



Performance of Broilers Reared under Monochromatic Light Emitting Diode Supplemental Lighting

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ABSTRACT

The purpose of this study was to evaluate the effect of green monochromatic light emitting diodes (LED) or white fluorescent lamps on the growth performance of broilers reared in open houses. Two hundred broilers (Ross 308) were sexed and divided into four treatments, according to sex and supplemental light source: T1, males under green LED; T2, males under fluorescent lamps; T3, females under green LED; and T4, females under fluorescent lamps, totaling 50 birds per treatment with five replicates each (n=10). Broilers of both sexes received natural light during the day and supplemental lighting (fluorescent or LED) during the night, according to age. Individual body weight, mortality, and feed intake were recorded weekly per replicate. Feed conversion ratio and the European Efficiency Index (EEI) were calculated. Data were analyzed by a two-way ANOVA. The results indicated differences ($p < 0.05$) in female body weight in week 6, (2202.31 ± 32.93 g green LED vs 2191.08 ± 62.13 g fluorescent lamp), but no differences in daily weight gain, feed conversion ratio, or mortality were detected. However, the use of green LED promoted higher EEI in males in weeks 5, 6, and 7, and in females in week 5 ($p < 0.05$). Green monochromatic LED may be used for supplemental lighting of male broilers reared in open houses with natural light. Its use for female broilers is recommended if the birds are marketed up to 5 weeks of age.

INTRODUCTION

Broiler production systems of broilers present different management and facility characteristics, leading the producers to apply alternatives to increase production efficiency. Among the features that enable sustainability of animal production systems, the highest productivity per area is essential, making of environmental control a key component of farm profitability. Artificial lighting programs have a proven influence on weight gain and feed conversion ratio (Abreu *et al.*, 2011), because they can be used as an exogenous element for the control of physiological and behavioral processes. Their manipulation modulates circadian rhythms, body temperature, and feed intake and digestion in poultry. Lighting is necessary for the bird's vision, influencing visual acuity and color discrimination (Calvet *et al.*, 2009). Light color modifies the patterns of secretion of hormones related to growth, maturation, and reproduction (Olanrewaju *et al.*, 2006).

The lighting process consumes a significant part of the electrical energy used on the farm. Fossil fuels used for electric power generation are becoming more difficult and expensive to obtain, and produce CO₂ emissions to the troposphere (Peñuelas and Carnicer, 2010). Additionally, Mexico's government regulation established that incandescent bulbs are would not allowed to be sold after December



2013. After that date, only fluorescent lamps, more efficient than incandescent bulbs, will be available, but are the only source of the use of mercury that will grow in the years to come, because fluorescent bulbs contain Hg dust and vapor, harmful to both humans and the environment when inappropriately disposed (Pawlowski, 2011). Compared with other light sources, the Light Emitting Diodes (LED) have long life (50,000 hours) and low power consumption, there are evidences that they may improve broiler productivity (Karakaya *et al.*, 2009). Broilers reared under green LED showed better performance and muscle growth (Rozemboim *et al.*, 2013). However, the information on the use of LED as a source of supplemental lighting in broiler houses with natural illumination is limited, even when open houses or negative-pressure ventilated houses with clear curtains are used because the consumer's preference for pigmented meat, or when mobile curtains are used in open-sided houses for temperature control.

The objective of this study was to evaluate the effect of monochromatic green LED light on the performance and production efficiency of broilers reared in open houses.

MATERIALS AND METHODS

The experiment was conducted in Yucatán, México, at 20° 58 '04" north latitude and 89° 37' 18" west longitude.

Two hundred on-day-old Ross 308 broilers were sexed (100 males and 100 females) and vaccinated against Marek's disease at hatch. Birds were housed in an open-sided broilers house receiving natural lighting during the day, and equipped with fans, 500 watt infrared lamps, plastic feeders and automatic drinkers. A two-phase feeding program was applied in order to minimize management variation. The starter feed (1-21 days) contained 22% crude protein (CP) and 3,100 kcal of metabolizable energy (ME), and the finisher feed (22-49 days) contained 18% CP and 3,200 kcal of ME. Feed was offered *ad libitum*. Feeder and drinker height and position were established by the Ross 308 Broiler Management Handbook (2014).

