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Influence of red and white led lamps on the productive performance and egg quality of commercial laying hens

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ABSTRACT. This study aimed to evaluate the effectiveness of different LED lamp colors (red and white) on the productive performance and egg quality of light laying hens. A total of 144 birds of the commercial strain Hy-Line® W-36 aged 44 weeks were distributed in a completely randomized design with two treatments (red and white LEDs) and 12 replicates, totaling 24 experimental plots with six birds each. Treatment means were compared by the F Test (5% probability) on the statistical software SISVAR. This study found that laying hens under red LED lamps showed a trend of greater egg production bird^{-1} day^{-1} (%) ($p = 0.084$), average egg weight (g) ($p = 0.0826$), egg mass ($p < 0.05$), and shell thickness (mm) and height (mm) ($p < 0.01$), whereas birds under white LED light showed better yolk color ($p < 0.05$). It is concluded that red LED illumination increases egg production and quality in light laying hens.

Keywords: light stimulus; egg mass; light laying hens; rgg quality.

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Introduction

Brazil produced 52.44 billion eggs in 2023, 99.00% of which was consumed by the domestic market and about 1,00% were destined for export. Such data show the importance of egg production for the national economy and feeding the population since the per capita consumption of eggs totaled 242 eggs per Brazilian in 2023. Nevertheless, consumption exceeds the world average: 230 eggs per inhabitant/year (*Associação Brasileira de Proteína Animal* [ABPA], 2024).

Artificial lighting serves to manage laying poultry since their physiological processes respond to light stimuli. Thus, artificial lighting has been widely used in poultry breeding systems to increase production (Er, Wang, Cao, & Chen, 2007). Open sheds prevail in Brazil due to their lower need for daily artificial lighting, but birds still require photostimulation.

In total, four basic light aspects can affect birds: intensity, photoperiod (duration), spectral content (color), and source (Gongruttananun & Guntapa, 2012). Birds identify light by their retina and extraretinal photoreceptors. The light these photoreceptors (pineal and hypothalamic glands) perceive ensures their sexual development and reproductive success (Raziq, Hussain, Mahmud, & Javed, 2020). However, extraretinal photoreceptors can only be activated by the long-wavelength radiation that can penetrate their skull and head tissues (Raziq et al., 2020).

Studies that can contribute to improving egg production are necessary to increase laying hen efficiency and production rates. Thus, studying and evaluating differently colored LED lights in these animals has aroused researchers and producers' interest and curiosity. Common light bulbs have gradually given way to modern, economical, and efficient light-emitting diodes (LEDs).

Although commonly used as artificial lighting in poultry sheds, incandescent lamps consume more energy and produce intense heat, whereas LED lamps emit cold light and offer an economical and viable option due to their great lighting efficiency (Cervi, Pappis, Marchesan, Campos, & Prado, 2005). LED light bulbs consume less energy and have a longer lifespan than conventional and fluorescent incandescent bulbs, making them a viable alternative for the poultry industry (Gongruttananun, 2011).

The reproductive performance of domestic birds depends highly on adequate light control, which involves amount (duration and intensity), color (or wavelength), and spectral frequency (Gongruttananun & Guntapa, 2012). The ideal lighting program would provide maximum production with minimum consumption of feed and electricity (Freitas, Cotta, Oliveira, Murgas, & Gewehr, 2010). Moreover, the appropriate provision of a light regime can anticipate or delay laying onset, influence laying rates and alter their intervals, improve shell quality, optimize egg size, and maximize feed efficiency (Etches, 1996).

Borille et al. (2013) evaluated LED and incandescent lamps of five colors, finding superior results for red, white, and incandescent lamps than for green, yellow, and blue bulbs. Lewis and Morris (2000) suggested that this may be related to red wavelength radiation penetrating the hypothalamus and offering greater stimuli. Thus, this study aimed to evaluate the influence of red and white LED lamps on production and egg internal and external quality in commercial laying hens of the Hy-Line W-36® strain.

Material and methods

The experiment was conducted at the Instituto Federal Minas Gerais Poultry Sector – IFMG Campus Bambuí – from September to December 2021 for 84 days (four 21-day periods) across 12 weeks.

A total of 144 birds of the commercial strain Hy-Line W-36® that were aged 48 weeks were used and distributed in a completely randomized design with two treatments (red and white LEDs) and 12 replicates, totaling 24 experimental plots with six birds each. The experimental protocol was approved by the IFMG Ethics Committee on the Use of Animals in Experimentation – CEUA – under protocol number 05/2020.

