, followed by those hatched from eggs of T1 and the control group (Table 5). Birds hatched from eggs of T3 and T2 had the heaviest body weight (241 and 233.7 g, respectively) at 8 weeks of age, the greatest daily body weight gain during 6–8 weeks of age (2.90 and 2.45 g/bird/day, respectively) and the lowest FCR during the same period (6.08 and 7.03 g, respectively). Carcass traits of the quail were not significantly affected ($P > 0.05$) by early heat acclimation (Table 6). There were insignificant differences in the blood biochemistry of the quail due to early heat acclimation (Table 7). Mortality rate (%) was not significantly different between the treatment groups (Table 7).

Table 2 Means of indoor temperature and humidity values of the house

Intervals (month)	Temperature (C°)			Humidity (%)			THI		
	Max	Min	Aver	Max	Min	Aver	Max	Min	Aver
Jun	33.60	24.80	29.20	58.60	43.80	51.20	31.14	22.99	26.96
Jul	34.00	25.60	29.80	61.20	45.90	53.55	31.64	23.72	27.58
Aug	35.70	27.20	31.45	60.40	45.20	52.80	33.09	25.03	28.96
Overall mean	34.43	25.87	30.15	60.07	44.97	52.52	31.95	23.91	27.83

THI = Temperature-humidity index, Max. = maximum, Min. = minimum and Aver. = average

Table 3 Effect of heat acclimation on embryo development and hatching performance of Japanese quail eggs

Traits	Treatments				SEM	*P* value
	Control	T1	T2	T3		
6^{th}	2.62	2.73	2.65	2.80	0.204	0.6956
Embryo weight (g) at 10^{th}	17.25	18.58	17.41	18.24	1.590	0.6968
14^{th}	45.30[b]	49.05 [a]	45.08 [b]	49.24 [a]	1.364	0.0074
6^{th}	1.74	1.80	1.75	1.85	0.0900	0.4573
Embryo length (cm) at 10^{th}	4.77	4.96	4.84	5.10	0.1745	0.1801
14^{th}	8.41	8.87	8.36	9.15	0.4590	0.1850
Hatchability (%)	66.72	68.14	66.18	70.53	4.634	0.6750
Early death embryo (%)	15.37	12.02	12.45	9.52	2.924	0.1903
Late death embryo (%)	7.65	6.93	5.41	6.96	3.101	0.8397
Pipping (%)	6.01	8.65	9.69	6.06	3.147	0.4230
Dead in shell (%)	4.25	4.26	6.28	6.93	3.237	0.6635
Egg weight loss (%)	9.18	9.69	9.11	9.72	0.333	0.1031
Incubation period (h)	409.63 [a]	404.27 [b]	409.30 [a]	405.53 [b]	1.434	0.0037

[a]–––––[b]Means within a row followed by different superscripts are significantly different ($P \leq 0.05$)

T1 = The group was exposed to 39.1 °C for 2 h/day during 4–14 days of embryogenesis and the hatched chicks were reared under a gradual decrease in temperature from 35 to 24 °C. T2 = The group was incubated under 37.5 °C and the hatched chicks were exposed to 39 ± 1 °C for 2 h/day during 4–14 days of age. T3 = The group was exposed to 39 ± 1 °C for 2 h during 4–14 days of embryogenesis and the hatched chicks were exposed to 39 ± 1 °C for 2 h/day during 4–14 days of age

Table 4 Effect of heat acclimation on chick traits and quality of Japanese quail

Traits	Treatments				SEM	*P* value
	Control	T1	T2	T3		
Chick weight at hatch	7.56	7.97	7.65	8.09	0.567	0.6311
Chick weight loss %	3.68	3.43	4.10	3.55	0.412	0.2805
Chick lengths (cm)	11.14	10.70	11.61	10.59	0.690	0.3235
Body temperature (°C)	39.37	39.94	39.46	39.74	0.665	0.7169
Chick sex (F/M)	1.34	1.26	1.62	1.31	0.302	0.5023
Culled Chicks (%)	1.43	2.13	1.46	2.00	1.404	0.8937
Chick quality (%)	90.02	91.94	92.27	91.75	1.715	0.4284

T1 = The group was exposed to 39.1 °C for 2 h/day during 4–14 days of embryogenesis and the hatched chicks were reared under a gradual decrease in temperature from 35 to 24 °C. T2 = The group was incubated under 37.5 °C and the hatched chicks were exposed to 39 ± 1 °C for 2 h/day during 4–14 days of age. T3 = The group was exposed to 39 ± 1 °C for 2 h during 4–14 days of embryogenesis and the hatched chicks were exposed to 39 ± 1 °C for 2 h/day during 4–14 days of age

