ISSN 1807-1929
Revista Brasileira de Engenharia Agrícola e Ambiental
Brazilian Journal of Agricultural and Environmental Engineering
v.26, n.4, p.313-318, 2022
Campina Grande, PB – http://www.agriambi.com.br – http://www.scielo.br/rbeaa

DOI: http://dx.doi.org/10.1590/1807-1929/agriambi.v26n4p313-318

Water salinity and air temperature on quail production and organ characteristics[1]

Salinidade da água e temperatura do ar nas características de produção e dos órgãos de codornas

Dermeval A. Furtado[2*], Ladyanne R. Rodrigues[3], Valéria P. Rodrigues[3], Neila L. Ribeiro[4], Rafael C. Silva[2] & Soahd A. R. Farias[2]

[1] Research developed at Universidade Federal de Campina Grande, Laboratório de Construções Rurais e Ambiência, Campina Grande, PB, Brazil
[2] Universidade Federal de Campina Grande/Centro de Tecnológia e Recursos Naturais/Unidade Acadêmica de Engenharia Agrícola, Campina Grande, PB, Brazil
[3] Universidade Federal de Campina Grande/Programa de Pós-graduação em Engenharia Agrícola, Campina Grande, PB, Brazil
[4] Bolsista PCI/CNPq, Instituto Nacional do Semiárido, Campina Grande, PB, Brazil

HIGHLIGHTS:

The electrical conductivity of the water does not decrease quail performance.
At air temperature of 32 °C the birds consume less feed.
Water with electrical conductivity of 6.0 dS m^{-1} does not affect the weight of the organs.

ABSTRACT: The supply of salt water in the semiarid region is a recurrent practice, as there is a severe shortage of water for use in animal consumption. Thus, most of the times the water offered to the birds can contain salts above the recommended amount. The present study aimed to evaluate the production performance and morphometry of the organs of Japanese quails as they were supplied with drinking water with different concentrations of sodium chloride, while being maintained in comfort and under thermal stress. The birds received water with increasing electrical conductivity (1.5, 3.0, 4.5 and 6.0 dS m^{-1}) and were kept in a climate chamber at thermoneutral air temperature (24 °C) and under thermal stress (32 °C), being distributed in a completely randomized design and 2 × 4 factorial scheme. Water electrical conductivities did not affect the performance of the birds, except for the weight of the gizzard, which showed an increasing linear effect as the electrical conductivities increased. At the stress temperature, there was reduction in feed intake, egg weight and mass, and in feed conversion per dozen eggs, but with no effect on the weights of the heart, liver and gizzard. Japanese quails in the production phase can consume water with electrical conductivity of up to 6.0 dS m^{-1}, showing good production performance and without compromising organ morphometry.

Key words: animal behavior, stress physiology, thermal stress, egg quality, feed intake

RESUMO: O fornecimento de água salgada no semiárido é uma prática recorrente, visto que existe uma grande escassez de água para uso na alimentação animal. Assim, na maioria das vezes a água oferecida às aves pode apresentar sal acima do recomendado. O presente estudo teve como objetivo avaliar o desempenho produtivo e a morfometria dos órgãos de codornas japonesas à medida que eram abastecidas com água potável com diferentes concentrações de cloreto de sódio, sendo mantidas em conforto e sob estresse térmico. As aves receberam água com valores crescentes de condutividade elétrica (1,5, 3,0, 4,5 e 6,0 dS m^{-1}), e foram mantidas em câmara climática em temperatura do ar termoneutra (24 °C) e sob estresse térmico (32 °C), sendo distribuídas em um delineamento inteiramente casualizado e esquema fatorial 2 × 4. As condutividades elétricas da água não afetaram o desempenho das aves, exceto para o peso da moela, que apresentou efeito linear crescente com o aumento da condutividade elétrica. Na temperatura de estresse, houve redução no consumo de ração, peso e massa do ovo e na conversão alimentar por dúzia de ovos, porém sem efeito no peso do coração, fígado e moela. Codornas japonesas na fase de produção podem consumir água com condutividade elétrica de até 6,0 dS m^{-1}, apresentando bom desempenho produtivo e sem comprometer a morfometria dos órgãos.