The birds were housed in a shed with ceramic tiles in 24 metal cages (50 cm wide and 45 cm deep) with six birds per cage and a housing density of 375 cm^2 per bird. Each experimental unit was composed of one cage, all of which contained trough-type metal feeders and nipple-type drinkers.

An all-white plastic tarpaulin was used to insulate the birds from external illumination, blocking 100% of it during the experiment. On one side of the shed, the birds were illuminated with Red LED light (aisle) and on the other side with White LED light (side of the shed).

Daily management consisted of collecting and counting eggs (the number of broken, cracked, fecal, blood-stained, double-yolked, soft-shelled, and shell-less eggs were computed daily).

Water was supplied *ad libitum* and an isonutritive diet was used in all treatments following the Hy Line W-36 strain manual recommendations (Table 1).

Egg laying and quality were evaluated in four production cycles (21 days each), totaling 84 experimental days. At the end of the research, the average of the four evaluated production cycles was calculated, resulting in a single variable for analysis.

Treatments were set as follows:

- Use of a FOXLUZ red LED lamp with a wavelength of 640 nm, a power of 7 W, three lighting points in the shed, a linear distance between lamps of six meters, and an installation height of 2.26 m from the floor (distance between the floor and the bases of the 50 cm cages);
- Use of a PHILIPS cold white light LED bulb with a wavelength of 540 nm, a power of 7 W and 560 lumens, three lighting points in the house, a linear distance between lamps of 5.90 m and, an installation height of 2.10 m from the floor (distance between the floor and the bases of the 50 cm cages).

The following analyses were performed to control productive performance: egg production and loss (%), poultry viability (%), feed intake (g), average egg weight (g) and mass (g), and feed conversion (per kg and dozen).

The following analyses were performed to determine the internal and external quality of the laid egg: egg weight (g); specific gravity (g cm^{-3}); shell thickness (mm); albumen height (mm); yolk height and diameter (mm); Haugh unit (HU); yolk, shell, and albumen percentages (%) and weight (g); and yolk color.

The temperature and relative humidity inside the shed were recorded daily by an HT-70 Instruterm datalogger that was installed at the height of the birds in each treatment and set to record every 30 min. The mean temperature and relative humidity equaled 24.91°C and 70.16% and 25.38°C and 70.47% for the red and white LED treatments, respectively.

Table 1. Calculated formula and nutritional composition of the experimental diet administered to commercial laying hens of the Hy-Line W-36® strain aged from 44 to 59 weeks.

Ingredients	Ingredient Amount (kg)
Ground corn kernels	57.865
Soybean meal	27.600
Degummed soybean oil	2.500
Fine Limestone	2.500
Thick Limestone	4.500
DL- methionine (98%)	0.035
Compound feed for Layer hens[1]	5.000
Total	100.000
Calculated Nutritional Analysis	
Nutrients (%)	Value
AME (kcal kg^{-1})[2]	2.816.3
Crude Protein (%)	17.2964
Crude Fiber (%)	2.2257
Ether Extract (%)	5.1622
Total Methionine	0.4099
Methionine + Total Cystine (%)	0.6972
Total Lysine (%)	0.9544
Total Tryptophan (%)	0.2083
Total Threonine (%)	0.6662
Total Isoleucine (%)	0.7602
Poultry Digestible Lysine (%)	0.8309
Poultry Digestible Methionine (%)	0.3910
Poultry Digestible Tryptophan (%)	0.1978
Digestible Poultry Threonine (%)	0.5910
Sodium (Na) (mg kg^{-1})	2,204.4
Calcium (%)	4.0994
Total phosphorus (%)	0.7636
Available phosphorus (%)	0.5315

[1]Ensured levels per kg of the product core forlayer hens: Calcium (maximum): 280 g, Calcium (minimum): 240 g, Phosphorus (min.): 30 g, Sodium (min.): 25 g, Methionine (min.): 16 g, Choline (min.): 6,000 mg, Vitamin A (min): 200,000 IU, Vitamin D3 (min): 50,000 IU, Vitamin E (min): 150 IU, Vitamin K3 (min.): 50 mg, Vitamin B1 (min.): 50 mg, Vitamin B2 (min.): 130 mg, Vitamin B6 (min.): 40 mcg, Vitamin B12 (min.): 360 mcg, Calcium Pantothenate (min.): 180 mg, Niacin (min.): 400 mg, Biotin (min.): 2 mg, Folic Acid (min.): 20 mg, Iron (min.): 1,000 mg, Copper (min.): 600 mg, Cobalt (min.): 5 mg, Iodine (min.): 20 mg, Manganese (min.): 1,400 mg, Zinc (min.): 1,200 mg, Selenium (min.): 4 mg, Phytase: 10,000 FTU, BHT: 100 mg. [2]Apparent Metabolizable Energy.

