

Magnesium in the water of Japanese quails kept under comfort zone and under thermal stress

Magnésio na água de codornas japonesas mantidas em zona de conforto e sob estresse térmico

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Highlights

Japanese quails can consume water with magnesium levels of up to 350 mg/L.

Japanese quails can be maintained at temperatures of up to 32°C.

Water with magnesium levels of 350 mg L⁻¹ does not affect quail performance.

Abstract

The objective was to evaluate the increasing levels of magnesium in the water supplied to laying quails (*Coturnix coturnix japonica*), kept in climatic chambers under thermoneutral temperature and thermal stress, on their performance and morphometry of their organs. The birds were distributed in a completely randomized design, 2x4 factorial arrangement, 2 temperatures (24 and 32 °C) and 4 levels of magnesium in the water (50, 150, 250 and 350 mg L⁻¹), with six replicates and eight birds per experimental unit. The data were subjected to analysis of variance and the means compared by the Tukey test at 5% probability level. The magnesium levels in the water did not affect ($P > 0.05$) the production performance and morphometry of the organs, with less water consumption at the magnesium level of 150 mg L⁻¹, and birds kept at 32 °C had a reduction in feed consumption and feed conversion, but without affecting organ morphometry. Japanese quails in the production phase can consume water with magnesium levels up to 350 mg L⁻¹ without having their production performance and morphometry of organs affected and raised in an environment with temperatures of up to 32 °C.

Key words: Ambience. Climate chamber. Quail farming. *Coturnix coturnix japonica*.

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Resumo

O objetivo foi avaliar os níveis crescentes de magnésio na água fornecida a codornas (*Coturnix coturnix japonica*) em postura, mantidas em câmaras climáticas sob temperatura termoneutra e estresse térmico, sobre o desempenho e morfometria dos órgãos das aves. As aves foram distribuídas em delineamento inteiramente casualizado, arranjo fatorial 2x4, 2 temperaturas (24 e 32 °C) e 4 níveis de magnésio na água (50, 150, 250 e 350 mg L⁻¹), com seis repetições e oito aves por unidade experimental e os dados submetidos à análise de variância e as médias comparadas pelo teste de Tukey a 5% de probabilidade. Os níveis de magnésio na água não afetaram ($P > 0,05$) o desempenho produtivo e a morfometria dos órgãos, com menor consumo de água ao nível de 150 mg L⁻¹ de magnésio e, as aves mantidas a 32 °C tiveram uma redução no consumo de ração e conversão alimentar, mas sem afetar a morfometria dos órgãos. Codornas japonesas em fase de produção podem consumir água com níveis de magnésio de até 350 mg L⁻¹ sem ter o desempenho produtivo e a morfometria dos órgãos afetados e criados em ambiente com temperatura de até 32 °C.

Palavras-chave: Ambiente. Câmara climática. Criação de codornas. *Coturnix coturnix japonica*.

Introduction

Quail farming is an expanding activity in semi-arid regions, which are characterized by strong sunshine, high temperatures of up to 40 °C (Sousa et al., 2014), and scarce and irregular rains, which can compromise the quantity and quality of the water stored in sources (Abdelsattar, Hussein, Abd El-Ati, & Saleem, 2020). Japanese quail is a bird that is adapted to arid and semi-arid regions, with a small size, earliness, productivity, which uses small spaces and little labor for production (Guimarães et al., 2014; Khalilipour, Maheri, & Shaddel, 2019). In semi-arid regions, the available waters may have a high concentration of minerals, such as magnesium (Melo et al., 2017; Adimalla, 2019), which is an essential micronutrient in the diet of birds and participates in cell metabolism, bone development, cell energy metabolism, ribosomal integrity, and cell membrane (Shastak & Rodehutsord, 2015). Quails are tolerant to magnesium-rich waters (Tao, Fry, & Fox, 1983), as well as saline waters (Petrucci et al., 2017; Lima, Morais, & Barreto,

2020). Magnesium levels between 14 and 125 mg L⁻¹ can be added to the water with no harm to birds (Hevia & Quiles, 1998). However, supplies above this limit may cause adverse effects, such as intestinal irritation, diarrhea, and reduced growth and egg production rates (Casey & Meyer, 2001). Seo et al. (2010) and Kim, Paik, & Kil (2013) cite increased weight and improved egg quality of laying hens supplemented with magnesium in the diet with ambient temperatures at 21 °C and 22±3 °C, respectively. Different concentrations of salts in the water can cause changes in the weight of the birds and their organs (Lima et al., 2014; Khalilipour et al., 2019), constituting physiological adjustments. Age, sex, and nutrient content in the diet can increase metabolism (Loyau et al., 2015) and, consequently, change the weight of the organs, such as heart, liver and gizzards.

