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Effect of Led Lighting Colors for Laying Japanese Quails

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ABSTRACT

Time of exposure and light intensity rearing house may affect the performance and egg quality of laying quails. This research aimed at evaluating the live performance, egg quality, biometry of the reproductive system, and the gastrointestinal tract of Japanese quails (*Coturnix coturnix japonica)* exposed to artificial light-emitting diodes (LED) of different colors in comparison with fluorescent lamps. A total of 240 Japanese quails were distributed in completely randomized experimental design with four treatments (fluorescent lamp, and green, red, or blue LED lamps) with six replicates of 10 birds each. Average egg weight and eggshell thickness were different ($p<0.05$) when LED bulbs were compared with fluorescent lamps. The egg weight of the birds exposed to the red LED was similar to those under a fluorescent lamp ($p>0.05$). The oviduct of 64-d-old hens exposed to green LED lighting was shorter ($p<0.05$) than those exposed to the fluorescent lamp. Red LED can be used to replace the fluorescent lamps, as they promote the same live performance, egg quality, and morphological development of the reproductive tract of laying Japanese quails.

INTRODUCTION

Japanese quails are easily adapted to rearing conditions with adverse climates, and present rapid growth, early sexual maturity (42 days of age), high egg production, low feed intake, and high resistance to diseases. However, current literature still has little information on the nutritional requirements, ideal weight gain during each rearing phase, lighting program, and management (Molino *et al.,* 2015) of Japanese quails.

The application of adequate lighting programs is essential for egg production, as the light stimulus directly influences the physiological responses of the bird. Light stimulates the release of reproductive hormones, may accelerate or delay sexual maturation, and stimulate egg laying (Freitas *et al.,* 2005). Ambient lighting technology has made considerable progress in recent years, and the adequacy of the lighting system in terms of better cost-benefit ratios, should be taken into account when choosing the light source for laying quails during the egg-production stage. Light emitting diode (LED) lamps provide lower energy consumption and longer lifetime than conventional incandescent and fluorescent lamps, and may be a viable lighting alternative for the poultry industry (Gongruttananun, 2011).

Studies have shown that laying chickens exposed to white light produce heavier eggs with better eggshell quality than those exposed to green light (Er *et al.,* 2007). On the other hand, Borille *et al.* (2013) did not find any differences in the egg quality of layers exposed to different LED colors. These differences indicate the need of further studies to identify the effect of LED colors on the production and quality of Japanese quail (*Coturnix coturnix japonica*) eggs. Investigation of the possible impact of the type (fluorescent and LED) and light color (green, blue, and red) on the development of the reproductive tract and gastrointestinal tract of birds is also needed.

This study evaluated the live performance, egg quality, and development of the reproductive and gastrointestinal tracts of Japanese quails (*Coturnix coturnix japonica*) exposed to light emitting diode (LED) lamps of different colors or fluorescent lamps.

MATERIAL AND METHODS

The experimental protocol applied in the present experiment was approved by the Ethics Committee on Animal Use - CEUA (Protocol No. 031/2014), of the School of Agricultural Sciences of Dourados, Federal University of Grande Dourados (UFGD), Brazil.

Management and rearing conditions

The experiment was conducted in the sector of poultry layers of the School of Agricultural Sciences, Federal University of Grande Dourados (UFGD) state of Mato Grosso do Sul, Brazil. The climate is classified as Cwa (humid mesothermal), with rainy summers and dry winters, according to Köppen's classification.

During the rearing and development phases, birds were reared in floor pens, provided with wood-shavings litter, tube feeders, and nipple drinkers. Infrared lamps in hoods were used for brooding, maintaining the ambient temperature at 32 °C. At 38 days of age (pre-laying phase), the birds were transferred to galvanized wire cages. Each cage was divided in four 32x33x17-cm partitions, each equipped with nipple drinkers, and trough feeders connected to the cages, with one feeder for each experimental unit. Water and feed were supplied *ad libitum*. Feed was supplied twice daily, in the morning and in the afternoon. The experimental diets were based on corn and soybean meal and formulated according to the nutritional requirements for laying Japanese quails proposed by Rostagno *et al.* (2011).