Palavras-chave: comportamento animal, fisiologia do estresse, estresse térmico, qualidade do ovo, consumo de ração

• Ref. 250751 – Received 06 Apr, 2021
* Corresponding author - E-mail: araujodermeval@gmail.com
• Accepted 27 Oct, 2021 • Published 11 Nov, 2021
Editors: Ítalo Herbet Lucena Cavalcante & Carlos Alberto Vieira de Azevedo

Introduction

The difficulty to obtain drinking water has caused farmers to supply poultry with saline water. This is a recurring scenario in arid and semi-arid regions, such as northeastern Brazil, where the water offered may have salt levels above what is recommended (Melo et al., 2017; Khalilipour et al., 2019; Abdelsattar et al., 2020). Water with such characteristics can increase plasma osmolality, which stimulates the secretion of renin and angiotensin, enzymes that modulate thirst; this causes increased water consumption and renal excretion, which is rich in minerals such as sodium, chlorine and potassium (Alahgholi et al., 2014).

Excess or deficiency of minerals can be harmful to the animal organism and its production performance, as happens with quails (Nunes et al., 2014; Lima et al., 2020), and can affect internal organs, such as the liver, heart and kidneys (Barbosa et al., 2014). Saline waters can also lead to inappropriate consumption or refusal by birds. Quails are tolerant to saline waters (Petrucci et al., 2017; Scottá et al., 2017), and the levels of tolerance to this type of water for bird consumption are between 1.5 and 5.0 dS m^{-1} (Ayers & Westcot, 1994), as well as birds that adapt and produce in the most varied environments.

Birds kept under thermal stress decrease feed intake and increase water consumption (Barbosa et al., 2014; Guimarães et al., 2014; Villanueva et al., 2015), as a way to replace the water lost by breathing and fecal and urinary excretion, to avoid dehydration, maintain homeothermy, and minimize thermal stress (Scottá et al., 2017), but it can negatively affect the production and quality of quail eggs (Vercese et al., 2012; Barbosa et al., 2014). Laying quails have good production in warm environments (Petrucci et al., 2017; Silva et al., 2017; Akdemir et al., 2019). However, in order to obtain maximum performance, birds must be raised in appropriate and thermally comfortable facilities (Rodrigues et al., 2016). The thermal comfort zone for laying quails is between 18 and 26 °C (Castro et al., 2017; Santos et al., 2017; Silva et al., 2017), with an average relative air humidity of 60%.

Therefore, the present study aimed to evaluate the production performance and morphometry of the organs of Japanese quails as they were supplied with drinking water with different electrical conductivities, while being maintained in comfort and under thermal stress.

Material and Methods

All procedures used were approved by the Animal Use Ethics Committee of the Federal University of Campina Grande (Protocol number 089.2017). The experiment was carried out in two climate chambers, with dimensions of 3.07 × 2.77 × 2.6 m in width, length and height, respectively (Figure 1), located in the Laboratory of Rural Constructions and Ambience of the Federal University of Campina Grande, Paraíba state, Brazil.

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 rate (average) of 300 mL per hour. The relative humidity of the air was controlled

