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INFLUENCE OF COLORED LIGHT-EMITTING DIODE ILLUMINATION ON THE GROWTH PERFORMANCE AND MEAT QUALITY TRAITS OF PEKIN DUCKS (*ANAS 1PLATYRHYNCHOS*)

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Abstract

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The present experiment has been executed to find out the impact of different colors of light-emitting diode (LED) on growth performance and meat quality traits of Pekin ducks (*Anas platyrhynchos*). For this purpose, a total of 360 day-old mixed sex ducklings were allocated to six lightproof rooms separated from each other by wooden chip board. These six rooms were equipped with six colored LED viz. white light (WL), blue light (BL), red light (RL), green light (GL) and yellow light (YL) and incandescent light bulb (IL, 60 Watt) as a control. Each room was divided into six replicates with ten ducks in each replicate. At the end of wk 6, when data were pooled, the body weight (BW), BW gain (BWG) and feed intake (FI) were positively influenced by RL whereas YL showed poor performance ($P<0.05$). The RL and BL responded significantly to influence feed conversion ratio (FCR). The high pH and red color of duck meat were noticed in BL while low pH and light red color were observed in GL. The meat pH and color were correlated with each other and these attributes were improved in GL. It can be concluded that growth performance of ducks can be improved by using red and blue LED whereas meat quality traits can be improved in ducks by using green LED.

Key words: Growth, Light-emitting diode (LED) colors, Meat quality, Pekin ducks

Abbreviations: Light emitting diode (LED), Whilte light (WL), Blue light (BL), Red light (RL), Green light (GL), Yellow light (YL), Body weight (BW), Body weight gain (BWG), Feed intake (FI), Feed conversion ratio (FCR), Korean Feeding Standards for Poultry (KFSP), Lightness (L *), Redness (a *), Yellowness (b *)

Introduction

In order to combat rising problems in poultry, genetics and nutrition are not enough to overcome the challenges. There is a need to fine tune housing factors particularly light, temperature, ventilation. The bird eye is susceptible and respond differently to different wavelength of visible spectra. Moreover, among the light variables, source of light like newly-emerging source light-emitting diode (LED), is gaining popularity over traditional light sources such as incandescent, fluorescent, compact fluorescent, fluorescent tube lighting and high intensity discharge lighting, due to its high energy efficiency and availability in different wavelengths/colors (Huber-Eicher et al., 2013). The LED light give monochromatic light from different wavelengths. The impact of various intensities and wavelengths of light on production performance of poultry birds has been extensively studied by many researchers (Barrott and Pringle, 1951; Cherry and Barwick, 1962; Classen

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and Riddell, 1989; Manser, 1996). The color of light has been investigated to improve performance in different species of poultry like Japanese quail (Woodard et al., 1969), turkeys (Leighteon and Mason, 1976), laying chicken (Pyrzak et al., 1987) and broiler chicken (Hakan and Ali, 2005; Cao et al., 2008). The improvement in egg production in these studies has been noticed in red light while growth performance was ameliorated under green-blue light. Recently, the LED has been found to improve post-hatch performance in broiler chickens given LED during embryogenesis (Zhang et al., 2012). But the data on growth performance of growing ducks in different LED colors are very scarce.

Besides growth, meat quality is another aspect that is usually studied with respect to nutrition but there is limited information regarding LED and its impact on meat quality. As light has influence on growth and enhanced myoblasts thus can alter myofiber formation (Halevy et al., 2006). The green-blue LED has been found to improve the structure of broiler muscles in growing broiler chickens (Karakaya et al., 2009). In our previous experiment on broilers (Kim et al., 2013) it is noticed that short wavelength LED (e.g. yellow LED) could be a potential replacement for incandescent bulbs and other LED colors for better growth efficiency. As there is no study about the impact of LED on growth performance and meat quality of growing ducks, therefore, the present study has been conducted to find out the influence of monochromatic light produced by the LED on growth and meat quality parameters of growing Pekin ducks (*Anas platyrhynchos*).

Materials and Methods

All the experimental procedure was in compliance with the laws of Committee on Animal Research and Ethics, National Institute of Animal Science, Rural Development Administration, Republic of Korea.

