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Productive performance, egg quality and the morphometry of the organs of Japanese quails (*Cotournix cotournix japônica)* kept at different temperatures

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Abstract

The objective of this study was to evaluate the productive performance, egg quality and the morphometry of the organs of Japanese quails (*Cotournix cotournix japônica)* when kept in comfort and under thermal stress. 192 nine-week-old quail were used, distributed in a completely randomized design at two temperatures (T1 = 24 °C and T2 = 32 °C), with 12 replicates of eight birds each, with an experimental period of 63 days, divided into three 21-day periods. Feed intake (g fowl-1 day-1), water consumption (mL fowl-1 day-1), egg production (%), egg weight (g), egg mass (g fowl- 1 day-1) and feed conversion (kg kg-1 and kg dozen-1). Laying quails after their production cycle are marketed as beef animals. It is observed that the average final live weight was reduced (P = 0.0362) by 27.58 g in birds kept at a temperature of 32 ºC, which can compromise its commercial value. The feed intake of the birds was reduced (P = 0.0051) by 14.75% with an increase in ambient temperature. Birds kept at a temperature of 32 ºC for 12 h daily showed a reduction in feed intake, final weight, yolk, and gizzard weight, but without affecting egg production, weight and mass.

Keywords: laying birds; heart; heat stress; production.

Pratical Application: That high temperatures decrease the weight of organs and the productive performance of quails.

1 Introduction

Quail farming is an expanding activity in tropical regions, which is characterized by strong insolation, high air temperatures of up to 40 °C (Furtado et al., 2018) and sparse and irregular rainfall (Abdelsattar et al., 2020). The Japanese quail is a bird adapted to hot climates, presenting small size, precocity, productivity, requiring small spaces for production and little labor (Khalilipour et al., 2019; Hajati et al., 2020; Ismail et al., 2020).

Quails are sensitive to heat stress due to their high metabolic activity, with modern genotypes producing more body heat. Laying quails can breed in hot climates, with their thermal comfort zone between 22 and 26 °C, relative humidity between 65 and 70% (Castro et al., 2017; Silva et al., 2017; Furtado et al., 2022). High temperatures can hinder exploration and maximize quail production (Akdemir et al., 2019). Small environmental changes are perceived by birds (Castro et al., 2017; Santos et al., 2017; Furtado et al., 2022), causing an increase in the consumption of water and a reduction in feed consumption, which can reduce egg production and quality (Ferreira et al., 2019; Xavier et al., 2020; Nnadi et al., 2022).

The increase in water consumption is a way to replace the water lost through respiration, fecal and urinary excretion, to avoid dehydration, maintain homeotherm and minimize thermal stress (Scottá et al., 2017) but can negatively affect the production and quality of quail eggs (Nnadi et al., 2022). Laying quails produce good production in hot environments (Petrucci et al., 2017; Silva et al., 2017; Akdemir et al., 2019). However, to obtain maximum performance, birds must be reared in thermally comfortable facilities (Rodrigues et al., 2016).

The central hypothesis of this study is that high temperatures decrease the weight of organs and the productive performance of quails. Therefore, study aimed to evaluate the productive performance, egg quality and the morphometry of the organs of Japanese quail when kept in comfort and under thermal stress.

2 Material and methods

2.1 Experiment site

The Animal Use Ethics Committee approved all procedures used by the Federal University of Campina Grande (Protocol No. 089.2017).

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The experiment was carried out in Campina Grande, Paraíba, Brazil (7º13'11"S; 35º53'31"W and 547 m altitude). According to the Köppen climate classification, the region's climate is tropical, with wet and dry seasons (AS'), with a maximum annual temperature of 32 °C and a minimum of 17 °C, and average annual precipitation of 765 mm.

2.2 Climatic chambers

The experiment was carried out in two climatic chambers, with dimensions of 3.07 mx 2.77 mx 2.6 m, in length, width, and height, located in the Laboratory of Rural Constructions and Ambience, of the Academic Engineering Unit Agricultural, Federal University of Campina Grande, PB.

For environmental control, the chambers are equipped with: electric resistance air heater; hot/cold split air conditioner, Samsung brand, model AS18UWBUXXAZ, with the power of 1750 W, and cooling capacity of 18,000 BTU/h, a flow rate of 828 m3/h; and Britânia brand air humidifier, model BUD04B, with a capacity of 4.5 L and a mist flow (average value) of 300 mL h-1.