Birds are sensitive to thermal stress due to their high metabolic activity. Modern genotypes produce more body heat, and laying quails are tolerant to hot climates, but their thermal comfort zone is between 22

and 26 °C (El-Tarabany, 2016; Castro, Yanangi, Ferraz, & Fassani, 2017; Silva et al., 2017), with relative humidity between 65 and 70%. High temperatures can make it difficult to exploit and maximize quail production (Lima et al., 2014; Akdemir, Köseman, & Şeker, 2019), and small environmental changes are perceived by birds (Castro et al., 2017; Santos, Gates, Tinôco, Zolnier, & Baêta, 2017), causing an increase in water intake and a reduction in feed intake, which reduces egg production and quality (Vercese et al., 2012; El-Tarabany, 2016; Castro et al., 2017; Soares et al., 2019).

Therefore, the objective of this study was to evaluate increasing levels of magnesium in the water supplied to laying

quails (*Coturnix japonica*), kept in climatic chambers under thermoneutral temperature and under thermal stress, on their performance and morphometry of their organs.

Material and Methods

All procedures used were approved by the Animal Use Ethics Committee of the Federal University of Campina Grande - UFCG (Protocol Number 089.2017). The experiment was carried out in two climatic chambers, dimensions of 3.07 x 2.77 x 2.6 m, in length, width and height, respectively (Figure 1), located at the Rural Construction and Ambience Laboratory at UFCG.

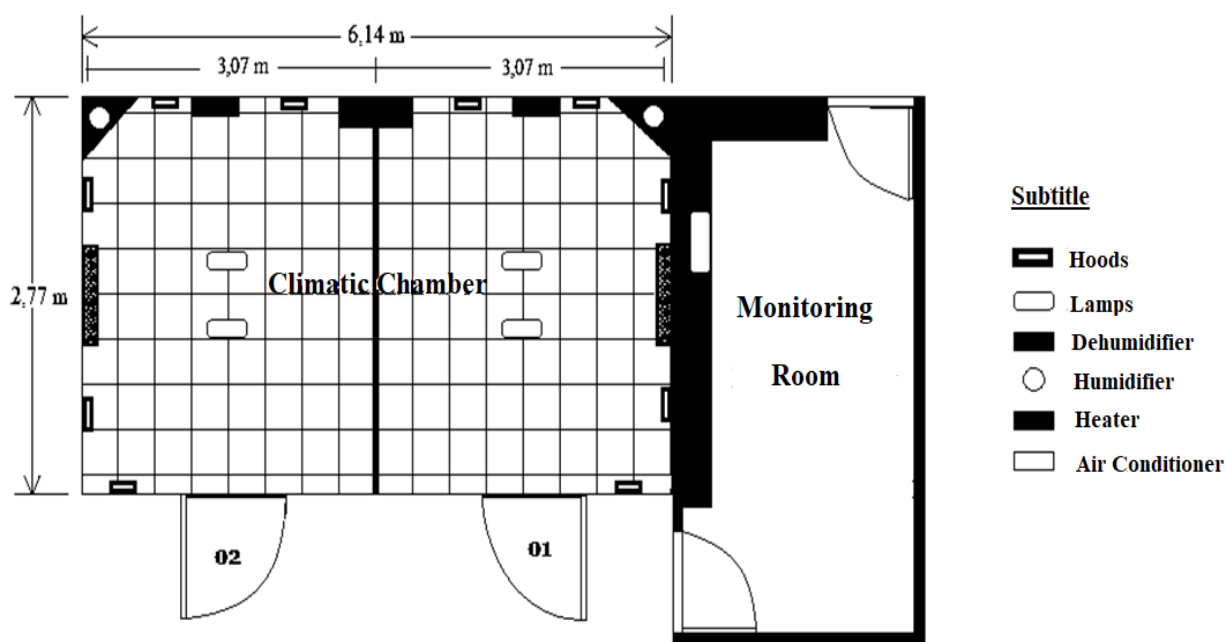


Figure 1. Internal layout of the climatic chambers and the monitoring room.