Discussion

The major interest of this study was to determine whether thermal acclimation during embryogenesis and/or at post-hatch period, would further enhance thermotolerance at hatch and during their production cycle. Using early thermal acclimation during incubation in avian species has shown that incubation temperature is a critical element in the incubation process, affecting hatching, embryo and chick quality. One of the main worries in dealing with poultry species is how to preserve or even advance performance when different manipulative treatments are practical (Alkan et al. 2013). It is not well-defined from this work whether the impact of thermal conditioning during embryogenesis on the embryo weight of quail was owing to differential muscle cell proliferation or gastrointestinal growth. Uni et al. (2001) indicated that an early thermal manipulation boosted the growth of the gastrointestinal tract and directed to weightier birds. Halevy et al. (2001) stated that muscle mass is related to improved multiplying and enhanced differentiation of satellite cells. Due to that thermal conditioning during embryogenesis persuaded alterations in T_3 levels but augmented body weight, it is proposed that thermal manipulation during embryogenesis may cause variations of kinetics of satellite cell

Table 5 Effect of heat acclimation on growth performance of Japanese quail

Traits	Age (wks)	Treatments				SEM	*P* value
		Control	T1	T2	T3		
Body weight (g)	0	7.56	7.97	7.65	8.09	0.690	0.4925
	2	55.67	56.33	55.67	55.33	5.22	0.9961
	4	130.67	135.33	138.00	146.33	9.746	0.3213
	6	189.33	186.33	199.33	200.33	7.847	0.141
	8	216.33[b]	217.33 [b]	233.67 [a]	241.00 [a]	7.230	0.0074
Daily body weight gain (g/bird/day)	0 – 2	3.40	3.48	3.38	3.41	0.372	0.9871
	2 – 4	5.36	5.64	5.88	6.50	0.478	0.0891
	4 – 6	4.19	3.64	4.38	3.86	0.238	0.0519
	6 – 8	1.93 [c]	2.21 [bc]	2.45 [b]	2.90 [a]	0.219	0.0036
	0 – 8	3.69	3.85	4.08	4.14	0.230	0.1299
Feed consumption (g/bird/day)	0 – 2	8.46	8.58	7.90	8.01	0.599	0.4745
	2 – 4	14.03	13.93	12.71	12.20	1.440	0.2122
	4 – 6	16.94	17.19	16.76	16.99	0.899	0.9494
	6 – 8	18.00	17.63	17.14	17.62	0.709	0.5597
	0 – 8	13.51	13.65	13.15	13.07	0.79	0.7787
Feed conversion ratio (g feed/g gain)	0 – 2	2.53	2.48	2.34	2.39	0.375	0.9284
	2 – 4	2.62 [a]	2.47 [a]	2.17 [ab]	1.90 [b]	0.250	0.0312
	4 – 6	4.04	4.72	3.86	4.43	0.359	0.0732
	6 – 8	9.40 [a]	8.00 [b]	7.03 [bc]	6.08 [c]	0.692	0.0022
	0 – 8	3.67	3.55	3.24	3.16	0.30	0.1885

[a–––c]Means bearing different superscripts are significantly different ($P \leq 0.05$)

T1 = The group was exposed to 39.1 °C for 2 h/day during 4–14 days of embryogenesis and the hatched chicks were reared under a gradual decrease in temperature from 35 to 24 °C. T2 = The group was incubated under 37.5 °C and the hatched chicks were exposed to 39 ± 1 °C for 2 h/day during 4–14 days of age. T3 = The group was exposed to 39 ± 1 °C for 2 h during 4–14 days of embryogenesis and the hatched chicks were exposed to 39 ± 1 °C for 2 h/day during 4–14 days of age

Table 6 Effect of heat acclimation on carcass traits of Japanese quail

Traits	Treatments				SEM	*P* value
	Control	T1	T2	T3		
Dressed carcass, %	74.03	74.84	76.54	75.12	1.943	0.0508
Heart, %	0.86	0.85	0.88	0.88	0.058	0.9284
Liver, %	2.51	2.88	2.53	2.80	0.305	0.4012
Gizzard, %	2.19	2.21	2.15	2.23	0.293	0.9857
Giblets, %	5.56	5.94	5.56	5.91	0.500	0.6684
Spleen, %	0.10	0.10	0.11	0.11	0.019	0.8946
Pancreas, %	0.29	0.29	0.26	0.25	0.037	0.5575
Testes, %	0.30	0.33	0.34	0.30	0.031	0.3551
Ovary, %	1.86	1.77	1.74	1.83	0.099	0.4824