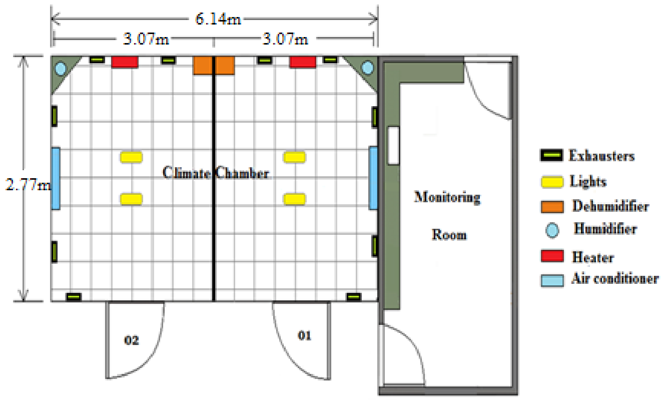

Figure 1. Internal layout of the climate chambers and the monitoring room

by air humidifiers and measured by using sensors, and the wind speed was obtained through side fans and exhaust fans. The chambers had interior air temperature and air humidity sensors (SB-56 from Full Gauge). Environmental data were collected and recorded every 15 min by sensors coupled to a data acquisition system, by using an MT-530 PLUS controller from Full Gauge Controls®, controlled via computer through SITRAD® (software for data acquisition, control, monitoring and visualization inside the climate chambers). For lighting in the chambers, 20 W fluorescent lamps were used. Relative air humidity inside the climate chambers throughout the experimental period was 65 ± 5% and the average wind speed was 2.0 ± 0.5 m s^{-1}.

Three hundred and eighty-four female Japanese quails (*Coturnix japonica*) at an average age of 14 weeks were distributed in a completely randomized design and 2 x 4 factorial scheme, at two air temperatures (24 and 32 °C) and four electrical conductivities of water (1.5, 3.0, 4.5 and 6.0 dS m^{-1}), with six replicates, with eight birds per experimental unit, subjected to a stocking rate of 206 cm^2 per bird.

The nine-week-old birds were housed in cages arranged in clusters inside climate chambers, where they remained 24 hours a day with the doors closed under comfort air temperature (24 °C), for a pre-experimental period of four weeks, in order to adapt to the physical environment of cages and the climate chamber. Two battery cages were placed in each chamber, made of galvanized wire, with four floors each, subdivided into three cages per floor, with dimensions of 50 x 33 x 20 cm (width, depth and height). The cages were equipped with trough-type feeders and individual drinkers made up of hermetically sealed containers. The water was consumed through nipple drinkers, and there were excreta-collecting trays under the floors.

After the pre-experimental period, the quails were distributed into the treatments with homogeneous weight and egg production. One hundred ninety-two birds were housed in an environment with air temperature within the thermal comfort zone (24.0 ± 1.0 °C) and 192 birds in an environment with an air temperature above this zone (32 ± 1.2 °C), kept constant for a period of 12 hours daily (7 a.m. to 7 p.m.). At 7 p.m., at a room temperature of 22 ± 2.0 °C, the doors were opened until 7 a.m. the following morning, simulating the environmental conditions of semi-arid regions, where temperatures are high during the daytime and milder at night.

Water electrical conductivities were obtained by dissolving sodium chloride (NaCl) in water from the local supply system (1.3 dS m^{-1}). Four drums with 200 L capacity were filled and the reading of electrical conductivity of the water (ECw) was performed with a portable digital conductivity meter (model ITCD - 1000 from Instrutemp, São Paulo, SP, Brazil). Depending on the result, NaCl was dissolved and mixed until the solution reached the desired ECw level. The amount of salt was determined based on the ECw, according to the equation "Q (mg L^{-1}) = 640 x ECw (dS m^{-1}), by Richards et al. (1954).

During the entire experimental period, the birds were subjected to identical food management, receiving feed for laying quails based on corn and soybean meal. The nutritional composition of the feed ingredients was obtained based on charts by Rostagno et al. (2011). Water and feed were provided daily, manually and ad libitum. Leftovers and waste were weighed and discounted from the amount of feed weighed initially.

The program adopted for lighting was 17 hours of light and seven hours of darkness, according to Vercese et al. (2012) and Castro et al. (2017). The average weight of the birds at the beginning of the experiment was 170 ± 5 g (fourteen-week-old birds) and 228 ± 5 g at the end (twenty six-week-old birds). The experimental phase was divided into four periods of 21 days each. The data from feed intake (g per bird per day), water consumption (mL per bird per day), egg production (%), egg weight (g), egg mass (g per bird per day), feed conversion (kg kg^{-1} and kg per dozen eggs) were evaluated. At the end of the experimental period, 96 quails (two birds per replicate), 48 raised in a thermoneutral environment and 48 raised under thermal stress, were subjected to fasting from solids for 12 hours, then weighed and euthanized by using the cervical dislocation method. They were then taken to the laboratory, where they were weighed, plucked and had their organs withdrawn through necropsy for morphometric weight analysis of the heart, gizzard and liver. The gizzard was opened and the contents were removed, then it was washed under running water, dried on paper towels, and then weighed.

