Kasetsart J. (Nat. Sci.) 48 : 412 - 424 (2014)

Effects of Green or a Combination of Green and Blue Monochromatic Light on Growth, Carcass Yield, the Heterophil-to-Lymphocyte Ratio and Eye Morphology of Thai Indigenous Chickens

Nirat Gongruttananun

ABSTRACT

In total, 240 one day old Thai-native chickens (*Gallus domesticus*) were housed in floor pens, located in a light-proof shed and exposed to one of the following lighting treatments: 1) white fluorescent light throughout the 16 wk of the experimental period (WF), 2) green light provided by a light emitting diode (LED) throughout the experimental period (GLED) and 3) green LED light for the first 3 wk then switching to blue LED light provided for the remaining 13 wk (G-BLED). All treatments were provided with a daily light:dark photoperiod of 23:1 hr over the 16 wk growing period, and there were four replicate pens of 20 straight-run chickens for each treatment. Live performance and the mortality rate were recorded during the experimental period. Feed and water were available at all times. Cumulative feed consumption, feed conversion ratios and mortality rates were similar among the treatment groups. At 6 wk of age, the body weight of the GLED birds was significantly heavier than that of the WF birds, whereas the G-BLED birds had an intermediate value compared with those of the other two treatment groups. Whole carcass and carcass yield characteristics of male chickens processed at age 16 wk were similar for all light treatments, except for relative weights, expressed as percentages of body weight and lean carcass weight, of the liver where the liver relative weights of the WF treatment group were significantly greater than those of the GLED treatment group. There were no significant differences among the treatment groups for weights of the spleen, thymus and bursa of Fabricius. Neither the hematocrit value nor eye morphology of the male birds measured at age 16 wk were influenced by the light treatments. However, the WF birds had a higher heterophil-to-lymphocyte ratio ($P < 0.05$) compared with the GLED and G-BLED birds.

It was concluded that green or blue light has little effect on growth stimulation and the carcass yield of Thai-native chickens without any deleterious effect on eye morphology. The results suggested that the light spectra reduced aggression and activity in the birds. Nevertheless, an additional effect of light intensity may exist and should not be excluded. The LED lighting regimens could be beneficial for energy conservation, the reduction of rearing costs and the improvement of the well-being of the birds.

Keywords: indigenous chicken, light emitting diode, carcass, leukocyte, eye morphology

Department of Animal Science, Faculty of Agriculture, Kasetsart University, Bangkok 10900, Thailand.
E-mail: agrnig@ku.ac.th

Received date : 14/10/13 Accepted date : 19/03/14

INTRODUCTION

Light is an important environmental factor for birds as it not only allows vision but influences important physiological responses such as activity and behavior (Lewis and Morris, 2000). The growth performance of the domestic fowl is highly dependent on appropriate light manipulation and studies have been conducted involving both the quantity (duration and intensity) and the quality (color or wavelength) of light and the effects of the spectrum (color of light) on the growth performance of the domestic fowl. For example, it is well documented that light from the green and blue spectra has a positive effect on growth and development (Ookawa, 1970; Foss *et al*., 1972; Wabeck and Skoglund, 1974; Rozenboim *et al*., 1999), whereas red light has a gonadal activating effect (Harrison *et al*., 1970; Pyrzak *et al*., 1987; Gongruttananun, 2011). Halevy *et al*. (1998) demonstrated that green light accelerated muscle growth in male broiler chickens and suggested a possible mechanism for the acceleration of growth associated with light stimulation. Cao *et al*. (2008) reported that broilers reared under blue or green light had significantly heavier body weights than those raised under white or red light. Xie *et al*. (2008) found that green or blue light enhanced the immune response and increased the proliferation of peripheral blood T-lymphocytes, which may play a role in alleviating the stress response in broilers. In addition, Rozenboim *et al*. (1999) stated that the effect of monochromatic light on growth and development in broiler chickens was age related. Rozenboim *et al*. (2004) demonstrated that the growth performance of male broiler chickens could be improved by switching light from blue to green at age 20 d. Karakaya *et al*. (2009) reporting on female broiler chickens indicated that the growth performance and meat quality properties could be improved by exposing the birds to green light at an early age and blue light in older birds.

The Thai government policy is to promote the raising of indigenous chickens by small holders to increase their household income and keep this local strain for the conservation of genetic resources (Aini, 1990). Local consumers consider the meat of the indigenous chickens to have a better taste and texture than that of commercial broilers. Wattanachant *et al*. (2004) reported that Thai-native chicken muscles contained a higher protein content but lower fat and ash contents compared with those of broiler muscles. In general, Thai-native chickens have been reared extensively for generations in suburban areas and in free-range or integrated farming systems. Due to the increase in demand, the backyard farms have been turned into commercial native-chicken farms. However, the growth performance of the birds is considerably lower than that of commercial broiler chickens. Under commercial farm conditions, the body weight of the birds at age 16 wk is only 1.25 kg, and an average feed conversion ratio during the age interval 0 to 16 wk of the birds is 5.9 (Kongruttananun, 1992). This is a costly problem for the producers, resulting in substantial losses in production of the birds to meet the market weight.

