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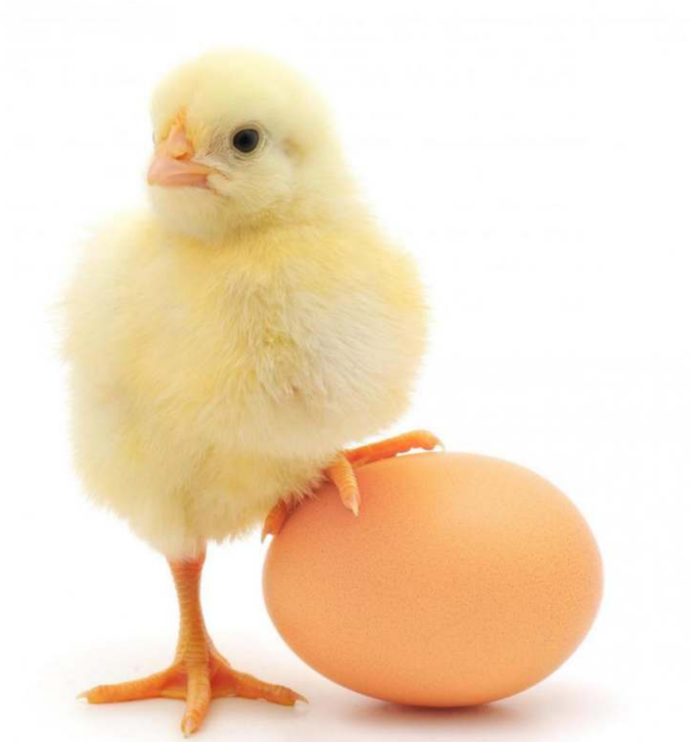

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Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorijps@gmail.com

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Research Article
Efficacy of Various Wavelengths of Monochromatic Light Emitting Diode Illumination on Growth and Performance of Broiler Chickens

M. B. Leigh, T. B. McFadden, L. Schumacher and J.D. Firman

University of Missouri-Columbia, 116 Animal Sciences Research Center, 920 East Campus Drive Columbia, 65211 MO, USA

Abstract

Background and Objective: Lighting is a powerful exogenous stimulus that controls many physiological and behavioral processes in the broiler chicken. Traditionally, incandescent lighting has been used as the standard throughout the broiler industry. New technology has recently become available including LED lighting. Previous studies have shown possible advantages in broiler performance under lighting by various colored LED lights. These reports are ambiguous and it is still quite unclear as to which lighting source would be most advantageous. The objective of this study was to evaluate the effects of various wavelengths of monochromatic light emitting diode illumination on growth and performance of broiler chickens raised in a commercial-style setting. **Methodology:** The experiment was designed as a randomized complete block with 4 treatments applied to each of 12 replicate pens of 30 birds/pen. Broilers were reared under standard white LED, green LED, blue LED and red LED lighting from 0-49 days of age and were monitored at days 17, 35 and 49 for individual bird body weight gain, feed intake and feed conversion ratio. **Results:** There were no statistical differences between treatment groups for daily and overall body weight gain, daily and overall feed intake, feed conversion ratio and percent mortality, with the exception of slightly lower body weight (BW) at 35 days in the green LED treatment. Overall, there were no statistical differences in performance for the trial. At day 50, birds were processed for parts yield. No statistical differences between treatments were observed for carcass yield, fat pad, pectoralis major, total pectoralis, thigh, wing or leg as a percentage of cold carcass. However, pectoralis minor and wing yield showed minor differences. **Conclusion:** Broiler performance was similar under all wavelengths of LED lights compared in this study.

Key words: Light emitting diode (LED) lights, growth performance, lighting source, light intensity, photoperiod, wavelength

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Corresponding Author: Jeffre D. Firman, University of Missouri-Columbia, 116 Animal Sciences Research Center, 920 East Campus Drive Columbia, 65211 MO, USA Tel: 573-882-9427 Fax: 573-882-6827

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Globally, chickens are reared under various production systems including outdoor enclosures that do not allow for extensive environmental control. However, in the United States, large houses with extensive control over environmental factors including lighting source, light intensity, photoperiod and wavelength are used as a means of achieving productivity goals. Improving these management practices is essential to improve production efficiency in commercial operations since the sole means of lighting for broilers in the US is artificial[1]. Whereas extensive research has been conducted on lighting sources, intensities and photoperiods, more research is needed in the area of using various wavelengths of light.

