



Performance and Egg Quality of Japanese Quails Submitted to Cyclic Heat Stress

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ABSTRACT

Aiming at evaluating the influence of cyclic temperatures on the performance and egg quality of Japanese quails an experiment was carried out with 480 birds after egg production peak. Birds were housed in a bioclimatic chamber with automatic temperature control that contained two rooms, one maintained at thermoneutral temperature (21 °C) and the other adjusted for the tested cyclic temperatures (24, 27, 30, 33 and 36 °C at a time). Each room had a battery of five floors and ten cages, with a capacity of 24 birds per cage, totaling 240 birds per battery. Birds were fed iso-nutritious and iso-caloric diets. Data obtained under the tested cyclic temperatures were compared with those obtained under thermoneutral temperature. At the end of each experimental period (14 days) performance and egg quality parameters were evaluated. A completely randomized experimental design with two treatments (thermoneutral temperature and tested temperature) and ten replicates of 24 birds each. Cyclic increases of 27 °C and higher in environmental temperature negatively affected bird performance, with reduced feed intake and consequent reductions in egg weight and mass. A cyclic increase of the environmental temperature to 36 °C reduced the percentage of saleable eggs and egg production.

INTRODUCTION

The increasing productivity and development of the poultry production brought about by advances in genetics, management, nutrition, health, and facilities allows reducing production costs and improving the quality of the final product. The domestic and international markets demand today excellent product quality, and are increasingly concerned with animal welfare and food safety, as well as with the management practices adopted by the poultry meat and egg production chain (Mazzuco, 2006).

As well as meat-type poultry production, Brazilian chicken egg exports have entered new markets, especially for the Arab countries, and this may also be an opportunity for Brazilian quail eggs.

According to Tinôco (1995), thermal factors, including air temperature, humidity, heat radiation, and air movement are the environmental factors that have the most direct influence on bird comfort, as they affect the maintenance of body temperature. The achievement of the best economic and productive results in modern poultry production requires taking into consideration not only genetics, nutrition and health, but also environmental factors (Baêta, 1998).

Environmental thermal comfort was considered a secondary issue for a long time, both from animal behavior and performance perspectives. It was assumed that thermal discomfort could be solved by the use of air conditioning, and no consideration was given to the costs and



problems related to the implementation of an air-conditioning system. However, as mentioned by Silva (1999), there has been an increasing concern with the thermal comfort of animals during the last decade, particularly with aspects related to physiological and performance responses.

As all homeothermic animals, birds present constant internal body temperature. According to thermodynamic principles, this means that these animals continuously exchange heat with the environment, but this process is efficient only if the environmental temperature is within the thermoneutral range (Hannas, 1999).

When environmental temperatures are above that range, bird rectal temperature increases, as well as its respiratory rate, that is, panting is used by birds to promote heat evaporative loss, thereby trying to maintain body temperature (Silva *et al.*, 2001; Macari *et al.*, 2004). Bottje & Harrison (1985) and Furlan *et al.* (1999) also associated the increase in respiratory rate to reduce body temperature by evaporation under heat-stress situations. At the same time, physiological processes are activated to increase heat dissipation and to reduce metabolic heat production (Yahav *et al.*, 2005). Under heat stress, chicken respiratory rate may increase from 29 cycles per minute to over 100 cycles per minute, resulting in an increase in carbon dioxide loss from the lungs, which leads to lower partial blood pressure of carbon dioxide, and therefore, reduced bicarbonate blood levels, increasing blood pH, a condition called alkalosis. This limits the availability of anions required for the formation of calcium carbonate crystals of the eggshell (Mongin, 1968), and consequently, poor egg quality. According to Campos (2000), this may result in 12% reduction in eggshell thickness.

Therefore, environmental temperature and humidity are important for egg production. Birds managed outside thermoneutral ranges may suffer severe physiological changes, including reduced feed intake, and consequent low egg production and poor egg quality, including light eggs, low yolk percentage and weight, and low specific gravity (Macari *et al.*, 1994; Nääs, 1992). Taking these facts into consideration, this study aimed at evaluating the effects of cyclic temperatures on the performance and egg quality of Japanese quails housed in a bioclimatic chamber.