The data were subjected to analysis of variance, and Tukey test was used to compare the two temperatures, at $p \leq 0.05$, and the effects of water electrical conductivity were evaluated by regression analysis, using the statistical software SAS (2008).

Results and Discussion

No effect of the interaction between temperatures and water electrical conductivities was observed on quail performance. The electrical conductivities of water did not influence ($p > 0.05$) the evaluated variables. However, air temperature influenced ($p \leq 0.05$) feed intake, egg weight and egg mass, and feed conversion per dozen eggs (Table 1).

The electrical conductivity of the water did not influence feed intake; despite consuming saline water and being raised under stress temperature, the quails maintained average intake within the normal range, between 25 and 30 g per bird per day (Vercese et al., 2012; Guimarães et al., 2014; Rodrigues et al., 2016; Lima et al., 2020), showing their adaptability to saline waters and warm environments. At the air temperature of thermal stress, the feed intake of the birds was reduced, since this is one of the mechanisms used by birds to reduce the production of endogenous heat, such as that produced by digestion and metabolism of nutrients. This reduction was also reported by Vercese et al. (2012) when studying quails kept in cyclic comfort temperatures (21 to 23 °C) and under thermal stress (27 to 36 °C), receiving feed and water with increasing levels of salts. Barbosa et al. (2014) and Akdemir et al. (2019) report a reduction in feed intake by quails kept at air temperature between 29 and 34 °C.

Water electrical conductivities of up to 6.0 dS m^{-1} did not affect the egg production of the quails, revealing their adaptability to these waters. Birds consuming excess minerals use mechanisms for excretion, such as increased frequency of urination containing high levels of minerals, such as sodium, chlorine and potassium (Khalilipour et al., 2019; Abdelsattar et al., 2020). Lima et al. (2020) mention that the increase in sodium concentrations in the feed (27.07 to 36.00 mg L^{-1}) did not influence egg production.

Thermal stress can affect the ingestive behavior of quails (Castro et al., 2017; Silva et al., 2017; Santos et al., 2017), but even keeping animals at temperatures of 32 °C was not enough to affect egg production. Vercese et al. (2012) and Akdemir et al. (2019) found a reduction in the egg production of laying quails housed in temperature-controlled rooms at 22 ± 2 °C for 24 hours per day (TN) or 34 ± 2 °C between 09h00 and 17h00 followed by 22 ± 2 °C for 16 hours per day (HS).

Although chlorine and sodium increase the palatability of the water, the use of increasing electrical conductivity in the

Table 1. Effect of water electrical conductivities and temperatures on quail performance

Factors		Feed consumption (g per bird per day)	Production (%)	Water consumption (mL per bird per day)	Egg weight (g)	Egg mass (g)	Conversion per egg mass (%)	Conversion per dozen eggs (%)
Salinity (dS m^{-1})	1.5	26.30	84.03	68.52	12.00	10.09	3.34	0.38
	3.0	26.04	85.43	63.29	12.05	10.29	3.32	0.37
	4.5	25.79	84.02	64.81	12.04	10.10	3.34	0.37
	6.0	25.90	83.80	71.04	11.92	10.03	3.34	0.37
Temperature (°C)	24	26.89 a	84.41 a	65.85 a	12.20 a	10.31 a	2.64 a	0.38 a
	32	25.11 b	84.22 a	67.97 a	11.80 b	9.95 b	4.03 a	0.36 b
p-value								
CV (%)		3.01	4.09	5.83	2.73	4.89	4.96	4.81
Salinity		0.8792	0.4367	0.0802	0.7629	0.3763	0.4250	0.6170
Temperature		< 0.0001	0.0930	0.3548	< 0.0001	< 0.0004	0.4621	< 0.0002
Salinity x Temperature		0.6160	0.1143	0.9360	0.1870	0.7910	0.9036	0.6891