For environmental control, the chambers were equipped with an electric resistance air heater, a hot/cold split air conditioner, with a power of 18,000 BTUs and an air humidifier, 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. The wind speed was obtained through side fans and exhaust fans. The chambers had temperature and humidity sensors, and environmental data were collected and recorded every 15 min by sensors coupled to the data acquisition system, through a *Full Gauge Controls*® MT-530 PLUS controller, controlled via computer through SITRAD® (software for data acquisition, control, monitoring and visualization in climatic chambers).

Fluorescent lamps of 20W and 220V were used to light the chambers, and the daily light program adopted was of 17 hours of light and 7 hours of darkness. The relative humidity of the air in the chambers during the experimental period was 65.0 ± 5.0% and the average wind speed was 2.0 ± 0.5 m s⁻¹.

In the pre-experimental period, 494 nine-week-old quails were used, housed in clusters of cages in the chambers, each cluster consisting of four floors, three cages per floor, made of galvanized wire, dimensions of 50 x 33 x 20 cm (width, depth, and height, respectively), submitted to the stocking rate of 206 cm² bird⁻¹. The cages were equipped with zinc sheet trough feeders and individual nipple drinkers.

The birds went through an adaptation period of three weeks, in which the chambers were pro-programmed to keep the quails under temperature of thermal comfort (24 °C) during the day and under room temperature at night.

Egg production was counted and, at 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 the distribution, the chamber temperatures were adjusted to 24 °C, within the thermal comfort zone, and 32 °C, above the thermal comfort zone. These values were maintained for a period of 12 hours (7 am to 7 pm). The chamber doors were opened from 7:01 pm to 6:59 am at room temperature, simulating the conditions of the Brazilian semi-arid region.

For the experimental period, 384 14-week-old quails were selected and distributed in a completely randomized experimental design, in a 2 x 4 factorial scheme [two temperatures (24 and 32 °C) x four levels of magnesium in the water (50, 150, 250 and 350 mg L⁻¹)], totaling eight treatments, with six repetitions of eight birds each.

To obtain these four magnesium levels, magnesium chloride (MgCl₂.6H₂O), A.R. with 203.3 molecular weight of salt, was added to mineral water with low salt content (1.45 mg L⁻¹ Mg) and correcting to obtain total treatment weight (Tn)

In the composition of the salt, as the magnesium chloride is hexahydrate, the weight of magnesium in the composition represented 12% of the total weight of the added salt. The remainder was composed of chloride ions (Table 1) and water molecules. The waters with magnesium concentrations were stored in 200-L buckets with lids and used daily in the drinkers according to the treatments. The water was prepared by weighing the proportion of MgCl₂ salt for each 10 liters of water for each treatment, and the electrical conductivity level was checked

at completion of each prepared dilution by using a digital conductivity meter (ITCD - 1000 model - Instrutemp). Water analysis was

carried out at the UFCG Irrigation and Salinity Laboratory (Table 1).

Table 1
Water already added with magnesium chloride (MgCl₂)

Variable	Magnesium chloride (mg L ⁻¹)			
	50	150	250	350
Ph	7.70	7.70	7.70	7.20
Electric conductivity (uS Cm ⁻¹)	737.50	2.016.00	3.219.00	4.204.00
Calcium (mg L ⁻¹)	4.00	4.80	7.00	5.60
Magnesium (mg L ⁻¹)	50.00	150.00	250.00	350.00
Sodium (mg L ⁻¹)	92.68	97.06	94.76	94.76
Potassium (mg L ⁻¹)	0.78	0.78	0.78	0.78
Chlorides (mg L ⁻¹)	173.70	492.05	866.75	1.152.00
Bicarbonates (mg L ⁻¹)	42.70	42.09	41.48	43.31
Carbonates (mg L ⁻¹)	-	-	-	-
Iron (mg L ⁻¹)	0.07	0.07	0.07	0.07

During the experimental period, the birds were subjected to identical food management, consuming feed for laying quails based on corn and soybean meal. The nutritional composition of the ingredients used was obtained based on the tables by Rostagno et al. (2011), with water and feed being provided daily, manually and *ad libitum*. Leftovers and waste were weighed and discounted from the amount of feed weighed initially to calculate the feed and water intake of the birds.