The lighting program was carried out following the recommendations of the Hy- Line W- 36® strand manual (16 hours of daylight – natural + artificial light). Light intensity was measured at the upper height of each cage corresponding to the experimental plot by a UNITY 1001U lux meter (Measuring Test Instruments). The device was aimed toward the lamp on two sides and that with the highest luminous intensity (lux) was chosen. The mean light intensity measurement of the Red LED light treatment totaled 12 Lux (ranging from 6 to 26 lux) and the mean light intensity measurement of the White LED light, 18.41 Lux (ranging from 9 to 45 lux).

To weigh the eggs, all intact eggs from each plot were collected. Broken, cracked, shelled, and yolkless eggs were recorded and discarded. All intact eggs in each plot were weighed on a Marte BL3200H scale with a precision of e = 0.1 g and a maximum capacity of 3,200 kg. The average weight for each plot was then calculated.

Data were subjected to the Shapiro-Wilk normality test and to analysis of variance (ANOVA). The $\sqrt{x+1}$ variable transformation was used in case of abnormalities. Treatment means were compared by the F Test (5% probability) on the statistical software SISVAR (Ferreira, 2011).

Results and discussion

Birds under red LED light tended to have a better egg $bird^{-1}$ day^{-1} production (%) ($p = 0.084$) than those under white LED light (Table 2). This slight improvement in egg production can be attributed to the elevation of serum follicle-stimulating and luteinizing hormonal concentrations, increasing the number of ovarian follicles (Hassan, Sultana, Choe, & Ryu, 2013). Borille et al. (2013) found a higher production of eggs $bird^{-1}$ day^{-1} (%) in laying hens under red and white LED and incandescent illumination. However, the authors found white LED light to be the best, with a higher average egg $bird^{-1}$ day^{-1} production (91.95%), followed by incandescent (91.58%) and red LED lamps (91.25%) — averages resembling those of white LED. Our results stem from the greater penetration of long-wavelength red light through the transcranial route (Mendes, Reffati, Restelatto, & Paixão, 2010) and greater hypothalamic stimulation, the latter of which configuring a greater sexual stimulus toward triggering physiological reproductive stimuli than white wavelengths (Lewis & Morris, 2000, Borille et al., 2013) and positively impacting egg production and mass.

Feed intake per bird per day (g) failed to significantly differ ($p > 0.05$) for birds under different LED lighting (Table 2), corroborating Nunes, Garcia, Borille, Nääs, and Santana (2013) and Gongruttananun and Guntapa (2011), who found no difference in feed intake in birds under different light sources. These results indicate that the birds showed varying visual sensitivity to the tested light sources and failed to change their feeding behavior according to the light source. Both treatments having the same light period may have contributed to the non-difference in feed intake, as per Etches (1996). The feed conversion ratio per kg of eggs and per dozen failed to show significant differences ($p > 0.05$) for birds under white or red LED lamps (Table 2). This corroborates Nunes et al. (2013), who evaluated the two variables and found no significant differences for fluorescent and red LED lamps. Wells (1971) found that using red and white lights during rearing had no effect on peak egg production, feed intake, or feed conversion in laying hens. Our feed conversion results agree with these previous findings.

Birds under red LED light tended toward better average egg weight (g) in each treatment ($p = 0.0826$) (Table 2). Gongruttananun and Guntapa (2012) found no differences in egg weight in birds under red LED light. However, Nunes et al. (2013) observed a higher average egg weight in birds under red LED light than in those under fluorescent lamps for the evaluated cycles. On the other hand, Er et al. (2007) found that laying hens exposed to red LED showed lower egg weight than those under incandescent lamps. Jácome, Rossi, and Borille (2014) and Borille et al. (2013) found no difference in egg weight from quails and laying hens under several types of light. Result contradictions indicate that this subject should be further investigated.

Birds treated with red LED light showed higher egg mass (g) ($p < 0.05$) (Table 2). Borille et al. (2013) found no effects of different light colors on egg mass, which can be explained by birds showing a second laying cycle in which eggs have larger sizes and lower egg production percentages. When comparing egg mass between treatments, it is worth mentioning that the birds under red lights tended toward better egg production as an inductive factor, i.e., light color more greatly stimulated the secretion of egg components. Thus, a stimulating light color may gradually increase the secretion of egg components.

Total lost eggs (%), egg loss week^{-1} (%), egg loss day^{-1} (%), viable eggs week^{-1} (%), viable eggs day^{-1} (%), and bird viability (%) showed no significant differences ($p > 0.05$) between White and Red LED treatments to which the birds were subjected until the end of the experiment (Table 2).