T1 = The group was exposed to 39.1 °C for 2 h/day during 4–14 days of embryogenesis and the hatched chicks were reared under a gradual decrease in temperature from 35 to 24 °C. T2 = The group was incubated under 37.5 °C and the hatched chicks were exposed to 39 ± 1 °C for 2 h/day during 4–14 days of age. T3 = The group was exposed to 39 ± 1 °C for 2 h during 4–14 days of embryogenesis and the hatched chicks were exposed to 39 ± 1 °C for 2 h/day during 4–14 days of age

proliferation (Alkan et al. 2013). Druyan et al. (2012) and Yahav (2009) emphasized the positive effects of elevated incubation temperature on the improvement of long-lasting thermotolerance of broilers. Thermal changes during incubation have the advantage of mimicking natural incubation conditions in avian species (Ipek and SÖZCÜ 2015). The increased temperature might directly affect molecular steps needful for the generation and differentiation of myoblasts or indirectly impacts myogenesis by general energizing of the metabolism and the in ovo motion of the embryo

Table 7 Effect of heat acclimation on blood biochemicals and mortality rate of Japanese quail

Traits	Treatments			SEM	*P* value
	Control	T1	T2		
Total protein (g/dl)	3.89	3.95	4.13	0.354	0.7999
Albumin (g/dl)	2.32	2.37	2.47	0.205	0.7750
Globulin (g/dl)	1.57	1.58	1.67	0.211	0.9285
A:G ratio	1.49	1.50	1.49	0.187	0.9994
Glucose (mg/dl)	15.62	15.29	16.56	1.600	0.6259
Cholesterol (mg/dl)	168.52	161.52	164.61	12.38	0.9196
AST (u/ml)	204.84	201.73	196.90	12.04	0.6168
ALT (u/ml)	10.78	12.30	9.97	1.294	0.0866
Mortality rate, %	4.00	5.33	4.00	1.27	0.8018

T1 = The group was exposed to 39.1 °C for 2 h/day during 4–14 days of embryogenesis and the hatched chicks were reared under a gradual decrease in temperature from 35 to 24 °C. T2 = The group was incubated under 37.5 °C and the hatched chicks were exposed to 39 ± 1 °C for 2 h/day during 4–14 days of age. T3 = The group was exposed to 39 ± 1 °C for 2 h during 4–14 days of embryogenesis and the hatched chicks were exposed to 39 ± 1 °C for 2 h/day during 4–14 days of age

(Werner and Wicke 2008). During the period of embryogenesis or postnatal, the neuro-endocrine thermoregulatory system is still able to adapt, especially through the thermosensitivity of neurons from the preoptic region of the frontal hypothalamus (Yahav 2009).

In this work, hatchability and embryo mortality were not affected by early thermal acclimation, indicating that incubation at 39.1 °C may not be a limiting thermal factor for embryo development and there are many factors like relative humidity, egg size, parent stock and other factors, which contribute to this phenomenon. Similar findings were achieved by Sgavioli et al. (2016) in broiler breeder and of Walstra et al. (2010) in layer chicks. Early thermal acclimation in our study decreased incubation period, which is comparable to prior investigations (Walstra et al. 2010; Sgavioli et al. 2016). Hatching rate was 86.6% for eggs incubated for the whole incubation period at 37.5 ℃ and 82.4% for those incubated at 38.5 ℃ between 7–10 days of incubation (Werner and Wicke 2008). High incubation temperature (38.5 ℃) has been shown to reduce hatchability, chick weight and hatching period of the hatched broilers (Shafey et al. 2012).

In this study, chick quality traits at hatching were not influenced by early thermal acclimation, which signals that chick quality criteria did not change between thermal adaptation groups. However, the reduction in chick weight at hatching in the groups (T1 and T3) exposed to thermal acclimation during incubation process might be related to the use of egg protein as an energy source, instead of glycogen, that resulted in lower protein deposition in the embryo (Shafey et al. 2012). On contrast, Alkan et al. (2013) found low chick weights at hatch in a thermally treated group (41℃ for 3 h during 6–8 and 12–14 days of incubation) of quail eggs. Similar observations were observed by Leksrisompong (2005) who showed that thermal acclimation during incubation cannot affect hatchability and body weight of chicks at hatching. No unfavourable influences of the long-term high-thermal environment in the early and late times of incubation were revealed on the embryo development and chick weight at hatching, while the thermal manipulation extremely decreased chick quality (Narinc et al. 2016). The body temperature of hatched chicks in the present study was not different. Thermosensitive neurons located in the preoptic anterior hypothalamus integrate afferent temperature signals from several parts of the body to evoke adequate thermoregulatory responses via the control of physiological, endocrinological, and behavioural responses to keep body temperature relatively constant (Boulant 1996).