Gongruttananun (2011) reporting on Thai-native laying hens indicated that the reproductive development could be accelerated by exposing the pullets to red light without deleterious effects on the eggshell ultrastructure, eye morphology or mortality rate. Information about the effects of the color of light on the growth performance and carcass yield of the indigenous Thai chickens during the growing period is lacking. Therefore, the objective of the present study was to determine the influence of monochromatic light applied from age 0 to 16 weeks on the growth performance, carcass yield, the ratio of heterophil-to-lymphocyte and eye morphology in Thai-native chickens.

MATERIALS AND METHODS

Experimental birds and lighting regimens

The experimental animals and procedures used in this study were approved by the Animal Ethics Committee of Kasetsart University, Thailand. A total of 240 Thai native chickens aged 1 d were used in this study. The chicks were reared in slat-floor pens located in a light-proof house and were randomly divided into three light treatment groups (n = 80), each group consisting of 4 replicates of 20 birds (straight-run chicks) per replicate. Light treatments were: 1) white light provided by fluorescent tubes (Model EFD 13D/6D-E 2U; Toshiba Co., Ltd.; Bangkok, Thailand) throughout the 16 wk experimental period (WF); 2) green light provided by a light emitting diode (LED; Model 5 mm round ultra bright green; ENGINEO Co., Ltd.; Chiang Mai, Thailand) throughout the experimental period (GLED); and 3) green LED light provided for the first 3 wk then switching to blue LED light (Model 5 mm round ultra bright blue; ENGINEO Co., Ltd.; Chiang Mai, Thailand) for the remaining 13 wk (G-BLED). Each pen was 2.9 × 2.9 × 3.0 (width × height × length), and enclosed with polyvinyl chloride black plastic and mechanically ventilated. The light schedule was constant at 23 hr light (L):1 hr dark (D) photoperiod throughout the study.

The chicks were vaccinated at the hatchery for infectious bursal disease, Marek's disease, Newcastle disease and infectious bronchitis disease. Birds were brooded at 35°C during the first week by electric brooders, and the temperature was reduced 3°C per week to 3 wk of age, at which time the brooders were removed. The birds were provided *ad libitum* access to feed and water. A starter ration (19% crude protein and 2,900 kcal of metabolizable energy (ME).kg^{-1} of feed) was provided from day 1 to age 5 wk, a grower ration (15% crude protein and 2,800 kcal of ME.kg^{-1} of feed) was provided from 5 to 12 wk and a finisher ration (13% crude protein and 2,750 kcal of ME.kg^{-1} of feed) was provided from age12 to 16 wk.

The experiment commenced in November 2012 and terminated in February 2013. The ambient temperature in the pens was recorded daily. Throughout the study, the temperatures (mean ± SE) of the WF, GLED and G-BLED groups were 29.4 ± 2.2, 30.1 ± 3.5 and 29.9 ± 2.8°C, respectively.

Lighting devices

In each pen of the WF treatment, artificial light was provided from one 13 W white light fluorescent tube hung from the ceiling in the middle part of the pen. The green and blue light used in the GLED and G-BLED treatments, respectively, was produced from a light emitting diode (LED). The LED lamp was made by using 20 diodes installed in two parallel lines 4.5 cm apart on a plastic board (7 cm × 10.5 cm, width × length). The green and blue LED lamps were hung from the ceiling in the middle part of each pen subjected to the GLED and G-BLED treatments, respectively. The light intensity was measured with a luxmeter (model TES-1330, TES Electrical Electric, Corp., Taiwan) with a measuring range of 1×10^{-2} to 1×10^{5} lx and an accuracy of ± 3% at the level of the heads of the birds at five locations within each pen. The light intensity measurements were taken on a weekly basis, recorded at 1200 hours and repeated at 1800 hours to establish a pen mean light intensity, over the 16 wk experimental period. The mean light intensity of the WF, GLED and G-BLED treatments was 188.6, 31.1 and 22.4 lx, respectively. The physical characteristics of these light sources are detailed in Table 1.

Body weight and performance variables

Body weights were recorded at the beginning of the study and repeated biweekly until the end of the trial (age 16 wk). Biweekly feed consumption was measured, and the feed conversion ratio was calculated. In addition, the mortality rate was recorded throughout the experimental period.

Table 1 Radiometric and electrical characteristics of the three light sources used in the experiment.

Light type	Peak of wave length (nm)	Spectrum bandwidth (nm)	Viewing angle (degree)	Luminous intensity (mcd)	Luminous intensity (Lumen.W^{-1})	Power dissipation (W)
White Fluorescent	-	-	-	-	37	13.00
Green LED	517	35	15	13,000	-	0.10
Blue LED	468	25	70	450	-	0.19

LED = Light emitting diode; mcd = millicandela.