The analysis of egg internal and external quality showed no significant effect ($p > 0.05$) of light color on egg components, yolk weight, shell weight, albumen height, yolk diameter, yolk index, Haugh unit, specific gravity, and shell, yolk, and albumen percentages (Table 3),

However, light color significantly affected shell thickness ($p < 0.05$), yolk color ($p < 0.05$), and yolk height ($p < 0.01$) (Table 3). Min et al. (2012) showed that birds reared under red light showed a significant increase in eggshell thickness than those under incandescent light and blue light. The results of this study generally agree with most findings in previous studies.

Table 2. Evaluation of the influence of Red and White LED light on the production of Hy-Line W-36® laying hens under an experimental period of 84 days.

Analyzed Variable	WL[1]	RD[2]	CV (%)[3]	Standard Error of the Mean	P-value
Bird/day egg production (%)	92.65	94.15	2.17	0.5861	0.084
Total lost eggs (%)	0.89	1.09	47.17	0.1356	0.305
Feed intake bird/day (g)	97.5	98.2	0.84	0.0239	0.345
Average egg weight (g)	60.1	61.2	2.43	0.4260	0.082
Feed Conversion (kg feed kg^{-1} egg)	1.697	1.719	2.52	0.0119	0.723
Feed Conversion (kg feed egg^{-1} dozen)	1.245	1.273	3.40	0.0123	0.129
Egg mass (g)	55.7	57.6	2.99	0.4885	0.011*
Egg loss week^{-1} (%)	2.38	2.82	50.52	0.3792	0.416
Egg loss day^{-1} (%)	0.34	0.40	50.52	0.1588	0.416
Viable eggs week^{-1} (%)	97.18	97.62	1.35	0.3792	0.416
Poultry Viability (%)	97.22	98.61	4.15	0.1189	0.640

[1]Treatment of birds with WL - White LED Light, [2]Treatment of birds with RL - Red LED Light. [3]CV (%) coefficient of variation. *$p < 0.05$; **$p < 0.01$.

Table 3. Evaluation of the influence of red and white LED lights on the internal and external quality of laying hen eggs.

Analyzed Variable	WL[1]	RL[2]	CV[3]	Standard error of the mean	P-value
Yolk weight (g)	16.54	16.87	3.12	0.1505	0.1323
shell thickness (mm)	0.446	0.459	3.30	0.0043	0.0487
Shell weight (g)	5.74	5.76	2.85	0.0473	0.7190
Albumen height (mm)	10.14	10.32	3.5	0.1034	0.2538
Yolk color	4.81	4.60	4.99	0.0679	0.0415*
Yolk height (mm)	17.23	17.59	1.45	0.0729	0.0020**
Yolk index	0.399	0.404	0.20	0.0007	0.0573*
Haugh unit	99.70	100.25	1.53	0.4422	0.3808
Specific gravity (g cm^{-3})	1.088	1.089	0.22	0.0007	0.3863
Yolk percentage (%)	27.21	27.55	2.35	0.1856	0.2117
Shell Percentage (%)	9.44	9.42	2.85	0.0777	0.8112
Albumen percentage (%)	63.35	63.04	1.04	0.1903	0.2601

[1]Treatment of birds with WL - White LED Light, [2]Treatment of birds with RL - Red LED Light. [3]CV (%) Coefficient of variation. *$p < 0.05$; **$p < 0.01$.

The observed shell thickness corroborates Borrile (2013) and Li et al. (2014), who studied different LED light colors in laying poultry, finding an increase in the ovarian hormone estradiol - which influences the production of vitamin D and regulates several reproductive functions in laying hens, including calcium metabolism for eggshell formation. Gongruttananun (2011) observed that chickens exposed to red LED light had higher serum estradiol concentrations and better ovarian development. The observed value also corroborates Er et al. (2007), who exposed chickens to red light and found greater shell thickness than those exposed to lights of other colors.

Yolk height showed a significant value ($p < 0.01$) but, according to Borille et al. (2013), neither light quality and quantity nor color affect this factor, although bird age and nutrition do so. An explanation refers to the increase in egg size as birds get older since larger eggs have higher yolk height values.

The eggs of the birds exposed to white LED had a more intense yolk color than those under red LED ($p < 0.05$); a difference stemming from dilution as both treatments shared the same diet. However, further studies are needed to confirm this fact.

Conclusion

It is concluded that the use of red LED lamps improved egg production (egg mass) and quality indicators in birds under white LED light. The use of LEDs is recommended as they are economically viable, sustainable, and have a longer useful life.

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