



## Effect of Monochromic Light-emitting Diode Light with Different Color on the Growth and Reproductive Performances of Breeder Geese

S. C. Chang<sup>1,2</sup>, M. J. Lin<sup>1,2</sup>, Z. X. Zhuang<sup>1</sup>, S. Y. Huang<sup>1</sup>, T. Y. Lin<sup>2</sup>, Y. S. Jea<sup>2</sup>, Y. K. Fan<sup>1</sup>, and T. T. Lee<sup>1,\*</sup>

<sup>1</sup> Department of Animal Science, National Chung Hsing University, Taichung 402, Taiwan

**ABSTRACT:** The purpose of this study was to investigate the effect of monochromic light-emitting diode (LED) light with different color on the growth and reproductive performances of white Roman breeder geese. A randomized complete batch design was utilized for the trial, and the replicate was regarded as one batch. Twenty ganders and fifty-five dames were used in batch 1 (started on 2011/6/17 and ended on 2012/1/31), thirty ganders and eighty-four dames were used in batch 2 (started on 2012/3/23 and ended on 2012/10/26), and thirty ganders and seventy-two dames were used in batch 3 (started on 2013/3/12 and ended on 2013/12/20). Two hundred and ninety-one geese were randomly assigned to 6 rooms in an environmentally controlled house. They were randomly allotted into one of three monochromatic light treatments: Blue, red, or white. The results showed that there was no significant difference in body weight among the three lighting groups at any point throughout the experimental period. However, compared to the blue light group, significantly more eggs were produced by the red and white light groups ( $p < 0.05$ ). Furthermore, the laying period of the red light group was significantly longer than that of other two groups ( $p < 0.05$ ). In conclusion, our results suggested that red LED-light has the best effect on reproductive performance (i.e. longer laying period and higher total eggs number) at 30 lux light intensity, and is therefore a better choice for the management of breeding geese than blue or white LED-light. (**Key Words:** Monochromatic Light, Reproductive Performance, Breeder Geese)

### INTRODUCTION

Under natural light conditions, domestic geese show an obvious seasonal pattern of reproductive activity (Zeman et al., 1990). The photoperiod not only plays an important role in initiating egg production, but is also beneficial in sustaining persistent egg production (Gongruttanun and Guntapa, 2012).

Light plays a pivotal role in vision, the release of various hormones; it also increases the efficacy of important factors related to the behavior and reproduction of birds (Biyatmoko, 2014). Moreover, it also activates the development of reactive substances, such as enzymes and vitamins in embryos (Er et al., 2007). Evidently, the source, spectrum, intensity and regimen of artificial light

supplementation are critical factors for the modern management of the poultry industry (Borille et al., 2013; Morrill et al., 2014; Lee et al., 2015; Wang et al., 2015).

Like the human eye, the chicken eye is capable of viewing a narrow part of the light spectrum, 380 to 760 nm (Rozenboim et al., 2012). In addition to the eyes, the extra-retinal photoreceptors (in the hypothalamus or other sites of the brain) are sensitive to different wavelengths and are involved in photostimulation (Lewis and Morris, 2000; Kram et al., 2010). Chickens are typical of most diurnal birds in possessing seven photoreceptor cell types: One rod and six cones (Kram et al., 2010). Tetrachromatic color vision is mediated by four types of single cones that are maximally responsive to violet, red, blue and green light, respectively (Bowmaker and Knowles, 1977). Nuboer et al. (1992) showed that a better way to present the relative luminance of a lamp for domestic fowl ('galluminance') is by multiplying the spectral power distribution of lamps. Prescott and Wathes (1999) reported that broilers are able to 'see' into the UVA and differ from that of humans, showing

\* Corresponding Author: T. T. Lee. Tel: +886-4-2287-0613, Fax: +886-4-2286-0265, E-mail: [ttlee@dragon.nchu.edu.tw](mailto:ttlee@dragon.nchu.edu.tw)

<sup>2</sup> Changhua Animal Propagation Station, Livestock Research Institute, Council of Agriculture, Changhua 512, Taiwan.

Submitted Jul. 22, 2015; Revised Sept. 9, 2015; Accepted Sept. 27, 2015

higher sensitivities between 380<math>\lambda</math>507 nm. Moreover, Prescott et al. (2003) proposed that a minimum dark period of 6 h duration should be used in cases of pecking damage and cannibalism impacting bird welfare.

Hsu et al. (1990) reported that light intensity of 0 to 40 lux showed no significantly effect on egg production in geese. Pyrzak et al. (1984) indicated that the geese under light intensity of 20 lux had a higher egg production than that of 50 lux. The effects of monochromatic light on the productivity and egg quality in hens have been reported in a previous study (Borille et al., 2013). They concluded the commercial layers (Institut de Sélection Animale [ISA] Brown) had the best egg production when exposed to red and white light-emitting diode (LED) and incandescent lamps. However, the feed intake, egg weight and egg quality were not influenced by the light sources. Conversely, Morrill et al. (2014) pointed out that under blue and green monochromatic illumination, chicken broilers exhibited up to 6.0% and 8.9% increases in final body weight, respectively, compared to chickens kept under red or white light. Mobarkey et al. (2013) showed that selective photostimulation under green light caused a significant delay in the onset of egg production of chickens compared to the use of red light. However, little is known about the effect of monochromic light of each different color on the growth and reproductive performances of breeder geese. The objective of this study, therefore, was to find the most suitable single monochromatic light, among the colors chosen in this study, during the laying period of white Roman geese.

