Growth performance and hematological traits of broiler chickens reared under assorted monochromatic light sources

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ABSTRACT A study was conducted to investigate the effect of different monochromatic lights on growth performance and hematological response of growing broiler chickens. A total of 360 one-day-old broiler chicks were randomly divided into 6 lighting treatments, which were replicated 6 times with 10 chicks in each replicate. Six light treatments include incandescent bulbs (as a control) and light-emitting diode white light, blue light, red light, green light, and yellow light (YL). The birds were provided with similar nutritional specifications and environmental management facilities, except for the lights throughout the experimental period. Growth performance was evaluated in terms of BW, BW gain, feed intake, and feed conversion ratio at weekly intervals. At the end of 5 wk, 2 birds from each replicate were randomly selected for blood collection to determine hematological response. The BW and feed intake was numerically higher in YL at 5 wk of age. But interestingly, this did not result in improved feed conversion ratio in YL; nevertheless, numerical values were lower in YL at 5 wk ($P > 0.05$). Red blood cells, blood platelet count, and percent hematocrit were numerically higher under YL, whereas white blood cell counts and percent hemoglobin remained unaffected due to light treatments. It was concluded that monochromatic light is a potential light source that might provide a beneficial effect on growth performance but is inconclusive for hematological measures of broilers.

Key words: monochromatic light, light-emitting diode, growth performance, hematological response, broiler chicken

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INTRODUCTION

It has been known for centuries that light (duration, intensity, and wavelength) is possibly the major environmental stimulus affecting physiology, behavior, immunity, and growth rate of birds. Early studies on the impact of variation in light intensity and wavelength have shown profound effects on growth performance of broilers (Barott and Pringle, 1951; Cherry and Barwick, 1962; Classen and Riddell, 1989; Buyse et al., 1996; Manser, 1996). In poultry housing, variation in light during the brooding period can result in poor performance and low profitability. Various types of lighting systems, including incandescent, fluorescent, and compact fluorescent, have been used in the last few decades. Recently, the light-emitting diode (**LED**) technology has been used in the poultry industry as a way to minimize lighting cost and energy usage in broiler production facilities. Additionally, the use of LED is also gaining popularity in other fields such as the study of plant behavior (Okamoto et al., 1996), eradication of mosquitoes (Mann et al., 2009), and repair of bone defects (Pinheiro et al., 2012).

The color of light is a vital exogenous parameter that affects bird performance and is dictated by the wavelength. It has been reported that blue light has a calming effect, red light reduces feather pecking and cannibalism, orange-red light stimulates reproduction, and blue-green light stimulates growth in chickens (Rozenboim et al., 1999a,b, 2004). In modern broiler production, blue, green, and red lights are being used for improved growth performance. In early studies it was reported that chickens preferred to be reared under red light (Taylor et al., 1969; Berryman et al., 1971). Olanrewaju et al. (2006b) observed that during the early growth period, short wavelengths (blue-green) increase growth; however, when the bird approaches the time of sexual maturity, long wavelengths (orange-red) increase growth and are effective in stimulating sexual hormonal pathways. Heshmatollah (2007) found that broilers showed no preference when given different light

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Table 1. Dietary composition of the diets in different growing phases

Item	0 to 2 wk	2 to 4 wk	5 wk
Ingredient (%)			
Corn	53.6	58.3	63.2
Wheat bran	1.5	2.0	1.8
Soybean meal	34.4	30.1	26.3
Corn gluten meal	3.5	3.0	2.5
Soybean oil	2.5	2.5	2.5
Calcium carbonate	1.1	1.0	1.0
Calcium phosphate	1.5	1.35	1.1
Methionine	0.4	0.3	0.15
Lysine	0.15	0.1	0.1
Vitamin premix[1]	0.5	0.5	0.5
Trace mineral premix[1]	0.5	0.5	0.5
Salt	0.25	0.25	0.25
Binding agent	0.1	0.1	0.1
Nutrient (%, unless otherwise stated)			
CP	232	212	194
ME (kcal/kg)	3,062	3,102	3,155
Ca	1.0	0.90	0.80
Available P	0.45	0.40	0.35

