Effect of Monochromatic Light on the Egg Quality of Laying Hens

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Primary Audience: Researchers, Complex Managers, Producers

SUMMARY

The chicken eye can discriminate light color, and different light wavelengths affect egg quality. In this study, we used blue (B), green (G), and red (R) light produced by light-emitting diode lamps, as well as incandescent light (W) to illuminate Hy-Line Brown hens from 19 to 52 wk. All light sources were equalized to a light intensity of 15 lx and applied for 16 h daily. The results showed that egg weight in W light (61.1 g) was significantly ($P < 0.05$) greater than those in R light (59.2 g) throughout the experimental stage. Beginning at the age of 30 wk, egg weight in R light was consistently smaller than those in other lights. The egg length in B light was significantly ($P < 0.05$) shorter than those in other lights, and its width was significantly ($P < 0.05$) shorter than those in W light from 38 to 52 wk. The egg width in R light was significantly ($P < 0.01$) shorter than those in W light and to a lesser extent ($P < 0.05$) shorter than those in B and G lights from 19 to 52 wk. Similarly, eggshell strength in G light was significantly ($P < 0.01$) better than those in W and B lights, and eggshell thickness in G light was significantly ($P < 0.05$) better than those in other lights from 21 to 45 wk. Our results indicate that egg weight in R light was less than those in other lights, the egg length and egg width in B light became shorter, and the egg width in R light became shorter with age; the egg quality in G light was found to be the best.

Key words: monochromatic light, egg weight, eggshell index, eggshell quality, laying hen

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DESCRIPTION OF PROBLEM

Light is an important environmental factor that influences the behavior, egg production, and health of laying hens; therefore, artificial illumination (light duration and light intensity) is widely used to increase the reproductive performances of laying hens in modern poultry houses.

The chicken eye is superior to the livestock eye and can discriminate light color [1]; furthermore, it can see a broader portion of the light spectrum compared with humans (380 to 760 nm) [1]. In addition to the eyes, the extraretinal photoreceptor, in the hypothalamus or in other sites of the brain, is sensitive to different wavelengths and is involved in transduction of photostimulation [2, 3]. The monochromatic light effect on the egg weight and eggshell quality have been reported previously; however, little is known about the monochromatic

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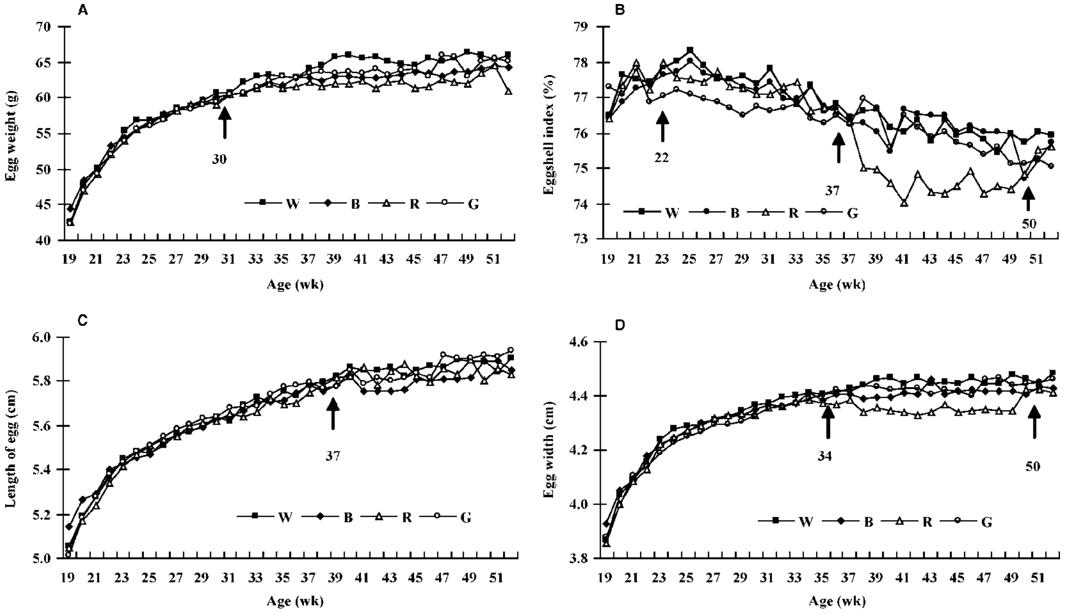