Hematological studies

Blood samples (5 mL) were obtained from the brachial vein of two male birds at age 16 wk from each replicate. The time of bleeding was between 0900 and 1000 hours. The hematocrit value was determined using heparinized microcapillary tubes by centrifuging in a Hettich Microliter centrifuge (Hettich, Tuttlingen, Germany) at 21,382×*g* for 5 min. The physiological stress of chicks was determined by counting leukocytes in the blood and calculating the heterophil:lymphocyte ratio (an elevated ratio indicating increased stress) using methods described by Gross and Siegel (1983). In brief, the blood samples were collected in tubes containing ethylene diamine tetraacetic acid as an anticoagulant. A blood smear was prepared using May Gründwald-Giemsa stains, approximately 2 hr after methyl alcohol fixation, and the numbers of heterophils and lymphocytes were counted for a total of 60 cells.

Carcass yield

Two male birds per replicate were randomly selected and killed for determination of the carcass yield at the termination of the study (age 16 wk). Feed was removed 12 hr before slaughter (Lyon *et al*., 1991). The birds were killed by exsanguination (jugular veins cut by a scalpel; bleed time 105 s) and moved through a rotary feather picker. Vents were opened with a knife. Viscera and the lungs were removed. The carcasses were passed through a water wash. Eviscerated carcass weights before (prechilled carcass) and after (chilled carcass) chilling (slush ice for 1 hr) and abdominal leaf fat weights were measured. The carcasses were cut into wings, drumsticks, thighs, breast fillets (*Pectoralis major*) and tenders (*Pectoralis minor*), and weighed according to the methods described by Renden *et al*. (1991).

At necropsy, lymphoid organs (thymus, spleen and bursa of Fabricius) were then harvested for relative weight determinations; connective tissue was taken off before weighing. The thymus glands (only seven lobes on the right side of the neck) were immediately removed and weighed to the nearest 0.1 mg.

Eye morphology

On the day of euthanasia, the left and right eyes were taken out and weighed to the nearest 0.1 mg immediately following their removal. The eye dimensions were measured with a vernier caliper (Mitutoyo Corp., Kawasaki, Kanagawa, Japan) to the nearest 0.1 mm, including the transverse diameter (width), according to the methods described by Siopes *et al*. (1984). In brief, transverse diameters were measured across the eye with the calipers held parallel to the anterior-posterior plane and perpendicular to the dorsal-ventral plane of the cornea, with the optic nerve in its most downward position. The anterior-posterior diameter was measured from the most anterior edge of the cornea to the most posterior edge of the ocular globe, and the corneal height was measured as the perpendicular height above the most anterior plane of the sclera ossicle.

Statistical analysis

The experiment was conducted as a completely randomized design with three treatments. Data were analyzed using the statistical software package SAS, version 9.0 (SAS Institute, 2002). The GLM procedure was used to analyze the effect of the treatment on the body weight, feed intake, feed conversion ratio, mortality rate, carcass yield, hematological values and eye morphology. An arcsine transformation was used for all percentage data. When the means of the GLM procedure were statistically different, these means were further compared between the experimental groups using Duncan's multiple range test. Significance was based on $P < 0.05$. The experimental unit was a group of 20 birds for all traits studied. For determination of the carcass yield, hematological values, morphological characteristics of the eye and lymphoid organ weights, only two samples per replicate were used. Data were presented as means and the pooled standard error of the means.

RESULTS

Body weights of the experimental birds subjected to the three light treatments at various ages are shown in Table 2. At age 6 wk, the birds of treatment GLED were significantly heavier than birds of treatment WF, whereas birds of treatment G-BLED had an intermediate body weight compared with the other two treatments. At age 8 wk, average values of the body weight of the GLED (616.6 g) and G-BLED (630.7 g) birds tended to be greater than that of the WF birds (576.3 g; $P = 0.05$). There were no significant differences in the cumulative feed conversion ratio or cumulative feed consumption among the light treatments throughout the experimental period, although the means of the G-BLED treatment were numerically less than those of the WF and GLED treatments (Table 3). There were no significant differences among treatments for the mortality rate over the 16 wk experimental period, which averaged 9.37, 6.38 and 4.01% for birds of treatments WF, GLED and G-BLED, respectively (data not shown).

Data for the carcass yield of male birds processed at age 16 wk are summarized in Table 4. No effect of lighting treatment was found among the treatment groups within the bird performance criteria of live body weight, whole carcass weight (prechilled carcass), and weights of chilled carcass, abdominal leaf fat, lean carcass, wings, drumsticks, thighs, breasts (fillets and tenders), heart, liver, gizzard and skeletal frame.

Table 2 Body weights of Thai-native straight chickens subjected to different light treatments.

Light	Age (wk)								
Treatment	1 day	2	4	6	8	10	12	14	16
					(g)				
WF	33.10	96.10	213.20	368.80[b]	576.30	828.20	1056.40	1279.60	1485.80
GLED	33.00	101.00	225.60	403.00[a]	616.60	845.60	1068.20	1322.50	1515.20
G-BLED	32.90	97.00	225.90	389.50[ab]	630.70	861.30	1106.20	1307.10	1464.50
SEM	0.60	3.60	19.70	16.50	28.10	38.20	42.60	52.70	85.70
P–value	0.91	0.18	0.59	0.04	0.05	0.49	0.27	0.53	0.71

[a,b] Means within the same column without a common superscript are significantly different ($P < 0.05$).