## MATERIALS AND METHODS

### Animals and experiment design

A total of 80 ganders and 211 dames in their first laying season, with an average age of 10 months, were used as the objects of this study. Once the geese were moved into an environmentally controlled house, a restricted amount of resting rations (13.0% crude protein [CP] and 2,350 kcal/kg metabolizable energy [ME]) was provided according to the experimental protocol, and the photoperiod was adjusted to 7 L:17 D for the first 6 weeks. Thereafter, the photoperiod was adjusted to 9 L:15 D and the laying geese were fed *ad libitum*. The laying diet contained 18.0% CP and 2,700 kcal/kg ME. The care and use of all geese followed the guidelines set by the Regulations of Laboratory Animals, Changhua Animal Propagation Station, Livestock Research Institute, Council of Agriculture, Taiwan. Drinking water was provided *ad libitum*. A randomized complete batch design was utilized for testing, and the replicate was regarded as one batch. Twenty ganders and fifty-five dames were used in batch 1 (started on 2011/6/17 and ended on 2012/1/31), thirty ganders and eighty-four dames were used

in batch 2 (started on 2012/3/23 and ended on 2012/10/26), and thirty ganders and seventy-two dames were used in batch 3 (started on 2013/3/12 and ended on 2013/12/20). In total, each light spectrum involved 6 repeats/pens (included 3 batches). Each pen was 2.4 m×6.5 m (15.6 m<sup>2</sup>), signifying 0.77 bird per m<sup>2</sup> in batch 1, 1.22 bird per m<sup>2</sup> in batch 2 and 1.09 bird per m<sup>2</sup> in batch 3. The randomized complete design included three monochromatic lights (LED lights), i.e. blue, red and white light, for a total of 3 groups at the Changhua Animal Propagation Station (23°51'N, 120°33'E), Taiwan (Figure 1). For focusing on the effect of light color, the light intensity was fixed at 30 lux for all the 3 light colors at the height of geese eyes when they were standing.

### Growth performance

The body weight and feed consumption were measured and recorded immediately after the birds entered the environmentally controlled house. The peak of egg production was defined as the average of laying rate for 2 consecutive days reached 35% for all the geese. The peak reaching at approximately 8 weeks after geese entered the environment controlled house. The egg production ceased (EPC) at approximately 38 weeks after geese entered the house. The EPC was defined as the average of laying rate for 2 consecutive days dropping to 5% for all the geese.

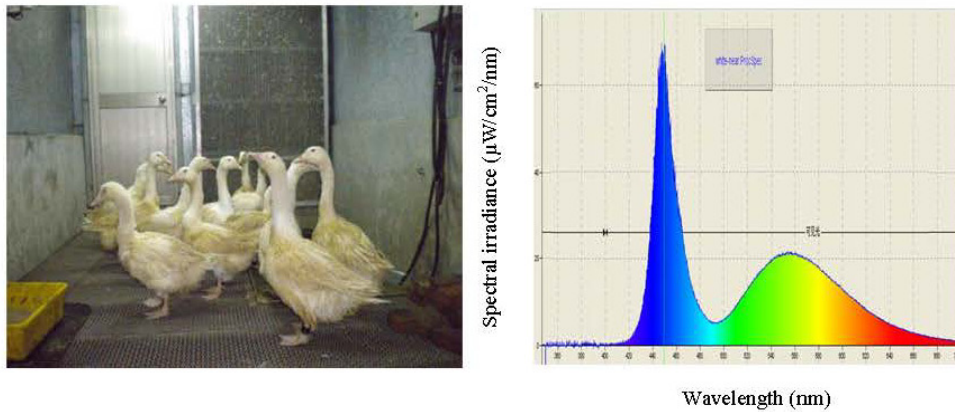
### Fertilization rate and hatchability

A total of 13,077 eggs were collected from the 3 blocks. To determine fertilization rate, hatchability and gosling output, eggs were collected in batches every 2 weeks from July 26, 2011 to January 20, 2014. Eggs were incubated with an automatic incubator (Tonz Nan Incubators Manufactured Co. Ltd., Yunlin, Taiwan). The temperature of the incubator was set at 37.7°C from day 0 to 14, 37.5°C from days 15 to 28, and 37.2°C during hatching. The transparency of the fertilized eggs was judged with the naked eye on the 7th d of incubation. The percentage of fertilized eggs served as the fertilization rate. Hatchability was defined as the percentage of goslings hatched over the number of total eggs incubated. The hatchability of fertilized eggs was defined as the percentage of goslings hatched over the total number of fertilized eggs.