At the beginning of the experiment the birds were 168 ± 5 g (14 weeks of age) and at the end 175 ± 5 g (24 weeks). Egg quality analysis was carried out every 21 days, with three evaluation periods, analyzing the following performance characteristics: feed intake (g/bird/day), water consumption (ml/

bird/day), egg production (%), egg weight (g), egg mass (g/bird/day) and feed conversion (kg/kg and kg/dozen).

The average egg production was obtained by collecting the number of eggs daily, correcting for mortality, with the ratio of whole eggs produced expressed as a percentage, considering the average of birds of the period (%/bird/day), corresponding to the production of marketable eggs. All eggs produced in each repetition were weighed during the last three days of each period to obtain the average weight, which was multiplied by the total number of eggs produced during the period to obtain the total egg mass. This mass was divided by the total number of birds per day, expressed in grams of egg/bird/day. The feed conversion per dozen eggs was determined by the total feed intake

(kg) divided by the dozens of eggs produced (kg/dozen) and the conversion per egg mass, by the egg mass in kilograms (kg/kg).

To analyze the weight of the organs, 96 quails were slaughtered, two birds per repetition (48 in each environment). These quails were subjected to fasting of solids for twelve hours to empty the contents of the gastrointestinal tract, while receiving only water. After this period, they were stunned, slaughtered, plucked, eviscerated and subjected to organ separation: heart, liver and gizzard, which were weighed by using a 0.01 g precision digital scale. The heart and liver were removed and weighed. The gizzard was opened and the contents removed, then it was washed under running water, dried on paper towels and weighed.

The data were subjected to analysis of variance (ANOVA) and the averages were compared by Tukey's test at the level of 5% probability using PRO GLM. The effects of magnesium levels were estimated by PROC REG of SAS (2001).

Results and Discussion

There was no significant effect ($P > 0.05$) of the interaction between temperatures and water magnesium levels for performance variables. Magnesium influenced water consumption ($P = 0.0401$) of the birds. At the highest temperature, there was a reduction ($P < 0.05$) in feed intake and feed conversion, with no significant differences ($P > 0.05$) in the other performance variables (Table 2).

Table 2

Performance averages of Japanese quails subjected to different levels of magnesium in water, at comfort temperature (24 °C) and heat stress temperature (32 °C)

Effect	Feed consumption (g/bird/day)	Water consumption (mL/bird/day)	Production (%)	Egg weight (g)	Egg mass (g/bird/day)	Feed conversion (g/g)	
Magnesium (mg L ⁻¹)	50	22.88	38.75a	73.10	11.70	8.58	0.38
	150	22.67	36.43b	69.95	11.64	8.16	0.40
	250	22.93	42.66a	71.56	11.72	8.38	0.39
	350	23.38	38.70ab	72.91	11.47	8.37	0.39
Temperature (°C)	24	23.98a	39.48	71.43	11.64	8.33	0.41a
	32	21.96b	38.79	72.34	11.62	8.41	0.36b
MSE	1.63	5.14	9.27	0.42	1.14	0.05	
P-value							
Temperature	0,0001	0.6475	0.7365	0.8656	0.7919	0.0076	
Magnesium	0.7502	0.0401	0.8278	0.4629	0.8489	0.7626	
Temperature x Magnesium	0.9410	0.8553	0.5638	0.8243	0.5874	0.4095	
P-value							
Linear	0.4657	0.3802	0.9304	0.2394	0.7750	0.7859	
Quadratic	0.5397	0.5991	0.3909	0.4197	0.5262	0.5084	

Means followed by different letters differ statistically by Tukey's test at 5% probability; MSE = mean standard error.

