Egyptian J. Anim. Prod., (2008) 45(1):55-69

EFFECTS OF THERMAL CONDITIONING DURING HATCHING AND EARLY GROWTH ON HEAT TOLERANCE OF JAPANESE QUAIL

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SUMMARY

The purpose of the present study was to investigate the effect of thermal conditioning on heat tolerance of Japanese quail. A 3 x 2 factorial experimental design included three incubation temperature treatments: low (L, 36.1°C), control (C, 37.7°C) and high (H, 39.4°C), and two housing temperatures: natural winter climate (N, average, 25.7°C) and constant high (H, 35.0°C). A total of 360 chicks were involved (60 in each experimental group). Data were collected on body weight, feed intake and conversion, rectal temperature, hematocrit, oviposition day time and mortality rate until 14 wks of age.

Incubation treatments had significant impacts on most of the studied traits. Juvenile body weight was depressed in birds incubated at low temperature. From 6 wks, however, birds incubated at high temperature reached the highest body weights under housing heat stress indicating long-term adaptation effects of incubation under high temperature.

High housing temperature exerted significant adverse effects on most of the studied traits. Rectal temperatures were significantly higher in heat stressed birds (42.57 vs. 41.92°C). Total mortality rate was increased under high temperature (22.8 vs. 17.8%).

It was concluded that, adequately increased incubation temperature might help to increase heat tolerance in particular in adult Japanese quail by enhancing early physiological adaptation processes.

Keywords: Japanese quail, thermal conditioning, heat stress, body weight, rectal temperature, hematocrit value, oviposition day time

INTRODUCTION

High ambient temperature has a negative effect on Japanese quail performance and broiler production (Sandercock *et al.,* 2001 and Khalil, 1998 & 2004). Increasing the environmental temperature by thermal conditioning at early age increased heat tolerance in birds (Sykes and Fataftah, 1986; Sykes and Silah, 1986; Arjona *et al.,* 1988; Zhou *et al.,* 1997; Yahav *et al.,* 1997 and Tzschentke *et al.,* 2001 & 2002).

Arjona *et al.* (1988) found that, early age thermal conditioning caused a significant decrease in mortality rates and increase in feed efficiency when broiler chicks were exposed to a high environmental temperature at 42 day of age compared with control group. Similar improvements in chicken performance were reported by De Basilio *et al.* (2001) and Yahav and McMurtry (2001). They found that early age thermal conditioning caused increase in growth rate and feed efficiency by (+4%) in heat stressed group compared with control group. Also, mortality rate during later heat stress was reduced in heated group compared with control group.

Body temperature is a good indicator of the level of metabolic rate and is directly linked to acclimation, the major metabolic hormone (triiodothyronine) decreased during heat stress (Hai Lin *et al.,* 2006). Chicks exposed to early heat stress, maintained lower triiodothyronine concentration during their life span. Thus, the relationship between low metabolic rate and relatively low body temperature can predict the ability to successfully coping with thermal challenge or improvement in thermotolerance (May *et al.,* 1997; Yahav *et al.,* 1997; Yahav and Plavink, 1999; Yahav, 2000; Yahav and MCMurty, 2001 and Moraes *et al.,* 2003).

The aim of the present study was to evaluate (i) the response of Japanese quail to heat stress (during housing) and (ii) the influence of thermal conditioning during hatching on subsequent heat tolerance in the adult birds.

MATERIALS AND METHODS

Birds, feed and management

The experimental work was carried out at the Poultry Farm, Department of Animal Production, Faculty of Agriculture, Suez Canal University, Ismailia, Egypt. The experiment was arranged in 3 X 2 factorial design, which resulted in six experimental groups.

Three incubation temperatures were used: low (L, 36.1°C), control (C, 37.7°C) and high (H, 39.4°C). After hatching the chicks were subjected to one of two different ambient temperatures in different rooms (3x3m). High (35.0°C) and natural winter temperature (25.7°C). The birds were kept in battery cages (100x80x25cm) throughout the experimental period (14 weeks of age). The birds kept under continuous lighting program from the initial brooding period until 5 weeks of age after that, lighting was changed to give 16L-8D per day until the end of the experiment. Both food and water were provided *ad-libitum*. The growing diets (0-6 wks of age) contained 24% CP and 3000 Kcl(ME)/Kg and laying diet (after 6 wks) containing 20% CP and 3000 Kcl(ME)/Kg.