### Egg measurements

Eggs were transferred to the laboratory and stored in a refrigerator until analysis (within two days of collection). Egg weight, eggshell shape index (ESI), egg length, egg width, eggshell strength, and eggshell thickness were recorded once every month. Egg weight was measured to the nearest 0.01 g using an electronic balance. Egg length and egg width at midpoint on the outer surface of the egg were measured in micrometers (0.01 mm, Mitutoyo, Kawasaki, Japan), and ESI was calculated using the formula

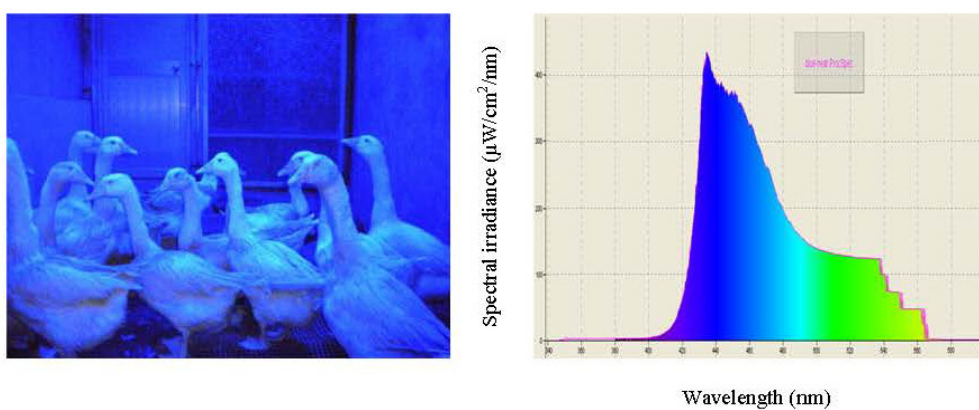
(A)



(B)



(C)



**Figure 1.** The monochromatic light and wavelength in goose house. (A) Geese rearing under white light-emitting diode (LED)-light and spectral sensitivity; (B) Geese rearing under red LED-light and spectral sensitivity; (C) Geese rearing under blue LED-light and spectral sensitivity.

ESI = width/length $\times$ 100, where width is the transverse diameter, and length is the long vertical length of an egg.

#### Serum biochemical parameters

During the experiment periods, 4 geese (2 male and 2 female 10-month-old geese) per pen were randomly chosen

for collecting serum samples for biochemical determinations at the first day at each month. Blood samples were processed approximately 4 to 5 h after collection by centrifuging at 3,000×g for 10 min at 4°C, and serum samples were stored at -4°C for up to 1 d until analysis (Lee et al., 2013). Serum biochemical parameters analyses were performed by an Automatic Biochemical Analyzer (Hitachi, 7150 auto-analyzer, Tokyo, Japan). For reproductive hormones assay, the serum was analyzed by electrochemiluminescence immunoassay (ECLIA) using an Elecsys and cobase immunoassay analyzer (UniCel DxI 800 Access Immunoassay System, Beckman Coulter Inc., Fullerton, CA, USA).

### Measurement of serum melatonin concentration

Blood samples collected from geese that had adapted to the dark for 6 h were then centrifuged at 3,000×g for 15 min.

**Table 1.** Ingredients and nutrient compositions of the experimental diets (as fed basis)

	Resting diet	Laying diet
<b>Ingredients</b>		
Yellow corn	50.35	57.35
Soybean meal	12.7	25.7
Wheat bran	20.0	-
Rice bran	10.0	-
Alfalfa meal	-	2.0
Fish meal	-	2.5
Oyster shell	-	3.5
Molasses	3.0	3.0
Salt	0.3	0.3
Dicalcium phosphate	1.9	3.5
Limestone, pulverized	1.3	1.7
Choline chloride, 50%	0.1	0.1
DL-methionine	0.1	0.15
Vitamin premix <sup>1</sup>	0.1	0.1
Mineral premix <sup>2</sup>	0.15	0.1
Total	100	100
<b>Calculated values</b>		
Crude protein (%)	13.0	18.0
ME (kcal/kg)	2350	2700
Total calcium (%)	1.02	3.11
Available phosphorus (%)	0.35	0.50

ME, metabolizable energy.

<sup>1</sup> Resting diet was supplied per kilogram of diet: vitamin A, 10,000 IU; vitamin D<sub>3</sub>, 2,000 IU; vitamin E, 20 mg; vitamin K<sub>3</sub>, 1.5 mg; vitamin B<sub>1</sub>, 1.00 mg; vitamin B<sub>2</sub>, 4.8 mg; vitamin B<sub>6</sub>, 3.00 mg; vitamin B<sub>12</sub>, 16 µg; folic acid, 0.50 mg; calcium pantothenate, 10.0 mg; niacin, 25 mg; Biotin, 2.00 mg; Fe (FeSO<sub>4</sub>), 120 mg; Cu (CuSO<sub>4</sub>·5H<sub>2</sub>O), 22.5 mg; Mn (MnSO<sub>4</sub>·H<sub>2</sub>O), 120 mg; Zn (ZnO), 75.0 mg; I (KI), 1.275 mg; Co (CoSO<sub>4</sub>), 0.375 mg; Se (Na<sub>2</sub>SeO<sub>3</sub>), 0.27 mg.