Lighting treatments

The 3 x 9m facility with a 3m height was divided with a geomembrane, allowing the allocation of the two lighting treatments in a 12 m² area each. The number and position of LED and fluorescent lamps were determined by adjustments in lamp height,

number, and distribution. A light intensity of 45 lux at the level of chick, was achieved with two 4 watts/h monochromatic green LED at 50 cm height, and one white fluorescent bulb of 12 watts/h at 1.6 m height. Light homogeneous distribution and intensity at the bird's level, and luminous isolation of the treatments were verified with a Digital Light Meter (HER-410, Range 0 ~ 50000 Lux, Steren, México).

The chicks were exposed during the first four days of age to a lighting program of 23 h of light and one h of dark. Subsequently, the lighting schedule duration decreased 0:30 min of light per day until 18 h of light and 6 h of darkness was achieved. The supplemental lighting program started at sunset, and ended at sunrise.

Birds were distributed according to a completely randomized design into four different groups (two groups of males and two of females). The house was divided into 20 pens of 1.5 x 1.8 m with 2.54 cm hexagonal poultry netting. Discounting the feeder (37 cm diameter) and drinker areas, pen density of 11 birds/m² (Fig. 1). The treatments were consisted of sex and source of supplemental light: T1, males with green LED; T2 males with fluorescent lamps; T3, females with green light LED; T4, females with fluorescent lamps, with 50 birds per treatment and five replicates (pens) of 10 each.

Each individual chick was weighed at placement (day zero), on day 4, and weekly thereafter to determine body weight. Feed intake was measured by weighing the food offered and rejected on weekly basis. Daily weight gain was calculated as body weight (g) at the determined age minus body weight on day zero, divided between days of age. Feed conversion ratio (FCR) was calculated as weekly feed intake divided by body weight per pen. Mortality was recorded daily and weekly. The European Efficiency Index (EEI) was calculated as [livability (%) × body weight (kg) / age (days) × FCR] × 100.

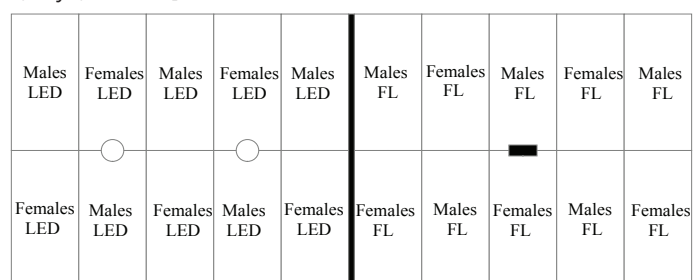


Figure 1 – Top View of experimental poultry house, indicating LED, (Green LED treatments); FL, (Fluorescent lamp treatments), circles indicates LED placement, and the black rectangle the Fluorescent lamp. (Not to scale)



Data were submitted to two-way analysis of variance and means were compared by the test of Bonferroni, with an experimental error of $p < 0.05$, using GraphPad Prism version 5.00 for Windows statistical software.

RESULTS

Male and female body weights were similar (Table 1), except in week 6, when females under fluorescent light were significantly lighter ($p < 0.05$) than those submitted to the other treatments. In general, body weights were slightly lower than those indicated by the standards of the commercial line.

No body weight differences ($p > 0.05$) were detected between males and females under LED. However, it cannot be ascertained that this effect was due to poor male performance or good female performance.

Lighting programs must be designed to allow sufficient time for broilers to perform vital functions required for adequate growth. In the commonly practiced lighting schemes, with alternating periods of light and darkness, a primordial principle is to provide the birds with light intervals that allows them to ingest enough feed during the hours of light and to allow feed

flow from the crop during the dark period. Therefore, it was expected that the LED light would promote heavier weights, as reported by Rozemboim (2013) and Cao *et al.* (2013), who showed higher weight gain and better feed conversion ratio in broilers when monochromatic green, blue or their combinations was applied compared with white lamps.

Daily weight gain may explain the lack of differences in body weight between treatments (Table 2), as no statistical differences were found among treatments. Males presented poorer performance compared to the genetic line standard, and was not influenced light source.

No feed conversion ratio differences were detected among treatments (Table 3). Due to the growth dynamics of broilers after week 5, females were expected to present worse FCR than males, but this trend was not observed in the present study, and both males and females had worse FCR than the standards of their genetic line. When LED was used as light source, the average FCR was 2.29 in week 5, which were lower than the FCR of 3.0 obtained by Cao *et al.* (2008) using white LED light; however, the latter evaluated FCR in week 7.