Three hundred and sixty unsexed one-day-old quail chicks were used in this experiment (60 chicks in each treatment group (Table 1). Temperature and relative humidity (RH) were recorded daily during the experimental period. Average temperature and relative humidity were (25.7°C & 46.05%) in room under natural winter climatic conditions and (35.0°C & 51.71%) in heated room.

Table 1. Number of chicks under each experimental treatment

Sex	Incubation treatment (temperature)					
	Low (36.1°C)		Control (37.7°C)		High (39.4°C)	
	Housing temperature					
	Natural*	High**	Natural	High	Natural	High
Males	32	35	31	34	32	26
Females	28	25	29	26	28	34
Total	60	60	60	60	60	60

* Natural winter temperature (25.7°C). ** Constant hot condition (35.0°C).

Studied Traits

1- Body weight, weight gain, feed conversion and mortality rate

Live body weights of male and female quails were recorded at weekly intervals till 6 weeks and biweekly till 14 weeks of age. Feed consumption was recorded during 1- 6 weeks of age. Weight gain and feed conversion values were calculated, the mortality rate was recorded during two period of age, 0-6 and 6-14 weeks.

2- Body temperature

Body temperature (°C) was recorded at 2, 6, 10 and 14 weeks of age in 20 birds (10 males and 10 females) in each group by inserting a thermometer 1.5 cm into the cloaca for one minute.

3- Blood samples

A total of 256 blood samples were obtained at 3, 6, 12 and 14 weeks of age from 16 birds in each treatment group (8 males and 8 females). The hematocrit value was recorded after centrifuging the samples at 3000 (r/min) for 15 minutes.

4- Oviposition day time

Ninety-six 12-week-old females (16 hens from each treatment group) were held in individual cages and were used to record the oviposition day time. The oviposition day time and the average time interval (hr) between two consecutive days were recorded daily from 13.00 till 22.00 o'clock for 5 consecutive days. The oviposition incidence for each individual hen was recorded using a special instrument designed by Mady (1996). The percentages of eggs before and after 17.00 o'clock were computed.

Statistical Analyses

Data were analysed using the General Linear Model (GLM) procedure of SAS (SAS Institute Inc., 1998). Least Square Means (LSM) were calculated, and Least Square Differences (LSD) differentiated differences among mean were tested.

RESULTS AND DISCUSSION

Body weight and gain

Body weights of male and female quails with respect to incubation and housing temperatures are presented in Table (2). Birds hatched from eggs incubated at the low temperature had a highly significantly lighter weight at 6 weeks of age, whether housed under winter climate or under constant high temperature. While the heaviest values were obtained in birds incubated at high temperature at 6, 10 and 14 weeks of age.

Data in Table (3) show weight gain of male and female quails as affected by incubation and housing temperatures. Through the period from hatching to 6 weeks of age, birds hatched from control and high temperatures gave significantly greater weight gain than those incubated at low temperature under the two housing conditions.

High housing temperature caused reduction in body weight and weight gain from any of the incubated groups. Birds kept under natural winter climate had significantly greater values than those kept under constant high temperature. Present results indicate that, juvenile body weight was depressed in birds incubated at low temperature, from 6 weeks of age, however, birds incubated at high temperature reached heaviest body weights under the hot environment (Table 2), indicating long term adaptation effects. Also, high housing temperature exerted significant adverse effects on body weight and weight gain. These results are consistent with many investigations. Body weight and weight gain were significantly reduced in chicks housed under high temperature 30-35°C as compared to those housed under moderate temperature 20-25°C (Leeson and Caston, 1993; Eberhart and Washburn, 1993; Peguri and Coon, 1993; Mioya and Picard, 1994 and Khalil, 1998 & 2004). Several authors stated that increasing environmental temperature increased heat tolerance in birds (such as early age thermal conditioning). On the contrary, lowering the temperature during hatching or early age of live can reduce the bird's ability to tolerate heat stress (Sykes and Fataftah, 1986; Sykes and Silah, 1986; Arjona *et al*., 1988; Zhou *et al*., 1997; Yahav *et al*., 1997; De Basilio *et al*., 2001; Tzschentke, 2002 and Moraes *et al*., 2003).