The relative humidity of the air was controlled by air humidifiers and measured by sensors. Ventilation was made available by using side fans and exhausts; these were installed at the height of the geometric center of the birds. Wind speed was collected at five different points, with the aid of a digital thermohygroluximeter anemometer (model LM-8000 AKSO ® brand with measuring range: 0.4 to 30.0 m/s and accuracy: ± 3%).

The chambers have temperature and humidity sensors, and environmental data were collected and recorded every 15 min by sensors (SB-56 from Full Gauge) coupled to the data acquisition system, through a controller of the type MT-530 PLUS Full Gauge Controls®, controlled via computer through SITRAD® (software for acquisition, control, monitoring and visualization of data in climate chambers).

2.3 Animals and experimental arrangement

Were used 192 Japanese quails (*Cotournix cotournix japônica)* at nine weeks of age, distributed in a completely randomized design at two temperatures (T1 = 24 °C and T2 = 32 °C), with 12 replicates of eight birds each, with an experimental period of 63 days, divided into three periods of 21 days.

The quails were nine weeks old, the average weight of birds of 168 ± 5 g at the beginning of the experimente and the end of 175 ± 5 g (24 weeks old), housed in sets of cages in the chambers, each cage composed of four floors, three cages per floor, made of galvanized wire, dimensions 50 x 33 x 20 cm (width, depth, and height, respectively), subjected to a stocking rate of 206 cm^2 birds-1, eight birds per cage. The cages were equipped with zinc foil feeders and individual nipple drinkers.

The birds underwent an adaptation period of three weeks, in which the chambers were programmed to keep the quails at a thermal comfort temperature (24 °C) during the day and room temperature at night. Egg production was counted, and,in the end, the quails were weighed for homogeneous distribution in the experimental units, considering the body weight and the average laying rate of the birds. After distribution, the chamber temperatures were adjusted to 24.0 ± 1.0 °C within the thermal comfort zone and 32 ± 1.2 °C above the thermal comfort zone (Castro et al., 2017; Soares et al., 2019b). These values were maintained for 12 hours (7:00 to 19:00), and the chamber doors were opened from 19:01 to 6:59 at room temperature (22 ± 2.0 °C), simulating the environmental conditions of the semiarid region. The relative humidity of the air in the chambers during the experimental period was 65.0 ± 5.0%, and the mean wind speed was 0.6 ± 0.5 m s-1. The daily light program adopted was 17 hours of light and 7 hours of darkness, using 20W and 220V fluorescent lamps.

2.4 Diet

During the experimental period, the birds were subjected to identical feeding management, consuming corn and soybean meal-based food for laying quails (Table 1). The nutritional composition of the ingredients used was obtained based on the tables by Rostagno et al. (2011). Water and feed are provided at will. Leftovers and residues were weighed and deducted from the amount of feed weighed initially to calculate the feed and water consumption of the birds.

2.5 Performance and egg quality variables

Performance and egg quality variables were evaluated every 21 days, totaling three evaluation periods. Feed intake (g $fowl^{-1}$ day^{-1}), water consumption (mL $fowl^{-1}$ day^{-1}), egg production (%), egg weight (g), egg mass (g fowl- 1 day^{-1}) and feed conversion (kg kg^{-1} and kg $dozen^{-1}$).

Table 1. Percentage composition and nutritional profile of the feed.

Ingredient	%
Corn Grain 7.88%	57.4
Soybean Meal 45.22%	28.5
Soy oil	4.54
Limestone	7.20
Dicalcium phosphate	1.19
salt	0.32
DL-Methionine	0.41
L-Lysine	0.31
L-Threonine	0.07
Choline chloride	0.07
Mineral Premix	0.05
Posture Vitamin Premix	0.02
Chemical composition	
Metabolizable energy (kcal/kg)	2800
Crude protein (%)	18.00
Methionine + Cysteine (%)	0.88
Lysine (%)	1.08
Threonine (%)	0.65
Calcium (%)	3.09
Available phosphorus (%)	0.32

Mineral Premix per kg of feed: Mn, 60 g; Fe, 80 g; Zn, 50 g; Cu, 10 g; Co, 2 g; I, 1 g; and vehicle q.s.p., 500 g.Vitamin Premix (Concentration/kg): Vit. A - 15,000,000 IU, Vit. D3 - 1,500,000 IU, Vit. E - 15,000 IU, Vit.B1 - 2.0 g, it.B2 - 4.0 g, Vit B6 - 3.0 g, Vit.B12 - 0.015 g, Nicotinic acid - 25 g, Pantothenic acid - 10 g, Vit.K3 - 3.0 g, Folic acid - 1.0 g, Selenium - 250 mg, and vehicle. q.s.p. - 1,000 g. 3 Ethoxyquin – 10g, and q.s.p. – 1,000g.