[1]Provided per kilogram of diet (calculated): iron, 71.6 mg; copper, 11.0 mg; manganese, 178.7 mg; zinc, 178.7 mg; iodine, 3.0 mg; selenium, 0.4 mg; vitamin A (retinyl acetate), 18,904.3 IU; vitamin D_3 (cholecalciferol), 9,480.0 IU; vitamin E (DL-α-tocopheryl acetate), 63.0 IU; vitamin K activity, 6.4 mg; thiamine, 3.2 mg; riboflavin, 9.4 mg; pantothenic acid, 34.7 mg; niacin, 126.0 mg; pyridoxine, 4.7 mg; folic acid, 1.6 mg; biotin, 0.5 mg; vitamin B_{12}, 35.4 g; choline, 956.9 mg.

intensities but did show a preference for green light compared with red, orange, or yellow. In a previous experiment examining the effect of LED on production performance in laying hens, it was found that birds performed better when reared under red light without affecting feed conversion ratio (**FCR**; Kim et al., 2012). Green and blue LED enhance cellular and humoral immune responses in broilers (Xie et al., 2008). Broilers had a higher heterophil: lymphocyte ratio and lower antibody titers to Newcastle disease virus in continuous lighting compared with intermittent lighting (Zulkifli et al., 1998; Onbasilar et al., 2007).

However, research on LED comparing efficacy of different wavelength is scarce; hence, the present experiment is designed to determine the impact of different colors of monochromatic light (white, blue, red, green, and yellow) on growth performance and hematological and immune responses of broiler chickens during their rapid growth period over wk 1 to 5.

MATERIALS AND METHODS

The experimental protocol was approved by the Animal Care and Welfare Committee of the National Institute of Animal Science, Rural Development Administration, Republic of Korea.

Birds and Husbandry

A total of 360 one-day-old mixed sex broilers were obtained from the hatchery of the National Institute of Animal Science. After equalizing for mean BW (Table 2), all the chicks were divided into 6 groups. The birds were placed in environmentally controlled lightproof rooms separated from each other by a wooden chip board. Each room was divided into 6 replicate pens. There were 10 birds in each replicate, hence 60 birds per treatment/room. A floor space of 0.05 m^2 was provided for each bird. The birds were reared for 3 growing phases, i.e., 0 to 2, 2 to 4, and 5 wk of age, with 3 diets with 23.2, 21.2, and 19.4% CP and ME of 3,062, 3,102, and 3,155 kcal/kg for the 3 growing periods, respectively (Table 1). The diets were formulated as per the Korean Feeding Standards for Poultry (2007). Feed and water were provided ad libitum throughout the experimental period. The room temperature was maintained at 32°C for first 3 d and then reduced by 0.5°C daily until 24°C was attained. This temperature was maintained at the end of the experiment.

Light Source and Management

A 60-W incandescent light bulb (**IL**, 2,600–3,200 K) as a control, and white light (**WL**, 2,800–3,200 K), blue

Table 2. Body weight of broilers under different light treatments at 1 d and 1 to 5 wk of age

	BW (g)	
Treatment[1]	Initial weight (1 d)	Final weight (1–35 d)
IL	41.9 ± 0.09	2,442 ± 23[b]
WL	41.8 ± 0.08	2,559 ± 37[a]
BL	41.9 ± 0.09	2,551 ± 24[ab]
RL	41.9 ± 0.18	2,515 ± 36[ab]
GL	42.0 ± 0.18	2,549 ± 55[ab]
YL	41.9 ± 0.09	2,598 ± 28[a]

[a,b]Means with different superscripts in the same column differ significantly ($P < 0.05$).

[1]WL = white light; BL = blue light; RL = red light; GL = green light; YL = yellow light; IL = incandescent light (control).

Table 3. Body weight gain of broilers under different light treatments from 1 to 5 wk of age

	BW gain (g)					
Treatment[1]	1 wk	2 wk	3 wk	4 wk	5 wk	Total
IL	154 ± 10	323 ± 12[ab]	496 ± 16	705 ± 32	805 ± 18[ab]	2,484 ± 24
WL	162 ± 3	312 ± 12[b]	545 ± 15	735 ± 29	763 ± 53[b]	2,518 ± 37
BL	170 ± 3	329 ± 4[ab]	524 ± 8	715 ± 11	769 ± 47[b]	2,509 ± 24
RL	159 ± 6	323 ± 9[ab]	531 ± 17	717 ± 26	743 ± 18[b]	2,473 ± 36
GL	165 ± 8	301 ± 9[b]	509 ± 8	746 ± 28	785 ± 68[ab]	2,506 ± 56
YL	155 ± 5	349 ± 9[a]	512 ± 26	709 ± 45	831 ± 18[a]	2,556 ± 28

[a,b]Means with different superscripts in the same column differ significantly ($P < 0.05$).