As new, colored technology has become available, studies have shown that the use of blue and green illumination alone or in combination could improve performance of the broiler. There are indications that using various colored lights can lead to increased growth and performance of broilers. Studies have shown that green light can stimulate growth at an early age, whereas blue light stimulates growth in older broilers[2]. Andrews and Zimmerman[1] noted that broilers initially placed under green light were slightly heavier at 4 days of age. When switched to blue light at 10 days of age, this caused a further increase in body weight compared to birds exposed to traditional white LED lighting. Finally, Lee *et al.*[3] concluded that enhanced growth can be achieved by manipulating the light spectra and rearing broilers under green/green-blue combination lighting. This manipulation increased feed consumption and improved meat quality.

Additionally, red LED illumination is becoming a popular alternative to white LED lighting, especially in the commercial layer and broiler breeder facilities. Firouzi *et al.*[4] found improved feed conversion ratios for broilers raised under red lighting as compared to birds raised under blue lighting. This is more than likely due to the stimulation of the extra-retinal receptors in the broiler brain. Mobarkey *et al.*[5], reported that reproductive activity can be accelerated due to red LED illumination stimulation.

Therefore, the objective of this study was to compare the effects of various wavelengths of monochromatic light emitting diode (LED) illumination on the growth and production efficiency of broilers managed for food production from hatch to 49 days of age.

MATERIALS AND METHODS

One thousand five hundred Cobb 500 strain chicks were procured from a commercial hatchery. Upon arrival, 1440 chicks were selected based on average bird weight and randomly allocated into groups of 30 birds/48 pens. If chicks were ill or exhibited any abnormalities they were excluded from the study and were disposed of according to standard operating procedures approved by the University of Missouri Institutional Animal Care and Use Committee. Chicks were placed into 48 separate 4′×8′ floor pens. External lighting was excluded by lining pens with black plastic, which was attached to all sides and the top of the pens. This blocked out external natural light and LED light from adjacent pens. The pens were contained in a curtain-sided, environmentally controlled house modeled after an industry curtain house. Large box fans (24″*24″) were set in front of 2 pens to facilitate adequate ventilation. More specifically, one fan was allocated/2 pens thus having 24 fans. Six other box fans were placed around the barn to help with air circulation and ventilation. Block randomization was done for each set of treatments, resulting in 12 randomly assigned pens for each of the 4 treatment groups.

From hatch to day 49, chicks had access to a standard commercial corn-soybean meal-based diet and water *ad libitum*. During the first 7 days, chicks were provided feed pans placed on the floor of each pen to allow for easy access to feed. After day 7, feed pans were removed and chicks accessed feed *ad libitum* from the feeder placed in the pen. Diets were formulated for 0-17 days, 18-35 days and 36-49 days (Table 1). Therefore, diet changes occurred at 17 and 35 days. At these times, birds were also weighed in order to determine weight gain, feed intake and feed conversion ratio. The feed conversion ratio was adjusted for mortality weight/pen/period. On day 0, building temperature was set at 85°F and each pen was allocated one infrared heat lamp for the brooding period. After a brooding period of 7 days, heat lamps were removed from pens. Building temperature was decreased by 5° weekly. The trial was conducted in accordance with University of Missouri standard operating procedures and approved by the University of Missouri Animal Care and Use Committee.

Treatments were applied to each pen, which received a single LED bulb in white, LED bulbs of green (wavelength of 510 nm), blue (wavelength of 475 nm) and red (wavelength of 660 nm). All 10 watt multicolor LED bulbs used were the same brand for consistency (Kuler Bulb, Brightech). Intensity of light was measured weekly and recorded after heat lamps were removed at 7 days. Lighting intensity was set at 10 lux on day 0 and reduced to 5 lux at 28 days and remained at this intensity for the duration of the trial. After the brooding period, birds were kept on a constant light cycle of 16 h of light and 8 h of darkness via a light timer. During the course of