WF = White fluorescent light, 23 hr light:1 hr dark from day 1 to 16 wk; GLED = Green light emitting diode (LED) light, 23 hr light:1 hr dark from day 1 to 16 wk; G-BLED = Green LED light, 23 hr light:1 hr dark for the first 3 wk, then switching to blue LED light, 23 hr light:1 hr dark for remaining 13 wk.

SEM = Pooled standard error of the mean (4 replicates of 20 birds each per treatment).

Table 3 Cumulative feed conversion ratio (FCR) and feed consumption (FC) of Thai-native straight chickens subjected to different light treatments.

Light Treatment	Age intervals (wk)					
	0-6		0-12		0-16	
	FCR (kg:kg)	FC (kg)	FCR (kg:kg)	FC (kg)	FCR (kg:kg)	FC (kg)
WF	4.48	1.49	3.22	3.29	3.84	5.57
GLED	4.35	1.60	3.32	3.45	3.86	5.73
G-BLED	4.04	1.43	2.81	3.02	3.48	4.97
SEM	0.77	0.25	0.32	0.38	0.36	0.54
P–value	0.72	0.64	0.11	0.32	0.30	0.17

FCR = Cumulative feed consumed (kg/bird)/cumulative body weight gain (kg/bird).
FC = Feed consumption (kg/bird).
WF = White fluorescent light, 23 hr light:1 hr dark from day 1 to 16 wk; GLED = Green light emitting diode (LED) light, 23 hr light:1 hr dark from day 1 to 16 wk; G-BLED = Green LED light, 23 hr light:1 hr dark for the first 3 wk, then switching to blue LED light, 23 hr light:1 hr dark for remaining 13 wk.
SEM = Pooled standard error of the mean (4 replicates of 20 birds each per treatment).

Table 4 Carcass and yield characteristics of male Thai-native chickens subjected to different light treatments processed at age 16 wk.

Variable (g)	Light treatment			SEM	*P*–value
	WF	GLED	G-BLED		
Live body weight	1,488.8	1,521.3	1,491.3	143.4	0.881
Prechilled carcass	1,251.3	1,298.1	1,250.0	137.4	0.730
Chilled carcass	1,275.0	1,322.8	1,273.7	140.0	0.730
Abdominal leaf fat	7.3	8.4	8.6	7.9	0.941
Lean carcass	1,267.6	1,314.3	1,265.1	136.8	0.724
Wings	138.8	145.6	142.4	15.9	0.701
Drumsticks	170.9	185.0	174.0	24.2	0.484
Thighs	206.7	213.8	210.2	27.9	0.879
Fillets	185.0	197.0	185.9	28.1	0.640
Tenders	53.9	53.3	50.8	7.5	0.700
Heart	5.7	5.9	6.4	1.0	0.406
Liver	23.3	21.4	22.4	2.0	0.317
Gizzard	20.7	20.5	20.2	2.4	0.916
Skeletal frame	467.5	469.5	461.6	45.2	0.935

WF = White fluorescent light, 23 hr light:1 hr dark from day 1 to 16 wk; GLED = Green light emitting diode (LED) light, 23 hr light:1 hr dark from day 1 to 16 wk; G-BLED = Green LED light, 23 hr light:1 hr dark for the first 3 wk, then switching to blue LED light, 23 hr light:1 hr dark for remaining 13 wk.
SEM = Pooled standard error of the mean (4 replicates of 8 samples each per treatment).
Lean carcass = Chilled carcass – abdominal leaf fat.
Skeletal frame = Lean carcass – (wings + drumsticks + thighs + fillets + tenders + heart + liver + gizzard).

When body parts were expressed on a live body weight basis, the yield of liver was significantly greater in treatment WF than GLED, whereas treatment G-BLED had an intermediate value compared with the other two treatments (Table 5). A similar difference was also noticed among the treatment groups for the yield of liver expressed as percentage of the lean carcass weight.

Table 6 presents the effects of lighting treatments on hematocrit and relative weights

Table 5 Carcass components of male Thai-native chickens subjected to different light treatments expressedas percentage of live body weight and lean carcass at age 16 wk.