Table 1 – Mean body weight (g) of broilers reared under green light emitting diodes (LED) or white fluorescent bulbs as supplemental light source.

Age Weeks	Males LED		Males Fluorescent		Females LED		Females Fluorescent
	Mean	S.E	Mean	S.E	Mean	S.E	Mean
1	156.18	±1.96	156.68	±0.98	146.24	±2.97	149.98
2	385.39	±60.9	383.80	±5.95	375.95	±7.42	368.21
3	751.10	±4.28	768.97	±8.44	748.37	±10.30	755.71
4	1154.60	±9.62	1205.20	±7.96	1139.35	±19.57	1154.70
5	1702.60	±28.12	1729.22	±10.75	1654.75	±21.94	1666.72
6	2262.49 ^{cb}	±27.67	2288.93 ^b	±26.53	2202.31 ^b	±32.93	2191.08 ^a
7	2601.87	±27.25	2642.67	±38.34	2579.59	±22.97	2565.32

^{a,b,c} means in the same row not sharing a common superscript statistically differ ($p < 0.05$).

Table 2 – Average daily weight gain (g) of broilers reared under green light emitting diodes (LED) or white fluorescent lamps as supplemental light source.

Age Weeks	Males LED		Males Fluorescent		Females LED		Females Fluorescent
	Mean	S.E	Mean	S.E	Mean	S.E	Mean
1	22.31	±0.280	22.38	±0.140	20.890	±0.420	21.43
2	27.53	±0.440	27.41	±0.420	26.850	±0.530	26.3
3	35.77	±0.200	36.62	±0.400	35.640	±0.490	35.99
4	41.24	±0.340	43.04	±0.280	40.690	±0.700	41.24
5	48.64	±0.800	49.41	±0.310	47.280	±0.630	47.62
6	53.87	±0.660	54.5	±0.630	52.440	±0.780	52.17
7	53.1	±0.560	53.93	±0.780	52.640	±0.470	52.35



Table 3 – Feed conversion ratio (kg/kg) of broilers reared under green light emitting diodes (LED) or white fluorescent bulbs as supplemental light source.

Age Weeks	Males LED		Males Fluorescent		Females LED		Females Fluorescent
	Mean	S.E	Mean	S.E	Mean	S.E	Mean
1	1.6	±0.020	1.63	±0.037	1.78	±0.044	1.7
2	1.67	±0.048	1.71	±0.048	1.64	±0.049	1.23
3	2.11	±0.092	2.18	±0.065	2.35	±0.040	1.98
4	2.13	±0.096	2.1	±0.061	2.92	±0.022	2.12
5	2.09	±0.103	2.05	±0.059	2.19	±0.033	1.91
6	2.37	±0.106	2.26	±0.116	2.38	±0.066	2.1
7	2.64	±0.111	2.59	±0.123	2.62	±0.062	2.42

There were no differences ($p < 0.05$) in cumulative mortality (Table 4)

However, the low mortality rates recorded during the experiment indicates that overall management conditions were satisfactory for animal growth. Another important parameter in broiler production that aids evaluating management conditions is flock weight uniformity. In this case, the coefficients of variation of weekly body weight were not statistically different among treatments, and were consistent with the recommended average for the broiler strain used (Table 5).

Until here, individual performance parameters per treatment were analyzed. The European Efficiency

Index (EEI) consolidates performance parameters into a general index, which allows comparing productivity among flocks in an integrated and objective approach. Although no statistical differences were found in performance parameters in general, the calculated EEI was statistically different among treatments ($p < 0.05$; Table 6).

Male reared under green LED showed the best performance. The differences between males and females under LED or fluorescent treatments are due to inherent better performance of male broilers. The exception were the males reared under fluorescent lights on week 7, which EEI was not different from the females under LED or fluorescent light. Females under

Table 4 – Cumulative mortality of broilers reared under green light emitting diodes (LED) or white fluorescent bulbs as supplemental light source.

Age Weeks	Males LED		Males Fluorescent		Females LED		Females Fluorescent
	Mean	S.E	Mean	S.E	Mean	S.E	Mean
1	0	±0	0.4	±0.4	0.8	±0.49	0.4
2	0	±0	0.8	±0.49	0.8	±0.49	0.8
3	0	±0	1.2	±0.8	1.2	±0.49	1.2
4	0	±0	1.2	±0.8	1.2	±0.49	1.2
5	0	±0	1.2	±0.8	1.2	±0.49	1.2
6	0.4	±0.4	1.6	±0.75	1.6	±0.75	2
7	0.8	±0.49	2	±0.63	1.6	±0.75	2

Table 5 – Coefficients of variation of weekly body weight of broilers reared under green light emitting diodes (LED) or white fluorescent bulbs as supplemental light source.