The average egg production was obtained by collecting the number of eggs daily, constantly correcting for mortality, so that the ratio of intact eggs produced was expressed as a percentage for each treatment over the average number of birds in the period (%/bird/day), corresponding to the production of marketable eggs.

All intact eggs produced in each repetition were weighed during the last three days of each period (19th, 20th, and 21st day) to obtain the average weight, which in turn was multiplied by the total number of eggs produced in the experimental period, thus obtaining the total egg mass. This mass was divided by the total number of birds per dayis expressed in grams of egg/bird/day.

The egg quality characteristics evaluated were: percentage of yolk, albumen and shell, specific gravity (g/mL), and shell thickness (mm). At the end of each experimental period, four eggs were separated per plot, two of which were destined to determine the weight and percentage of yolk, albumen, and shell, and two more destined to obtain the specific gravity, Tthe components were manually separated Furthermore, the weight and percentage of yolk, albumen, and shell were estimated. Thus, the yolks and albumens were individually weighed on a three-digit electronic digital scale (0.001 g), and the values obtained were used in the calculation to obtain the percentage. The percentage was determined by the relationship between the average weight of yolk and albumen over the average weight of the egg, and the result was multiplied by 100.

To determine the weight and percentage of yolk, albumin, and shell, the components were manually separated and then individually weighed on a digital electronic scale (0.001 g). All intact eggs produced in each repetition were weighed during the last three days of each period (19th, 20th, and 21st day) to obtain the average weight, which in turn was multiplied by the total number of eggs produced in the experimental period, thus obtaining the total egg mass. The values obtained were used to calculate the percentage.

The shells were identified and kept in an oven at 105 °C for 4 hours for drying and, after 30 minutes of cooling, they were weighed on a digital electronic scale (0.001 g) to obtain the average shell weight, which was obtained dividing the dry shell weight by the whole egg weight and multiplied by 100.

The analysis of specific gravity was determined and measured employing an Incoterm oil densimeter (OM-5565®), using the saline fluctuation method (Hamilton, 1982). Eggs were immersed and evaluated in saline solutions of NaCl, with the necessary adjustments for a volume of 25 liters of water with densities ranging from 1.070 to 1.090 with an interval of 0.0025. The shell thickness was determined after the egg had been broken in half (equatorial region), dried in an oven at 105 °C for 4 hours, and measured with a digital caliper from 0-150 mm, with an accuracy of 0.001 mm

The average egg production was obtained by collecting the number of eggs daily, constantly correcting for mortality, so that the ratio of intact eggs produced was expressed as a percentage for each treatment over the average number of birds in the period (%/bird/day), corresponding to the production of marketable eggs.

2.6 Organ weight

For the analysis of parameters related to the weight of the organs, 96 quails were slaughtered, two birds per repetition, which were submitted to solids fasting for twelve hours to completely empty the contents of the gastrointestinal tract, receiving only water ad libitum. After the fasting period, the birds were euthanized using the cervical dislocation method and taken to the laboratory, where they were individually weighed, plucked and, through necropsy, their organs were removed for morphometric analysis of the weight of the heart, gizzard and liver. with the aid of a precision balance of 0.01 g. The heart and liver were removed and weighed, the gizzard was opened; the contents removed, then washed in running water, then dried on a paper towel and then weighed.

2.7 Statistical analysis

The means were compared by the Student test at 5% probability using the General Linear Model (GLM) procedure of the SAS (Statistical Analyses System, 2001). The following mathematical model was used (Equation 1):

$$Yijk = \mu + Zi + \in ijk \quad (1)$$

where Yijk is the dependent variable; μ is the overall mean; Zi = is the effect of temperature Z (i = 1,2); and Ɛijk is the random error, considering mean 0 and variance σ2.