Variable	Lighttreatment			SEM	*P*–value
	WF	GLED	G-BLED		
	(g per 100g of body weight)				
Prechilled carcass	83.90	85.20	83.70	2.20	0.378
Chilled carcass	86.30	86.80	85.30	2.30	0.418
Abdominal leaf fat	0.40	0.50	0.50	0.40	0.978
Lean carcass	85.00	86.30	84.70	2.40	0.419
Wings	9.30	9.50	9.50	0.40	0.476
Drumsticks	11.40	12.10	11.60	0.60	0.178
Thighs	13.90	13.90	14.00	1.00	0.949
Fillets	12.40	12.80	12.40	1.10	0.709
Tenders	3.60	3.40	3.40	0.30	0.474
Heart	0.37	0.38	0.42	0.05	0.208
Liver	1.54[a]	1.36[b]	1.46[ab]	0.10	0.022
Gizzard	1.38	1.35	1.35	0.17	0.918
Skeletal frame	31.30	30.90	30.90	1.30	0.816
	(g per 100g of body weight)				
Abdominal leaf fat	0.50	0.60	0.60	0.50	0.984
Wings	10.90	11.00	11.20	0.40	0.278
Drumsticks	13.40	14.00	13.70	0.50	0.206
Thighs	16.30	16.10	16.50	1.10	0.765
Fillets	14.60	14.90	14.60	1.20	0.891
Tenders	4.20	4.00	4.00	0.30	0.392
Heart	0.44	0.44	0.50	0.06	0.182
Liver	1.80[a]	1.57[b]	1.71[ab]	0.12	0.024
Gizzard	1.62	1.56	1.59	0.22	0.877
Skeletalframe	36.80	35.90	36.50	1.80	0.586

[a,b] Means within the same row without a common superscript are significantly different ($P < 0.05$).

Lean carcass = chilled carcass – abdominal leaf fat.

WF = White fluorescent light, 23 hr light:1 hr dark from day 1 to 16 wk; GLED = Green light emitting diode (LED) light, 23 hr light:1 hr dark from day 1 to 16 wk; G-BLED = Green LED light, 23 hr light:1 hr dark for the first 3 wk, then switching to blue LED light, 23 hr light:1 hr dark for remaining 13 wk.

SEM = Pooled standard error of the mean (4 replicates of 8 samples each per treatment).

of lymphoid organs of the male birds measured at age 16 wk. It was apparent that there were no significant differences among the light treatments for the percentage of pack cell volume, or weights of the spleen, thymus and bursa of Fabricius. However, a significantly higher ratio of heterophil to lymphocyte was found in treatment WF compared with GLED and G-BLED treatments (Figure 1).

A summary of eye weight and eye dimensions of the male birds killed at the termination of the study is shown in Table 7. There were no significant differences in either eye weight or eye dimensions between the left and right eyes. Therefore, the data are presented as combined left and right eye weights and dimensions. No significant differences in corneal height, anterior-posterior diameter or transverse diameter occurred among the treatment groups.

Table 6 Hematocrit values and relative weights of lymphoid organs of male Thai-native chickens subjected to different light treatments measured at age 16 wk.

Light treatment	Hematocrit (%)	Lymphoid organ relative weight (g per 100 g of body weight)		
		Spleen	Thymus	Bursa of Fabricius
WF	33.57	0.13	0.16	0.18
GLED	37.18	0.11	0.14	0.13
G-BLED	36.58	0.117	0.13	0.15
SEM	5.65	0.03	0.03	0.06
P–value	0.432	0.446	0.338	0.399

WF = White fluorescent light, 23 hr light:1 hr dark from day 1 to 16 wk; GLED = Green light emitting diode (LED) light, 23 hr light:1 hr dark from day 1 to 16 wk; G-BLED = Green LED light, 23 hr light:1 hr dark for the first 3 wk, then switching to blue LED light, 23 hr light:1 hr dark for remaining 13 wk.
Thymus weight = Only seven lobes on the right side of the neck.
SEM = Pooled standard error of the mean (4 replicates of 8 samples each per treatment).

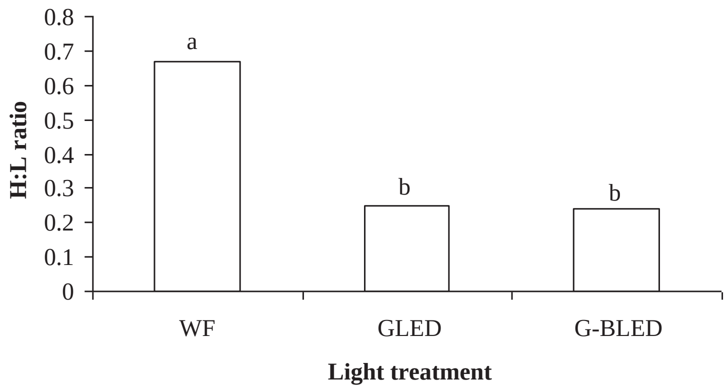

Figure 1 Effects of light treatments (WF = White fluorescent light provided throughout the experimental period, GLED = Green LED light provided throughout the experimental period; G-BLED = Green LED light provided for the first 3 wk, then switching to blue LED light for remaining 13 wk) on the ratio of heterophil to lymphocyte (H:Lratio) of male Thai-native chickens measured at age 16 wk. There were significant differences in the ratios of heterophil to lymphocyte among the experimental bird groups. Bars marked without a common lowercase letter are significantly different (*P* <0.05).

Table 7 Eye weights and eye dimensions of male Thai-native chickens subjected to different light treatments measured at age 16 wk.