Table 1: Ingredient composition of broiler chicken rations for 0-49 days

Periods	0-17 days	18-35 days	36-49 days
Ingredients			
Corn (Digestible 2011)	59.61	63.58	68.53
Soy (Digestible 1998)	25.56	20.82	16.41
Pork meal	5	5	5
Lard	1.55	2.6	2.64
Dicalcium phosphate	0.603	0.49	0.331
Limestone	0.471	0.441	0.341
Sodium bicarbonate	0	0	0
Salt	0.3	0.3	0.3
Trace mineral[1]	0.1	0	0
Vitamin premix[2]	0.25	0.25	0.25
Choline chloride	0	0	0
Copper sulfate	0	0	0
Avatec	0.05	0.05	0.05
DL-Methionine	0.464	0.421	0.352
L-Lysine HC1	0.457	0.517	0.424
Threonine	0.288	0.258	0.22
Valine	0.229	0.2	0.09
Corn DDGS (dig 2011)	5	5	5
Wheat, soft white	0	0	0
Phytase	0.05	0.05	0.05
Crude protein (%)	22	20	18
Metabolizable energy	3050	3150	3200
Crude fat (%)	4.99	6.13	6.3
Crude fiber (%)	2.76	2.66	2.6
Calcium (%)	0.9	0.84	0.76
Phosphorus (%) (avail)	0.45	0.42	0.38
Lysine	1.3	1.23	1.05
Methionine	0.74	0.68	0.595
Threonine	0.89	0.8	0.71

[1]Trace mineral premix provided kg^{-1}: Mn: 2428.87 mg, Zn: 2444.64 mg, Fe: 1437.61 mg, Se: 0.255 mg, Mg: 0.227 mg, [2]Vitamin premix provides kg^{-1}: Vitamin B: 12 3.514 mg, E: 32.43 mg, Biotin: 30.15 mg, Folate: 1.273 mg, Pyridoxine: 6.20 mg, Niacin: 53.25 mg, Riboflavin: 8.588 mg, Thiamin: 4.19 mg

the trial 4 pens were culled due to issues with mortality and growth. Mortality, bird weight, feed intake and feed efficiency were measured at 17, 35 and 49 days for the entirety of the trial. On day 49, three average weight birds were selected from each pen, wing banded in the right wing and transported to the abattoir for processing. Following on day 50, birds were slaughtered, eviscerated and then chilled in an ice water bath. After evisceration occurred, carcass and fat pad were measured and recorded. After chilling the carcasses, major and minor pectoralis muscles, wings, thighs and legs were removed and weighed individually. The weights of these individual parts were divided by chilled carcass weight to determine percent yield of each.

Data were analyzed using one way ANOVA according to the generalized least squares procedure of SAS[6]. The "pen" was the experimental unit. All statements of significance were based on the 0.05 level of probability. Means which were significant were separated with Fisher's LSD.

RESULTS

Growth and performance data for the various periods from 0-49 days are presented in Tables 2-6. Carcass data were collected and presented in Table 7. From hatch to 17 days of age and during the 17-35 days period, no differences were observed in initial body weight, final body weight, daily and overall body weight gain, daily and overall feed intake, feed conversion ratio and percent mortality between all treatment

Table 2: Performance of broilers reared under various wavelengths of LED Illumination from 0-17 days of age

	Treatments					
Variables	White LED	Blue LED	Green LED	Red LED	SEM[1]	p-value
Initial BW (g)	43.19	43.20	43.23	43.25	0.11	0.98
Final BW (g)	590.5	552.1	525.2	594.9	23.0	0.13
BW gain (g)	547.1	508.9	481.5	551.7	23.0	0.13
BW gain (g/day)	32.18	29.94	28.33	32.45	1.35	0.13
Feed intake (g)	574.6	598.1	585.2	596.5	11.0	0.39
Feed intake (g/day)	33.80	35.18	34.42	35.09	0.64	0.39
Feed conversion ratio ($g\ g^{-1}$)	1.06	1.14	1.20	1.09	0.04	0.08
Mortality (%)	0.61	2.12	3.67	1.94	0.75	0.06

a,bMeans with different superscript letters differ within row (p<0.05), [1]Pooled SEM

Table 3: Performance of broilers reared under various wavelengths of LED Illumination from 17-35 days of age

