Engenharia Agrícola

ISSN: 1809-4430 (on-line)
www.engenhariaagricola.org.br

Doi: http://dx.doi.org/10.1590/1809-4430-Eng.Agric.v38n4p504-509/2018

PRODUCTION AND QUALITY OF JAPANESE QUAIL EGGS SUBMITTED TO ENVIRONMENTS WITH DIFFERENT LIGHT SPECTRUMS

Dermeval A. Furtado[1*], José R. B. Braz[2], Jose W. B. do Nascimento[3], José P. Lopes Neto[3], Daniele L. Oliveira[3]

[1*]Corresponding author. Federal University of Campina Grande/ Campina Grande - PB, Brasil.
E-mail: araujodermeval@gmail.com

KEYWORDS

quail breeding, LED lamp, lighting technology.

ABSTRACT

The aim of this research was to evaluate the performance of Japanese quail (*Coturnix coturnix japonica*), with 94 (+49) days of age, through the production and quality of the eggs, with the birds kept in environments illuminated with LED lamps in the colors white, blue and red. The experimental design was a completely randomized design with three treatments (lamp colors) and seven replications. In the three environments, the relative air temperature averages can be considered above the thermal comfort zone for quails; however, the black globe temperature index, humidity and the thermal radiation load can be considered comfortable. The laying percentage of the birds kept under white LED was inferior to those maintained in the red LED. The feed intake, the feed conversion, the average weight and the egg quality were not affected by the different lamp colors (P <0.05) or by the climatic indexes that were within the average for the species, and these lamps could be used in the production of quail eggs.

INTRODUCTION

Two lines of quail are grown in Brazil, the *Coturnix coturnix japonica* and the *Coturnix coturnix coturnix*, for egg and meat production, respectively, and quail production is an activity that is expanding due to the animals' precocity, high productivity, small space requirement, low initial investment and quail resistance to heat and disease (Jácome et al., 2012; Guimarães et al., 2014; Sousa et al., 2014).

Due to energy costs, the poultry production systems are looking for technologies to rationalize energy use, such as the use of LEDs (light emitting diode), which can be used in poultry cutting and laying (Borille et al., 2013, Santana et al., 2014) and in quail production (Jácome et al., 2012, Molino et al., 2015). More efficient, cheaper and more durable lamps, such as LEDs, which can reduce energy consumption, are possible to adapt to the spectral sensitivity (vision) curve of the birds, providing adequate brightness and increased photoperiod, which for the egg production in quails should be, on average, from 14 to 17 hours of day^{-1} light, providing a greater production and adequate egg quality, as well as saving energy, reducing the cost of production (Jácome et al., 2012; Molino et al., 2015).

The high temperature of the air is harmful to laying birds due to the increase in mortality, loss of body condition, reduction of feed intake and quality and quantity of eggs produced (Umigi et al., 2012), elevation of rectal temperature, respiratory and cardiac frequency, compromising the performance of birds (Guimarães et al., 2014).The air temperature should be between 21 and 26°C and the relative air humidity between 65 and 70%, with the black globe temperature and humidity index (BGHI) from 69 to 77 (Vercese et al., 2012). In this sense, the research aim was to evaluate the productive performance and the quality of the quail eggs, as for the luminous effects using LED lamps in different color spectra.

MATERIAL AND METHODS

The research was carried out at the Laboratory of Rural Constructions and Ambience (LACRA) of the Federal University of Campina Grande, Campina Grande - PB. The municipality is in the geographical coordinates 07º 13' 50" S and 35º 52' 52" W at an altitude of 551m. The precipitation varies between 600 and 800 mm year^{-1} and the climate, according to Köppen, is As' type (tropical hot and humid with autumn-winter rains) according to AESA (2011).

[2] Federal University of Rio Grande do Norte/ Macaíba - RN, Brasil.
[3] Federal University of Campina Grande/ Campina Grande - PB, Brasil.
Received in: 4-27-2016
Accepted in: 6-15-2018

The experimental shed was built in masonry, covered with cement-sisal composite tiles and styrofoam lining, with an area of 7.30 m^2, divided into three environments (Figures 1a, b and c), illuminated with white LED lamps (G1), red (G2) and blue (G3), where each environment was illuminated with three lamps of 5 W power each. A digital portable digital luxmeter, THAL 300 model, Instrutherm manufacturer, with resolution of 1 lux and accuracy of ± 5%, whose measuring point was the front part of the cage, with a registered average value of 580 lumens, obtained the illuminance of each environment. The environment was cooled by an air conditioner of 2.640 W (9000 BTU).