Age Weeks	Males LED		Males Fluorescent		Females LED		Females Fluorescent
	Mean	S.E	Mean	S.E	Mean	S.E	Mean
1	7.25	±0.54	8.11	±0.59	12.96	±4.91	9.53
2	8.90	±0.88	10.06	±1.64	10.69	±2.10	11.71
3	10.34	±0.703	8.41	±1.02	9.49	±0.87	8.73
4	8.93	±1.03	8.82	±0.97	7.72	±1.21	9.10
5	9.80	±1.17	9.92	±0.70	8.86	±1.29	9.66
6	10.99	±1.33	10.73	±0.46	7.52	±1.14	11.33
7	11.94	±0.88	11.78	±0.53	10.14	±1.26	10.52



Table 6 – European Efficiency Index (EEI) of broilers reared under green light emitting diodes (LED) or white fluorescent bulbs as supplemental light source.

Age Weeks	Males LED		Males Fluorescent		Females LED		Females Fluorescent
	Mean	S.E	Mean	S.E	Mean	S.E	Mean
5	254.83 ^c	±4.21	226.46 ^b	±1.41	202.29 ^a	±2.68	215.5 ^b
6	251.64 ^c	±3.08	222.88 ^b	±2.58	202.80 ^a	±3.03	198.30 ^a
7	210.25 ^b	±2.20	187.68 ^a	±2.72	184.69 ^a	±1.64	179.06 ^a

^{a,b,c} means in the same row not sharing a common superscript differ ($p < 0.05$)

LED presented the same EEI in weeks 6 and 7, but fluorescent lighting promoted higher EEI in week 5. These findings indicate that supplemental light source must be chosen according to the final product desired.

DISCUSSION

There is evidence that light wavelength influences broiler performance, and our results are consistent with those of Rozemboin *et al.* (1999), who established that broilers respond differently to different light colors. Evaluating the effects of white (incandescent), blue, red, or green light on broiler performance, Rozemboin *et al.* (1999) obtained higher growth rates and heavier body weights in broilers reared under green and blue light, as well as higher testosterone plasma levels in blue light environments, and more development of breast muscles under green light. Based on these findings, Rozemboin *et al.* (2004) worked with blue and green lights and switching from one to another color, and their results suggest that green light stimulates broiler growth at an early age, and changing the birds to a different light environment at 10 or 20 days of age stimulated growth. The findings of the present study are consistent with the results of Mendes (2010), who found colored lights promoted better broiler performance than white light. The relevant difference between Rozemboim's studies and the present experiment is that artificial lighting was used as supplemental lighting, because broilers were under natural (solar) light during the day, and artificial light only in the afternoon and night. Other researchers also obtained better broiler performance with colored lights. Karakaya *et al.* (2009), for instance, found significantly higher feed intake, body weight and total muscle weight in broilers reared under green light or combined blue and green light compared with those reared under white incandescent light. This suggests that green light may be required for broiler growth. In study of Karakaya *et al.* (2009), only female broilers were used and performance in response to light is expected to be different between males and females,

as found in the present study. Santana *et al.* (2014) did not find any broiler performance differences when LED or fluorescent light were used. The main difference in the present study was detected when EEI was evaluated, as it allows comparing overall parameters.

Animal behavior and welfare may be affected by light color, according to Kristensen *et al.* (2007), who described that broilers preferred warm-white fluorescent light sources than incandescent light, regardless the intensity of light. Broilers also showed an "elastic time-budget". Resting behavior (61% of their time) of broilers was not affected by light wavelength, but there was less feather pecking behavior under white light and less foraging behavior in darker than in brighter light intensities.

CONCLUSIONS

Light wavelength affects broiler performance, including of those reared in open houses with natural (solar) lighting, which are frequent in tropical climates. Monochromatic green LED is an alternative to incandescent light bulbs, promoting similar performance as that obtained with fluorescent lights. In addition, LED reduces production costs, due to energy savings and their long lifetime. In the present study, the evaluation of the EEI showed differences in broiler responses to the type of light source, depending on sex and age, and therefore, when choosing light sources for broilers houses, the final product should be taken into consideration.

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