Means followed by different letters differ statistically from each other by the Tukey test at $p \leq 0.05$; CV - Coefficient of variation water did not influence its consumption by the birds. Scottá et al. (2017) report that the use of salts, such as sodium chloride, in the water or diet, aims to minimize the stress caused by thermal discomfort, and high concentrations of sodium in the water can increase its consumption by birds (Barbosa et al., 2014). The increase in plasma sodium can stimulate the thirst center (Villanueva et al., 2015), but up to 6.0 dS m^{-1} this fact has not been externalized, demonstrating the tolerance of quails to the concentration of salts used in this experiment, and quail adaptation to high-temperature environments.

Higher concentrations of sodium in the feed or water can increase water consumption in quails kept under thermal stress (Barbosa et al., 2014), a fact that was not observed in the present study, where there were 12 hours at elevated temperature followed by 12 hours at mild temperatures in a lighted environment. Therefore, the increase in water consumption in response to thermal stress can be offset by reduction in water consumption at night, under milder thermal conditions. Under thermal stress, birds can increase their frequency of ingestion (Santos et al., 2017) without significant changes in their total consumption.

The different levels of salinity in the water did not affect egg weight and mass, and the conversion per mass and per dozen eggs, demonstrating that physiologically and metabolically the birds were able to regulate the sodium content in their body through ingestion, absorption and excretion (Alahgholi et al., 2014; Khalilipour et al., 2019; Abdelsattar et al., 2020). Lima et al. (2015) did not find an effect on these variables, when using different sodium concentrations in quail feed. Scottá et al. (2017) cite that the combined addition of potassium carbonate and sodium carbonate increased the egg laying rate and mass. Petrucci et al. (2017) observed a quadratic effect for egg laying rate and egg mass when working with sodium concentrations in the diet (0.05 to 0.30%), with best estimated concentration at 0.208% sodium.

The ambient temperature did not influence egg production, although at thermal stress temperature, egg weight and mass were lower, with a reduction of 0.41 g (3.3%) in weight; however, the weight was within the average for the species (Guimarães et al., 2014; Lima et al., 2015; Rodrigues et al., 2016; Petrucci et al., 2017). Heat stress increases blood pH and can cause respiratory alkalosis, resulting in lower calcium absorption and lower efficiency in its use (Ma et al., 2014; Akdemir et al., 2019), causing electrolyte and mineral imbalance and reducing egg quality. Vercese et al. (2012) and Lima et al. (2015) also observed no changes in the weight of eggs of quails kept under thermal stress.

There was a reduction of 0.56 g per bird per day (5.3%) in egg mass, for birds raised in the warm environment, where there was also less feed intake, and consequently, fewer nutrients were made available for egg formation.

Feed conversion per dozen eggs was lower at an elevated temperature, which is associated with lower feed intake, and consequently, less nutrient availability. Feed conversion per egg mass was similar between temperatures, where the reduction in feed intake of the birds under stress caused a reduction in egg weight and mass. Vercese et al. (2012) report that quails kept under a thermoneutral temperature (21 °C) and quails under the cyclical temperatures tested (27, 30, 33 and 36 °C each time) reduced feed conversion per dozen eggs. Quails can adapt to conditions of high daytime temperatures, as long as the environment is comfortable at night, a fact that occurs in most tropical regions.

There was effect of the interaction between the temperatures and the electrical conductivities of the water for the weight of the gizzard, while the weights of the heart and liver did not suffer any effects of the interaction or of the levels of water salinity and air temperatures (Table 2).