Feed intake and feed conversion

Data in Table (3) show the average amounts of feed consumed by quail chicks and feed conversion under different temperature treatments. Feed intake and conversion rate were affected by incubation temperatures. Birds incubated at control temperature consumed more feed than those incubated at high and low temperature (674.13, 659.15 and 571.50 g/b, respectively), however feed conversion was improved in birds incubated at low and high temperatures than those incubated at control temperature (3.35, 3.44 and 3.62, respectively) through the period 0-6 weeks of age irrespective of housing temperatures. Housing hot condition reduced the amount of feed consumed/chick as compared with control condition. Birds housed under normal winter temperature consumed more feed than those housed under heat stress (678.34 *vs*. 598.45 g/b, respectively), but heat stress improved, slightly, feed conversion than the control condition (3.40 *vs*. 3.54, respectively), throughout the period 0-6 weeks of age irrespective of incubation temperatures.

These results agree with those obtained by Payne (1967) and Khalil (1998 & 2004) who reported that, feed intake was significantly reduced when exposing birds to high environmental temperature (30°C). Because the thermostatic mechanism of feed intake regulation results in an inverse relationship between environmental temperature and feed intake and the energy in consumed feed.

Rectal temperature

Effects of different incubation and housing treatments on rectal temperature of male and female quails are presented in Table (4). From 2 to 14 weeks of age, there were significant differences ($P \leq 0.01$) between the housing groups. All groups housed under heat stress had significantly higher rectal temperature compared with the groups housed under natural winter temperature. Birds incubated at low temperature and housed under hot temperature had significantly higher rectal temperature than those incubated at control and high temperature at 6 and 10 weeks of age. However, the lowest values were obtained in the birds incubated at control temperature under both natural and high housing temperatures at the same ages. The females had significantly higher rectal temperature than the males (42.21 *vs*. 41.86) at all studied ages irrespective of incubation and housing temperatures and age.

These results agree with Becker and Harrison (1975) and Walter and Paul (1975) who found that, Japanese quail reared for 14 days under 4 temperature treatments (20, 25, 30 and 35°C) showed negative correlation (r = -0.90) between heat production by their body and ambient temperature, with the most rapid change (-4.5% / 1°C) occurring between 20 and 25°C. The rate of change with temperature then averaged (-1.5% / 1°C) and flanked between 25 and 35°C. They also reported that, female's body temperature was higher than the males.

Hematocrit values

Results in Table (5) showed that, the males had significantly higher hematocrit values than the females at all studied ages with average (30.37 *vs*. 27.18%). Also, juvenile birds had highly significant lower hematocrit values than in adult birds (26.83, 29.32, 29.77 and 29.27 at 3, 6, 12 and 14 weeks of age irrespective to treatments. Hosing temperatures had a significant effect on hematocrit value. The birds housed under natural temperature had significantly higher values than the birds housed under high temperature at 3 and 14 weeks of age. Also, incubation temperatures had significant effect on hematocrit value. The birds hatched under low temperature had higher values than the birds hatched under other treatments. The definition of high and low hematocrit value is somewhat difficult as this may vary greatly, depending on environmental factors related to ambient temperature, age, sex, water intake, dietary sodium, copper and iron (Goodwin *et al.,* 1992). Khalil *et al*. (2006) found that a negative correlation between both feed intake and water consumed and hematocrit values (-0.16 and -0.39), respectively with highly significant correlation in Japanese quail. In the present study, the deprivation of feed and increase water consumed during the high housing temperature may be decreased hematocrit values.

Oviposition day time

Effects of different incubation and housing temperatures on oviposition day time are presented in Table (6). Birds hatched under low temperature showed significantly higher percentage of egg laid before 1700 o'clock compared with the other groups. Also, highly significant differences ($P \leq 0.01$) were found between the housing groups in oviposition time. Birds housed under constant heat stress showed higher percentage of eggs laid before 1700 o'clock than those housed under natural winter conditions (45.00 *vs*. 25.66%, respectively). These results indicate that, birds housed under hot temperature were earlier in egg laying before the night, compared with those housed under natural winter temperature. Heat stress may be accelerate egg formation.