MATERIALS AND METHODS

After the peak of egg production (36 weeks of

age), 480 Japanese quails (*Coturnix coturnix japonica*) were housed in a climatic chamber with automatic temperature control containing two rooms (4.30 m long x 4.5 m wide x 2.60 m high, each). Each room was equipped with a battery with five floors with two cages made of galvanized iron per floor. Cages were 100cm long x 34 cm deep x 16 cm high and were divided into six internal compartments each with the capacity of housing four birds; therefore, 24 birds were housed per cage at a density of 141.67 cm²/birds.

One of the rooms was kept at thermoneutral temperature (21 a 23 °C), whereas in the other room, birds were submitted to cyclic heat stress at five different temperatures (24, 27, 30, 33 or 36 °C) per experimental period. Cyclic heat stress consisted of exposing the birds daily for 14 days to 12 hours at the tested temperature (24, 27, 30, 33 or 36 °C) from 07:00 to 19:00, after which the temperature was set to 21–23 °C for the next 12 hours.

All birds were submitted to the same feeding management, being fed twice daily an iso-nutritious and iso-caloric diet based on corn and soybean meal, containing 2,800 kcal ME/kg feed, 20% crude protein, 3.2% calcium, 0.35% available phosphorus, 0.45% methionine, 0.76% methionine + cystine, and 1.07% lysine. Feed and water were available *ad libitum*. A lighting program of 17h of light was adopted.

At the end of the experimental period (14 days), performance and egg quality data collected from birds maintained under thermoneutral temperature (daily temperatures of 21 to 23 °C) to those obtained from birds housed under cyclic temperature. A completely randomized experimental design was adopted, with two treatments (thermoneutral temperature and cyclic temperature) of ten replicates of 24 birds each.

Feed intake and egg weight were measured, and egg production percentage, saleable egg percentage, and feed conversion ratio (kg feed per dozen eggs and per kg eggs) were calculated.

Egg quality was evaluated by collecting a sample of two eggs per experimental unit for three consecutive days. Eggs were individually identified, and weight in a high-precision scale, totaling 60 eggs per temperature tested.

Egg specific gravity was determined using saline solutions with densities ranging between 1.060 and 1.100 at 0.005 intervals. Yolk, albumen, and eggshell were weighed and their percentages were calculated dividing their respective weights by egg weight, and multiplying the result by 100. Yolk index was calculated dividing yolk height by yolk diameter, measured



with a digital caliper. In order to determine eggshell thickness, eggshells were dried in an oven at 60 °C for three days, and their thickness was determined as the average thickness measured in three different points at the middle area zone using a digital caliper ruler.

Eggshell breaking strength was determined at the egg equatorial region using a texture analyzer (TA.XT Plus – Texture Analyser), with a 2-mm breaking probe, pre-test speed of 2 mm/s, test speed of 1.0 mm/s and post-test speed of 40 mm/s. The result is expressed in grams.

In order to calculate of Haugh units, albumen height was first determined using a digital caliper, which then was applied to the following equation, as described by Brant *et al.* (1951): $HU = 100 \log (H + 7.57 - 1.7 W^{0.37})$, where H = albumen height (mm); W = egg weight (g); 7.57= correction factor for albumen height; 1.7= correction factor for egg weight.

Performance and egg quality data were analyzed according to a completely randomized experimental design with two treatments (thermoneutral temperature and cyclic temperatures) and ten replicates of 24 birds each. Data were submitted to analysis of variance with the aid of SAS statistical package (2000). Means were compared by the test of Tukey at 5% significance level.

RESULTS AND DISCUSSION

The performance results of Japanese quails in the phase of after egg production peak submitted to cyclic heat stress are presented in Table 1.

Table 1 shows that there were no significant effects of treatments on none of the evaluated parameters when comparing 21 to 24 °C. These results allow us to assert that, despite being outside the optimal temperature range for laying, which according to Murakami & Arika (1998) is between 18 and 22 °C, quails presented good performance.

When the control temperature was compared to 27 °C cyclic temperature, feed intake was reduced in 7.8%, which negatively

influenced other performance parameters, such as egg weight, egg mass and feed conversion ratio per dozen. When feed intake obtained at thermoneutral temperature (21 °C) was compared those verified at cyclic temperatures of 30, 33 and 36 °C, there was a significant reduction in 11.97; 16.67 and 21.55%, respectively. This may be explained by the difficulty birds have to dissipate internal heat when environmental temperature is high (Yunis & Cahaner, 1999).

Egg production significantly dropped, in 6.67%, only when birds were submitted to cyclic heat stress of 36 °C. This is consistent with the findings of Jones *et al.* (1976), who submitted White Leghorn layers to 24.5 °C and 35 °C, concluding that birds submitted to a constant temperature of 35 °C produced significantly less eggs than those maintained at 24.5 °C.