There was no effect of water electrical conductivities and air temperature on heart weight (average of 1.64 g) (Table 2). A higher concentration of salts can affect the acid-base balance of the body, increasing the concentration of salts in the bloodstream, which can elevate the heartbeat and affect heart weight, but this was not verified with water salinity of up to 6.0 dS m^{-1} in this study. Villanueva et al. (2015) observed no effect on heart weight in broilers consuming NaCl in feed or water. Barbosa et al. (2014) report reduced heart weight (average of 1.14 g) in European quails under thermal stress consuming water with different levels of electrolyte balance.

Water electrical conductivities and ambient temperatures did not influence the weight of the liver (average of 5.45 g) (Table 2). When sodium consumption exceeds the normal level, renin secretion decreases and stimulates the hormone angiotensin II, which stimulates the thirst center in the hypothalamus, causing a reduction in water reabsorption and increasing its excretion (Alahgholi et al., 2014). These reactions can be stimulated with the concentration of salts in the body and affect liver weight. At thermoneutral temperature, there was a higher feed intake, which stimulates the digestion and metabolism of nutrients, but this increase was not enough to alter the quail liver weight.

When decomposing the interaction between air temperature and water electrical conductivity on gizzard weight, it was found that except in 3.0 dS cm^{-1}, there are differences in quail gizzards weight between the two air temperatures, and at comfort temperature (24 °C) there was no effect of the electrical conductivity on the weight of this organ. In birds subjected to heat stress (32 °C), the weight of the gizzard increased linearly ($y = 2.77 + 0.12^{*}x$; $R^2 = 0.86$) with the increase in water salinity (Table 3).

Table 2. Effect of water electrical conductivities and air temperatures on the weight of Japanese quail organs in the production phase

Factors		Weight (g)		
		Heart	Liver	Gizzard
Salinity (dS m^{-1})	1.5	1.60	5.16	3.19
	3.0	1.63	5.64	3.02
	4.5	1.69	5.51	3.48
	6.0	1.65	5.51	3.41
Temperature (°C)	24	1.64 a	5.40 a	3.35 a
	32	1.64 a	5.50 a	3.20 a
CV (%)		10.66	10.82	6.49
p-value				
Salinity		0.6646	0.2407	0.0001
Temperature		0.9674	0.5655	0.0261
Salinity x temperature		0.8929	0.2228	0.0500

Means followed by different letters differ statistically from each other by the Tukey test at $p \leq 0.05$; CV - Coefficient of variation

Table 3. Interaction between air temperature and water electrical conductivity on the weight of Japanese quail gizzards

Temperature (°C)	Salinity (dS m^{-1})			
	1.5	3.0	4.5	6.0
24	3.36 a	3.06 a	3.62 a	3.34 b
32[1]	3.01 b	2.99 a	3.35 b	3.47 a

Means with different letters in the column differ between temperatures by the Tukey test at $p \leq 0.05$.; [1]y = 2.77 + 0.12*x ($R^2 = 0.86$); * - Significant by F test at $p \leq 0.05$

In the comfort environment, the weight of the gizzard was similar for the different electrical conductivities of water, and in birds under thermal stress there was a linear effect on the weight of the gizzard with the increase of electrical conductivity in the water. The best estimated response of gizzard weight (3.49 g) ocurred for water conductiviry of 6.0 dS m^{-1}. At the stress temperature, the feed intake was lower, which could provide longer food retention time in the digestive tract and interfere with the weight and size of the organs.

Barbosa et al. (2014) report lower values (2.57 g) for the weight of the gizzards of European quails when receiving water with different values of electrolyte balance. In studies with broiler chickens subjected to different NaCl supply routes, Villanueva et al. (2015) report the greatest weight of the gizzard when the supply was 100% in water. Gizzard weight can be reduced in birds raised under thermal stress temperatures (Barbosa et al., 2014), and it can be higher with the increase of food intake, when there is more mechanical work to break up the food and greater availability of nutrients for organ growth and maintenance.

Conclusions

1. Japanese quails in the production phase can consume water with electrical conductivities of up to 6.0 dS m^{-1} without having the production performance and morphometry of their organs affected.