Figure 1. Egg weight (A), eggshell index (B), egg length (C), and egg width (D) of laying hens under 15 lx of light intensity and different light spectra. Different lines represent different light treatments: B = blue; G = green; R = red; W = incandescent light. The arrow indicates the age in weeks.

light effect on the egg length, egg width, and the eggshell index. For example, the greatest number of eggs was produced in a group treated with red light (R), and eggs laid under blue (B) or green (G) lights were consistently heavier than those laid under R light. The eggshell strength in G light was significantly stronger than those in other lights [4]. In turkeys, egg weight in R light was consistently heavier than those in other light treatments. The eggshell strength in G light was significantly stronger than those in other lights throughout the laying period [5]. In contrast, the reports of Woodard et al. [6] for quail and Rozenboim et al [7] for chickens suggested that egg weight was unaffected by light color. In general, studies regarding the effect of monochromatic light on egg weight and eggshell quality are limited and contradictory. Therefore, the objective of this study was to investigate the effect of monochromatic light on eggshell factors and laying performance of hens in modern poultry houses.

MATERIALS AND METHODS

Animals

A total of 180 eighteen-week-old Hy-Line Brown hens [8] were purchased from a commercial pullet grower farm. During the growing period up to 18 wk, the light regimen was 23 h for hens in the first week and then turned to permanent illumination of 12 h from 2 to 18 wk. Upon arrival, birds were randomly placed into a nontemperature-controlled, windowless house and separated within the room by light-tight partitions into 4 light treatment groups. In each group, birds were housed in a laying battery (15 cages, 3 birds per cage, n = 45). These are trideck houses, and each deck contains 5 cages (length × width × height = 50 × 38 × 35 cm). The space between the feed and water troughs was 6 cm. Water and a standard commercial diet containing 2,870 cal/kg, 17.0% protein, and 3.8% Ca were available ad libitum. The consumption followed the Hy-Line Brown Layers Guide Manual [8]. Feed was provided manually in feeders previously designed for 3 hens.

Light Systems

The R, G, and B lights were provided by light-emitting diodes (**LED**) [9]. The LED lamp devices were made by us. Thirty LED were installed in 2 parallel lines on a plastic board (width = 2 cm, length = 1 m). The distance separating the 2 lines was 1 cm. The electric current and voltage in blue and green LED lamp devices were the same, I_F = 100 mA, V_F =15 V; the electric current and voltage in the red LED lamp device were I_F = 25 mA, V_F = 9 V, respectively.

Light Treatments

The LED devices were installed at the top of each cage in B, G, R light treatments, respectively, and incandescent bulbs (15 W) were hung from the roof of the house in the W light treatment (control light). We determined the light intensity using an automatic range luminometer [10]. All light sources were equalized to a light intensity of 15 lx at bird head level.

At the age of 19 wk, birds were exposed to B, G, R, and W light for 13 h, and the light period was increased in equal increments at weekly intervals until a daily light schedule of 16L:8D was achieved at the age of 25 wk (lights on from 0500 to 2100 h) and maintained for the rest of the experimental period. The experimental stage was from the age of 19 to 52 wk, and the experiment was performed in the China Agricultural University.

Measurement Contents

Egg weight, eggshell index (**ESI**), egg length, and egg width were recorded daily. Eggshell strength, eggshell thickness, and eggshell color were recorded by using 990 eggs from the last 3 d consecutively at the age of 21, 23, 25, 27, 29, 31, 34, 37, 40, 43, and 45 wk, respectively. 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 centimeters using FHK [11], and ESI was calculated using the formula ESI = width/length × 100, where width is the transverse diameter, and length is the long vertical length of an egg. The eggshell strength was measured in kilograms per centimeters squared using Eggshell Force Gauge Model-II [12], and eggshell thickness was measured in millimeters using Mitutoyo [13] for eggshell thickness on the large end, equatorial region, and small end, respectively. The average of the 3 measurements was considered as the value for the egg. Eggshell color was measured on the large end, equatorial region, and small end, respectively, using an EQ-Reflectometer [14], and the average of the 3 measurements was considered as the value for the egg. The eggshell color values were represented by grades of 0 (black) to 100 (white).

Data Analysis

All data were analyzed by 1-way ANOVA, according to the design of the 3 experimental groups (3 LED groups or 3 wavelengths) and 1 control group. Differences among groups were tested using Duncan's multiple range test. All statistical analysis was done using SAS [15]. Egg data were also analyzed as a function of time (in wk) from the beginning of the experimental stage. The best-fit curve for each egg parameter was chosen by the result of the highest value of the coefficient of determination (R^2) by using the least squares method of the GLM of SAS. The differences among treatments with age were analyzed by comparisons of the regression lines.