A total of 387 quails of the *Coturnix coturnix japonica* line were used from the third week of age (posture stage) until the 143rd day (end of the research), housed in three battery cages (129 birds battery^{-1}), being called battery 1 (G1), battery 2 (G2) and battery 3 (G3), with each battery occupying an area of 1.80 m^2 (Figure 2a, b and c).

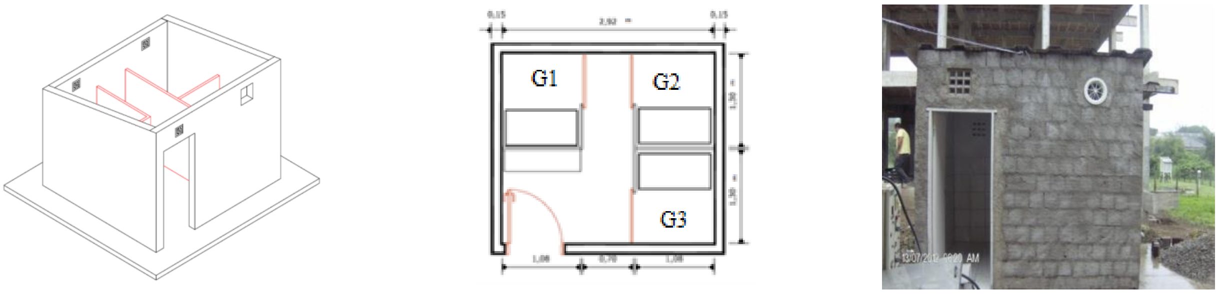

FIGURE 1. (a) Layout of the shed. (b) Ground floor of the shed. (c) External view of the shed.

The cages were of galvanized wire, each battery being composed of three cages, each one with capacity to shelter 43 birds. The cages were equipped with drinking fountains and feeders coupled of the zinc trough type and PVC (2.3 cm bird^{-1}). The cages presented dimensions 0.20 x 0.50 x 1m, had three divisions and creation density of 86 quails m^{-2}. The feed was distributed manually, twice a day at 8 a.m. and 4 p.m.

FIGURE 2. (a) Environment with white Led lighting. (b) Environment with red led lighting. (c) Environment with blue led lighting.

In the shed, the lighting system was connected to a timer in order to provide a daily program of 17 hours of light and 7 hours of darkness (17L: 7D), according to Molino et al. (2015). The air temperature and relative humidity inside the shed were collected every 30 min for 24 h throughout the experiment using HT 500 model sensors, Instrutherm, installed above each environment whose application range was -40 to 70 ºC ± 1 ºC and 0 to 100% ± 3% for air temperature and relative humidity, respectively.

The black globe temperature was also collected every 30 min for 24 h throughout the experiment using T-type thermocouples (copper-constantan) with measuring capacity of -270 to 400 ºC inserted in 38 mm diameter black globes previously calibrated and connected to a data acquisition system, CR-1000 model, Campbell Scientific manufacturer, managed by PC200 W software (freeware). For the measurement of the wind speed, an anemometer, THAL 300 model, from Instrutherm, with an application range of 0.4 to 30 m s^{-1}, positioned at a height equivalent to the center of mass of the birds at the measurements time. The Black Globe Temperature and Humidity Index (BGHI) was calculated according to Buffington et al. (1981) and the Radiant Heat Load (RHL) calculated according to the equation proposed by Esmay (1979).

Five laying cycles of 14 days each were performed and at the end of each cycle, the production characteristics and the egg quality parameters were evaluated, evaluating feed intake, feed conversion, posture percentage, average egg mass and, throughout the experimental period the specific gravity, Haugh unit, shell thickness, mass and percentage of albumen, mass and percentage of yolk and mass and shell percentage.