In our investigation, early thermal adaptation resulted in high growth performance, indicating that such a treatment may be beneficial to post-hatching chicks. The ontogenetic development of birds after hatching is characterized by the preferential growth of the heart, intestines, and liver (Sgavioli et al. 2016). Thermal conditioning of chicks results in refinements in performance and thermotolerance at marketing age (Yahav and McMurtry 2001). Thermal manipulation during incubation causes changes in thermoregulatory threshold response when the feedback mechanisms of body temperature organization is yet immature (Nichelmann 2004) until the axis in the brain related to thermoregulation is stimulated (Yahav 2009). Although, heat confront of thermal manipulated broilers at marketing age did not display any thermal features of these chickens (Collin et al. 2007), our results showed an improvement in growth performance at 6–8 weeks of age. Thermal treatment during embryogenesis had positive effect on body weight of quails at 5-weeks old (Alkan et al. 2013). Quail eggs incubated under 39.4 °C attained the highest body weight and improved FCR in the hatched quails, indicating long-term adaptation effects of incubation under high temperature (Khalil et al. 2008). Yalçin et al. (2008) recorded a transitory increase in body weight in chicks that were heat-treated from day 10 to day 18 of embryogenesis (6 h/d at 38.5 °C). The same authors added that exposure for 3 h/d to 39.5 °C between days 16 and 18 of embryogenesis did not seem to decrease growth performance up to slaughter age. Sengor et al. (2008) showed that survival rate was improved but FCR was poorer in the treated group (39 °C for 2 h on days 14 and 15 of incubation). Thermal manipulation at 19–20 days of incubation of broilers resulted in improvement in FCR (Sardary et al. 2015). In this respect, Collin et al. (2007) and Walstra et al. (2010) observed non-significant changes in body weight and feed consumption of chickens.

It was reported that perversion from optimum incubation temperature suppresses the development of organs

and growth (Ipek and SÖZCÜ 2015). Werner and Wicke (2008) indicated that carcass, breast and leg weights were comparable between chickens of a normal treatment group during incubation and those of a higher temperature group (38.5 °C). Thermal manipulation during embryogenesis resulted in change of liver weight (Leksrisompong 2005). The relative weight of liver was different between the early age heat conditioning group (38 °C ± 1° for 24 h at the day 5 post-hatching) and non-conditioning group without affecting all carcass parameters studied (El-Moniary et al. 2010). The later authors added that early age treatment showed no significant impact on all the carcass parameters studied. Fernandes et al. (2016) reported comparable findings.

Plasma total protein and the increased synthesis of a group of proteins known as the heat-hock proteins might be indicative of the effect of heat stress in birds (Al-Zghoul et al. 2015), which might explain the slight and numerical increase in serum total protein in this work. Similarly, El Azim (2012) exposed broilers to heat treatment during the first two weeks of age (40 °C for 4 h daily) and found insignificant differences in blood biochemicals. Thermal manipulation (to 40 °C) during embryogenesis induced an elevation in total protein and albumin in thermal manipulated chicks (Al-Zghoul et al. 2015). The same authors confirmed that thermal manipulation modulates the thermoregulation process during embryogenesis and post-hatch stages. In ostriches, serum total protein, albumin and globulin concentrations were low in the thermal manipulated group during late embryonic development, while the reverse was the case for glucose level (Elsayed 2016).

Contradicting outcomes were stated by Sengor et al. (2008) who indicated that high incubation temperature appeared to decrease postnatal mortality. Leksrisompong (2005) found non-significant differences between the mortality of broilers incubated under high and standard incubation conditions. Elsayed (2016) postulated that exposure of eggs to high incubation temperature may help avoid the negative effect of high environmental temperature post-hatch in ostrich chicks. The differences in studies related to thermal acclimation may be due to the length of acclimation period and timing, species and incubation temperatures, which may alter the results. Thermal acclimation process in broiler chickens requires from 4 to 7 days to be completed in broilers (Yahav 2009). In our study, we extended this process to 10 days even in the incubation period or early post-hatch. The results of the present work demonstrate that thermal acclimation during early life is of great importance to improve thermotolerance of quail birds to heat stress in the summer season. This complex issue has to be intensively investigated to spotlight epigenetic adaptation in different poultry species.

Conclusion

Thermal acclimation of eggs and newly hatched chicks could be beneficial to quail production especially post-hatch. The contemporary results demonstrate that thermal acclimation during early life is important to improve thermotolerance of quails to heat stress during summer season. The present work suggests that thermal acclimation during embryonic life and post-hatching might offer an additional workable process for easing heat stress especially under tropical conditions. Incubation temperatures above those recommended may compromise embryo development. The differences in studies related to thermal acclimation may be probably due to the length of acclimation period, timing of acclimation (during incubation and/or post-hatch), different species and incubation temperatures, which may alter the results. This complex issue has to be intensively investigated in order to spotlight on epigenetic adaptation in different domestic poultry species.

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Data availability Not applicable.

Code availability Not applicable.

Declarations

Ethics approval All experiential steps were implemented according to the Local Experimental Animal Care Panel and permitted by the animal ethics board of Poultry Production Department, Asyut University.

Consent to participate Not applicable.

Consent to publish All authors give consent for publication.

Conflict of interest There is no conflict of interest.

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