RESULTS AND DISCUSSION

Changing egg weight (Figure 1A and 2A), ESI (Figure 1B and 2B), egg length (Figure 1C and 2C), egg width (Figure 1D and 2D), eggshell strength (Figure 2E), eggshell thickness (Figure 2F), and eggshell color (Figure 2G) are presented for eggs laid by hens from 19 to 52 wk of age (laying period) in W, B, R, and G light treatments. Egg weight, egg length, and egg width increased as a function of time in egg production and were fit best by a hyperbolic model, $y = ax^b$, in all light treatments (Figure 2), whereas the eggshell index, eggshell strength, eggshell thickness, and eggshell color were best fit to the linear model, $y = a + bx$, where y = egg parameter, x = time in weeks, a = intercept, and b = slope (Figure 2).

Egg Weight

The egg weight in the W light group was significantly ($P < 0.05$) greater than those in the R light group but were not significantly ($P > 0.05$) different in other light groups from 19 to 52 wk (Table 1). The egg weight in W light was significantly ($P < 0.05$) greater than those in B light from 38 to 52 wk. Beginning at the

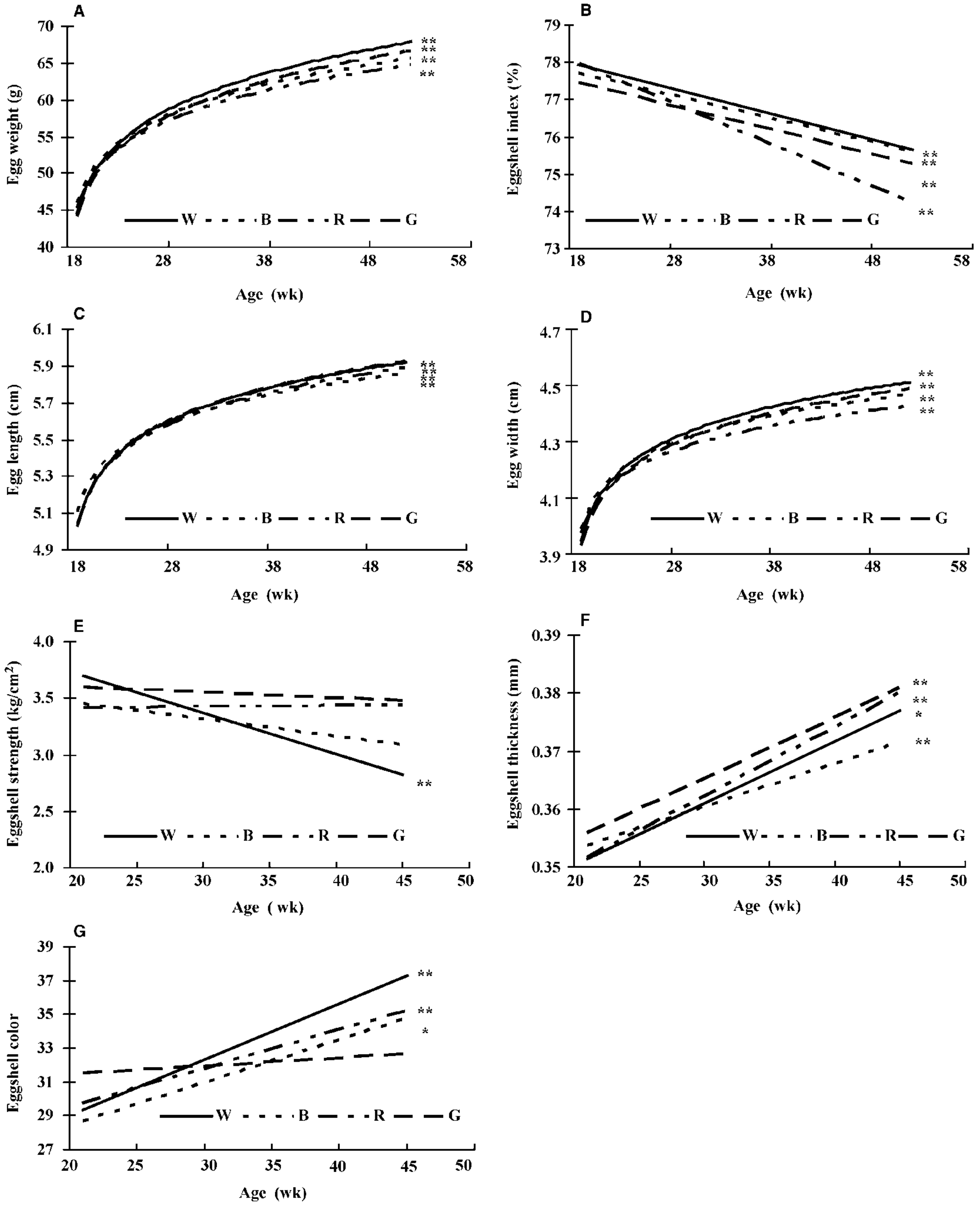

Figure 2. Egg weight (A), egg length (C), and egg width (D) as a function ($y = ax^b$) and eggshell index (B), eggshell strength (E), eggshell thickness (F), and eggshell color (G) as a function ($y = a + bx$) of the laying hens under 15 lx of light intensity and different light spectra. Asterisks indicate the *P*-value of the correlation coefficient *Significant difference from zero at $P < 0.05$. **Significant difference from zero at $P < 0.01$. W = incandescent; B = blue; R = red; G = green.

age of 30 wk, the egg weight in W, B, and G light groups was consistently greater than those in the R light group throughout the remaining experimental stage (Figure 1A). These results were similar to the reports of Pyrzak et al. [4] for chicken but different from the reports of