2. Japanese quails can be raised at air temperatures up to 32 °C, for a period of up to 12 hours daily.

Acknowledgements

The authors would like to thank the Universidade Federal de Campina Grande and the Universidade Federal da Paraíba for their technical assistance, as well as Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for supporting this study.

Literature Cited

Abdelsattar, M. M.; Hussein, A. M. A.; Abd El-Ati, M. N.; Saleem, A. M. Impacts of saline water stress on livestock production: A review. International Journal of Agricultural Science, v.2, p.1-12, 2020. https://doi.org/10.21608/svuijas.2020.67635

Alahgholi, M.; Tabeidian, S. A.; Toghyani, M.; Fosoul, S. S. A. S. Effect of betaine as an osmolyte on broiler chickens exposed to different levels of water salinity. Archiv Tierzucht, v.57, p.1-12, 2014. https://doi.org/10.7482/0003-9438-57-004

Akdemir, F.; Köseman, A.; Şeker, I. Alchemilla vulgaris effects on egg production and quality expressed by heat stressed quail during the late laying period. South African Journal of Animal Science, v.49, p.857-868, 2019. https://doi.org/10.4314/sajas.v49i5.8

Ayers, R. S.; Westcot, D. W. Water quality for agriculture. Produced by: Agriculture and Consumer Protection, Food and Agriculture Organization of the United Nations (FAO). Irrigation and Drainage Paper. 1994.

Barbosa, L. R.; Silva, J. H. V. da; Givisiez, P. E. N.; Martins, T. D. D.; Saraiva, E. P.; Costa, F. G. P. P.; Macari, M. Influence of environmental temperature and electrolyte balance on the performance of quails Coturnix coturnix coturnix. Brazilian Journal of Poultry Science, v.16, p.249-256, 2014. https://doi.org/10.1590/1516-635x1603249-256

Castro, J. de O.; Yanangi Junior, T.; Ferraz, P. F. P.; Fassani, É. J. Japanese laying quails behavior under different temperatures. Energia na Agricultura, v.32, p.141-147, 2017. https://doi.org/10.17224/EnergAgric.2017v32n2p141-147

Guimarães, M. C. da C.; Furtado, D. A.; Nascimento, J. W. B. do; Tota, L. da C. A.; Silva, C. M. da; Lopes, K. B. de P. Efeito da estação do ano sobre o desempenho produtivo de codornas no semiárido paraibano. Revista Brasileira de Engenharia Agrícola e Ambiental, v.18, p.231-237, 2014. https://doi.org/10.1590/S1415-43662014000200015

Khalilipour, G.; Maheri, N. S.; Shadddel, A. T. Effects of saline drinking water on growth performance and mortality rate of japanese quails (*Coturnix coturnix* Japonica). Journal Agricultural National, v.22, p.942-947, 2019.

Lima, H. J. D.; Barreto, S. L. de T.; Paula, E. de; Dutra, D. R.; Costa, S. L. da; Abjaude, W. da S. Níveis de sódio na ração de codornas japonesas em postura. Revista Brasileira de Saúde e Produção Animal, v.16, p.73-81, 2015. https://doi.org/10.1590/S1519-99402015000100009

Lima, H. J. D.; Morais, M. V. M.; Barreto, S. L. de T. Sodium requirement of japanese laying quail Japanese laying quail. Research, Society and Development, v.9, p.1-4, 2020. https://doi.org/10.33448/rsd-v9i6.2486

Ma, X.; Lin, Y.; Zhang, H.; Chen, W.; Wang, S.; Ruan, D.; Jiang, Z. Heat stress impairs the nutritional metabolism and reduces the productivity of egg-laying ducks. Animal Reproduction Science, v.145, p.182-190, 2014. https://doi.org/10.1016/j.anireprosci.2014.01.002

Melo, D. F. de; Furtado, D. A.; Dantas Neto, J.; Matos, J. J. L. de; Leite, P. G.; Santos, R. T. dos. Composição físico-química de água de diferentes fontes utilizadas para consumo animal no semiárido brasileiro. Revista Espacios, v.38, p.28-35, 2017.