Birds and Experimental Design

A total of three hundred and sixty (n=360) day-old mixed sex ducklings (Pekin Ducks, *Anas platyrhynchos*) of average weight were procured from a commercial hatchery. All the ducklings were divided into six LED groups in six environmentally controlled lightproof rooms. Each room was divided in to six replicates by wooden chip board with 10 ducklings in each replicate. The height of the wooden chip boards was 6 fts so that no duckling could jump and see each other. The floor density for the growing ducklings in individual replicate was 0.21 m^2. The ducks were reared for two growing phases i.e. 0-3 and 3-6 wks of age, fed two diets viz. starter and grower, with 22.4 and 18.4% CP and ME of 2,906 and 3,016 kcal/kg, respectively (Table 1). The birds were fed standard diets formulated as per Korean Feeding Standards for Poultry (KFSP, 2007). The feed and water were provided *ad libitum* throughout the experimental period. The room temperature was maintained and controlled by using fan system at 30°C for first three days and then reduced by 0.5°C daily until 21°C was attained by the end of the experiment (i.e. d 42).

Light-Emitting Diode Colors and Installation

The six light colors viz. white light (WL, 2,800~3,200 K), blue light (BL, 450~460 nm), red light (RL, 600~630 nm), green light (GL, 510~530 nm) and yellow light (YL, 580~590 nm) and incandescent light bulb (IL, 60 Watt, 2,600~3,200 K) as a control, were used in the experiment. All the lights, except incandescent light, were produced by LED lamps and were designated as the six light groups. A Chroma Meter (CL 200, Konica Minolta Sensing Inc, Japan) was used to measure the wavelengths of LED's colors. The instrument displayed the values of each light color for X and Y axis which was matched with a standard chromatogram at both axis and the resultant values so obtained considered as the wavelength

Table 1
Ingredient and nutrient composition of the diets

	0-3 wk	3-6 wk
Ingredients, %		
Corn	53.95	58.90
Wheat bran	7.40	14.60
Soybean meal	33.50	15.35
Corn gluten meal	1.50	7.00
Soybean oil	0.50	1.00
Calcium carbonate	0.35	0.70
Calcium phosphate	1.30	1.00
DL-Methionine	0.10	0.05
Lysine.HCl	0.05	0.05
Premix	1.00	1.00
Salt	0.25	0.25
Binding agent	0.10	0.10
Nutrients, % or otherwise stated, Analyzed Results		
CP	22.4	18.4
ME, kcal/kg	2,906	3,016

[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 ICU; vitamin D3 (cholecalciferol), 9,480.0 ICU; vitamin E (DL-α-tocopheryl acetate), 63.0 ICU; vitamin K activity, 6.4 mg; thiamin, 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 B12 , 35.4 mg; choline, 956.9 mg.

of a particular color. The LED lamps were designed and assembled by National Institute of Animal Science. Sixty eight (68) LED bulls 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 volts, WL = 3.3 volts, and GL and BL = 3.4 volts. The LED lamps were provided with the same forward current of I = 20 mA. All light sources were equalized on the illuminance of 15 ± 0.2 lx at bird-head level and light period. The light schedule was 24 h for first three days and then 23L:1D until the termination of the experiment at d 42.

Data Collection

The body weight (BW) and feed intake (FI) were recorded from each replicate at the end of 3rd and 6th week of age. To calculate the feed wastage, an apron was provided in front of the feeding area, for collecting feed that is dropped or billed out during feeding. The FI was calculated by considering the wasted feed, replicate wise. The body weight gain (BWG) was used to divide FI to calculate feed conversion ratio (FCR).

At the end of the experiment, three ducks of average weight from each replicate were randomly selected for meat quality traits.These ducks were anesthetized with diethyl ether and killed. The pH of breast meat samples was measured just after slaughtering by using a Deep Carcass pH meter (pH-K21, KWK-Binar GmbH, Celiusstr, Germany). The pH meter was calibrated using standard buffers of pH 4.0 and 7.0 at 25°C.

The surface color of each breast meat sample (with and without skin) was determined using a Minolta Chromameter (Minolta CR300, Japan), designed by CIE (Commision Internationale de Leclairage) as lightness (L *), redness (a *), yellowness (b *). The color meter was calibrated against a standart white ceramic tile (Y = 92.40, x = 0.3136, y = 0.3196) provided by the manufacture (Park et al., 2007). The chromameter was calibrated using a standard white ceramic tile before measuring. Five random readings were taken from each sample of breast meat.

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

Body weight and BW Gain

The data for BW and BWG gain of ducks reared under different LED colors is presented in Table 2. The LED lights significantly affected the BW and BWG gain of the growing ducks during different stages of growth. During initial growth period (wk 1-3), the BW and BWG gain was higher (P<0.05) in IL (control) as compared to different colors of LED. However, during wks 4-6 and 1-6, the RL and GL responded equally in increasing BW and BWG gain of the growing ducks (P<0.05).