A lighting program of 17 hours of light per day (12 h of natural daylight + 5 h of artificial light) was used. During the rearing, development, and pre-laying phases, birds were kept under natural light. When birds were 50 days old, flock uniformity was checked, and birds with similar body weight were subjected to the light program sources according with the treatments.

The poultry house was divided vertically and horizontally with black plywood boards to avoid interference and reflection of the different sources of light tested. The lights were arranged in front of the cages, according to the luminance requirement of laying Japanese quails (20 lx) Murakami & Ariki (1998). The amount of light available at height of the head of the birds was measured using a digital light meter at various parts of the cages.

Experimental design and treatments

A total of 240 50-d-old Japanese quails (*Coturnix coturnix japonica*) were distributed in a completely randomized experimental design, consisting of four treatments (fluorescent lamp, and green, red, or blue LED lamps), with six replicates of 10 birds each (experimental unit).

Live performance

The performance parameters feed intake, egg production and feed conversion ratio (kg/kg and kg/dz) were evaluated. The experiment was divided into four cycles of 21 days each, and evaluations were carried out on the 21st day of each cycle. The egg production of each experimental unit was recorded daily. Feed intake was determined as the difference between the amount of feed offered on the first and the amount of feed residues in the feeders on last day of each cycle per experimental unit.

Feed conversion ratio (kg/kg, kg/dz) was calculated by dividing feed intake (kg) by total egg weight (kg) and by the number of eggs produced (dz), respectively, per experimental unit.

Egg quality

Egg quality was evaluated in eggs produced during the last three days of each experimental cycle. Six eggs per experimental unit were collected to determine average egg weight; Haugh units; yolk index;albumen, yolk and eggshell percentages; and eggshell thickness were determined. Average egg weight was calculated by dividing total egg weight by the number of eggs laid per experimental unit. A random sample of three eggs per experimental unit was selected then and individually weighed in semi-analytical scale (± 0.001g), and broken on a flat glass plate. Albumen and yolk height was measured with the aid of a digital caliper.

Haugh units were determined using albumen height and egg weight data, according to the following equation (Eq. 1) (Nesheim *et al.,* 1979)

$$UH = 100 \times \log (H - 1.7P^{0.37} + 7.57) \qquad \text{Eq. 1}$$

Where: UH= Haugh unit; H = albumen height (mm); P=egg weight (g)

Subsequently, yolk diameter was measured with the aid of a caliper (precision of ± 0.01 mm) to allow the calculation of the yolk index (yolk height/yolk diameter).

Three eggs per experimental unit were used to determine the percentage of egg components (albumen, yolk, and eggshell). The eggs were identified, broken, and the albumen, yolk, and eggshell were separated. Each component was individually placed in nontoxic polystyrene containers and weighed to determine their weight relative to total egg weight, expressed as percentage of egg weight. Eggshells with the egg membrane were washed under running water, dried at room temperature for 48 hours, and then weighed in a semi-analytical scale (precision of ± 0.001g). Their weight relative to total egg weight was calculated and their results expressed as percentages. Eggshell thickness was calculated as the average of three measurements made three different points of the egg equator with the aid of a digital caliper.

Biometrics of the reproductive and gastrointestinal tract

Six birds per treatment, with body close to the average body weight of the experimental unit, were selected at 57 and 64 days of age. Birds were stunned, sacrificed by cervical dislocation, and the organs of their reproductive and gastrointestinal (GIT) tracts were removed. The reproductive tract parameters evaluated were ovary weight relative to body weight and oviduct length. As to GIT parameters, the relative weights of of the proventriculus, gizzard, small intestine, large intestine, pancreas, and liver relative to live body weight at slaughter, and small intestine length were determined.