Quails are tolerant to high levels of minerals in water and feed (Lima et al., 2015; Scottá et al., 2017; Lima et al., 2020), and the levels of Mg ingested did not influence feed intake, demonstrating the tolerance of the birds to magnesium-rich waters (Tao et al., 1983). Bird organisms do not have adaptations to chronic low or high ingestions of Mg; excretion in urine is the main regulator of Mg body homeostasis (Shastak & Rodehutsord, 2015).

Poultry kept under thermal stress decreased feed intake by 8.42% (2.02g) and this is due to the need to reduce body heat (Tao et al., 1983; El-Tarabany, 2016; Santos et al., 2019). Quails may have difficulty exchanging heat with the environment due to the absence of sweat glands and because their bodies are covered with feathers. The reduction in feed intake is an adjustment in energy ingestion and reduces the production of body heat (Vercese et al., 2012; Castro et al., 2017), but it may cause an energy deficit by reducing the availability of nutrients for production, since heat dissipation occurs with energy expenditure (Loyau et al., 2015). Tao et al. (1983) cite that weight gain and feed intake of Japanese quails kept under cyclic temperatures of thermal stress (34 °C) and mild temperatures were higher in birds supplemented with magnesium oxide and Mg-protein.

Water consumption was reduced with the level of Mg in the water at 150 mg L⁻¹, but similar to that obtained with the level of 350 mg L⁻¹. To avoid any compromise in poultry production, the recommendation is that the water should not have more than 1000 mg L⁻¹ (National Research Council [NRC], 1994). An average water consumption of 1.7 L for each kilogram of feed consumed and higher

Mg concentrations can stimulate urinary frequency and cause diarrhea, facts that stimulate water replacement via consumption; however, up to the level of 350 mg L⁻¹ this stimulus was not externalized. The increase of salt in water can elevate the sensation of thirst due to the increase in plasma osmolality and the neurohormonal mechanisms that stimulate the center of thirst.

Under thermal stress, the birds' demand for water can be high to meet non-evaporative caloric loss (Santos et al., 2019). However, water consumption was not affected by the increase in ambient temperature. These results may be due to the management in which quails were subjected to cyclic heat stress for 12 hours.

The production performance of quails may be influenced by genetic variability in the breeding environment, poultry management, feed, and the water offered (Ribeiro et al., 2017; Akdemir et al., 2019), although increasing levels of magnesium did not interfere in the performance of the birds, which stayed within the standard for the species (Vercese et al., 2012; Guimarães et al., 2014). High concentrations of magnesium in the water can result in a bitter taste and low palatability, which can limit consumption. However, when supplying water with up to 350 mg L⁻¹ of magnesium to quails, this was not found. Kudo, Shiraishi, Nishimura, Bungo, & Tabata (2010) mention that sensitivity to bitter taste is related to the number of gustatory papillae, which in chickens is lower than in mammals. This makes them less sensitive to palatability.

The weight of a quail egg can vary between 10 and 13 g. Even under thermal stress, quails are able to maintain production and quality of the products (Guimarães et al.,

2014; Rodrigues, Furtado, Costa, Nascimento, & Cardoso, 2016; Petrucci et al., 2017). However, these variables can be reduced in quails kept under thermal stress (El-Tarabany, 2016; Santos et al., 2017; Silva et al., 2017; Akdemir et al., 2019), due to the reduction in food intake, reduced digestibility of diet components, and mobilization and use of body reserves to maintain body temperature. Although quails kept at a temperature of 24 °C consume more feed, the percentages of egg laying, weight and mass were similar to those of quails kept at stress temperature.

The variables of performance and egg quality of birds can be reduced by the oxidative stress that results from high environmental temperatures (Akdemir et al., 2019; Soares et al., 2019), and there was a reduction in feed conversion of the birds at the stress temperature, a fact that may be correlated with lower feed intake.

There was no interaction between temperatures and magnesium levels in the water for organ morphometry, and the different levels of magnesium in the water and temperatures did not affect ($P < 0.05$) the weight and percentage of the quail heart, liver, and gizzard (Table 3).