The percentage of saleable eggs was not different between that produced by quails under thermoneutral temperature and those submitted to cyclic heat stress of 24, 27, 30 and 33 °C. However, when birds were submitted to severe cyclic heat stress (36 °C), the percentage of saleable eggs was reduced in 14.33%, possibly due to poor eggshell quality as a result of respiratory alkalosis. When poultry increase their respiratory rate to loose body heat by evaporation, excessive carbon dioxide is lost, with consequent reduction of CO₂ and bicarbonate blood levels, compromising the dissociation of Ca required for eggshell deposition during egg formation.

Table 1 - Feed intake (FI), Egg production (EP), percentage of saleable eggs (SE), egg weight (EW), egg mass (EM), feed conversion ratio per dozen (FCR/dz) and per kg (FCR/kg) of egg produced by Japanese quails submitted to cyclic heat stress.

Temp (°C)	FI (g/bird/day)	EP (%)	SE (%)	EW (g)	EM (g/bird/day)	FCR/dz	FCR/kg
21	30.9	83.06	80.80	12.28	10.36	0.45	2.98
24	30.1	83.64	81.00	12.05	10.09	0.43	3.00
CV (%)	4.54	4.10	4.88	2.45	4.47	5.62	6.01
21	28.2A	81.47	76.12	12.02A	9.79A	0.42A	2.90
27	26.0B	80.71	75.54	11.41B	9.20B	0.39B	2.81
CV (%)	4.11	4.06	5.20	1.93	3.95	5.84	5.12
21	28.4A	79.96	75.56	12.14A	9.71A	0.43A	2.92A
30	25.0B	79.91	75.00	11.42B	9.12B	0.38B	2.74B
CV (%)	4.48	4.85	5.21	1.40	4.36	5.70	5.92
21	27.6A	80.76	74.97	12.03A	9.71A	0.41A	2.84
33	23.0B	77.25	71.21	11.19B	8.64B	0.36B	2.66
CV (%)	8.52	5.17	7.05	2.93	5.42	9.37	9.09
21	28.3A	79.04A	72.84A	12.32A	9.74A	0.43A	2.93
36	22.2B	73.77B	62.40B	10.85B	8.01B	0.36B	2.79
CV (%)	6.96	5.28	7.03	2.51	6.53	8.60	9.29

A,B - Means followed by different capital letters in the same column within each temperature cycle are different by the test of Tukey ($p \leq 0.05$).



The cyclic heat stress of 27 °C resulted in a significant drop of 5.07% in egg weight compared with the comfort temperature. When birds were subjected to cyclic heat stress of 30, 33 and 36 °C egg weight was reduced in 5.93%; 6.98% and 11.93%, respectively. These results may have been caused by the significant reduction in feed intake when the birds were submitted to temperatures of 27 °C and higher, as the essential nutrients consumed were deviated to maintain homeostasis and therefore were unavailable for egg production. Bordas & Minville (1997) also observed negative effects of heat stress in a study with different strains of layer chickens. When the birds were submitted to environmental temperatures of 21°C or 35°C, the authors observed reductions of 13% in egg production and of 4% in egg weight at 35°C, but no differences were detected among layer strains.

Egg mass (EM) was significantly lower when birds were submitted to heat stress, starting at 27°C, with 6.37% reduction as compared with that of birds submitted to thermoneutral temperature. Egg mass reduced in 6.04, 10.93, and 17.78% when cyclic temperatures of 30, 33 and 36 °C were applied, respectively. This was a result of the lower egg production and egg weight observed at those temperatures. However, Emery *et al.* (1984) did not report any differences in egg production and in egg mass when the performance and egg quality of 33-week-old layer chickens housed in three climatic chambers (constant temperature of 23.9 °C; cyclic temperature

between 15.6 and 37.7 °C and; cyclic temperature between 21.1 and 37.7 °C) were evaluated.

As to feed conversion ratio per dozen eggs, the best results were obtained when birds were exposed to cyclic temperature of 27 °C, because in this group, feed intake was greatly reduced, but there was no proportional decrease in egg production. Significant results in feed conversion ratio per kg were obtained only when birds were exposed to a temperature of 30 °C, with 6.16% improvement compared with thermoneutral temperature. However, if birds were exposed to heat stress for longer periods, they would probably need to mobilize their body reserves to supply their maintenance requirements, thereby reducing nutrients available for performance requirement, including egg production.