Nunes, K. C.; Garcia, R. G.; Nääs, I. A.; Santana, M. R. de; Caldara, F. R. Efeito da temperatura ambiente e energia na ração de codornas japonesas (*Coturnix coturnix* japonica). Enciclopédia Biosfera, v.10, p.829-836, 2014.

Petrucci, F. B.; Bonaparte, T. P.; Scottá, B. A.; Vargas Júnior, J. G. de; Vieira, D. de V. G.; Marin, J. F. V. Níveis de sódio na alimentação de codornas japonesas na fase de postura. Revista Verde de Agroecologia e Desenvolvimento Sustentável, v.12, p.338-342, 2017. https://doi.org/10.18378/rvads.v12i2.4391

Richards, L. A.; Allison, L. E; Bersnstein, L.; Bower, C. A.; Brown, J. W.; Fireman, M.; Hatcher, J. T.; Hayward, H. E.; Pearson, J. A.; Reeve, R. C.; Wilcox, L. V. Diagnosis and improvement of saline and alkali soils. Washington: USDA Agricultural Handbook, n.60, 1954. 160p.

Rodrigues, L. R.; Furtado, D. A.; Costa, F. G. P.; Nascimento, J. W. B. do; Cardoso, E. de A. Thermal comfort index, physiological variables and performance of quails fed with protein reduction. Revista Brasileira de Engenharia Agrícola e Ambiental, v.20, p.378-384, 2016. https://doi.org/10.1590/1807-1929/agriambi.v20n4p378-384

Rostagno, H. S.; Albino, L. F. T.; Donzele, J. L.; Gomes, P. C.; Oliveira, R. F. de; Lopes, D. C.; Ferreira, A. S.; Barreto, S. L. de T.; Euclides, R. F. Tabelas brasileiras para aves e suínos: Composição de alimentos e exigências nutricionais. 3.ed. Viçosa: UFV, 2011. 251p.

Santos, T. C. dos; Gates, R. S.; Tinôco, I. de F. F.; Zolnier, S.; Baêta, F. da C. Behavior of Japanese quail in different air velocities and air temperatures. Pesquisa Agropecuária Brasileira, v.52, p.344-354, 2017. https://doi.org/10.1590/s0100-204x2017000500008

SAS - Statistical Analyses System. Statistical Analysis System user's guide. Version 9.2. Cary: Statistical Analyses System Institute. 2008.

Scottá, B. A.; Bonaparte, T. P.; Vargas Júnior, J. G. de; Petrucci, F. B.; Vieira, D.; Vieira, G.; Marin, V.; Da, R.; Soares, N.; Francisco, J.; Pastore, S. M.; Ribeiro, T. Sodium and potassium at different levels of crude protein for laying quails. Revista Agrarian, v.10, p.76-83, 2017. https://doi.org/10.30612/agrarian.v10i35.4437

Silva, R. C.; Nascimento, J. W. B. do; Rodrigues, L. R.; Leite, P. G.; Sobrinho, T. G.; Furtado, D. A. Quality of quail eggs confined in thermoneutral environment and heat stress. Journal of Animal Behaviour and Biometeorology, v.5, p.139-143, 2017. https://doi.org/10.31893/2318-1265jabb.v5n4p139-143

Vercese, F.; Garcia, E. A.; Sartori, J. R.; Silva, A. de P.; Faitarone, A. B. G.; Berto, D. A.; Molino, A. de B.; Pelícia, K. Performance and egg quality of Japanese quails submitted to cyclic heat stress. Brazilian Journal of Poultry Science, v.14, p.37-41, 2012. https://doi.org/10.1590/S1516-635X2012000100007

Villanueva, A. P.; Cardinal, K. M.; Krabbe, E. L.; Penz Junior, A. M.; Ribeiro, A. M. L. Influence of the way of sodium chloride supplementation -water or feed- in broilers from one to seven days of age. Revista Brasileira de Saúde e Produção Animal, v.16, p.865-873, 2015. https://doi.org/10.1590/S1519-99402015000400010