Effects of colored light-emitting diode illumination on behavior and performance of laying hens

B. Huber-Eicher,[1] A. Suter, and P. Spring-Stähli

Bern University of Applied Sciences, School of Agricultural, Forest and Food Sciences, Länggasse 85, CH-Zollikofen, Switzerland

ABSTRACT The best method for lighting poultry houses has been an issue for many decades, generating much interest in any new systems that become available. Poultry farmers are now increasingly using colored LED (light-emitting diodes) to illuminate hen houses (e.g., in Germany, Austria, the Netherlands, and England). In Switzerland all newly installed systems are now equipped with LED, preferably green ones. The LED give monochromatic light from different wavelengths and have several advantages over conventional illuminants, including high energy efficiency, long life, high reliability, and low maintenance costs. The following study examines the effects of illumination with white, red, and green LED on behavior and production parameters of laying hens. Light intensities in the 3 treatments were adjusted to be perceived by hens as equal. Twenty-four groups of 25 laying hens were kept in identical compartments (5.0 × 3.3 m) equipped with a litter area, raised perches, feed and drinking facilities, and nest boxes. Initially, they were kept under white LED for a 2-wk adaptation period. For the next 4 wk, 8 randomly chosen compartments were lit with red LED (640 nm) and 8 others with green LED (520 nm). Behavior was monitored during the last 2 wk of the trial. Additionally weight gain, feed consumption, onset of lay, and laying performance were recorded. The results showed minor effects of green light on explorative behavior, whereas red light reduced aggressiveness compared with white light. The accelerating effect of red light on sexual development of laying hens was confirmed, and the trial demonstrated that this effect was due to the specific wavelength and not the intensity of light. However, an additional effect of light intensity may exist and should not be excluded.

Key words: domestic fowl, *Gallus gallus domesticus*, light-emitting diode, colored lighting, behavior

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INTRODUCTION

Laying hens, like many other birds, rely heavily on vision, and light is an important factor within their natural environment. Light affects physiology as well as behavior. These effects are mainly elicited by spectral composition, intensity, and photoperiod (Manser, 1996). Modern poultry husbandry tries to manipulate these with the intention of controlling behavior and improving production. Although the effects of photoperiod are well understood, results of studies looking at spectral composition and intensity are inconsistent. One reason for this may be that certain studies (e.g., Kondra, 1961; Osol et al., 1980) did not control intensity when investigating effects of specific wavelengths. Where intensity was controlled, this was done by measuring lux, which measures intensity as it is perceived by humans but not by poultry (Lewis and Morris, 2000). Differences in perception of light intensity may reach 20% and will depend on the different spectral sensitivity of humans and poultry and the type of illuminant used (Nuboer et al., 1992; Prescott et al., 2003). Additionally, the illuminants usually used to produce colored light have a rather varied range of spectrum (e.g., incandescent and fluorescent lamps). This is not the case with light-emitting diodes (**LED**), which are now available from different suppliers in a form suitable for lighting poultry houses (Rozenboim et al., 1998). They give monochromatic light and have other advantages over conventional illuminants such as high energy efficiency, long life, high reliability, and low maintenance cost. Because LED are increasingly used in poultry houses, the following trial was concerned with examining the effect of white, red, and green LED on behavior and production parameters of laying hens, while controlling that intensities were perceived by hens as equal.

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[1]Corresponding author: beat.huber-eicher@bfh.ch