<sup>2</sup> Laying diet was supplied per kilogram of diet: vitamin A, 10,000 IU; vitamin D<sub>3</sub>, 2,000 IU; vitamin E, 20 mg; vitamin K<sub>3</sub>, 1.5 mg; vitamin B<sub>1</sub>, 1.00 mg; vitamin B<sub>2</sub>, 4.8 mg; vitamin B<sub>6</sub>, 3.00 mg; vitamin B<sub>12</sub>, 16 µg; folic acid, 0.50 mg; calcium pantothenate, 10.0 mg; niacin, 25 mg; Biotin, 2.00 mg; Fe (FeSO<sub>4</sub>), 80.0 mg; Cu (CuSO<sub>4</sub>·5H<sub>2</sub>O), 15.0 mg; Mn (MnSO<sub>4</sub>·H<sub>2</sub>O), 80.0 mg; Zn (ZnO), 50.0 mg; I (KI), 0.85 mg; Co (CoSO<sub>4</sub>), 0.25 mg; Se (Na<sub>2</sub>SeO<sub>3</sub>), 0.18 mg.

The serum melatonin concentration was measured using a commercial enzyme-linked immunosorbent assay (ELISA) kit (USCN Life Science Inc., Wuhan, China) as per the manufacturer's protocol. Standard curve and regression equations were used; based on the degree of fitness, as well as the conciseness of the regression curve, a quadratic equation was ultimately selected. Using this equation, the melatonin concentration of all of the samples was calculated with an ELISA reader (Sunrise-Basic-Tecan, Grödig, Austria) set to an optical density at 450 nm and a standard range of 4.940 to 10,000 pg/L.

### Statistical analysis

The data were statistically analyzed using the general linear model procedure (GLM) of SAS software (2004) following a random arrangement.

The mathematical model was:

$$Y_{ijk} = T_i + B_j + \varepsilon_{ijk}$$

where,  $Y_{ijk}$  = observed response of bird in a pen;  $T_i$  = fixed effect of colored light treatment;  $B_j$  = fixed effect of batch;  $\varepsilon_{ijk}$  = residual error when the pen was regarded as an experimental unit,  $\varepsilon_{ijk} \sim N(0, \sigma_\varepsilon^2)$ . The mean values were compared between the three colored light treatment groups using the LSMEANS, with the significant level at  $p < 0.05$ .

## RESULTS

### Growth performance and serum biochemical parameters

The effect of monochromatic light on the growth of breeder geese is shown in Table 2. There was no significant

**Table 2.** Effect of monochromatic light on the growth performances in breeder geese<sup>1</sup>

Item	Monochromatic light source <sup>2</sup>		
	Blue	Red	White
<b>Body weight (kg/bird)</b>			
EH <sup>3</sup> (kg)	4.08±0.14	3.98±0.03	4.00±0.03
PK <sup>3</sup> (kg)	5.07±0.09	5.25±0.19	5.09±0.16
EPC <sup>3</sup> (kg)	5.76±0.01	5.70±0.14	5.74±0.20
<b>Body weight gain (kg/bird)</b>			
From EH to PK	0.99±0.22	1.27±0.16	1.09±0.14
From PK to EPC	0.68±0.06	0.45±0.32	0.66±0.33
From EH to EPC	1.68±0.17	1.72±0.18	1.75±0.20

<sup>1</sup> Results are given as the means of 6 pens of 3 batches.

<sup>2</sup> Means±standard error.

<sup>3</sup> EH, the time point when the birds entered the house; PK, approximately 8 week after EH, representing an average of 2 d in regard to the laying rate, reached 35% among the entire pens; EPC, approximately 38 week after EH, it represented a drop of 5% compared to an average laying rate of 2 d among the entire pens.

difference in the body weight among the three lighting groups throughout the experimental period, from the point in time when the birds entered the house, through peak egg production, until egg production ceased ( $p>0.05$ ). The effect of monochromatic light on blood biochemical parameters in breeder geese is presented in Table 3. The glucose level in the white light group was significantly higher than that in the red and blue light groups ( $p<0.05$ ). Other blood biochemical parameters did not differ among the treatment groups ( $p>0.05$ ).