Table 1. Effect of monochromatic light on egg weight, laying rate, egg length, egg width, eggshell index, eggshell strength, eggshell thickness, and eggshell color in laying hens[1]

		Light source[2]			
Egg parameters	Weeks	W	B	R	G
Egg weight (g)	19 to 52	61.13 ± 0.27^{a}	60.00 ± 0.43^{ab}	59.22 ± 0.51^{b}	60.14 ± 0.41^{ab}
	19 to 37	57.72 ± 0.22^{a}	57.35 ± 0.48^{a}	56.81 ± 0.14^{a}	56.99 ± 0.53^{a}
	38 to 52	65.45 ± 0.46^{a}	63.35 ± 0.44^{b}	62.28 ± 0.62^{b}	64.13 ± 0.7^{ab}
Egg production, hen day (%)	19 to 52	85.15 ± 0.7^{a}	85.98 ± 0.5^{a}	85.53 ± 0.8^{a}	84.39 ± 0.6^{a}
	19 to 37	83.59 ± 0.6^{b}	87.31 ± 0.4^{a}	83.58 ± 0.7^{b}	83.99 ± 0.3^{b}
	38 to 52	86.71 ± 0.8^{ab}	84.66 ± 0.2^{b}	87.47 ± 0.5^{a}	84.78 ± 0.7^{b}
Eggshell index (%)	19 to 52	76.80 ± 0.446^{a}	76.69 ± 0.574^{a}	76.13 ± 0.379^{a}	76.37 ± 0.287^{a}
	19 to 37	77.38 ± 0.074^{a}	77.19 ± 0.086^{a}	77.21 ± 0.110^{a}	76.86 ± 0.044^{b}
	38 to 52	76.07 ± 0.230^{A}	76.06 ± 0.170^{A}	74.77 ± 0.112^{B}	75.78 ± 0.172^{A}
Egg length (cm)	19 to 52	5.68 ± 0.011^{a}	5.659 ± 0.012^{a}	5.659 ± 0.011^{a}	5.683 ± 0.011^{a}
	19 to 37	5.606 ± 0.006^{ab}	5.601 ± 0.008^{ab}	5.592 ± 0.012^{b}	5.623 ± 0.004^{a}
	38 to 52	5.853 ± 0.004^{a}	5.787 ± 0.005^{b}	5.833 ± 0.012^{a}	5.834 ± 0.01^{a}
Egg width (cm)	19 to 52	4.36 ± 0.009^{a,A}	4.339 ± 0.009^{a,AB}	4.305 ± 0.004^{b,B}	4.339 ± 0.007^{a,AB}
	19 to 37	4.339 ± 0.005^{a}	4.327 ± 0.017^{a}	4.316 ± 0.005^{a}	4.314 ± 0.004^{a}
	38 to 52	4.454 ± 0.006^{a,A}	4.413 ± 0.004^{b,A}	4.345 ± 0.008^{c,B}	4.43 ± 0.019^{ab,A}
Eggshell strength (kg/cm^{2})	21 to 45	3.29 ± 0.009^{c,B}	3.28 ± 0.02^{c,B}	3.43 ± 0.05^{ab,AB}	3.53 ± 0.042^{a,A}
Eggshell thickness (mm)	21 to 45	0.363 ± 0.001^{b}	0.362 ± 0.008^{b}	0.365 ± 0.008^{ab}	0.368 ± 0.002^{a}
Eggshell color	21 to 45	33.0 ± 0.14^{a}	31.58 ± 0.25^{b}	32.35 ± 0.19^{ab}	32.07 ± 2.0^{ab}