To determine the breaking strength of eggshell, a machine adapted for compression, TSG 70-140 model, was used, Zepellin manufacturer, connected to a datalogger, Spider 8.0 model, HBM manufacturer, managed by Catman software. The eggs were placed in the directions of their largest and smallest diameter, between the compression plates, and was triggered the compression mechanism that moved with the velocity of 2 mm min^{-1} (Figure 3).

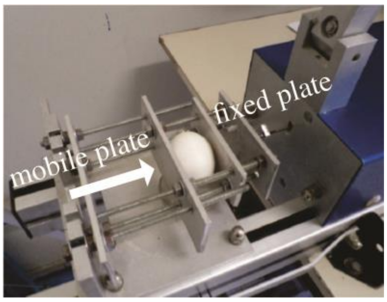

FIGURE 3. Egg compression test.

The experimental design was completely randomized (DCR), with three treatments (lamp colors) and seven replicates. The data were submitted to the STATISTICAL ANALYSIS SYSTEM (SAS, 1999) using the Tukey test (P<0.05) to compare the averages.

RESULTS AND DISCUSSION

In the three environments, the average air temperature was 26.7°C (± 1.9) and the relative air humidity was 71.5% (± 6.8), with no significant difference (P <0.05) between the environments (Table 1); these values can be considered above that recommended for the quails' thermal comfort zone (TCZ), which should be between 21 and 26°C and relative air humidity between 65 and 70%. Sousa et al. (2014) report that, for quails in the final stage of growth, the average temperatures of 26.7 and 25.6°C characterize the environment as comfort with 60% relative humidity. Vercese et al. (2012) point out that laying quails grown at temperatures above 27°C reduced feed intake, weight, egg production and mass. The quails kept at high temperatures may show a decrease in production, in the internal and external quality of the eggs, in addition to the resistance of the eggshell (Silva et al., 2012, Oliveira et al., 2014).

In relation to the BGHI, there was a statistical difference between the treatments (P <0.05), in which the red and blue LEDs showed no difference, but differed from the white LED treatment, which presented lower BGHI (Table 1), which have occurred due to the first two environments being on the west side of the shed, receiving more heat coming from the wall exposed by convection in the afternoon. Sousa et al. (2014) state that BGHI values between 75.3 and 75.8 are considered ideal for the final stage of quail breeding, so it is observed that the environment based on this BGHI can be considered comfortable.

TABLE 1. Average values and standard deviations (in parentheses) of room temperature (RT), relative humidity (RH), black globe temperature and humidity index (BGHI) and radiant heat load (RHL) in the different treatments.

	Environmental Parameters			
Treatments	**AT (°C)**	**RH (%)**	BGHI	**RHL (Wm^2)**
White Led	26.70 (±2.17)a	71.13 (±4.08)a	73.47 (±3.86)b	441.62 (±69.59)c
Red Led	26.83 (±2.21)a	71.77 (±3.76)a	75.93 (±3.34)a	470.73 (±95.12)b
Blue Led	26.62 (±2.17)a	71.77 (±3.76)a	75.93 (±3.34)a	474.74 (±95.12)a

Averages followed by same letter in column do not differ from each other by Tukey test (P<0.05).

The highest radiant heat load (RHL) was 474.74 W m^{-2} in the blue light environment (Table 1), differing statistically from the RHL values observed in the red light environments (470.73 W m^{-2}) and white (441.62 W m^{-2}), respectively, as the red and blue LED environments were in the west position of the shed, receiving more heat during the afternoon.

The feed intake was not statistically influenced (P> 0.05) by different light sources, within the normal range for the species (Table 2). Jácome et al. (2012) did not observe in quails created with different LED colors, in comparison to the incandescent lamp, significant differences (P> 0.05) in feed intake between treatments and the values cited by the authors are similar to those of this research. Santana et al. (2014) and Borille et al. (2013), did not find differences in the feed intake of broiler chickens and laying hens exposed to different LED colors, respectively, and concluded that birds can be kept in environments with different luminous spectra.