Table 6. Oviposition time and egg laid (%) before and after 1700 o'clock with respect to incubation and housing temperatures

Incubation temperature	Before 1700 o'clock (%)	After 1700 o'clock (%)
Low (L) Housing temperature		
Natural	42.40 ± 11.08^a	57.80 ± 11.18^a
High	51.60 ± 25.85^a	48.40 ± 25.85^b
Overall mean	47.00 ± 15.12^a	53.10 ± 18.15^b
Control (C) Housing temperature		
Natural	20.40 ± 13.33^b	80.20 ± 13.29^a
High	42.20 ± 15.44^a	57.80 ± 15.44^b
Overall mean	31.30 ± 20.45^b	69.00 ± 20.15^a
High (L) Housing temperature		
Natural	14.20 ± 7.56^b	85.80 ± 7.56^a
High	41.20 ± 21.41^a	58.80 ± 21.41^b
Overall mean	27.70 ± 14.13^b	72.30 ± 14.12^a

Mortality rate

The average mortality rate of Japanese quail males and females as affected by incubation and housing temperatures are presented in Table (7). Birds housed under heat stress showed higher mortality rate than birds housed under natural winter conditions (22.77 *vs*. 17.77 %, respectively) irrespective of incubation treatments.

The highest mortality rate was found in birds incubated at high temperature, while the lowest value was found in birds incubated at control temperature, under high housing temperature (26.66 *vs*. 18.33%, respectively). On the other hand, under normal winter conditions, the highest mortality rate was obtained in birds incubated at control temperature, while the lowest rate was found in birds incubated at low temperature (23.33 *vs*. 11.66%, respectively).

In general high housing temperatures exerted significant adverse effects on most traits studied. However, thermal conditioning during incubation improved adaptation to heat stress in adult birds. It is concluded that, adequately increased incubation temperature might help to increase heat tolerance particularly in adult Japanese quail by enhancing early physiological adaptation processes.

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دراسة أثر النظم الحرارية أثناء التفريخ والنمو المبكر على التحمل الحرارى في السمان اليابانى

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أستهدفت هذه التجربة دراسة تأثير الحرارة المرتفعة داخل ماكينات التفريخ ومساكن التربية على أداء السمان اليابانى. كما أستهدفت دراسة تأثير إرتفاع درجة حرارة التفريخ على التحمل الحرارى للطيور الناتجة. صممت هذه التجربة كتجربة عامليه محتويه على عاملين هما 1- حرارة التفريخ (منخفضة 36.1°C وكنترول 37.7°C ومرتفعة 39.4°C) 2- حرارة التسكين (حرارة الشتاء الطبيعية 25.7°C والحرارة المرتفعة 35.0°C). وكانت أهم النتائج المتحصل عليها ما يلى:

1- وجد أن الطيور الفاقسة على درجة الحرارة المنخفضة كانت الأقل معنويا فى وزن الجسم فى معظم الأعمار المدروسة حتى 14 أسبوع. بينما تفوقت الطيور الفاقسة على درجة الحرارة العالية فى وزن الجسم ابتداء من الأسبوع السادس حتى نهاية التجربة. كما أوضحت النتائج أن هناك فروق معنوية لتأثير درجات حرارة المسكن على وزن الجسم وكذلك الزيادة فى وزن الجسم. حيث تفوق وزن الجسم وكذلك الزيادة فى وزن الجسم للطيور المرباة تحت الظروف الطبيعية شتاء عن الطيور المرباة تحت ظروف الحرارة المرتفعة بغض النظر عن معاملات حرارة التفريخ.

2- أظهرت النتائج أن أعلى معدل استهلاك علف كان فى مجموعة الطيور الفاقسة والمرباة على درجة الحرارة الطبيعية شتاء مقارنة بالمجاميع الأخرى حيث أدى ارتفاع حرارة المسكن إلى انخفاض كميه العلف المستهلكة بغض النظر عن معاملات التفريخ الحرارية. كما أظهرت النتائج وجود تحسن ملحوظ فى الكفاءة الغذائية لكلا من مجموعتى الطيور الفاقسة على درجتى الحرارة المنخفضة والعالية. كما وجد تحسن طفيف فى الكفاءة الغذائية للطيور المرباة تحت ظروف حرارة الكنترول مقارنة بمجموعة الإجهاد الحرارى بغض النظر عن معاملات التفريخ الحرارية.