### Reproductive performance

The effect of monochromatic light on the reproductive characteristics of breeder geese is shown in Table 4. The eggs in the red and white light groups were significantly more numerous than those of the blue light group ( $p<0.05$ ). The laying period for the red light group was also significantly longer than that of the white and blue light

**Table 3.** Effect of monochromatic light on the blood biochemical parameters in breeder geese<sup>1</sup>

Item	Monochromatic light source <sup>2</sup>		
	Blue	Red	White
WBC ( $10^3/\mu\text{L}$ )	250.00±1.40	251.00±7.97	253.00±2.56
RBC ( $10^6/\mu\text{L}$ )	1.93±0.03	1.86±0.10	1.91±0.10
HB (g/dL)	11.20±0.58	10.90±0.54	11.00±0.46
HT (%)	32.50±1.08	32.00±2.6	32.80±1.49
MCV (fL)	170.00±3.35	173.00±3.50	173.00±2.15
MCH (pg)	59.50±1.90	59.20±0.50	58.20±0.97
MCHC (g/dL)	34.80±0.34	34.30±1.02	33.70±0.19
PLT ( $10^3/\mu\text{L}$ )	25.50±4.40	23.30±1.19	22.30±6.56
GLU (mg/dL)	112.00±7.67 <sup>b</sup>	116.00±0.67 <sup>b</sup>	126.00±9.51 <sup>a</sup>
BUN (mg/dL)	3.82±0.43	3.82±0.32	3.77±0.19
CREA (mg/dL)	0.35±0.01	0.36±0.02	0.35±0.02
UA (mg/dL)	4.59±1.59	4.38±0.04	4.83±0.25
GOT (U/L)	55.50±6.36	57.20±4.98	57.02±7.75
GPT (U/L)	21.50±1.54	20.00±0.93	18.40±2.86
TP (g/dL)	7.01±0.18	7.32±0.18	7.27±0.02
ALB (g/dL)	2.96±0.10	2.99±0.09	2.88±0.02
GLO (g/dL)	24.10±5.81	19.20±0.72	20.40±0.27
TC (mg/dL)	194.00±9.05	195.00±12.1	205.00±15.8
TG (mg/dL)	633.00±23.9	691.00±289	686.00±187
HDL (mg/dL)	75.30±3.09	74.00±9.38	76.80±6.69
LDL (mg/dL)	65.30±4.82	66.40±13.0	64.10±3.05

WBC, white blood cell; RBC, erythrocyte; HB, haemoglobin; HT, hematocrit; MCV, HT/RBC; MCH, HB/RBC; MCHC, HB/HT; PLT, platelet; GLU, glucose; BUN, blood urea nitrogen; CREA, creatinine; UA, uric acid; GOT, glutamyl oxaloacetic transaminase; GPT, glutamyl pyruvic transaminase; TP, total protein; ALB, albumin; GLO, globulin; TG, triglycerides; TC, total cholesterol; HDL, high density lipoprotein; LDL, low density lipoprotein.

<sup>1</sup> Results are given as the means of 6 pens for 4 geese each pen (2 male and 2 female) of 3 batches.

<sup>2</sup> Means±standard error.

<sup>a,b</sup> Means without the same superscripts within the same row under treatment differ significantly ( $p<0.05$ ).

**Table 4.** Effect of monochromatic light on reproductive characteristics in breeder geese<sup>1</sup>

Item	Monochromatic light source <sup>2</sup>		
	Blue	Red	White
Egg number (egg/geese)	57.0±10.9 <sup>b</sup>	71.4±12.6 <sup>a</sup>	72.1±12.0 <sup>a</sup>
Laying period (d) <sup>3</sup>	224.0±35.2 <sup>b</sup>	247.0±65.7 <sup>a</sup>	229.0±30.1 <sup>b</sup>
Egg production (%)	22.6±5.3	24.4±6.9	28.6±7.3
Survival (%)	91.8±5.8	98.5±3.7	97.3±4.2

<sup>1</sup> Results are given as the means of 6 pens of 3 batches.

<sup>2</sup> Means±standard error.

<sup>3</sup> Laying period was defined by the period required for laying rate 5%.

<sup>a,b</sup> Means within the same row under lighting intensity treatment without the same superscripts differ significantly ( $p<0.05$ ).

groups ( $p<0.05$ ).

### Fertilization rate and hatchability

The effect of monochromatic light on the fertilization rate and hatchability of breeder geese is shown in Table 5. The fertilization rate, the hatchability and the hatchability of fertilized eggs in the blue light group was similar to those of the other two groups ( $p>0.05$ ).

### Egg measurements

The effect of monochromatic light on egg measurements in breeder geese is shown in Table 6. The lengths of the eggs in the red and white light groups were significantly longer than those of the blue light group ( $p<0.05$ ). Accordingly, the egg shape indices for the red and white light groups were significantly lower than that of the blue light group ( $p<0.05$ ).

### Serum melatonin concentration

The effect of monochromatic light on the concentration of melatonin in the serum of the breeder geese is shown in Table 7. Melatonin levels were significantly higher in the white light group compared to those of the blue and red light groups ( $p<0.05$ ).