The feed conversion ranged from 401.39 g dz eggs^{-1} on the blue LED to 481.91 g dz. eggs^{-1} in the white LED, did not differ statistically (P> 0.05) between treatments; this conversion depends on the food intake, the nutritional levels of the feed and the environmental parameters. Guimarães et al. (2014) cite higher feed conversion values in the rainy season (440 g dz eggs^{-1}) in Japanese and European quails in the Paraiba semi-arid region compared to the dry season (400 g dz eggs^{-1}). The feed conversion values were higher than those reported by Umigi et al. (2012) using different levels of digestible threonine and Garcia et al. (2012), using millet in the feed composition, in experiments carried out in the south region of Brazil, both in the basal diet and in the different levels, being therefore the feed conversion dependent on the region's climate, ration, age and the genetic variability existing between the strains of quails grown in Brazil (Prioli et al., 2010).

TABLE 2. Average values and standard deviations (in parentheses) of feed intake, feed conversion, egg production and average egg mass throughout the trial period in different environments.

Treatments	**Feed intake (g animal^{-1} day^{-1})**	**Feed conversion (g dz. eggs^{-1})**	**Laying (%)**	**Mass (g)**
White Led	29.39 (± 0.47)a	481.91 (±67.4)a	78.00 (±4.48)b	13.17 (±0.48)a
Red Led	29.09 (±4.02)a	417.70 (±70.20)a	82.00 (±3.63)ab	12.99 (±0.48)a
Blue Led	29.08 (±4.80)a	401.39 (±69.01)a	86.00(±5.02)a	12.96 (±0.48)a
CV%	25.17	17.93	12.38	7.29

Averages followed by same letter in column do not differ from each other by Tukey test (P<P<0.05).

The percentage of laying (Table 2) in the white LED (78%) differed statistically (P <0.05) from the blue (86%), but was similar to that of the red LED (82%). Jácome et al. (2012) verified the influence of different artificial lighting colors on the quality of Japanese quail eggs, which the production of quail eggs kept in green and red LED environments was superior to the production of quail eggs exposed to incandescent lamps, which also has light color.

The lowest production of the birds maintained in environments with white LED in relation to blue may be due to the fact that such color interferes in the laying because of its greater luminous intensity, exteriorized by the lower values of RHL and consequently also lower values of the average radiant temperature.

During the experimental period, the average egg mass (Table 2) did not differ statistically (P> 0.05) among the different environments, remaining within the average for the species. Guimarães et al. (2014) cited Japanese egg quails as 10.6 g and 11.7 g in the European species, while Japanese had a higher production of eggs birds^{-1}. These values were similar to those cited by Jácome et al. (2012) and Umigi et al. (2012), but higher than those cited by Garcia et al. (2012), demonstrating once again the genetic variability among the quail lineages created in Brazil.

The quails in the different treatments were maintained under average temperatures of 26.7°C and the relative humidity of the average air of 71.5%, considered above the TCZ, but the feed intake, the feed conversion, the posture percentage and the average mass of the egg remained within the average, there was no negative effect of these climatic elements on production, corroborating with the BGHI values, which characterized the environment as comfortable. Vercese et al. (2012) pointed out that, in the case of laying quails created under different temperatures, a negative influence on the productive indices occurred at 27°C.

The specific gravity (SG) did not show statistical difference (P> 0.05) in any of the illuminations used (Table 3). Jácome et al. (2012) did not find significant difference in SG of quails created under different lighting systems, ranging from 1.074 to 1.080 g cm^{-3}, the values of this research being similar to those reported by Garcia et al. (2012), demonstrating that there are different lamp colors that do not interfere with this index.

The results of the Haugh unit are between 88.50 and 89.38; this unit is correlated with the egg mass and the egg white height, and the higher the value is the better will be the egg quality; therefore, the values can be considered good. These values were similar to those cited by Garcia et al. (2012), but below those cited by Jácome et al. (2012), which ranged from 91.17 (Orange Led) to 94.14 (White Led), even with birds being reared with the same feed and breeding system, facts that may alter this value.

TABLE 3. Average values and standard deviations (in parentheses) of specific gravity (SG), Haugh unit (HU) and shell thickness (ST) of Japanese quail eggs submitted to environments with LED lamps in different light spectra.

Treatments	SG (g ml^{-1})	H.U	ST (mm)
White Led	1.08 (±0.014)a	89.38 (±4.3)a	0.34 (±0.04)a
Red Led	1.07 (±0.013)a	89.15 (±4.3)a	0.33 (±0.04)a
Blue Led	1.07 (±0.013)a	88.50 (±4.2)a	0.34 (±0.04)a
CV%	1.27	4.80	11.48

Averages followed by same letter in column do not differ from each other by Tukey test (P<0.05).