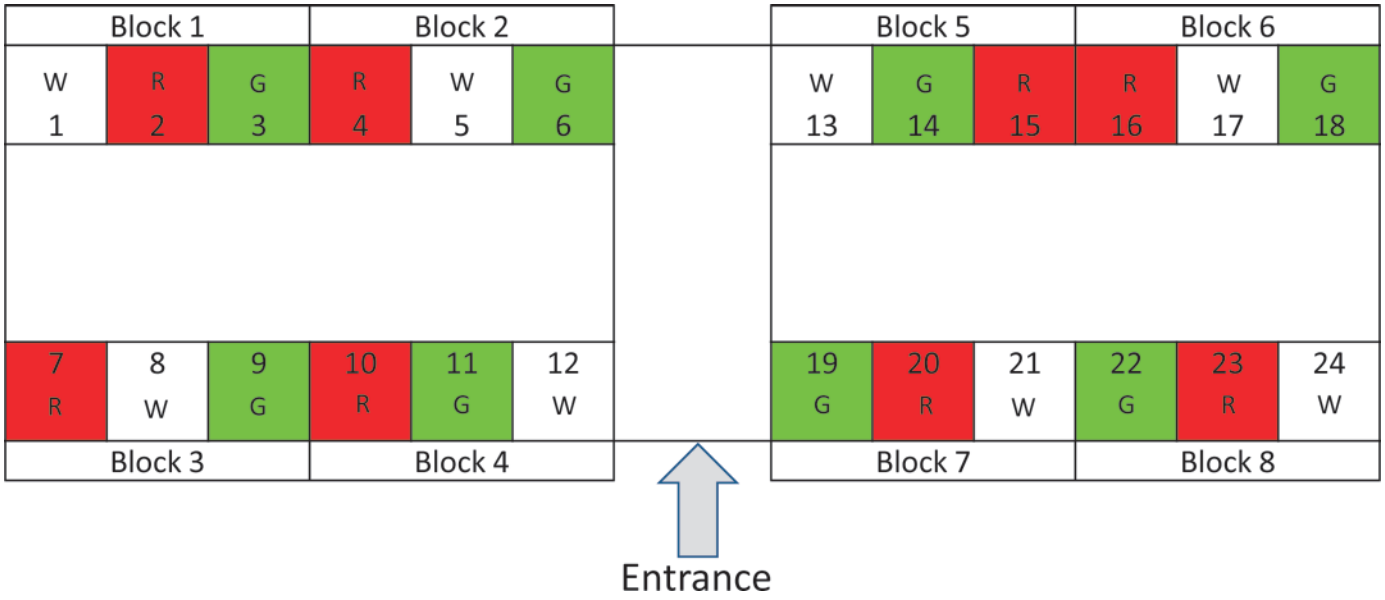

Figure 1. Layout of the poultry house and allocation of the lighting colors to the compartments (W = white; R = red; G = green). Color version available in the online PDF.

MATERIALS AND METHODS

Experimental Design

Domestic hens (n = 600, Brown Nick from H&N, Cuxhaven, Germany) were obtained from a commercial breeder at 16 wk of age and randomly allocated to 24 identical compartments (5.0 × 3.3 m) forming groups of 25 individuals. Compartments were equipped with a litter area (3.3 × 1.8 m), raised perches, commercial feed and drinking facilities, and 2 colony nests (1.28 × 0.64 m). To adapt hens to their new environment, compartments were lit with white LED (approximately 17 lx) for 10 h per day for 2 wk. Subsequently, 8 compartments were lit with red LED (640 nm) and 8 with green LED (520 nm). Allocation of light colors was done pseudorandomly within blocks of 3 compartments (Figure 1). Lights were left on for 12 h a day. Voltage for white, red, and green LED was adjusted according to the spectra of the LED and the relative sensitivity curve published by Prescott and Wathes (1999) so that the 3 lightings appeared iso-illuminant to hens.

Behavioral observations started after 2 wk and lasted for an additional 2 wk. Each compartment was observed 4 times for 35 min. One such observation consisted of 7 repetitions of one scan taking 2 min followed by 3 min of event sampling (Altmann, 1974). Observations were randomly distributed over the light period and observation days but balanced between white, red, and green compartments. Total observation time for each light color was 18 h 40 min.

During a scan, the following behavior patterns were distinguished: standing, sitting, walking, feeding, foraging, pecking at objects, drinking, dust bathing, preening, dozing, resting, sleeping, and orienting upward or downward. In addition, the bird's location within the compartment was recorded. For each group, percentage of time spent exhibiting a specified behavior was calculated, and the mean and SE from the 8 groups exposed to each lighting color is given in the Results. Once the results were collated, percentage of time spent walking, feeding, foraging, pecking at objects, drinking, dust-bathing, and orienting upward or downward was calculated to give a measure of the bird's general activity.

Sampled events included fighting, vigorous pecks at conspecifics, and emitting distress calls. For analysis, vigorous pecks and distress calls were combined into vigorous pecks/distress calls because the latter is an exclusive reaction to vigorous pecks. Distress calls emitted as a reaction to an observed vigorous peck were not counted. Although initially it was intended to record frequency of feather pecking, due to an ambiguous definition it was not possible in retrospect to distinguish between real feather pecks and pecks at particles in the plumage. The observed behavior was therefore classified as pecks at conspecifics. As a qualitative observation, it may be added that no signs of excessive feather pecking, such as distortion of the plumage or injuries, were observed. Frequencies are given as occurrences per 10 min for 25 birds.

The measured production parameters included BW gain and feed consumption, both in grams per day and per bird, over time period of the experiment.