## DISCUSSION

The eyes and the extra-retinal photoreceptors located in the hypothalamus or other sites of the brain are sensitive to different light wavelengths, and are involved in

**Table 5.** Effect of monochromatic light on the fertility and hatchability in breeder geese<sup>1</sup>

Item	Monochromatic light source <sup>2</sup>		
	Blue	Red	White
Fertilization rate (%)	62.9±12.2	74.3±11.4	58.4±16.8
Hatchability (%)	52.4±8.6	57.5±6.8	46.9±13.2
Hatchability of fertilized eggs (%)	80.3±5.5	78.8±4.0	78.7±4.9

<sup>1</sup> Results are given as the means of 6 pens of 3 batches.

<sup>2</sup> Means±standard error.

**Table 6.** Effect of monochromatic light on egg measurements in breeder geese<sup>1</sup>

Item	Monochromatic light source <sup>2</sup>		
	Blue	Red	White
Egg weight (g)	169.0±2.0	172.0±1.3	171.0±1.0
Egg length (mm)	87.2±1.0 <sup>b</sup>	88.6±0.3 <sup>a</sup>	88.4±0.1 <sup>a</sup>
Egg width (mm)	58.8±0.1	58.4±0.0	58.4±0.3
Egg shape index <sup>3</sup>	67.4±0.7 <sup>a</sup>	66.0±0.3 <sup>b</sup>	66.2±0.5 <sup>b</sup>

<sup>1</sup> Results are given as the means of 6 pens for 12 geese each pen (3 eggs per pen and per week, totally 22 weeks) of batch 3.

<sup>2</sup> Means±standard error.

<sup>3</sup> Egg shape index (EI = egg width/egg length×100).

<sup>a,b</sup> Means within the same row under lighting intensity treatment without the same superscripts differ significantly ( $p<0.05$ ).

photostimulation. Therefore, we designed 30 lux light intensity in this study during the experiment. No obvious difference on the performance was observed.

Rozenboim et al. (1999) reported that broilers reared under blue or green light were significantly heavier than those reared under white or red light. This suggests that blue or green light may have an effect on the number of satellite cells per gram of breast muscle, as well as the total number of satellite cells derived from the broilers (Halevy et al., 1998). In contrast, the results in this study showed that there was no significant difference in either body weight or body weight gain among different lighting groups during the laying period. Moreover, there were also no significant differences in the laying rate and survival rate among birds in the blue, red, and white light groups during the laying period. However, Rozenboim et al. (1999) reported that blue light enhancement of growth was probably due to an elevation in plasma androgens at later age in the broilers. Therefore, the authors suggested that lower light intensity, as well as specific light spectra, could enhance the growth of muscles. The discrepancy between our results and those of Rozenboim et al. (1999) may be caused by differences in species, age, and experimental conditions applied.

Hassan et al. (2013) found that laying hens under red light had higher egg numbers compared to those under blue or green light. The authors suggested that hens in the red light group had significantly higher organ weights (stroma of ovaries) and ovarian follicle numbers (1 to 3 and 4 to 6

**Table 7.** Effect of monochromatic light on melatonin concentration in breeder geese<sup>1</sup>

Item	Monochromatic light source <sup>2</sup>		
	Blue	Red	White
Melatonin (pg/mL)	125.0±29.5 <sup>b</sup>	125.0±10.1 <sup>b</sup>	265.0±92.8 <sup>a</sup>

<sup>1</sup> Results are given as the means of 6 pens for 4 geese each pen (2 male and 2 female) of 3 batches.

<sup>2</sup> Means±standard error.

<sup>a,b</sup> Means without the same superscripts within the same row under light treatment differ significantly ( $p<0.05$ ).

mm). In the present study, the red light group also had a significantly higher egg number than that of the blue light group, that is to say the red light group had a longer laying period than the blue or white light groups, suggesting a prolonged period of onset to laying peak. Serum glucose level is a stress indicator and birds under stress condition have elevated the serum parameter (Puvadolpirod and Thaxton, 2000). Hassan et al. (2013) showed that hens under red light had significantly higher serum glucose and triglyceride levels than those under white or blue light. However, Firouzi et al. (2014) showed that birds under red and blue lights had lower levels of serum glucose than yellow and green lights and the authors also demonstrated that wavelength had calming effect on broilers (Prayitno et al., 1997). The observed is in agreement with our results.

Monochromatic LED light colors were tested and it was found that red light enhances egg production of laying hens (Kim et al., 2012; Hassan et al., 2014). In this study, we found that the breeder geese under red light showed a higher fertilization rate than that of the white light group, the result is in agreement with Li et al. (2014). The results suggested that the birds under red light had increased follicle-stimulating hormone and estradiol (E2) concentrations compared to the blue light group (Hassan et al., 2013). Furthermore, Gongruttananun and Guntapa (2012) also showed that hens under red light had a significantly higher concentration of serum estradiol compared to the hens exposed to daylight supplemented with fluorescent light.