Light treatment	No. of birds	Eye weight		Eye size[1]		
		Actual[2] weight	Relative[3] weight	Anterior-posterior diameter	Transverse diameter	Corneal[4] height
WF	8	5.02	0.32	0.77	0.79	2.75
GLED	8	4.93	0.30	0.82	0.80	2.69
G-BLED	8	5.09	0.32	0.78	0.82	2.72
SEM		0.18	0.03	0.05	0.04	0.20
P–value		0.232	0.491	0.124	0.372	0.829

WF = White fluorescent light, 23 hr light:1 hr dark from day 1 to 16 wk; GLED = Green light emitting diode (LED) light, 23 hr light:1 hr dark from day 1 to 16 wk; G-BLED = Green LED light, 23 hr light:1 hr dark for the first 3 wk, then switching to blue LED light, 23 hr light:1 hr dark for remaining 13 wk.
[1] = Combined left and right eyes (millimeters per 100 mg of eye weight).
[2] = Combined left and right eyes (g).
[3] = Combined left and right eyes (g per 100 g of body weight).
[4] = Combined left and right eyes (cm above the scleral ossicles).
SEM = Pooled standard error of the mean.

From the results of the present study, it was apparent that the average cumulative feed conversion ratio over the 16 wk experimental period of the G-BLED birds (3.48) tended to be lower than those of the WF (3.84) and GLED (3.86) birds (Table 3). As a consequence, feed savings could be obtained by using green light during the first 3 wk and switching to blue light during the remaining period of the experiment compared to the cost of the birds reared under white fluorescent light or green light throughout the study (Table 8). The calculation based on 80 birds (20 birds per replication) in the G-BLED treatment, indicated a reduction in rearing costs (-10.8% in feed and -72.11% in light energy costs). In addition, light savings of approximately 84.61% were observed in the GLED treatment.

Table 8 Cost effectiveness of light-emitting diode (LED) lamps compared with fluorescent tubes used in the experiment.

Light treatment	Energy		Feed	
	Consumption (W/d)	Savings (%)	Consumption (kg/d)	Savings (%)
WF	1,196.0	-	3.98[1]	-
GLED	184.0	84.61	4.09[2]	-2.76
G-BLED	333.5	72.11	3.55[3]	10.80

WF = White fluorescent light, 23 hr light:1 hr dark from day 1 to 16 wk; GLED = Green light emitting diode (LED) light, 23 hr light:1 hr dark from day 1 to 16 wk; G-BLED = Green LED light, 23 hr light:1 hr dark for the first 3 wk, then switching to blue LED light, 23 hr light:1 hr dark for remaining 13 wk.
[1] Consumption = 49.75 g of feed per day × 80 chicks.
[2] Consumption = 51.24 g of feed per day × 80 chicks.
[3] Consumption = 44.46 g of feed per day × 80 chicks.

DISCUSSION

Lighting manipulation is a powerful exogenous factor controlling many physiological and behavioral processes in poultry. Light consists of three different aspects: intensity, duration and wavelength (light color). Light of different wavelengths has varying stimulatory effects on the retina and can result in behavioral changes that will affect the growth and development of poultry (Lewis and Morris, 2000). The color of light is dictated by wavelength and it has variable effects on poultry performance. Daylight (white light) has a relatively even distribution of wavelengths between 400 and 700 nm (Olanrewaju, *et al.*, 2006). Green and blue lights stimulate growth, while orange and red lights stimulate reproduction (Rozenboim *et al*., 1998). Prayitno *et al.* (1997) demonstrated that broiler chickens preferred blue or green light over white or red light. Rozenboim *et al*. (2004) reported that a combination of blue and green light stimulated growth in broiler chickens. In the present study, the body weight at age 6 wk of the GLED birds was significantly heavier than that of the WF birds, whereas the G-BLED birds had an intermediate mean compared with the other two treatments (Table 2). In addition, at age 8 wk, the body weights of the G-BLED and GLED treatments tended to be greater than that of the WF treatment (P = 0.05). This effect of light on growth performance could have resulted from the physiological and behavioral responses of the birds to the shorter wavelengths of light. Throughout the course of the trial, docile behavior was clearly noticed among the birds subjected to the monochromatic lighting regimens especially in the G-BLED treatment group, whereas birds exposed to white fluorescent light were more active and showed aggression, feather pecking and cannibalism. Lewis and Morris (2000) reported that poultry perceive light from various types of lamps at a different intensity from humans because they are more sensitive to the blue part of the spectrum. The investigators also concluded that growth of turkeys or chickens reared under red illumination is inferior to that of birds reared under blue or green light, and this may be a result of the birds exposed to the longer wavelength of light being more active and showing more aggression than birds exposed to shorter wavelength light. In the present study, aggression such as fighting for a dominant position and cannibalism occurred among the WF birds which could be displays of stress-induced behavior (Vecerek *et al*., 2006). These stressors may lead to a deviation from physiological homeostasis, in turn, impairing bird well-being (Prayitno *et al*., 1997). This was confirmed by evidence of a higher ratio of heterophil to lymphocyte (H:L) in the WF birds compared with those of the GLED and G-BLED birds (Figure 1). The ratio H:L has been used as a physiological indicator of stress in the evaluation of chicken responsiveness to environmental factors and various stressors (Gross and Siegel, 1983; Beuving *et al*., 1989; Maxwell, 1993). Xie *et al*. (2008) reported that green or blue light enhanced the immune response and increased the proliferation of blood T-lymphocytes. However, not only the wavelength but also the intensity of light is believed to affect activity of the domestic fowl; Newberry *et al*. (1988) reported that light intensity increased activity, feather pecking and cannibalism in chickens. Low light intensities have been associated with reduced walking and standing, as well as with decreased incidences of fighting, feather pecking and cannibalism (Buyse *et al*., 1996). In the present study, the treatments differed for light intensity which could have affected the behavior of the birds. Therefore, an additional effect of light intensity may exist and should not be excluded.