Age at first lay is usually defined as the day when at least 50% of the hens lay an egg. Because several groups did not reach this criterion during the trial, it was redefined as the day when 5 out of 25 hens (20%) laid an egg. To record laying performance of a group,

Table 1. Time spent with different behaviors (% of total observation time)[1]

	White		Red		Green	
Item	Mean %	SE	Mean %	SE	Mean %	SE
Standing	17.7	1.5	17.6	0.7	17.9	1.4
Sitting	2.6	0.2	2.0	0.3	2.2	0.4
Walking	14.4	0.6	15.5	1.4	14.6	0.7
Feeding*	21.1	1.7	21.9	1.5	17.2	1.0
Foraging	4.1[ab]	0.4	2.7[b]	0.3	4.9[a]	0.7
Pecking at objects	8.7[b]	0.8	10.9[ab]	0.8	13.0[a]	0.6
Drinking	5.1	0.2	5.7	0.3	4.8	0.6
Dustbathing	6.4	0.5	6.5	1.0	6.0	0.6
Preening	16.6	1.3	14.7	1.5	16.1	1.3
Dozing	0.5	0.2	0.2	0.1	0.3	0.1
Resting	1.0	0.3	0.4	0.1	0.8	0.1
Sleeping	0.1	0.2	0.1	0.1	0.0	0.0
Oriented up	0.2	0.1	0.4	0.1	0.4	0.1
Oriented down	0.9	0.2	0.9	0.1	1.3	0.1
Activity	61.1	1.7	64.7	1.9	62.5	1.3

[a,b]Within a row, different superscripts show significant differences ($P < 0.05$).

[1]Mean % and SE of n = 8 groups with each light color.

*Behavior in this row tended to show differences ($0.05 < P < 0.10$).

the number of eggs laid during the last 3 d of the experiment (wk 22) was divided by 75 (25 hens × 3 eggs) and multiplied by 100.

The trial was conducted in accordance with the principles and specific guidelines presented in the Guide for the Care and Use of Agricultural Animals in Research and Teaching (FASS, 2010). All 16 groups under red or green light were sold at the end of the trial. Eight groups under white light took part in an additional experiment for 4 wks.

Statistical Analysis

Groups were treated as statistical units. One-way ANOVA was used to compare means of the groups exposed to the 3 different lighting colors. Tukey-Kramer's test was used as a multiple comparison test when results of the ANOVA were significant. In case data did not meet the assumptions for ANOVA, the Kruskal-Wallis test and Dunn's test, respectively, were used instead. Significance was at 0.05.

RESULTS

Behavior

No significant differences for light treatment were found in the time birds spent standing, sitting, walking, drinking, dust bathing, preening, dozing, resting, sleeping, or orienting upward or downward (Table 1). In addition, birds under different light treatments were comparably active, but birds under green light tended to spend less time feeding (17.2%) compared with those under white (21.1%) or red light (21.9%; $F_{2;21} = 2.78$, $P = 0.084$). Significant differences were found for foraging and pecking at objects ($F_{2;21} = 4.23$, $P = 0.028$ and $F_{2;21} = 7.01$, $P = 0.004$, respectively), whereby birds under green light spent significantly more time foraging than those under red light (4.9 vs. 2.7%). Birds under white light spent 4.1% of their time foraging, which was not significantly different from 4.9 or 2.7% for green and red light, respectively. As for pecking at objects, birds under green light spent significantly more time exhibiting this behavior than birds under white light (13.0 vs. 8.7%). Birds under red light foraged 10.9% of the time, which was not significantly different from the 2 other lighting types.

Fighting was very rare and no differences were observed between treatments, although the number of pecks at conspecifics showed significant differences ($F_{2;21} = 5.98$, $P = 0.008$, Table 2). Birds under green lighting pecked significantly more often at conspecifics than birds under white or red light (6.8 vs. 5.1 and 5.2, respectively). Additionally, the number of vigorous pecks and distress calls emitted differed between groups under the 3 lighting colors (Kruskal-Wallis H = 10.86, df = 2, $P = 0.004$). Birds under red lighting showed this behavior significantly less often than birds under white light (0.8 vs. 5.0). The frequency of birds under green light was intermediate with 2.9 events per 10 min for 25 birds, but not significantly different from the other 2 treatments.

Production Parameters

Body weight gain, feed consumption, and age at first lay were comparable under white, red, or green light, and differences between means were not statistically significant (Table 3). However, differences were seen in performance at the end of wk 22 ($F_{2;21} = 21.55$, $P < 0.001$), when laying performance under red light was significantly superior to performance under white or green light, which were not different from each other.