Statistics analysis

Data were submitted to analysis of variance (ANOVA). , and means were compared by The test of Dunnett test at 5% probability level was used to compare the of the results obtained with LED lamps with those obtained with the fluorescent lamps. The test of Scott-Knott test was applied to analyze the impact of the different LED colors. Statistical analysis were carried out using the statistical program ASSISTAT (Silva, 2012).

RESULTS AND DISCUSSION

Changes in light intensity, color, and duration can influence the performance, egg quality, and behavior of poultry (Gongruttananun & Guntapa, 2012).

In the present study, the applied treatments did not influence ($p>0.05$) the parameters egg production, feed intake, or feed conversion ratio (kg/kg and kg/dz), as shown in Table 1. These results are consistent with those obtained by Jácome *et al.* (2012) and Huber-Eicher *et al.* (2013), who did not find any differences in the performance of Japanese quails and laying chickens, respectively, exposed to different LED light colors. On the other hand, Borille *et al.* (2013) observed that laying chickens presented better egg production when exposed to red LED, white LED, and incandescent light sources.

Table 1 – Mean values of the variables performance of Japanese quails exposed to different LED colors and fluorescent light.

Light source	Egg production (%)	Feed consumption (g/bird/day)	Feed conversion (kg/kg)	Feed conversion (kg/dz)
Green LED	72.92	20.93	2.000	0.240
Red LED	71.87	20.19	2.010	0.223
Blue LED	73.91	20.93	2.039	0.238
Green LED	73.54	20.05	1.905	0.209
p-value (Dunnett test)	0.902	0.448	0.472	0.116
p-value (Scott Knott test)	0.774	0.452	0.356	0.181
StE	0.959	0.243	0.031	0.523

Probability= 95%. StE= standard error.

The production and the behavior of birds can be affected by many factors related to light (photoperiod, wavelength, light intensity). However, these responses depend on the photoreception of the retina, because the reproductive responses are influenced by the perception of light by the hypothalamus. In the present study, egg production was apparently not affected by light wavelength (Lewis & Morris, 2000).

According Blatchford *et al.* (2012), photons with longer wavelengths wavelengths tend to stimulate the locomotor activity of broilers, and influence their live performance by stimulating feed intake. However, in the present study, the evaluated light sources provided sufficient illumination to the birds, and did not affect their live performance.

The egg-quality parameters Haugh units, yolk index, and percentage of egg components were no influenced ($p>0.05$) by evaluated light sources and colors. On the other hand, average egg weight and eggshell thickness were different when light sources were compared (LED lights *vs*. fluorescent lamps) (Table 2). The average weight for the eggs of Japanese quails exposed to green and blue LED lamps was lower compared with those reared under the fluorescent lamp (Table 2).

Table 2 – Mean values of the index of egg quality from Japanese quails exposed to a different color of LED light and fluorescent lamps.

Light	Egg weight (g)	Haugh unit	Egg yolk (mm)	Eggshell (mm)	Albumen (%)	Egg yolk (%)	Eggshell (%)
Fluorescent	9.85	94.62	0.446	0.139	55.23	29.19	15.55
Green LED	9.33*	95.85	0.458	0.138b	56.89	28.82	14.29
Red LED	9.61	94.98	0.458	0.143a	55.88	29.47	14.72
Blue LED	9.30*	94.99	0.456	0.144a*	56.27	28.29	15.43
p-value (Dunnett test)	0.014	0.141	0.319	0.005	0.055	0.196	0.078
p-value (Scott Knott test)	0.157	0.129	0.910	0.001	0.279	0.172	0.152
StE	0.074	0.194	0.003	0.001	0.226	0.205	0.203

*Means differ (p<0.05) by the Dunnett test about the fluorescent lamp. Means in the same column followed by letters differ between themselves by the Scott Knott test (p<0,05). StE= standard error.