Laying hens under red light had lower average egg weight during the laying period; the average egg length was also lower than those under blue, green or white light (Er et al., 2007). However, Gongruttananun and Guntapa (2012) found no significant difference in average egg weight, egg or eggshell quality between hens kept under red light or those exposed to natural daylight supplemented with fluorescent light. The present study did not find any difference in average egg weight or egg width, but the blue light group had a significantly greater egg shape index compared to those in the other groups. This result depended on egg length in blue light becoming shorter than in red and white lights, and the result is in agreement with Li et al. (2014) who reported that the egg length in blue light was significantly shorter than red and white lights, but no difference in egg width in laying hens.

Melatonin is synthesized from serotonin; it can stimulate gonadotropin-inhibitory hormone (GnIH) secretion which may ultimately inhibit reproduction (Ubuka et al., 2005). Due to its effect on the anterior pituitary gland and the gonadotropin-releasing hormone system, GnIH can regulate avian reproduction by inhibiting gonadotropin release and synthesis (Bentley et al., 2006). Jin et al. (2011) indicated that the concentration of plasma melatonin under

green light was the highest, followed by white light, and was the lowest in red light and blue light for broilers. Gordijn et al. (2005) showed that the melatonin increase in the evening was significantly suppressed under blue light as compared to the red light. In fact, the concentration of serum melatonin under red light is 3.8-fold higher than the melatonin under blue light. Huang (2008) also concluded that long photoperiod causes earlier cessation of laying and the effect cannot be abolished by melatonin feeding. It is implied that melatonin is not the main mediator for the effect of photoperiod on reproduction in geese. Therefore, we suggest that melatonin is not the main mediator of reproduction in breeding geese.

### CONCLUSION

Our results suggested that red LED-light has the best effect on reproductive performance (i.e. longer laying period and higher total eggs number) at 30 lux light intensity, and is therefore a better choice for the management of breeding geese than blue or white LED-light.

### CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

### ACKNOWLEDGMENTS

The authors would like to thank colleagues in the Changhua Animal Propagation Station, COA-LRI in Taiwan, for managing the breeder geese.

### REFERENCES

- Bentley, G. E., J. P. Jensen, G. J. Kaur, D. W. Wacker, K. Tsutsui, and J. C. Wingfield. 2006. Rapid inhibition of female sexual behavior by gonadotropin-inhibitory hormone (GnIH). *Horm. Behav.* 49:550-555.
- Biyatmoko, D. 2014. Effects the combinations of light color and intensity of light to age at first laying and production egg of Alabio Laying ducks. *Int. J. Biosci.* 5:80-85.
- Bowmaker, J. K. and A. Knowles. 1977. The visual pigments and oil droplets of the chicken retina. *Vision Res.* 17:755-764.
- Borille, R., R. G. Garcia, A. F. B. Royer, M. R. Santana, S. Colet, I. A. Naas, F. R. Caldara, I. C. L. Almeida Paz, E. S. Rosa, and V. A. R. Castilho. 2013. The use of light-emitting diodes (LED) in commercial layer production. *Rev. Bras. Cienc. Avic.* 15:135-140.
- Er, D., Z. Wang, J. Cao, and Y. Chen. 2007. Effect of monochromatic light on the egg quality of laying hens. *J. Appl. Poult. Res.* 16:605-612.
- Firouzi, S., H. Haghbin Nazarpak, H. Habibi, S. S. Jalali, Y. Nabizadeh, F. Rezaee, R. Ardali, and M. Marzban. 2014. Effects of color lights on performance, immune response and hematological indices of broilers. *J. World's Poult. Res.* 4:52-55.
- Gongruttananun, N. and P. Guntapa. 2012. Effects of red light illumination on productivity, fertility, hatchability and energy efficiency of Thai indigenous hens. *Kasetsart J. (Nat. Sci.)* 46:51-63.
- Gordijn, M. C. M., D. G. M. Beerma, M. Rüger, and S. Daan. 2005. The effects of blue light on sleepiness. In: *Annual Proceedings of the NSWO* (Eds. G. S. F. Ruigt, A. L. van Bommel, T. de Boer, W. Hofman, and G. van Luijelaar). Sleep-wake research in the Netherlands, Groningen, Netherlands. pp. 67-70.
- 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. A Mol. Integr. Physiol.* 120:317-323.
- Hassan, M. R., S. Sultan, H. S. Choe, and K. S. Ryu. 2013. Effect of monochromatic and combined light colour on performance, blood parameters, ovarian morphology and reproductive hormones in laying hens. *Ital. J. Anim. Sci.* 12:e56.
- Hassan, M. R., S. Sultana, H. S. Choe, and K. S. Ryu. 2014. Effect of combinations of monochromatic led light color on the performance and behavior of laying hens. *J. Poult. Sci.* 51:321-326.
- Hsu, J. C., H. C. Pen, and Y. H. Chen. 1990. Effects lighting program on the laying performance of geese. I. Effects of the lighting intensity on laying performance of geese. *J. Agric. Forest* 39:15-25.
- Huang, H. Y. 2008. The role of melatonin in the action pathway of photoperiod on the geese reproduction. Master thesis, Tunghai University Institutional Repository, Taichung, Taiwan.
- Jin, E., L. Jia, J. Li, G. Yang, Z. Wang, J. Cao, and Y. Chen. 2011. Effect of monochromatic light on melatonin secretion and arylalkylamine n-acetyltransferase mRNA expression in the retina and pineal gland of broilers. *Anat. Rec.* 294:1233-1241.
- Kim, M. J., M. S. Hossian, A. Nazma, C. N. Jae, T. B. Han, K. K. Hwan, W. K. Dong, H. C. Chae, H. C. Choi, and S. S. Ok. 2012. Effect of monochromatic light on sexual maturity, production performance and egg quality of laying hens. *Avian Biol. Res.* 5:69-74.
- Kram, Y. A., S. Mantey, and J. C. Corbo. 2010. Avian cone photoreceptors tile the retina as five independent, self-organizing mosaics. *PLoS ONE* 5:e8992.
- Lee, T. T., J. Y. Ciou, C. N. Chen, and B. Yu. 2015. The effect of *Pleurotus eryngii* stalk residue dietary supplementation on layer performance, egg traits and oxidative status. *Ann. Anim. Sci.* 15:447-461.
- Lee, T. T., J. Y. Ciou, C. L. Chen, and B. Yu. 2013. Effect of *Echinacea purpurea* L. on oxidative status and meat quality in *Arbor Acres* broilers. *J. Sci. Food Agric.* 93:166-172.
- Lewis, P. D. and T. R. Morris. 2000. Poultry and coloured light. *Worlds Poult. Sci. J.* 56:189-207.
- Li, D., L. Zhang, M. Yang, H. Yin, H. Xu, J. S. Trask, D. G. Smith, Z. Zhang, and Q. Zhu. 2014. The effect of monochromatic light-emitting diode light on reproductive traits of laying hens. *J. Appl. Poult. Res.* 23:367-375.
- Mobarkey, N., N. Avital, R. Heiblum, and I. Rozenboim. 2013. The effect of parachlorophenylalanine and active immunization