Feed Intake and FCR

The data for FI and FCR of growing duck is presented in Table 3. A significantly higher FI in ducks was observed in IL group during initial growing period (wk 1-3; P<0.05) which was statistically similar to red LED group. Likewise, during the later development stages (wk 4-6) and overall experimental period (wk 1-6), the FI was significantly higher in RL (P<0.05) but not in IL. The YL showed poor FI during the observed periods (P<0.05).

The LED lights significantly affected the FCR of the growing ducks (Table 3). During wk 1-3, the improved values for FCR (1.58) was observed in GL group (P<0.05). During wk 4-6, the BL had a significant impact in improving FCR. However, when the data of FCR was pooled for overall period

Table 2
Body weight and weight gain of growing ducks under different LED colors during different phases of growth

Treatment[1] wks/	Body weight, g			Weight Gain, g		
	1-3	4-6	1-6	1-3	4-6	1-6
IL	1329±6.7^{a}	2158±8.5^{bc}	3487±14.6^{b}	1272±6.7^{a}	2158±8.5^{bc}	3430±14.4^{b}
WL	1307±9.8^{ab}	2123±44.4^{cd}	3430±35.1^{b}	1251±9.55^{ab}	2123±44.4^{cd}	3374±35.3^{b}
BL	1276±16.9^{bc}	2202±13.5^{b}	3478±8.7^{b}	1218±16.9^{bc}	2202±13.3^{b}	3420±8.6^{b}
RL	1286±4.2^{b}	2308±17.2^{a}	3594±17.1^{a}	1229±4.2^{b}	2308±17.2^{a}	3537±17.0^{a}
GL	1286±12.6^{b}	2273± 28.5^{a}	3559±20.8^{a}	1229±12.7^{b}	2273±28.5^{a}	3502±20.9^{a}
YL	1249±13.1^{c}	2084±5.9^{d}	3334±10.3^{d}	1192±13.1^{c}	2084±5.9^{d}	3277±10.3^{c}

^{a,b,c,d} 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).

(wk 1-6), the highly improved value for FCR was observed under BL and RL (P<0.05).

Meat Quality Traits

The meat quality traits viz. pH and breast meat color (with and without skin) are presented in Table 4. The pH of breast meat has been influenced by various LED groups (P<0.05). A lower pH value (5.72) was observed under GL whereas it was higher (5.82) under BL. The redness and yellowness of breast meat (with skin) were lower under GL and RL color, respectively, whereas the redness of breast meat was higher under BL (P<0.05). The lightness of skinned breast meat was not affected by LED colors. On the other hand, the lightness of the skinless breast meat was lower under RL as compared to other lights whereas the yellowness of breast meat was higher under BL (P<0.05). The meat redness (without skin) remained unaffected due to light colors (P>0.05).

The correlation between different meat quality attributes is developed in Table 5. Yellowness of skinned breast meat was found to correlate positively to lightness (P<0.01) whereas negatively to pH and redness of skinned meat (P<0.05). Likewise, the lightness (P<0.05) and yellowness (P<0.01) of skinless breast meat were negatively correlated with redness of meat.

Discussion

Among all other duck strains, Pekin ducks have been recognized as the fast-growing ducks. Duck is considered as a special species of poultry in two prospects: 1) ducks have a very high initial growth rate (Shalev, 1995), 2) the whole body

Table 5
Correlation analysis of pH, L* (lightness), a* (redness) and b* (yellowness) of breast meat of ducks reared under different LED colors

	Breast meat (with skin)		
	pH	L*	a*
b*	-0.254*	0.439**	-0.259*
a*	0.157	-0.144	
L*	-0.128		
	Breast meat (without skin)		
	pH	L*	a*
b*	0.124	0.088	-0.536**
a*	0.149	-0.240*	
L*	0.119		

*p<0.05; **p<0.01

Table 3
Feed Intake and feed conversion ratio of growing ducks under different LED colors during different phases of growth