Table 2. Frequencies of pecks at conspecifics, vigorous pecks/distress calls, and fights per 10 min and 25 birds[1]

Item	White		Red		Green	
	Mean no./10 min and 25 birds	SE	Mean no./10 min and 25 birds	SE	Mean no./10 min and 25 birds	SE
Pecks at conspecifics	5.1[b]	0.4	5.2[b]	0.4	6.8[a]	0.1
Vigorous pecks/distress calls	5.0[a]	0.8	0.8[b]	0.2	2.9[ab]	0.9
Fights	0.1	0.1	0.1	0.0	0.1	0.0

[a,b]Within a row, different superscripts show significant differences ($P < 0.05$).

[1]Mean and SE of n = 8 groups with each light color.

DISCUSSION

Behavior

Hens under green light tended to spend less time feeding than birds exposed to the other 2 lighting types, but more time foraging (especially compared with those exposed to red light, with white light being intermediate), more time pecking at objects (compared with white, with red being intermediate), and more frequent pecking at conspecifics (compared with white or red). These results indicate that hens under green light were more engaged in explorative behavior. Kristensen et al. (2007) looked at the behavior of broiler chicks under 4 different light sources and 2 illuminances. Biolux and warm-white fluorescent lamps, both with a spectrum closer to daylight than the other 2 sources used, were preferred. Biolux increased pecking and object manipulation compared with warm-white light, independent of illuminance, but foraging was increased by higher illuminance, irrespective of the light source. Obviously, elements of explorative behavior may be influenced by the spectrum of a light source as well as by illuminance. It remains to be clarified what other colors apart from green may stimulate explorative behavior.

Literature on the effect of colored light on behavior is very scarce. Prayitno et al. (1994) published a comparable study looking at the effect of white, red, green, and blue light on 80 Ross broiler chickens. Intensity was controlled, but measured in lux. No differences were found in feeding time, but walking (comparable with our foraging) as well as pecking at the cage was reduced in birds under green light. The authors were conscious that they did not consider the spectral sensitivity of chickens. This current study does not confirm these findings, however, and because the light intensity was controlled, the data are not fully comparable.

The behavior between hens under white or red lighting did not show any differences except in aggressiveness, as measured by the frequency of vigorous pecks and distress calls. Red light reduced aggressiveness compared with white light (green was intermediate). This effect was due to the wavelength (i.e., the color per se) and should not be confused with eventual effects of intensity. In the study of Prayitno et al. (1994), red light increased aggression in broilers. This is likely a consequence of the perceived increased intensity, as broilers are more sensitive to this range of the spectrum than that measured by lux (Prescott and Wathes, 1999) and higher light intensity increases aggression. The reduction in aggressiveness under red light needs further evaluation because it could be of interest in commercial production situations.

Production Parameters

Hens under red light from wk 19 to 22 showed significantly better early laying performance (70.6%) than with white or green light (52.0 and 40.4%, respectively). This favorable effect of red light on egg production is known (Pyrzak et al., 1987) and is confirmed by our results and Gongruttananun (2011) who reported that native Thai-pullets (*Gallus domesticus*) under constant red LED lighting (16 h) had higher laying performance in the first 8 wk compared with hens under pure daylight (12 h) supplemented with white fluorescent (4 h) or red LED light (4 h). He also observed a significantly earlier onset of lay, which corresponds with the trend observed in this trial. Mobarkey et al. (2010) showed convincingly that these effects are due to the sensitivity of the hypothalamic extra-retinal photoreceptors to long-wave radiation and not to a reception through the retina. Light intensity was not found to have an effect on the onset of lay (Renema et al., 2001).

Table 3. Production parameters: the given values are means of n = 8 groups and the corresponding SE

Item	White		Red		Green	
	Mean	SE	Mean	SE	Mean	SE
BW gain per bird (g/d)	9.14	0.27	9.18	0.16	9.42	0.27
Feed consumption per bird (g/d)	78.62	0.80	80.56	0.79	79.51	1.21
Age at first lay (d)	146.62	1.05	144.50	0.42	146.00	1.46
Laying performance in wk 22 (%)	52.00[b]	2.66	70.66[a]	2.52	40.49[b]	4.33

[a,b]Within a row, different superscripts show significant differences ($P < 0.05$).

Gongruttananun (2011) did not find differences in BW or feed intake. In accordance, we did not find any differences of BW gain or feed consumption under red or green light when compared with groups exposed to white light.

Conclusions

In conclusion, the trial demonstrated mild effects of green light on explorative behavior (which might be more pronounced with a longer trial duration) and red light reduced aggressiveness compared with white light. The Results confirmed the accelerating effect of red light on sexual development of laying hens. Both observed effects were due to the specific wavelength and not light intensity, as the luminance perceived by hens was controlled in such a way as to be similar in all treatments.

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