	Treatments					
Variables	White LED	Blue LED	Green LED	Red LED	SEM[1]	p-value
Initial BW (g)	590.5	552.1	525.2	594.9	23.0	0.13
Final BW (g)	2030.4	2060.0	1968.4	2071.3	28.4	0.09
BW gain (g)	1439.8	1469.0	1461.1	1476.4	29.7	0.82
BW gain (g/day)	79.99	81.61	81.17	82.02	1.65	0.82
Feed intake (g)	2383.7	2516.8	2473.9	2496.2	45.0	0.17
Feed intake (g/day)	132.4	139.8	137.7	138.7	02.5	0.17
Feed conversion ratio ($g\ g^{-1}$)	1.66	1.72	1.60	1.69	0.04	0.29
Mortality (%)	2.22	2.90	4.00	3.85	1.06	0.61

a,bMeans with different superscript letters differ within row (p<0.05), [1]Pooled SEM

Table 4: Performance of broilers reared under various wavelengths of LED Illumination from 0-35 days of age

	Treatments					
Variables	White LED	Blue LED	Green LED	Red LED	SEM[1]	p-value
Initial BW (g)	43.19	43.20	43.23	43.25	0.11	0.98
Final BW (g)	2030.4[a]	2015.2[a]	1876.4[b]	2071.3[a]	44.3	0.02
BW gain (g)	1986.9[a]	1972.1[a]	1832.7[b]	2028.1[a]	44.3	0.02
BW gain (g/day)	110.4	112.0	106.9	112.7	01.6	0.08
Feed intake (g)	2958.3	3100.2	3060.2	3092.7	47.3	0.13
Feed intake (g/day)	84.52	88.57	87.43	88.36	1.35	0.13
Feed conversion ratio (g g^{-1})	1.49	1.58	1.51	1.53	0.04	0.33
Mortality (%)	2.73	5.46	8.00	6.39	1.40	0.08

[a,b]Means with different superscript letters differ within row (p<0.05), [1]Pooled SEM

Table 5: Performance of broilers reared under various wavelengths of LED Illumination from 35-49 days of age

	Treatments					
Variables	White LED	Blue LED	Green LED	Red LED	SEM[1]	p-value
Initial BW (g)	2030.4	2060.0	1968.4	2071.3	28.4	0.09
Final BW (g)	3327.3	3443.2	3302.2	3386.4	61.0	0.38
BW gain (g)	1297.0	1427.9	1362.0	1315.1	50.1	0.25
BW gain, (g/day)	92.64	101.99	97.29	93.94	3.58	0.25
Feed intake (g)	333.8	3478.8	3580.4	3391.6	80.4	0.19
Feed intake (g/day)	238.1	248.5	255.7	242.3	05.7	0.19
Feed conversion ration (g g^{-1})	2.59	2.46	2.66	2.56	0.08	0.41
Mortality (%)	2.96	3.96	3.80	2.13	1.14	0.64

[a,b]Means with different superscript letters differ within row (p<0.05), [1]Pooled SEM

Table 6: Performance of broilers reared under various wavelengths of LED Illumination from 0-49 days of age

	Treatment					
Variables	White LED	Blue LED	Green LED	Red LED	SEM[1]	p-value
Initial BW (g)	43.19	43.20	43.23	43.25	0.11	0.98
Final BW (g)	3327.3	3443.2	3302.2	3386.4	61.00	0.38
BW gain (g)	3283.9	3400.0	3258.5	3343.2	61.00	0.38
BW gain (g/day)	234.6	242.9	232.8	238.8	4.40	0.38
Feed intake (g)	6292.1	6579.0	6526.4	6484.3	98.20	0.19
Feed intake (g/day)	128.4	134.3	133.2	132.3	2.00	0.19
Feed conversion ratio (g g^{-1})	1.92	1.94	2.02	1.95	0.03	0.16
Mortality (%)	5.45	9.09	11.48	8.33	1.75	0.14

[a,b]Means with different superscript letters differ within row (p<0.05), [1]Pooled SEM

Table 7: Various sources of lighting on dressing percentage and weights and yields of broilers at 50 days of age