There were no effects (P> 0.05) of LED colors on shell thickness (Table 3), which may not only vary depending on the type of feed and mineral levels, but also increase or decrease this thickness, such as the genetic variability between animals. In the egg weight parameter, the birds submitted to the three conditions of LED light spectra showed no significant difference between averages (P> 0.05), demonstrating the adaptive capacity of the birds to the light spectra that were submitted.

The variables mass and percentage of albumen, yolk and shell did not present statistical difference (P> 0.05) between the treatments (Table 4), and they are in agreement with the results found by Jácome et al. (2012), who using light programs with LED and incandescent bulbs in the production of Japanese quail eggs, found no significant difference between treatments for specific gravity and Haugh unit. The percentage of albumen, yolk and shell may be justified by the egg mass since there is a correlation between these values, which are close to the average, since the albumen mass represents about 56 to 61%, the yolk 27 to 32 % and the shell 8 to 11% of the egg weight (Ordóñez et al., 2005). The average pH values of yolk and albumen did not present significant difference (P> 0.05) between the different treatments, which were 6.9 (±0.29), 6.6 (±0.28) and 6.8 (±0.29) for the white, red and blue LEDS, respectively, presenting satisfactory values of fresh eggs, similar to those cited by Xavier et al. (2011).

TABLE 4. Average values and standard deviations (in parentheses) of egg mass (EM), mass and percentage of albumen (AM), mass and percentage of yolk (YM) and mass and percentage of peel (PM) of Japanese quails subjected to environments with LED lamps in different light spectra.

Treatments	EM (g)	AM (g)	Albumen (%)	YM (g)	Yolk (%)	PM (g)	PM (%)
White Led	12.87 (±0.99)a	8.13 (±1.14)a	63.17 (±2.38)a	3.64 (±0.4)a	28.28 (±3.2)a	1.10 (±0.31)a	8.54 (±1.31)a
Red Led	12.82 (±0.98)a	7.77 (±1.1)a	60.37 (±2.27)a	3.95 (±0.42)a	30.81 (±3.46)a	1.10 (±0.31)a	8.58 (±1.31)a
Blue Led	12.47 (±0.96)a	7.76 (±1.1)a	62.22 (±2.34)a	3.68 (±0.39)a	29.51 (±3.31)a	1.03 (±0.29)a	8.25 (±1.27)a
CV%	7.74	14.10	3.77	10.69	11.25	28.26	15.35

Averages followed by same letter do not differ from each other by Tukey test ($P<0.05$).

The average values of compressive strength of the egg shell in the longitudinal (CSSL) and transverse (CSST) were similar among the different treatments ($P> 0.05$), presenting for white 12.83 ±4.0 N, red 15.14 ±4.72 N and blue 13.20 ±4.12 N in the longitudinal direction. In the transverse direction of the egg, the force was 14.93 ±4.16 N in the white and red LEDs and 14.11 ±3.93 N in the blue LED. The breaking strength of the eggs depends on several properties, such as egg specific gravity, mass, volume, surface area, shell thickness and mass, and shell percentage (Silva et al., 2012).

The resistance to egg shell compression is of great importance to the egg-producing poultry sector because breaks and perforations are the main causes of economic loss. The eggshell can be broken due to the impact fracture that occurs due to the collision between eggs or the collecting machine and compressive fractures in the packaging process.

CONCLUSIONS

The environments illuminated with LED lamps showed the black globe temperature index, humidity and radiation thermal load within the range of thermal comfort. The laying percentage of the birds kept under white LED was lower than those maintained in the red LED, but the feed intake, the feed conversion, the average mass, the egg quality and the resistance in the longitudinal and transverse directions were not affected by the different lamp colors ($P <0.05$), nor by the climatic indices.

REFERENCES

AESA - Agência Executiva de Gestão das Águas do Estado da Paraíba (2011) Available in: http://www.aesa.pb.gov.br. Accessed: Mar 25, 2011.