3- إرتفعت حرارة الجسم إرتفاعا معنويا فى الطيور الفاقسة على درجة الحرارة المنخفضة فى معظم الأعمار المدروسة. كما وجد أن الطيور المرباة تحت الحرارة العالية كانت الأعلى معنويا فى درجة حرارة المستقيم مقارنة بالطيور المرباة تحت ظروف حرارة الكنترول بغض النظر عن معاملات التفريخ الحرارية. كما أشارت النتائج إلى أن الإناث تفوقت معنويا فى درجة حرارة المستقيم عن الذكور فى جميع الأعمار المدروسة فيما عدا الأسبوع الرابع من العمر بغض النظر عن المعاملات الأخرى.

4- أظهرت النتائج أن الذكور تفوقت معنويا عن الإناث فى قيم الهيماتوكريت فى جميع الأعمار المدروسة. كما بينت النتائج أن الأعمار الصغيرة قبل البلوغ تميزت بانخفاض قيم الهيماتوكريت معنويا عنه بعد البلوغ وذلك بغض النظر عن المعاملات الحرارية المختلفة. كما وجد أن درجة حرارة المسكن لها تأثير معنوي على نسب المكونات الخلوية للدم. حيث وجد أن معظم القيم العليا كانت فى الطيور المرباة على درجة الحرارة الطبيعية شتاء كما أنخفضت قيم الهيماتوكريت لمعظم الطيور المرباة تحت الحرارة العالية.
5- كما أوضحت النتائج أن ميعاد وضع البيضة تأثر معنويا بالمعاملات الحرارية أثناء التفريخ حيث كان معظم البيض الموضع مبكرا من الإناث الفاقسة على درجة حرارة منخفضة مقارنة بالمجموعتين الأخيرتين. كما كان لحرارة المسكن تأثيرا معنويا حيث وضعت الطيور المرباة تحت الحرارة العالية معظم إنتاجها في وقت مبكر مقارنة بالطيور المراباة تحت درجة الحرارة الطبيعية شتاء.

وخلاصـة هـذه الدراسـة تؤكـد أن إرتفـاع حـرارة المسـكن لهـا تـأثير سـلبى علـى أداء السـمان اليابـانى كمـا أوضحت النتائج أن زيادة درجات حرارة التفريخ ساعد فى تحسن وزن الجسم والزيادة المكتسبة وكذلك الكفاءة الغذائية. لذلك توصى هذه الدراسة إلى زيادة درجات حرارة التفريخ فى المناطق الحارة والشبة الحارة شـي قليلا حتى يزداد التحمل الحراري لدى الطيور الناتجة.

Table 2. Body weight (g) of male and female quails at successive ages with respect to incubation and housing temperatures (LSQ-Means ± SD)

Age (wk)	Sex	Incubation temperature: Low (L) Housing temperature: Natural	Low (L): High	Control (C) Housing temperature: Natural	Control (C): High	High (H) Housing temperature: Natural	High (H): High
2	Male	54.50±8.24^{b}	50.87±7.06^{b}	61.19±8.29^{a}	58.48±8.24^{a}	53.34±7.45^{b}	52.46±5.54^{b}
	Female	55.85±8.31^{b}	55.56±9.41^{b}	62.60±8.21^{a}	62.04±7.74^{a}	56.10±9.24^{b}	51.02±6.25^{c}
	Overall	**55.17±8.25^{b}**	**53.21±8.57^{bc}**	**61.86±8.25^{a}**	**60.26±7.84^{a}**	**54.72±8.14^{bc}**	**51.74±5.68^{c}**
6	Male	179.92±17.39^{b}	167.22±13.87^{c}	190.17±17.87^{a}	177.54±18.25^{b}	191.78±13.35^{a}	184.76±12.94^{ab}
	Female	197.51±21.24^{b}	179.40±19.97^{c}	216.78±20.37^{a}	196.25±20.38^{b}	222.00±25.36^{a}	199.13±17.94^{b}
	Overall	**188.71±19.26^{b}**	**173.31±15.69^{c}**	**203.48±18.64^{a}**	**186.89±19.28^{b}**	**206.89±18.67^{a}**	**191.94±15.12 ^{b}**
10	Male	191.07±11.16^{bc}	185.53±13.36^{c}	203.25±24.26^{a}	189.67±19.34^{bc}	203.00±22.64^{a}	199.16±19.62^{ab}
	Female	224.20±15.64^{b}	207.75±19.37^{c}	248.26±19.34^{a}	207.73±17.54^{c}	238.15±25.94^{a}	211.95±12.28^{c}
	Overall	**207.63±13.61^{b}**	**196.64±16.39^{c}**	**225.75±22.67^{a}**	**198.71±18.64^{bc}**	**220.56±23.69^{a}**	**205.55±15.94^{b}**
14	Male	207.71±19.64^{abc}	202.80±16.62^{bc}	213.80±26.31^{ab}	197.85±16.04^{c}	215.80±18.25^{a}	214.43± 4.28 ^{ab}
	Female	246.08±16.37^{a}	222.15±13.58^{b}	251.40±25.22 ^{a}	206.42±21.64^{c}	252.45±32.68^{a}	221.25± 3.53 ^{b}
	Overall	**226.89±18.06^{ab}**	**212.47±14.36^{cd}**	**232.61±25.69^{a}**	**201.92±18.94^{d}**	**234.12±25.58^{a}**	**217.84± 2.83 ^{bc}**