3 Results and discussion

Laying quails after their production cycle are marketed as beef animals. It is observed that the average final live weight was reduced (P = 0.0362) by 27.58 g in birds kept at a temperature of 32 °C (Table 2), which can compromise its commercial value. This reduction in bird weight may be associated with lower feed intake, where under heat stress conditions, there is a lower need for nutrients for animal maintenance, with higher energy expenditure also occurring with the increased respiratory rate (Alves et al., 2012) and surface temperature, which can reduce nutrient availability for birds. Santos et al. (2017) cite a reduction in eating behavior in quail kept in warm environments (35 °C).

The welfare and production of birds are linked to animal-environment interaction, since changes in the environment, such as high temperatures, can influence the physiology of birds, causing stress. a decrease in egg production and quality occurs (Wasti et al., 2020)

Birdfeed consumption was reduced (P = 0.0051) by 14.75% with an increase in ambient temperature (Table 2), and this reduction is a mechanism used by birds to reduce endogenous heat production, such as that produced by ingestion, digestion, and metabolism of nutrients (Akdemir et al., 2019). Reductions in this consumption were reported by Vercese et al. (2012), when studying quails kept at cyclic comfort temperatures (21 to 23 °C) and under thermal stress (27 to 36 °C), receiving feed and water with increasing levels of salts and Akdemir et al. (2019), who cite a reduction in feed consumption by quails kept at a temperature between 29 and 34 °C.

Table 2. Mean and standard deviation of the variables of productive performance and egg quality of Japanese quail submitted to comfort temperature and heat stress.

Variable	Air temperature		*P-value*
	24 °C	32 °C	
	Quail performance		
Initial live weight (g)	170.83 ± 4.38	169.58 ± 5.57	0.6748
Final live weight (g)	190.41 ± 18.87[a]	165.83 ± 16.25[b]	0.0362
Feed consumption (g bird-1 day^{-1})	28.77 ± 2.35[a]	24.97 ± 2.44[b]	0.0051
Water consumption (g bird-1 day^{-1})	39.47 ± 4.99	38.79 ± 5.69	0.6603
Egg production (%)	82.06 ± 9.81	84.11 ± 6.35	0.3461
Food conversion (g g-1)	63.08 ± 14.14	63.44 ± 14.65	0.9222
	Quail Egg Quality		
Egg weight (g)	11.80 ± 0.73	11.96 ± 0.40	0.2790
Egg mass (g bird^{-1} day-^{1})	9.71 ± 1.46	10.07 ± 0.85	0.2565
FCEM	2.80 ± 0.31[a]	2.49 ± 0.23[b]	<.0001
FCDE	0.39 ± 0.03[a]	0.36 ± 0.04[b]	<.0001
Albumen weight (g)	6.46 ± 0.42	6.34 ± 0.44	0.2929
yolk weight (g)	3.82 ± 0.48[b]	4.11 ± 0.49[a]	0.0240
Shell weight (g)	1.01 ± 0.05[a]	0.98 ± 0.05[b]	0.0240
Specific gravity	1.06 ± 0.03	1.07 ± 0.00	0.2150
Album (%)	54.98 ± 4.51	53.08 ± 3.91	0.0854
Egg yolk (%)	32.49 ± 4.32	34.34 ± 3.77	0.0832
Bark (%)	8.61 ± 0.60[a]	8.20 ± 0.38[b]	0.0024
Shell thickness (µm)	267.33 ± 63.87	258.66 ± 52.77	0.5688

FCEM = feed conversion by egg mass; FCDE = feed conversion per dozen eggs; Different letters on the line differ from each other by the t-test at the 5% probability level.

Water consumption was similar (P = 0.6603) at both temperatures (Table 2), where the birds were kept at a temperature considered above the thermal comfort zone (Castro et al., 2017; Soares et al., 2019b), which can cause changes in physiological variables, such as increased respiratory rate and rectal and surface temperature (Nunes et al., 2014). Increasing the stewater demand, but raising quails at a temperature of 32 °C for 12 h, followed by the availability of milder temperatures during the night period, allowed similarity in this consumption, demonstrating the adaptability of quails to tropical climates, where the higher water consumption during times of stress may have been offset by lower consumption at night.

Egg production and feed conversion were not affected (P = 0.3461 and P = 0.9222, respectively) by the rise in temperature (Table 2), which remained within the mean for the species and similar to those mentioned by Soares et al. (2019 a,b). Even with lower feed intake and quails raised in stressful environments, these situations were not enough to change these variables, demonstrating less energy needed to maintain the birds' homeotherm. Furtado et al. (2022) and Rodrigues et al. (2022) found no difference in egg production in quails reared at two temperatures (24 and 32 °C).