Borille R, Garcia RG, Royer AFB, Santana MR, Colet S, Nããs IA, Caldara FR, Almeida Paz ICL, Rosa ES, Castilho VAR (2013) The use of light-emitting diodes (LED) in commercial layer production. Brasilian Journal of Brazilian Poultry, Campinas 15(2):135-140.

Buffington DE, Collazo Arocho A, Canton GH Pitt (1981) Black globe humidity comfort index (BGHI) as comfort equation for dairy cows. Transaction of the ASAE, St. Joseph 24(3):711-714.

Esmay ML (1979) Principles of animal environment. West Port, AVI Publishing, 325p.

Garcia AFQM, Murakami AE, Massuda EM, Urgnani FJ, Potença A, Duarte CR do A, Eyng C (2012) Milheto na alimentação de codornas japonesas. Revista Brasileira de Saúde e Produção Animal 13(1):150-159.

Guimarães MC da C, Furtado DA, Nascimento JWB do, Tota LCA, Silva CM da, Lopes KBP (2014) Efeito da estação do ano sobre o desempenho produtivo de codornas no semiárido paraibano. Revista Brasileira de Engenharia Agrícola e Ambiental 18(2):231-237.

Jácome IMTD, Borille R, Rossi LA, Rizzotto DW, Becker JA, Sampaio C de FR (2012) Desempenho produtivo de codornas alojadas em diferentes sistemas de iluminação artificial. Archives de Zootecnia 61(235):449-456.

Molino AB, Garcia EA, Santos GC, Vieira Filho JA, Baldo GAA, Almeida Paz ICL (2015) Photostimulation of Japanese quail. Poultry Science 94:156-161.

Oliveira DL, Nascimento JWB do, Nerandi L, Silva RC, Furtado DA, Araújo TGP (2014). Desempenho e qualidade de ovos de galinhas poedeiras criadas em gaiolas enriquecidas e ambiente controlado. Revista Brasileira de Engenharia Agrícola e Ambiental 18(11):1186-1191.

Ordóñez JA (2005) Ovos e produtos derivados. In: Ordónez JA. Tecnologia de alimentos. Alimentos de origem animal. Porto Alegre, Artmed, p269-279.

Prioli RA, Gasparino E, Soares MAM, Marques DS, Blanck SMA, Prioli SMA (2010) Diversidade genética entre três linhagens de codornas selecionadas para produção de ovos. Arquivo Brasileiro de Medicina Veterinária e Zootecnia 62(3):725-731.

Santana MR de, Garcia RG, Nããs IA, Paz ICLA, Caldara FR, Barreto B (2014) Light emitting diode (LED) use in artificial lighting for broiler chicken production. Engenharia Agrícola 34:422-427.

SAS INSTITUTE (1999) Statistical Analysis System. North Caroline, SAS/STAT User's Guide 8.0, p3365.

Silva RC, Nascimento JWB do, Oliveira DL, Camerini NL, Furtado DA (2012) Força de ruptura da casca do ovo em função das temperaturas da água e do ambiente. Revista Educação Agrícola Superior 27(1):13-18.

Sousa MS, Tinôco IFF, Barreto SL de T, Amaral AG do, Pires LC, Ferreira AS (2014) Determinação de limites superiores da zona de conforto térmico para codornas de corte aclimatizadas no Brasil de 22 a 35 dias de idade. Revista Brasileira de Saúde e Produção Animal 15(2):350-360.

Umigi RT, Barreto SLT, Reis RS, Mesquita Filho RM, Araújo MS (2012) Níveis de treonina digestível para codornas japonesas na fase de produção. Arquivo Brasileiro de Medicina Veterinária e Zootecnia 64(3):658-664.

Vercese F, Garcia EA, Sartori Júnior, Pontes Silva A de P, Faitarone ABG, Berto DA, Molino A de B, Pelícia K (2012) Performance and egg quality of Japanese quails submitted to cyclic eat stress. Brazilian Journal of Poultry Science 14(1):37-41.

Xavier IMC, Cançado SV, Figueiredo TC, Lara LJC, Lana AMQ, Souza MR, Baião NC (2011) Qualidade de ovos submetidos a diferentes condições de armazenamento. Arquivo Brasileiro de Medicina Veterinária e Zootecnia 63(3):712-720.