From the present study, it was apparent that the lighting treatments did not affect the carcass performance of the male birds considering either whole carcass or carcass yield characteristics. However, it is of interest to note that the live body weight, prechilled carcass weight, chilled carcass weight, lean carcass weight and weights of many parts of the carcass such as drumsticks, thighs and fillets of the GLED birds were greater than those of the other two treatment groups. El-Husseiny *et al*. (2000) evaluated the influence of the color of light (white, blue and green) on the performance of broiler chickens. They found that green light had a significant positive influence on feed consumption, the final body weight and dressed carcass weight compared with white light. In the current study, it was found that the WF birds had higher relative liver weights compared with the GLED birds, whereas the G-BLED birds had intermediate values ($P < 0.05$; Table 5). This could be related to stress-induced changes in liver function, such as metabolic changes or alteration of gluconeogenesis as seen in mammals (Ricart-Jan *et al*., 2002). Cheng and Jefferson (2008) reporting on broiler chickens indicated that stress-induced behavior caused an increase in the liver relative weight and the ratio of heterophil to lymphocyte of the birds. These researchers also suggested that the liver is a very susceptible organ to stress in domestic birds.

The results of the present study showed that the color of light had mild effects on the growth performance and carcass yield of Thai-native chickens which may have been due to genetic factors. It was likely that there is a genetic basis of variations in this chicken breed in response to the specific light wavelengths. This suggestion could be reasonably supported by the study of Gongruttananun (2011) who reported that the spectrum of red light had a positive effect only on accelerating the sexual maturity but did not affect the live performance, egg production or egg quality of the hens.

A beneficial effect of the monochromatic lighting regimens on energy saving was evident in the present study, as shown in Table 8. The calculation for 80 chickens (20 birds per replication) in the G-BLED treatment demonstrated a reduction in rearing costs (-10.80% in feed and -72.11% in light energy costs) as compared to those of the control treatment. In addition, approximately 84.61% of light energy savings was also found from treatment GLED. These results were in agreement with those of Rozenboim *et al*. (1998) and Gongruttananun (2011), who suggested that a reduction of rearing costs in domestic fowls could be obtained by using an LED lighting system.

CONCLUSION

Green or a combination of green and blue light had little effect on the growth performance and carcass yield of Thai-native chickens without detrimental effects on eye morphology. The LED lighting regimens could be useful for energy conservation, reduction of rearing costs and the well-being of the birds. Nevertheless, the light intensity is an important factor which affects the performance of the birds. An experimental design neutralizing this factor is recommended for further study.

ACKNOWLEDGMENTS

The research project was funded by the Kasetsart University Research and Development Institute (KURDI), Kasetsart University, Bangkok, Thailand.

LITERATURE CITED

Aini, I. 1990. Indigenous chicken production in South-east Asia. **World's Poult. Sci. J.** 46: 51–57.

Beuving, G., R.B. Jones and H.J. Blokhuis. 1989. Adrenocortical and heterophil/lymphocyte responses to challenge in hens showing short or long tonic immobility reactions. **Br. Poult. Sci.** 30: 175–184.

Buyse, J., P.C.M. Simons, F.M.G. Boshouwers and E. Decuypere. 1996. Effect of intermittent lighting, light intensity and source on the performance and welfare of broilers. **World's Poult. Sci. J.** 52: 121–130.

Cao, J., W. Liu, Z. Wang, D. Xie, L. Jia and Y. Chen. 2008. Green and blue monochromatic lights promote growth and development of broilers via stimulating testosterone secretion and myofiber growth. **J. Appl. Poult. Res.** 17: 211–218.

Cheng, H.W. and L. Jefferson. 2008. Different behavioral and physiological responses in two genetic lines of laying hens after transportation. **Poult. Sci.** 87: 885–892.

El-Husseiny, O., S.M. Hashish, S.A. Arafa and A.H.H. Madian. 2000. Response of poultry performance to environmental light colour. **Egypt. Poult. Sci.** 20: 385–402.

Foss, D.C., L.B. Carew, Jr. and E.L. Arnold. 1972. Physiological development of cockerels as influenced by selected wavelengths of environmental light. **Poult. Sci.** 51: 1922–1927.

Gongruttananun, N. 2011. Influence of red light on reproductive performance, eggshell ultrastructure, and eye morphology in Thai-native hens. **Poult. Sci.** 90: 2855–2863.