Quails had lower live weight and reduced feed intake at a temperature of 32 °C. However, egg weight and mass were similar in both treatments, demonstrating the adaptive capacity of quails (Soares et al., 2019a) to warm environments, where they part of the energy that would be destined for maintenance was used for production. The average egg weight (11.80 and 11.96 g for 24 and 32 °C, respectively) is similar to those reported by Santos et al. (2017), who mentions that this weight must be between 9 and 13 g. Akdemir et al. (2019) mention that egg production and weight were reduced in laying quails kept under cyclic thermal stress (7h at 34 ± 2 °C), followed by thermal comfort (17h at 22 ± 2 °C).

Rodrigues et al. (2022), evaluating the performance and quality of quail eggs at two temperatures (24 and 32 °C) did not observe any difference in egg weight, Furtado et al. (2022) observed a significant difference in egg weight as a function of temperatures of 24 and 32 °C.

The FCEM showed a reduction (P < 0.001) of 11% at the temperature of 32 °C, and there was a reduction (P < 0.001) of 7.69% in the FCDE. These reductions can be beneficial for the production of quail eggs in hot climates, already that the birds ingested the same amount of water and needed to consume smaller amounts of feed or with less energy density, maintaining the feed conversion, weight, and egg mass.

The weight and percentage of albumen and yolk were similar between treatments, with the yolk weight being higher in eggs produced at the stress temperature. The weight and percentage of shell in birds kept at 32 °C had a reduction of 2.97% and 4.76%, respectively (Table 2), reducing the quality of the shell, which can make the eggs more fragile, requiring more outstandingmore excellent care in the collection, transport, and storage of the product. Yolk weight increased by 7.06% with increasing temperature, which may increase the nutritive value of eggs (Akdemir et al., 2019). Oliveira et al. (2014), researching the performance and quality of eggs from laying hens in a controlled environment, mention a higher percentage of yolk for birds raised in a hot environment (32 °C).

Table 3. The mean and standard deviation of the organ weight of quails subjected to comfort temperature and heat stress.

Órgan (grama)	Air temperature		*P-value*
	24 °C	32 °C	
Heart	1.61 ± 0.25a	1.57 ± 0.20a	0.4147
Liver	5.77 ± 0.98a	5.46 ± 0.89a	0.1045
Gizzard	3.31 ± 0.38a	3.13 ± 0.43b	0.0330

Different letters on the line differ from each other by the t-test at the 5% probability level.

This gravity and eggshell thickness were not influenced (P > 0.05) by the different temperatures, noting that the eggs became lighter. Therefore, higher levels of voids in the shell, which can lead to shorter shelf life. Vercese et al. (2012) and Akdemir et al. (2019) found a significant reduction in the specific gravity of eggs from birds subjected to different conditions of heat stress.

The weight of quail organs can vary according to age, weight, sex, room temperature, and types of food and water (Vasconcelos et al., 2014) and, under heat stress, there may be an increase in respiratory and heart rate. These facts may increase heart activity, affecting its weight. However, the heart and liver weight of birds was not influenced by environmental temperatures (Table 3). Rodrigues et al. (2022) mention that quail reared in cyclic temperatures of 12 hours of heat and thermoneutral temperature did not affect liver weight.

The size and weight of the gizzard are related to its muscle mass, developed by mechanical work to macerate the food (Rodrigues et al., 2022). There was a reduction (P = 0.030) of 5.44% in the weight of the gizzard with the increase in ambient temperature, which may be associated with lower feed consumption by birds kept at this temperature, reducing the mechanical work to break down the food, which can cause a reduction in the mass and activity of internal organs (Salabi et al., 2011). Changes in the quantity and quality of birds' diet can affect the relationship between the rate of passage of food, organ size, microbial growth, and health of the gastrointestinal tract by decreasing substrates to maintain the intestinal microbiota (Hetland et al., 2003).

4 Conclusions

Birds kept at a temperature of 32 °C for 12 h daily showed a reduction in feed intake, final weight, yolk, and gizzard weight, but without affecting egg production, weight and mass.

The high temperature causes a decrease in the conversion of food into egg mass or a dozen eggs, because the animal decreases feed intake as a way to reduce endogenous heat production.

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