- against vasoactive intestinal peptide on reproductive activities of broiler breeder hens photostimulated with green light. *Biol. Reprod.* 88:83.
- Morrill, W. B. B., J. M. C. Barnabé, T. P. N. Da Silva, H. Pandorfi, A. S. Gouveia-Neto, and S. S. Wellington. 2014. The effect of RGB monochromatic and polychromatic LED lighting on growth performance, behavior, and development of broilers. *Proceedings of Society of Photo-Optical Instrumentation Engineers*. San Francisco, CA, USA. <http://dx.doi.org/10.1117/12.2036602>
- Nuboer, J. F. W., M. A. J. M. Coemans, and J. J. Vos. 1992. Artificial lighting in poultry houses: Are photometric units appropriate for describing illumination intensities? *Br. Poult. Sci.* 33:135-140.
- Prescott, N. B. and C. M. Wathes. 1999. Spectral sensitivity of the domestic fowl (*Gallus g. domesticus*). *Br. Poult. Sci.* 40:332-339.
- Prescott, N. B., C. M. Wathes, and J. Jarvis. 2003. Light, vision and the welfare of poultry. *Anim. Welf.* 12:269-288.
- Prayitno, D. S., C. J. Philips, and H. Omed. 1997. The effects of color of lighting on the behavior and production of meat chickens. *Poult. Sci.* 76:452-457.
- Puvadolpirod, S. and J. P. Thaxton. 2000. Model of physiological stress in chickens 5. quantitative evaluation. *Poult. Sci.* 79:391-395.
- Pyrzak, R., N. Snapir, B. Robinzon, and G. Goodman. 1984. The effect of supplementation of daylight with artificial light from various sources and at two intensities on the egg production of two lines of geese. *Poult. Sci.* 63:1846-1850.
- 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., N. Mobarkey, N. Avital-Cohen, Y. Kashash-Hanin, R. Heiblum, Y. Chaiseha, and M. E. Halawani. 2012. Photostimulation effects on reproductive activities of domestic birds. In *The XXIV World's Poultry Congress, Bahia, Brazil*. pp. 1-8.
- SAS Institute. 2004. *SAS/STAT Guide for Personal Computers*. Version 9.0.1. SAS Inst. Inc., Cary, NC, USA.
- Ubuka, T., G. E. Bentley, K. Ukena, J. Wingfield, and K. Tsutsui. 2005. Melatonin induces the expression of gonadotropin-inhibitory hormone in the avian brain. *Proc. Natl. Acad. Sci. USA.* 102:3052-3057.
- Wang, C. L., C. J. Chiang, Y. P. Chao, B. Yu, and T. T. Lee. 2015. Effect of *Cordyceps militaris* waster medium on production performance, egg traits and egg yolk cholesterol of laying hens. *J. Poult. Sci.* 52:188-196.
- Zeman, M., J. Košutzký, L. Micek, and A. Lengyel. 1990. Changes in plasma testosterone, thyroxine and triiodothyronine in relation to sperm production and remex moult in domestic ganders. *Reprod. Nutr. Dev.* 30:549-557.