Table 2
Averages of absolute and relative weight of the quail's organs submitted to different levels of magnesium in the water, at comfort temperature (24 °C) and thermal stress (32 °C)

Effect		Live weight		Heart		Liver		Gizzard	
		(g)	(g)	(%)	(g)	(%)	(g)	(%)	
Magnesium (mg L ⁻¹)	50	167.02	1.50	0.90	6.00	3.64	3.33	2.03	
	150	163.83	1.57	0.97	5.91	3.62	4.19	2.60	
	250	165.48	1.49	0.91	5.74	3.49	3.04	1.84	
	350	168.63	1.60	0.95	7.86	4.66	3.17	1.88	
Temperature (°C)	24	166.66	1.58	0.96	6.20	3.75	3.27	1.98	
	32	165.81	1.50	0.90	6.56	3.96	3.59	2.20	
SEM		15.95	0.25	0.17	4.07	2.42	2.02	1.31	
P-value									
	Temperature	0.8551	0.2395	0.2681	0.7573	0.7708	0.5834	0.5747	
	Magnesium	0.8958	0.6679	0.7073	0.5412	0.6187	0.5062	0.4734	
	Temperature x Magnesium	0.9165	0.7704	0.7360	0.2524	0.2713	0.5464	0.5259	
P-value									
	Linear	0.7406	0.4565	0.6886	0.3011	0.3506	0.5254	0.4740	
	Quadratic	0.4719	0.8238	0.7572	0.3459	0.3942	0.5349	0.4838	

Means followed by different letters differ statistically by Tukey's test at 5% probability; MSE = mean standard error.

The birds' weight was 168 ± 5 g at the beginning of the experiment, and 175 ± 5 g at the end, an average of 171.5 ± 5 g. Therefore, even consuming water with high levels of magnesium and kept under thermal stress, the birds managed to raise their weight. Part of the percentage of the magnesium ingested is fixed in the bones, and another percentage goes into the composition of the molecular mass and blood (Shastak & Rodehutsord, 2015); therefore, the concentration of magnesium in the water can help in the maintenance or gain of weight in quails under thermal stress. Harland, Fox, & Fry (1976) cite that 300 mg L^{-1} of magnesium was considered adequate to meet the requirements of Japanese quails of up to 14 days of age, and higher levels caused growth retardation and high mortality.

Weight of quail organs can vary according to age, weight, sex, ambient temperature and types of food and water (Vasconcelos, Pires, Lima, & Ballotin, 2014). The magnesium levels of the water did not interfere with the weight and percentage of the heart, an average of 1.54 g, similar to that reported by Rodrigues et al. (2016) in laying quails and by Camelo et al. (2015), in studies with guava bran in the diet of European quails.

The weights and percentages of the liver were similar between treatments. The birds' tolerance to Mg must be less than 125 mg L^{-1} (Hevia & Quiles, 1998), and this mineral participates in the metabolism of cellular energy and modulates the activities of various membrane transport systems with liver action. Higher levels of Mg can cause physiological disorders in the digestive organs, but the consumption of water with levels of up to 350 mg L^{-1} did not promote physiological changes, demonstrating tolerance of the quails to waters with higher magnesium contents. Lima et al. (2014) cite that increasing levels

of water electrolyte balance (0, 30, 60, 90, 120 mEq/L) reduced the relative weight of the heart and liver. Rodrigues et al. (2016) mention that quails raised in cyclic temperatures of 12 hours each of heat and thermoneutral temperature did not affect the weight of the liver. There may be a reduction in the weight of the organs due to the reduction in feed intake (Silva et al., 2017), associated with lower maintenance requirement, reduction in mass, and activity of internal organs (Salabi, Fayazi, Nazari, Boujarpoor, & Salari, 2011).

The weight of the gizzard is related to the feed intake, which was higher at the thermoneutral temperature, but not enough to affect this weight in comparison to the stress temperature. Ensuring ideal conditions for the production and action of these enzymes is essential in the supply and absorption of nutrients that will be destined for metabolic processes related to the growth and maturation of the organs of these animals (Yamauchi & Tarachai, 2000).

Conclusions

Japanese quails in the production phase can consume water with magnesium levels of up to 350 mg L^{-1} , and be maintained at temperatures of up to 32°C for up to 12 hours a day, without affecting productive performance and organ morphometry.

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