	Treatments					
Variables	White LED	Blue LED	Green LED	Red LED	SEM[1]	p-value
Carcass yield (%)	76.21	75.67	75.87	76.49	0.26	0.11
Fat pad yield (%)	1.35	1.17	1.12	1.27	0.09	0.28
Major pectoralis yield (%)	25.41	24.73	24.88	25.48	0.31	0.23
Minor pectoralis yield (%)	5.44[a]	4.99[c]	5.09[bc]	5.30[ab]	0.09	0.005
Total breast yield (%)	30.85	29.75	29.97	30.81	0.36	0.06
Wing yield (%)	11.42[a]	11.24[a]	11.39[a]	10.69[b]	0.11	<0.001
Thigh yield (%)	17.01	16.94	16.75	16.95	0.17	0.70
Leg yield (%)	13.84	13.98	13.95	13.87	0.17	0.93

[a-c]Means with different superscript letters differ within row (p<0.05), [1]Pooled SEM

groups. However, from hatch to 35 days of age, final body weight was statistically lower in the green LED treatment group compared to all other treatment groups. No other statistical differences were seen between other treatment groups for final body weight. Similarly, the green LED treatment group statistically had less body weight gain in comparison to all other treatment groups. No other significant differences were observed for initial body weight, daily body weight gain, daily and overall feed intake, feed conversion ratio and percent mortality. No significant differences were observed for the period from 35-49 days or 0-49 days.

Table 7 shows carcass yield of broilers at 50 days. Data analyzed included live fasted body weight, carcass weight and parts yield as a percentage of carcass weight. No differences between treatments were observed for carcass yield. Additionally, there was no statistical differences in fat pad, pectoralis major, total pectoralis, thigh, wing and leg yield as a percentage of cold carcass weight. However, for pectoralis minor, the red and white treatments were both greater than the blue LED treatment group and white LED was greater than green LED (Table 7). Wing yield as a portion of cold carcass was greater in white, blue and green LED lighting when compared to red LED lighting.

DISCUSSION

The focus of this study was to compare the use of various wavelengths of monochromatic lighting on broiler growth, feed intake, feed efficiency and carcass characteristics to 49 days of age in comparison to the standard white LED lighting that is currently used in industry. Since LED lighting is accepted as a superior alternative in the commercial setting to incandescent and fluorescent lighting, only LED lighting was used for this trial. During the production portion of this trial the only significant data that was produced came from the 0-35 days cumulative period. During this period, broilers in the green LED treatment had lower final body gain as compared to all other treatment groups. The white, blue and red LED treatment groups were not statistically different from each other. While other studies showed increased gains for green and blue LED lighting, this was not observed in this study[2,7,8]. This significant reduction in body gain and final body weight under green lighting was not seen by the conclusion of the trial at 49 days. At day 49, there were no significant differences in any variable measured.

It was noted in the literature that blue and green lighting could improve immune function in broilers. Blatchford *et al.*[9] discovered that immune function may be improved by increased intensity of lighting compared to lower intensity of lighting. When lux was calculated for each treatment in the present study, blue and green lighting had increased intensity compared to white and red treatment groups. These wavelengths could possibly be used in stressful or immunosuppressed situations. While green improves the response at an earlier age, blue improves at a later age[10]. These lighting options should be considered by the producer, since no differences were seen between treatment groups.

At day 50, when carcass characteristics were examined, no statistical difference was observed for carcass yield. Additionally, no difference was found for fat pad, pectoralis major, total pectoralis, thigh and leg yield as a portion of cold carcass weight. However, for pectoralis minor yield, statistical differences were noted between treatment groups. Pectoralis minor yield in the white treatment was greater than the blue or green LED treatment groups. The red LED treatment group was statistically greater than the blue group, but statistically similar to the green treatment group. The red LED treatment group had lower wing yield when compared to the other treatment groups. Down *et al.*[11] showed increased leg yields in lower intensity lighting, however, these researchers did not study light color. While there is little study to support the findings that light color affects yield in broilers, there are many studies showing the advantageous effects on reproductive performance[5] in laying hens[8,12].

CONCLUSION

The trial demonstrated no effects on production performance utilizing various alternative wavelengths of lighting in comparison to the standard white LED. The trial also demonstrated no advantageous effects on carcass characteristics utilizing blue, green and red wavelengths of light compared to white LED. However, the possibility of using blue and green lighting should be further researched in high stress conditions such as high temperature or poor litter conditions.

SIGNIFICANCE STATEMENT

This study discovered that broiler performance was similar under all wavelengths of LED lights.

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