However, egg weight of birds exposed to red LED was similar to that obtained with fluorescent lamp. Er *et al.* (2007) found that the eggs of laying chickens exposed to red LED lamps were lighter than those reared under the incandescent lamp. On the other hand, Jácome *et al.* (2012) and Borille *et al.* (2013) did not find any egg weight differences among Japanese quails exposed to different light sources and colors.

When chickens are exposed to light colors produced at the end of the spectrum, such as orange and red, they respond by producing a larger amount of reproductive hormones. The photons with longer wavelengths (red above 700 nm) have thousand times greater penetration power to reach the transcranial area than the shortest wavelength (400 nm), therefore stimulating higher production of reproductive hormones than shorter wavelengths (Blatchford *et al.,* 2012). This suggests that egg quality can be influenced by the spectrum emitted by the light source, and that some light colors may have stronger influence than others due to the wavelengths they emit(Nicholls *et al.,* 1988). Therefore, the positive influence of the red LED source on egg weight observed in the present study may be attributed to the the stimulation of the release of FSH and LH (Mobarkey *et al.,* 2010).

The eggshell of the Japanese quails exposed to red and blue LED light sources was thicker than that of the those exposed to the green LED source (Table 2). However, green and red LED sources promoted similar eggshell thickness (p<0.05) as fluorescent lamps. These results are different from the findings of Er *et al.* (2007), who observed thicker eggshells in laying chickens reared under green LED light source. Although literature reports that some factors, such as hen age (Morita *et al.,* 2010) and rearing environment temperature and humidity, influence eggshell thickness, information on the influence of artificial light on the eggshell quality is scarce.

The biometric parameters of the reproductive system measured when birds were 57 days old were not different (p>0.05) among light sources (Table 3). Possibly, there was no effect of light source due to the short time of exposure of the birds to the treatments.

Table 3 – Mean values referent to biometrics of the reproductive system of Japanese quails exposed to different light sources at 57 days of age.

Light source	Weight of quail (g)	Oviduct weight (%)	Ovary weight (%)	Oviduct length (cm)
Green LED	156.33	3.547	2.638	26.25
Red LED	151.70	3.729	2.787	26.55
Blue LED	163.20	5.917	2.574	24.72
Green LED	158.29	4.939	2.610	20.25
p-value (Dunnett test)	0.6491	0.4162	0.9727	0.5756
p-value (Scott Knott test)	0.6491	0.4162	0.9727	0.5756
StE	3.030	0.351	0.155	0.485

The probability of 95%. StE= standard error.

However, when birds were 64 days old, differences (p<0.05) in oviduct length were detected. Birds exposed to green LED presented shorted oviducts when compared with those exposed to the fluorescent lamp. Furthermore, when LED colors were compared, the oviduct of birds exposed to red and blue LED were longer than of those exposed to green LED (Table 4).

According to Lewis & Morris (2000), the infiltration of the red wavelength radiation in the hypothalamus promotes stronger stimulation of the production of sexual hormones relative to green and blue wavelengths. This may explain the longer oviducts of the Japanese quails exposed to the red LED source and the fluorescent lamp, compared with the green LED source in the present study. Hassan *et al.* (2013) observed that laying chickens exposed to red LED light presented heavier ovaries compared with those exposed to green and blue LED lights. These results suggest that long wavelengths stimulate retinal photoreceptors, influencing the pituitary gland and the brain, which consequently stimulate the secretion of the gonadotropin-releasing hormone, increasing the secretion of the follicle stimulating hormone (FSH) and of the luteinizing hormone (LH). The longer ovaries determined in the present experiment may explain the changes in the development of the reproductive tract of birds exposed to the red LED source.

Table 4 – Mean values referent to the biometrics of the reproductive system of Japanese quails exposed the different light source at 64 days old.