Gross, W.B. and H.S. Siegel. 1983. Evaluation of the heterophil/lymphocyte ratio as a measure of stress in chickens. **Avian Dis.** 27: 972–979.

Halevy, O., I. Biran and I. Rozenboim. 1998. Various light source treatments affect body and skeletal muscle growth by affecting skeletal muscle satellite cell proliferation in broilers. **Comp. Biochem. Physiol.** 120: 317–323.

Harrison, P.C., J.D. Latshaw, J.M. Casey and J. Mcginnis. 1970. Influence of decreased length of different spectral photoperiods on testis development of domestic fowl. **J. Reprod. Fert.** 22: 269–275.

Karakaya, M., S.S. Parlat, M.T. Yilmaz, I. Yildirim and B. Ozalp. 2009. Growth performance and quality properties of meat from broiler chickens reared under different monochromatic light sources. **Br. Poult. Sci.** 50: 76–82.

Kongruttananun, N. 1992. **A Study of Growth and Reproductive Development of the Native Compared with Those of Some Other Pure-Breed Chicken.** MSc thesis, Kasetsart University, Bangkok, Thailand. [in Thai]

Lewis, P.D. and T.R. Morris. 2000. Poultry and coloured light. **World's Poult. Sci. J.** 56: 189–207.

Lyon, C.E., C.M. Papa and R.L. Wilson, Jr. 1991. Effect of feed withdrawal on yields, muscle pH, and texture of broiler breast meat. **Poult. Sci.** 70: 1020–1025.

Maxwell, M.H. 1993. Avian blood leucocyte responses to stress. **World's Poult. Sci. J.** 49: 34–43.

Newberry, R.C., J.R. Hunt and E.E. Gardiner. 1988. Influence of light intensity on behavior and performance of broiler chickens. **Poult. Sci.** 67: 1020–1025.

Olanrewaju, H.A., J.P. Thaxton, W.A. Dozier, J. Purswell, W.B. Roush and S.L. Branton. 2006. A review of lighting programs for broiler production. **Int. J. Poult. Sci.** 5: 301–308.

Ookawa, T. 1970. Effects of bilateral optic enucleation on body growth and gonad in young male chicks. **Poult. Sci.** 49: 333–334.

Prayitno, D.S., C.J. Phillips and D.K. Stokes. 1997. The effects of color and intensity of light on behavior and leg disorders in broiler chickens. **Poult. Sci.** 76: 1674–1681.

Pyrzak, R., N. Spapir, G. Goodman and M. Perek. 1987. The effect of light wavelength on the production and quality of eggs of the domestic hen. **Theriogenology** 28: 947–960.

Renden, J.A., S.F. Bilgili, R.J. Lien and S.A. Kincaid. 1991. Live performance and yields of broilers provided various lighting schedules. **Poult. Sci.** 70: 2055–2062.

Ricart-Jan, D., V. Rodrguez-Sureda, A. Benavides,

J. Peinado-Onsurbe, M.D. Lpez-Tejero and M. Llobera. 2002. Immobilization stress alters intermediate metabolism and circulating lipoproteins in the rat. **Metabolism** 51: 925–931.

Rozenboim, I., I. Biran, Z. Uni, B. Robinzon and O. Halevy. 1999. The effect of monochromatic light on broiler growth and development. **Poult. Sci.** 78: 135–138.

Rozenboim, I., I. Biran, Y. Chaiseha, S. Yahav, A. Rosenstrauch, D. Sklan and O. Halevy. 2004. The effect of green and blue monochromatic light combination on broiler growth and development. **Poult. Sci.** 83: 842–845.

Rozenboim, I., Y. Ziberman and G. Gvaryahu. 1998. New monochromatic light source for laying hens. **Poult. Sci.** 77: 1695–1698.

SAS Institue. 2002. **SAS STAT User's Guide.** Version 9.0. SAS Inst. Inc., Cary, NC, USA.

Siopes, T.D., M.H. Timmons, G.R. Baughman and C.R. Parkhurst. 1984. The effects of light intensity on turkey poult performance, eye morphology, and adrenal weight. **Poult. Sci.** 63: 904–909.

Vecerek, V., S. Grbalova, E. Voslarova, B. Janackova and M. Melena. 2006. Effects of travel distance and the season of the year on death rates of broilers transported to poultry processing plants. **Poult. Sci.** 85: 1881–1884.

Wabeck, C.J. and W.C. Skoglund. 1974. Influence of radiant energy from fluorescent light sources on growth, mortality, and feed conversion of broilers. **Poult. Sci.** 53: 2055– 2059.

Wattanachant, S., S. Benjakul and D.A. Ledward. 2004. Composition, color, and texture of Thai indigenous and broiler chicken muscles. **Poult. Sci.** 83: 123–128.

Xie, D., Z.X. Wang, Y.L. Dong, J. Cao, J.F. Wang, J.L. Chen and Y.X. Chen. 2008. Effects of monochromatic light on immune response of broilers. **Poult. Sci.** 87: 1535–1539.