[1]WL = white light; BL = blue light; RL = red light; GL = green light; YL = yellow light; IL = incandescent light (control).

light (**BL**, 450–460 nm), red light (**RL**, 600–630 nm), green light (**GL**, 510–530 nm), and yellow light (**YL**, 580–590 nm) produced by LED lamps were provided as the 6 light treatment groups. The wavelengths of LED colors were measured with a Chroma Meter CL 200, Konica Minolta Sensing Inc., Osaka, Japan. The instrument displayed the values of each light color for the x- and y-axes, which were matched with a standard chromatogram at both axes, and the resultant values were considered as the wavelength of a particular color. The LED lamps were designed and assembled by the National Institute of Animal Science. Sixty-eight LED of the same color were installed in a single line on a plastic board (width = 3 cm, length = 1 m). The electric voltage for the LED lamps lights was as follows: RL and YL = 2.2 V, WL = 3.3 V, and GL and BL = 3.4 V. The LED lamps were provided with the same forward current of I = 20 mA. All light fixtures were installed above each replicate and equalized to a light intensity of 15 ± 0.2 lx at bird level. The light schedule was 24 h, except 1 h of darkness (23L:1D) and was applied from 1 d of age until the termination of the experiment at 5 wk.

Data Collection

Growth Performance. Body weight and feed intake (**FI**) were recorded from each replicate at weekly intervals. Weekly BW gain (**BWG**) was then calculated by subtracting the weight recorded at the end of the previous week from the current weight of the birds. Feed conversion ratio was calculated by dividing FI with BWG.

Hematological Traits. At the end of 5 wk, 2 birds of average weight from each replicate were selected and blood was collected from the wing. The hematological analysis was performed by using Hemavet 950 (Drew Scientific Inc., Waterbury, CT) immediately after collection of the blood. The hematological analysis includes red blood cells (**RBC**), white blood cells (**WBC**), hematocrit (**Hct**), and platelet count. The differential WBC composition (i.e., neutrophils, lymphocytes, monocytes, eosinophils, and basophils) was analyzed separately.

Statistical Analysis

Data was subjected to one-way ANOVA to test the effects of monochromatic colors on various attributes using a completely randomized design and the GLM procedure of the Statistical Analysis System (SAS Institute, 2003). Replicate means were used as the experimental units for all variables evaluated. Means were compared using Duncan's multiple range test (Duncan, 1955). The level of significance was based on $P < 0.05$.

RESULTS

Growth Performance

The BW and BWG of birds are presented in Tables 2 and 3, respectively. During the overall study period (1 to 5 wk), the BW of chickens was affected by the light source ($P < 0.05$). Birds reared under IL attained the lowest numerical BW. The BWG of birds differed ($P < 0.05$) during 2 wk of age, when the numerically high-

Table 4. Feed intake of broilers under different light treatments from 1 to 5 wk of age

	Feed intake (g)					
Treatment[1]	1 wk	2 wk	3 wk	4 wk	5 wk	Total
IL	178 ± 4	447 ± 9[ab]	684 ± 10	1,074 ± 22[b]	1,849 ± 41[ab]	4,234 ± 20[c]
WL	177 ± 1	446 ± 10[ab]	716 ± 15	1,112 ± 19[ab]	1,885 ± 14[ab]	4,339 ± 15[ab]
BL	183 ± 4	458 ± 7[ab]	720 ± 4	1,148 ± 9[a]	1,831 ± 56[b]	4,341 ± 38[ab]
RL	173 ± 8	420 ± 32[b]	700 ± 19	1,099 ± 24[ab]	1,861 ± 25[ab]	4,254 ± 38[bc]
GL	177 ± 6	438 ± 7[ab]	699 ± 3	1,133 ± 13[a]	1,898 ± 70[a]	4,348 ± 44[ab]
YL	187 ± 4	478 ± 11[a]	710 ± 21	1,109 ± 11[ab]	1,903 ± 12[a]	4,387 ± 24[a]

[a–c]Means with different superscripts in the same column differ significantly ($P < 0.05$).

[1]WL = white light; BL = blue light; RL = red light; GL = green light; YL = yellow light; IL = incandescent light (control).