$^{a–c}$Values within the same row with no common lowercase superscript differ significantly ($P < 0.05$).

^{A,B}Values within the same row with no common uppercase superscript differ significantly ($P < 0.01$).

[1] Values are given as mean ± SE.

[2] W = incandescent; B = blue; R = red; G = green.

Pyrzak and Siopes [5] for turkeys. The above results show that the R light produces smaller eggs, whereas the W light produces larger eggs.

In quail [6], long wavelength light had a stimulatory effect on the rate of egg production without an adverse effect on egg weight. In our study, the rate of egg production in B light was significantly higher than those in other light groups, but egg weight in the 4 light treatments was not significantly different from 19 to 37 wk (Table 1). Inversely, the egg weight in the W light group was significantly greater than those in R light group, but rate of egg production in both light groups was not significantly different from 38 to 52 wk (Table 1). So, our results support what Pyrzak et al. [4] suggested, that egg weight was affected by the light spectrum but not by the rate of egg production.

The increase in egg weight during the laying period from 19 to 52 wk in all treatments followed the hyperbolic function of $y = ax^{b}$ (Figure 2A). A similar response has been reported in chickens [4, 16] and turkeys [5]. Correlation coefficients (r) between egg weight and age in all treatments were highly significant ($P < 0.01$; Figure 2A, Table 2). Egg weight increased during the experimental stage by 52.2, 42.8, 43.3, and 54.9% in W, B, R, and G light groups, respectively.

Eggshell Index, Length, and Width of Egg

The ESI varies with age (Figure 1B) in all experimental stages. The ESI in G light was significantly ($P < 0.05$) smaller than those in other light groups from 19 to 37 wk, and the ESI in R light was significantly ($P < 0.01$) smaller than those in other groups from 38 to 52 wk (Table1, Figure 1B). The ESI was decreased during the experimental stage by 3.1, 2.8, 4.9, and 2.8% in W, B, R, and G light groups, respectively.

The egg length in B light was significantly ($P < 0.05$) smaller than those in other light groups, and its width was significantly ($P < 0.05$) shorter than those in W light from 38 to 52 wk (Table 1, Figure 1C and 1D). The tendency of the egg weight to increase with age in B light became lower than those in W and

Table 2. Intercepts (a), slopes (b), and correlations(r) of egg weight, eggshell index, egg length, egg width, eggshell strength, eggshell thickness, and eggshell color with age (wk) as affected by different light spectra during the experimental stage[1]

		Light source[2]			
Egg parameters		W	B	R	G
Egg weight, 19 to 52 wk (g)	a	44.59	45.95	45.19	44.05
	b	0.119	0.101	0.102	0.118
	r	0.8663**	0.8590**	0.7944**	0.8658**
Eggshell index, 19 to 52 wk (%)	a	78.01	77.78	78.09	77.51
	b	–0.070	–0.064	–0.114	–0.066
	r	0.8602**	0.8088**	0.8426**	0.9214**
Egg length, 19 to 52 wk (cm)	a	5.03	5.10	5.03	5.03
	b	0.046	0.039	0.045	0.046
	r	0.9167**	0.9195**	0.8983**	0.9114**
Egg width, 19 to 52 wk (cm)	a	3.94	3.98	3.97	3.93
	b	0.038	0.032	0.031	0.038
	r	0.8219**	0.8097**	0.7046**	0.8445**
Eggshell strength, 21 to 45 wk (kg/cm^2)	a	3.73	3.46	3.41	3.60
	b	–0.037	–0.015	0.001	–0.005
	r	–0.7517**	–0.4898	0.0436	–0.1728
Eggshell thickness, 21 to 45 wk (mm)	a	0.350	0.353	0.350	0.355
	b	0.0011	0.0007	0.0012	0.001
	r	0.6178*	0.8451**	0.8643**	0.7691**
Eggshell color, 21 to 45 wk	a	29.06	28.46	29.53	31.46
	b	0.328	0.254	0.229	0.049
	r	0.8593**	0.6654*	0.7264*	0.3258

[1] a, b = constants; r = correlation coefficient. Egg weight, egg length, and egg width have the equation $y = ax^b$; eggshell index, eggshell strength, eggshell thickness, and eggshell color were $y = a + bx$ (y = variable; x = week).