Treatment	Feed Intake, g/b FCR					
	1-3	4-6	1-6	1-3	4-6	1-6
IL	2103±8.4^{a}	6897±42.7^{ab}	9000±51.1^{ab}	1.60±0.007^{abc}	3.20±0.025^{ab}	2.41±0.014^{ab}
WL	2082±17.0^{ab}	6809±54.4^{b}	8892±47.3^{b}	1.60±0.003^{abc}	3.27±0.076^{a}	2.43±0.37^{a}
BL	2073±16.8^{ab}	6512±68.0^{c}	8585±63.8^{c}	1.64±0.020^{a}	2.99±0.032^{d}	2.32±0.01^{c}
RL	2082±7.3^{a}	7062±43.7^{a}	9145±43.9^{a}	1.62±0.007^{ab}	3.05±0.007^{cd}	2.34±0.006^{c}
GL	2049±24.7^{bc}	6991±70.2^{a}	9041±54.3^{ab}	1.58±0.016^{c}	3.13±0.036^{bc}	2.36±0.026^{bc}
YL	2016±17.2^{c}	6564±36.0^{c}	8581±77.5^{c}	1.63±0.005^{a}	3.25±0.045^{ab}	2.44±0.22^{a}

^{a,b,c,d}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

Table 4
Meat quality traits of duck reared under different LED colors

		Breast meat color (with skin)			Breast meat color (without skin)		
Treatment[1]	pH	L* (Lightness)	a* (redness)	b* (yellowness)	L* (Lightness)	a* (redness)	b* (yellowness)
IL	5.81± 0.01^{ab}	71.81± 0.34	8.45± 0.46^{ab}	21.50±0.74^{a}	39.18± 0.50^{a}	17.41± 0.34	6.37±0.19^{c}
WL	5.74± 0.02^{bc}	71.45± 0.39	7.37± 0.18^{bc}	19.93± 0.51^{ab}	38.32± 0.71^{a}	17.72± 0.64	6.56±0.28^{bc}
BL	5.82± 0.01^{a}	72.01± 0.36	9.26± 0.07^{a}	20.08± 1.16^{ab}	37.95± 0.45^{a}	18.58± 0.23	7.54±0.24^{a}
RL	5.78± 0.01^{bc}	72.28± 0.33	7.78± 0.44^{bc}	16.79± 0.05^{c}	35.92± 0.80^{b}	18.20± 0.57	6.79± 0.17^{abc}
GL	5.72± 0.02^{d}	72.42± 0.32	7.05± 0.21^{c}	17.47± 0.58$_{bc}$	39.30± 0.40$_{a}$	17.25± 0.34	6.37±0.25^{c}
YL	5.76± 0.01^{bc}	72.58± 0.27	7.51± 0.17^{bc}	21.89± 0.82$_{a}$	39.31± 0.03$_{a}$	17.84± 0.69	7.36± 0.14^{ab}

^{a,b,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).

is mainly composed of more meat and less bone percentage even with increasing aging (Bochno and Lewczuk, 1986). Moreover, the rising popularity of ducks is reflected from their customized behavior in various environmental conditions (Solomon et al., 2006). In the present study, we have evaluated both growth potential and meat quality of Pekin ducks under different monochromatic light colors. The higher body weight in RL during the overall experimental period depicted that ducks required the long-wavelength (i.e. RL) as compared to short-wavelengths to show their maximum growth potential. However, FCR was better in GL during early growth stage whereas it was better in BL during later growth stage and these results are in line with the results of Cao et al. (2008). Halevy et al. (1998) linked these results with the higher skeletal muscle growth and satellite cell proliferation in broiler chickens. Further, it was also confirmed in a series of experiements in broilers (Rozenboim et al., 2004; Hakan and Ali, 2005; Olanrewaju6 et al., 2006). According to Prayito et al. (1997), red light increased the activity of birds as compared to other light colors and this could be the probable reason of higher feed intake and then more weight gain in ducks under RL in the present study. But the response of RL to promote growth and feed efficiency in ducks is a new finding and further research is required to find out the exact mechanism.

In the current study, the BL showed higher pH along with more red (skinned) and dark (skinless) breast meat as compared to meat of ducks reared under GL. The higher pH is usually associated with redness of meat as is evident from previous studies (Allen et al., 1997; Fletcher, 1999) and is also apparent from the present study. When the pH of the meat is above the isoelectric point of the myofibrillar proteins in the meat, water molecules are tightly bound, causing more light to be absorbed by the muscle, and the meat appears darker in color (Cornforth, 1994; Allen et al., 1997). This dark meat could be led to bad odor owing to the growth of psychrotrophic bacteria in the muscles (Pooni and Mead, 1984). These bacterial species (*Pseudomonas and Shewanella*) grew faster on high pH than normal pH (Newton and Gill, 1981; Russell et al., 1995). So we would recommend GL for better meat color.

Conclusion

It can be incurred from the present observations that light-emitting diode particularly red and blue colors were found beneficial for growth whereas green color was found to improve meat traits in Pekin ducks. As like broiler chickens, the duck growth can be improved by adopting emerging light source (light-emitting diode) as compared to conventional lights.

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