$^{a, b, c}$ Means with the same letter in each row are not significantly different (P ≤ 0.05).

Table 3. Weight gain, feed intake and food conversion of quails with respect to incubation and housing temperatures (LSQ-Means ± SD)

Parameters	Age (Wks)	Incubation temperature: Low (L) Housing temperature		Control (C) Housing temperature		High (H) Housing temperature	
		Natural	High	Natural	High	Natural	High
Weight gain (g)	0-2	47.41±8.15[b]	45.61±8.26[bc]	53.36±8.39[a]	51.72±7.94[a]	46.42±8.16[bc]	43.55±5.64 [c]
	2-4	73.08±10.39[b]	62.38±9.67[c]	89.75±11.64[a]	75.78±9.64[b]	89.47±10.29[a]	84.68±12.64[a]
	4-6	60.32±15.64[a]	57.02±10.64[ab]	51.14±15.67[b]	50.91±11.71[b]	62.51±18.64[a]	55.03±11.93[ab]
	0-6	180.94±18.69[b]	165.71±16.12 [c]	194.95±18.67[a]	178.35±19.57[b]	198.59±19.25[a]	183.75±15.36[b]
Feed intake/bird (g)	0-2	99.82	102.90	108.15	118.44	104.37	94.22
	2-4	221.13	190.40	252.84	235.76	264.11	203.91
	4-6	297.50	252.07	335.09	297.99	352.03	299.67
	0-6	618.45	545.37	696.08	652.19	720.51	597.80
Feed conversion	0-2	2.105	2.256	2.027	2.290	2.248	2.163
	2-4	3.025	3.052	2.820	3.111	2.951	2.408
	4-6	4.932	4.420	6.571	5.853	5.631	5.445
	0-6	3.417	3.291	3.571	3.656	3.628	3.253

[a, b, c] Means with the same letter in each row are not significantly different ($P \leq 0.05$)

Table 4. Rectal temperature of male and female quails with respect to incubation and housing temperatures (LSQ-Means ± SD)

Age (Wks)	Sex	Incubation temperature: Low (L) Housing temperature: Natural	Low (L) Housing temperature: High	Control (C) Housing temperature: Natural	Control (C) Housing temperature: High	High (H) Housing temperature: Natural	High (H) Housing temperature: High
2	Male	41.17±0.37[b]	41.77±0.34[a]	41.21±0.12[b]	41.93±0.34[a]	41.41±0.39[b]	41.93±0.46[a]
	Female	41.38±0.41[b]	42.17±0.12[a]	41.51±0.15[c]	41.84±0.35[b]	41.29±0.37[c]	41.85±0.26[b]
	Overall	**41.27±0.39[c]**	**41.97±0.25[a]**	**41.36±0.16[b]**	**41.88±0.45[a]**	**41.35±0.34[b]**	**41.89±0.34[a]**
6	Male	41.79±0.37[b]	42.17±0.39[a]	41.37±0.21[cd]	41.54±0.38[bc]	41.24±0.37[d]	41.75±0.36[b]
	Female	41.81±0.29[bc]	42.58± 0.16[a]	41.57±0.26[d]	41.86±0.32[c]	41.53±0.19[d]	42.31±0.29[b]
	Overall	**41.80±0.39[c]**	**42.37±0.26[a]**	**41.47±0.27[d]**	**41.71±0.26[c]**	**41.38±0.39[d]**	**42.02±0.34[b]**
10	Male	41.78±0.29[bc]	42.28±0.36[a]	41.59±0.34[c]	41.97±0.26[b]	41.65±0.26[c]	42.19±0.16[a]
	Female	42.17±0.37[b]	42.91±0.34[a]	41.78±0.18[c]	42.31±0.24[b]	41.77±0.27[c]	42.23±0.18[b]
	Overall	**41.97±0.31[c]**	**42.59± 0.34[a]**	**41.68±0.26[d]**	**42.14±0.23[bc]**	**41.71±0.36[d]**	**42.21±0.16[b]**
14	Male	41.91±0.23[bc]	42.04±0.38[b]	41.74±0.34[c]	42.10±0.28[b]	41.76±0.34[c]	42.49±0.24[a]
	Female	42.25±0.21[c]	42.62±0.34[b]	42.28±0.36[c]	42.34±0.39[c]	42.31± 0.32[c]	43.00±0.34[a]
	Overall	**42.08±0.24[c]**	**42.33±0.36[b]**	**42.01±0.36[c]**	**42.22±0.38[bc]**	**42.03±0.34[c]**	**42.74±0.29[a]**