Table 5. Feed conversion ratio of broilers under different light treatments from 1 to 5 wk of age

	FCR (g/g)				
Treatment[1]	1 wk	2 wk	3 wk	4 wk	5 wk
IL	1.16 ± 0.05^{ab}	1.39 ± 0.04^{ab}	1.38 ± 0.03^{ab}	1.53 ± 0.05	2.30 ± 0.04
WL	1.10 ± 0.01^{b}	1.43 ± 0.05^{ab}	1.32 ± 0.02^{b}	1.52 ± 0.06	2.50 ± 0.20
BL	1.08 ± 0.01^{b}	1.39 ± 0.02^{ab}	1.37 ± 0.01^{ab}	1.61 ± 0.04	2.39 ± 0.08
RL	1.09 ± 0.04^{b}	1.30 ± 0.08^{b}	1.32 ± 0.01^{b}	1.53 ± 0.04	2.51 ± 0.06
GL	1.08 ± 0.02^{b}	1.46 ± 0.02^{a}	1.38 ± 0.02^{ab}	1.52 ± 0.04	2.45 ± 0.19
YL	1.21 ± 0.02^{a}	1.37 ± 0.01^{ab}	1.39 ± 0.03^{a}	1.58 ± 0.09	2.10 ± 0.04

[a,b]Means with different superscripts in the same column differ significantly ($P < 0.05$).

[1]WL = white light; BL = blue light; RL = red light; GL = green light; YL = yellow light; IL = incandescent light (control).

est BWG was obtained in the birds reared under YL. During 5 wk of age, the birds were heavier, however not statistically, under YL. The effect of all LED sources on BWG was not consistent throughout the experimental intervals in that it did not affect BWG during 1, 3, and 4 wk of age. Also, no difference in BWG was observed in the pooled data for the overall growth period (1–5 wk).

The data obtained for FI under different LED color schemes is presented in Table 4. The color of light affected FI during 2, 4, 5, and 1–5 wk of age, whereas it remained unaffected during the rest of the experimental weeks. During wk 2, YL birds consumed more feed, whereas IL birds had the lowest FI during wk 4. At 5 wk, the lowest FI was observed under BL. During the overall experimental period (1–5 wk), numerically higher and lower FI was recorded under YL and IL, respectively.

The FCR of birds reared under different LED color lights is shown in Table 5. Numerically, the FCR was aggravated in the birds reared under YL compared with other light groups during wk 1 and 3. During 2 wk of age, the poor FCR values were noted under GL. No difference ($P > 0.05$) in FCR was observed during 4 and 5 wk of age.

Hematological Traits

Hematological measures (RBC, WBC, Hct, hemoglobin, and platelets) under different light treatments is shown in Table 6. The WBC count and hemoglobin were similar among different LED color groups ($P > 0.05$). The higher numerical values of the rest of the blood parameters (RBC, Hct, and platelets) were found with the YL source. The WL treatment showed numerically lower values of RBC and Hct, whereas numerically lower platelet count was noticed under GL source.

Differential Cell Counts

The neutrophil, eosinophil, and basophil counts were not affected, whereas lymphocyte and monocyte counts were influenced by LED sources ($P < 0.05$; Table 7). The lymphocyte and monocyte counts were reduced, however not statistically, under WL and GL, respectively.

DISCUSSION

The birds reared under YL attained higher BW and BWG at 5 wk of age. The present finding is in accordance with Jiang et al. (2012), who found a rise in the BW in laying hens under YL. Hakan and Ali (2005) stated that blue (435–500 nm), green (500–565 nm), and yellow (500–600 nm) wavelengths have positive effects, whereas orange (600–630 nm) and red (630–700 nm) wavelengths have negative effects on broiler performance. Nonetheless, in an experiment by Heshmatollah (2007), when given the option of red, orange, yellow, or green light, broilers spent more time under green light with their second preference being yellow.

The better FI under YL might explain the color preference by birds and acceptance of specific wavelengths of light during the experimental period. Taylor et al.

Table 6. Hematological analysis of growing broilers under different light treatments

	Blood analysis[2] (%)				
Treatment[1]	RBC	WBC	Hct	Hb	Platelet
IL	2.51 ± 0.07^{ab}	0.86 ± 0.15	27.49 ± 0.63^{ab}	8.73 ± 0.30	24.63 ± 3.29^{ab}
WL	2.40 ± 0.08^{b}	1.13 ± 0.20	26.01 ± 0.78^{b}	8.65 ± 0.21	23.10 ± 2.70^{ab}
BL	2.42 ± 0.07^{b}	0.90 ± 0.18	26.77 ± 0.71^{ab}	8.40 ± 0.20	18.89 ± 1.99^{ab}
RL	2.49 ± 0.07^{ab}	1.07 ± 0.18	27.78 ± 0.69^{ab}	8.76 ± 0.21	26.89 ± 2.96^{ab}
GL	2.44 ± 0.06^{ab}	0.84 ± 0.23	26.74 ± 0.58^{ab}	8.44 ± 0.31	18.43 ± 2.84^{b}
YL	2.70 ± 0.15^{a}	0.98 ± 0.23	29.56 ± 1.59^{a}	8.59 ± 0.89	28.56 ± 4.33^{a}

[a,b]Means with different superscripts in the same column differ significantly ($P < 0.05$).