Light source	Weight of bird (g)	Weight oviduct (%)	Weight of ovary (%)	Length of oviduct (cm)
Green LED	160.88	4.020	2.327	31.27
Red LED	151.20	4.672	2.299	24.60b*
Blue LED	148.53	4.135	3.860	30.60a
Green LED	144.77	4.514	2.792	33.27a
p-value (Dunnett test)	0.3989	0.7599	0.3357	0.0056
p-value (Scott Knott test)	0.3989	0.7599	0.3357	0.0002
StE	3.351	0.230	0.286	1.047

*Mean differ by the Dunnett test (p<0.05) for the fluorescent lamp. Means in the same column followed by letter differ among themselves by the Scott Knott test (p<0.05). StE=standard error.

Each organ of the gastrointestinal tract (GIT) has its own function, such as nutrient catabolism, metabolism, digestion and/or absorption. Factors, such as nutrition, management, and health status may affect the development of the GIT organs. In the present trial, GIT organ weights determined on days 57 and 64 (Tables 5 and 6) were not influenced by the exposure to different LED colors and fluorescent lamps (p> 0.05). As there are no literature reports on the correlation of LED colors with the development of the GIT of Japanese quails, it is not possible to compare the results of the present study. However, our results are in agreement with Rodenburg & Middelkoop (2004), who determined that light source exerted no effect on broiler body weight. Likewise, Sagheer *et al.* (2004) found no weight differences in carcass, internal organs, head, neck, femur, wings and abdominal fat among different types of lighting. In a study with broilers, Ahmad *et al.* (2014) reported that light color did not impact liver, heart, gizzard, or intestine weights of broilers; however, the intestines of birds exposed to white LED were heavier than those exposed to fluorescent, incandescent and compact fluorescent lamps.

Table 5 – Mean values of the biometrics values of gastrointestinal tract of Japanese quails exposed to different sources of light at 57 days old.

Light source	Gizzard	Proventriculus	Liver	Pancreas	Small intestine	Large intestine	Small intestine (cm)
	(%)						
Green LED	2.116	0.430	4.357	0.342	2.487	1.018	46.32
Red LED	2.136	0.422	4.155	0.342	3.162	1.195	48.80
Blue LED	1.976	0.416	2.870	0.308	2.245	1.075	46.80
Green LED	1.927	0.364	5.014	0.292	2.599	0.693	47.80
p-value (Dunnett test)	0.4433	0.2941	0.0990	0.2798	0.4601	0.2188	0.5561
p-value (Scott Knott test)	0.4433	0.2941	0.0990	0.2798	0.4601	0.2188	0.5561
StE	0.052	0.013	0.171	0.011	0.102	0.059	0.628

Probability of 95%. StE=standard error.

Table 6 – Mean values of the biometrics of the gastric and intestine of Japanese quails exposed to different LED light colors at 64 days old.

Light source	Gizzard	Proventriculus	Liver	Pancreas	Small intestine	Large intestine	Length of the small intestine (cm)
	(%)						
Green LED	1.933	0.375	3.516	0.276	2.006	0.790	49.27
Red LED	2.008	0.387	4.079	0.192	2.435	0.885	45.75
Blue LED	2.010	0.286	3.550	0.275	2.123	0.678	33.42
Green LED	2.139	0.445	3.786	0.282	2.378	1.016	49.10
p-value (Dunnett test)	0.5754	0.2731	0.347	0.2642	0.1964	0.3683	0.2419
p-value (Scott Knott test)	0.5754	0.2731	0.347	0.2642	0.1964	0.3683	0.2419
StE	0.050	0.014	0.121	0.007	0.082	0.039	1.069

No letters mean that values did not differ when using the applied tests (p>0.05). StE=standard error.

CONCLUSION

The live performance, egg quality, and reproductive and gastrointestinal tract parameters of Japanese quails exposed to red LED source were similar to those exposed to fluorescent lamp. Therefore, fluorescent lamps may be replaced by LED light sources, which are efficient and sustainable light source alternatives for lighting laying Japanese quail housing facilities .

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