[a, b, c] Means with the same letter in each row are not significantly different ($P \leq 0.05$).

Table 5. Hematocrit values of male and female quail with respect to incubation and housing temperatures (LSQ-Means ± SD)

Age (wks)	Sex	Incubation temperature: Low (L), Housing temperature: Natural	Low (L), High	Control (C), Housing temperature: Natural	Control (C), High	High (H), Housing temperature: Natural	High (H), High
3	Male	29.55±4.67[a]	27.85±3.15[bc]	26.74±4.36[c]	28.44±2.36[ab]	27.58±3.36[bc]	26.39±3.94[c]
	Female	26.79±4.16	26.44±3.54	25.43±3.67	25.80±3.67	25.71±4.56	25.34±3.64
	Overall	**28.17±4.336[a]**	**27.14±3.12[ab]**	**26.08±4.12[b]**	**27.12±2.94[ab]**	**26.64±3.56[b]**	**25.86±3.25[b]**
6	Male	30.16±3.64[a]	31.75±5.15[a]	30.34±3.26[a]	26.31±4.36[b]	32.18±3.26[a]	30.08±3.36[a]
	Female	28.16±3.17[b]	27.52±2.67 [b]	27.24±2.29[b]	32.19±3.56 [a]	28.09±4.69[b]	27.92±2.56[b]
	Overall	**29.16±3.12**	**29.63±3.18**	**28.79±3.36**	**29.25±4.26**	**30.14±3.67**	**29.00±3.05**
12	Male	32.58±4.16	31.48±3.18	32.24±3.67	32.48±2.36	31.16±2.56	31.04±4.26
	Female	28.66±3.46[a]	26.42±4.64[b]	27.79±2.67[ab]	28.25±3.67[a]	27.91±3.29[ab]	27.24±2.25[ab]
	Overall	**30.62±3.34**	**28.95±3.94**	**30.01±2.94**	**30.37±2.97**	**29.53±3.45**	**29.14±3.26**
14	Male	33.45±4.16	31.37±4.36	31.51±2.37	30.72±2.13	32.83±3.69	30.81±5.45
	Female	27.85±5.18[a]	28.14±5.45[a]	28.73±2.39[a]	22.57±2.36[b]	26.18±5.15[a]	27.13±5.29[a]
	Overall	**30.65±4.35[a]**	**29.75±4.67[a]**	**30.12± 2.36[a]**	**26.64±2.39[b]**	**29.51±4.64[a]**	**28.96±5.34[b]**
Overall	Male	31.43±4.13[a]	30.61±3.25[ab]	30.21±3.36[ab]	29.49±3.45[b]	30.94±3.45[ab]	29.58±3.36[b]
	Female	27.86±3.18	27.13±3.19	27.30±3.45	27.21±4.26	26.97±3.46	26.91±3.46
	Overall	**29.65±3.84[a]**	**28.87±3.39[ab]**	**28.75±3.34[ab]**	**28.34±3.67[b]**	**28.95±3.36[ab]**	**28.24± 3.12[b]**

[a, b, c] Means with the same letter in each row are not significantly different (P ≤ 0.05).