Egg quality data of Japanese quails submitted to cyclic heat stress are presented in Table 2.

Egg specific gravity was significantly reduced only when birds were submitted to cyclic heat stress of 36 °C relative to thermoneutral temperature conditions. Molino *et al.* (2009) asserted that the best way to analyze eggshell quality is to evaluate eggshell breaking strength. In the present study, eggshell breaking strength was significantly reduced ($p < 0.05$) in 9.70% when the temperature of 24 °C was applied as compared to 21°C. At the temperature of 30 °C, eggshell breaking strength was reduced in 13.25% relative to that obtained under thermoneutral temperature.

No significant differences in this parameter between birds submitted to 27, 33 or 36 °C and those maintained at thermoneutral temperature were observed. These results may be related to the high coefficient of variation obtained for this parameter.

Eggshell thickness was significantly reduced in 4.37% when birds were submitted to cyclic heat stress of 27 °C compared with thermoneutral temperature. When quails were submitted to 33 °C, eggshell thickness was reduced in 4.33%. No eggshell thickness differences between birds submitted to 30 or 36 °C and those maintained at thermoneutral temperature were observed. Mashaly *et al.* (2004) submitted

Table 2 – Specific gravity (SG), eggshell breaking strength (BS), eggshell thickness (ET), eggshell percentage (ESP), yolk index (YI), yolk percentage (YP), albumen percentage (AP) and Haugh units (HU) of the eggs produced by Japanese quails submitted to cyclic heat stress.

Temp (°C)	SG (mg/cm ³)	BS (g)	ET (mm)	ESP (%)	YI	YP (%)	AP (%)	HU
21	1.072	962.71A	0.21	7.76	0.47	30.06	62.17	89.29
24	1.072	869.28B	0.21	7.84	0.48	29.71	62.45	89.13
CV (%)	0.21	8.20	2.10	3.10	2.18	1.74	0.93	2.39
21	1.073	886.41	0.21A	7.92	0.48	30.25	61.82	92.40
27	1.073	873.37	0.20B	7.83	0.47	29.81	62.39	88.65
CV (%)	0.21	9.13	3.88	3.14	4.18	3.18	1.52	4.86
21	1.075	961.06A	0.21	8.02	0.45	30.04	61.94A	85.09
30	1.075	833.71B	0.21	7.82	0.45	29.09	63.24B	86.35
CV (%)	0.16	10.07	3.06	2.74	2.72	3.51	1.81	3.50
21	1.073	942.49	0.21A	8.02	0.45	30.01	61.97	87.91
33	1.073	966.64	0.20B	7.92	0.45	29.63	62.71	88.78
CV (%)	0.28	11.52	4.68	3.45	3.48	4.12	1.94	2.78
21	1.073A	860.02	0.20	7.79	0.46	30.29	61.91	89.01
36	1.070B	844.65	0.19	7.79	0.45	29.86	62.34	88.63
CV (%)	0.16	9.24	6.08	3.16	4.38	3.73	1.66	2.30

A,B - Means followed by different capital letters in the same column within each temperature cycle are different by the test of Tukey ($p \leq 0.05$).



31-week-old layer chickens to three treatments in an environmental chamber, with cyclic temperatures and constant heat stress of 35 °C and 50% RH, and observed significant reductions in feed intake and weight gain, as well as in egg weight, eggshell thickness and weight, and egg specific gravity in layers submitted to heat stress. These results are consistent with the findings of the present study.

Egg internal quality is evaluated particularly by yolk index and Haugh units. There was no effect of the applied temperatures on these parameters. This suggests that the duration and magnitude of exposure to high environmental temperatures should be taken into account.

Table 2 also shows that yolk and eggshell percentages were not influenced by the thermoneutral temperature or by the tested temperatures. However, albumen percentage was significantly reduced in 2.10% in the eggs of quails exposed to cyclic heat stress of 30 °C as compared to the eggs of those maintained under the thermoneutral temperature (21 °C).

CONCLUSIONS

Under the conditions of the present study, Japanese quails exposed to 27 °C already presented signs of heat stress, as shown by reduced feed intake and egg weight and mass. The cyclic increase of the environmental temperature to 36 °C negatively influenced the percentage of saleable eggs and egg production. The effects of cyclic temperatures on egg quality parameters did not allow clear conclusions.

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