[2] W = incandescent; B = blue; R= red; G = green.

*$P < 0.05$; **$P < 0.01$.

G lights (Figure 1A and 2A). Egg width in R light was consistently shorter than those in other lights from 38 to 52 wk (Figure 1D). The tendency of the egg weight to increase with age in R light became the lowest among the 4 lights. It was found that B light results in a shorter egg length and egg width, and R light results in the egg width becoming shorter with age.

Correlation coefficients (r) among egg length, egg width, and age in all treatments were highly significant ($P < 0.01$; Figure 2C and 2D, Table 2). Egg length increased during the experimental stage by 17.6, 14.7, 17.1, and 17.8% in W, B, R, and G light groups, and egg width increased by 14.2, 12.1, 11.4, and 14.2% in W, B, R, and G light groups, respectively.

Eggshell Quality

From Table 1, we can see the eggshell strength in G light was significantly ($P < 0.01$) better than those in W and B lights. From 21 to 45 wk, eggshell strength in W, B, and G treatments decreased by 0.9, 0.38, and 0.12 kg/cm^2, respectively, but increased by 0.03 kg/cm^2 in the R light group. Correlation coefficients (r) between eggshell strength (kg/cm^2) and age among all light treatments were highly significant ($P < 0.01$) in W light only (Figure 2E). This result was similar to the report of Pyrzak et al. [4] for laying hens in the first laying cycle, in which eggshell strength in G light was significantly better than those in other groups. Nevertheless, our result was not similar to his report in the second laying cycle, in which eggshell strength in B and G lights was better than those in R light. These different results could be due to the measurement range; Pyrzak et al. [4] measured it in 2 laying cycles, and we measured it within 21 to 45 wk.

Eggshell thickness in the G light group was significantly ($P < 0.05$) thicker than those in

W and B lights, and there was no significant difference in other light groups (Table 1). Eggshell thickness increased significantly in all light treatments from 21 wk (W: 0.350, B: 0.345, R: 0.350, and G: 0.352 mm) to 45 wk (W: 0.375, B: 0.371, R: 0.378, and G: 0.373 mm). Correlation coefficients (r) between eggshell thickness and age in B, R, and G lights were highly significant ($P < 0.01$), and those in the W light group were significant ($P < 0.05$; Figure 2F). This result was different from that of Roland et al. [17] and Roland [18] for chicken. They reported that the amount of shell deposited on the egg does not decrease as the hen ages but remains relatively constant or increases slightly.

Eggshell color in B light was significantly ($P < 0.05$) lower than those in the W light group, and there were no significant differences among other light groups (Table 1). These results indicate that the egg color is significantly affected by B light from 21 to 45 wk. Eggshell color vastly increased ($P < 0.01$) in the W and R lights and increased significantly ($P < 0.05$) in B light at a rate of 0.328, 0.229, and 0.254 per/wk, respectively. However, the eggshell color in G light treatment did not increase significantly; the rate was 0.049 per/wk (Figure 2G, Table 2).

Our results indicated that egg weight in R light is the smallest and in W light is the heaviest among the 4 types of lights. Egg length and egg width in B light became shorter with age, whereas in R light, only egg width became shorter with age. Additionally, the egg quality in G light was the best.

CONCLUSIONS AND APPLICATIONS

1. Egg weight in the W light was the heaviest, whereas egg weight in the R light was generally smaller than those in other lights. Therefore, the R light should be used in producing small size eggs, whereas the W light should be used in producing large size eggs.
2. The B light causes the length and width of the egg to become shorter and changes the shape of the egg. The B light causes the egg shape to gradually become round with age. The R light causes the width of the egg to become shorter and gradually changes the egg shape into a more slender and oval shape with age. The above changes make the increasing tendency for the egg weight in B and R lights to become lower than those in W and G lights with age.
3. The G light has the most profound effect on eggshell quality. Therefore, if producing a quality eggshell is required, then the G light must be implemented.

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