[1]WL = white light; BL = blue light; RL = red light; GL = green light; YL = yellow light; IL = incandescent light (control).

[2]RBC = red blood cell ($10^6/\mu L$); WBC = white blood cell ($10^3/\mu L$); Hct = hematocrit value (%); Hb = hemoglobin (g/dL); platelets $10^3/\mu L$.

Table 7. Differential cell count of broilers under different light color treatments

Treatment[1]	Differential cell count (%)				
	Neutrophil	Lymphocyte	Monocyte	Eosinophil	Basophil
IL	21.0 ± 4.29	69.2 ± 2.70[ab]	5.75 ± 1.79[ab]	1.75 ± 0.80	2.25 ± 0.70
WL	26.0 ± 4.32	61.7 ± 5.00[b]	8.00 ± 1.92[a]	1.89 ± 0.39	2.33 ± 0.65
BL	18.3 ± 3.23	73.7 ± 3.26[ab]	4.78 ± 2.08[ab]	0.89 ± 0.48	2.22 ± 0.85
RL	15.3 ± 3.84	76.8 ± 4.99[a]	4.89 ± 1.34[ab]	1.11 ± 0.48	1.78 ± 0.70
GL	18.0 ± 1.80	74.2 ± 2.78[ab]	1.71 ± 0.52[b]	1.00 ± 0.85	3.57 ± 1.31
YL	15.3 ± 2.65	75.4 ± 4.21[a]	4.67 ± 1.53[ab]	2.22 ± 1.08	2.89 ± 1.25

[a,b]Means with different superscripts in the same column differ significantly ($P < 0.05$).

[1]WL = white light; BL = blue light; RL = red light; GL = green light; YL = yellow light; IL = incandescent light (control).

(1969) tested the chick color preference for different age groups and stated that chicks preferred the yellow color. The greater muscle weight might be due to the increased satellite cell proliferation during initial growth (Halevy et al., 1998). It seems that the monochromatic light source is effective somehow for feed utilization during the initial phase; however, it became nonresponsive during later phases of the life of broilers. It is speculated that the light of different wavelengths has varying capability of stimulation on the retina (Lewis and Morris, 2000), which might modify behavior that could further affect feed utilization. Moreover, the growth is the manifestation of the different hormonal response [e.g., thyroid hormones (T_3 and T_4)], which is stimulated by normal photoperiods (Blair et al., 2000).

Immune response in broilers is influenced by photostimulation, particularly the intensity and duration of light (Olanrewaju et al., 2008; Sadrzadeh et al., 2011). The influence of light color on cellular and humoral immune response in poultry has also been explicitly studied (Moore and Siopes, 2000; Xie et al., 2008). The higher RBC counts, Hct (%), and platelet counts under YL is obvious as they are closely associated with each other in blood. Theoretically, an increase in the number of erythrocytes of the same mean corpuscular volume always leads to an increase in Hct value. Nevertheless, the chickens that were characterized by a greater number of RBC (and hence, higher Hct value) could have erythrocytes with a lower hemoglobin content although its amount in blood was higher (Nowaczewski and Kontecka, 2012). It can be stated that the YL influenced the hematological measures that ultimately reflected in better growth response.

The granulocyte (neutrophil, eosinophil, and basophil) count was not affected by any of the light treatments in the present experiment, indicating a healthy flock. Xie et al. (2008), after studying the impact of different light colors on broiler immunity, reported that blue and green light could promote greater antibody production and humoral immune function in the broilers compared with red lights. In another recent study, when the chickens were vaccinated with infectious bursal disease and Newcastle disease vaccines, maximum T-lymphocyte proliferation was found under YL at 30 d of photostimulation (Sadrzadeh et al., 2011). Nevertheless, the present results are inconsistent for hematological measures. Therefore, this needs further investigations.

In conclusion, monochromatic light has a beneficial impact on the growth performance response of broilers. The monochromatic light has no direct impact on immune function per se. However, short-wavelength LED such as yellow, blue, or green could be a potential replacement for incandescent bulbs for sustainable commercial broiler production.

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