The Effect of Wavelength Conversions on Broiler Growth and Leg Disorders

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Abstract: The wavelength of light affects the behavior and psychology of chickens. In this study, the effects of several wavelengths and daily wavelength conversions on chickens were examined. The chicks, all Arbor Acres, were randomly assigned to 6 experiments, each repeated 3 times with 10 birds each time. LEDs were used as the source of light, and the birds in the 6 test groups were exposed to the following wavelength conversions: Group A: green light for 10 d, and blue light from the 11th day onward; Group B: a repeated cycle of green light for 3 h, red light for 1 h, then blue light for 3 h; Group C: alternating green and blue light, 3 h each; Group D: green light for 11 h, followed by blue light for 12 h; Group E: green light for 10 d, and a cycle of blue light for 3 h and red light for 1 h from the 11th day onward; Group F: a cycle of green, red, and blue lights for 11 h, 1 h, and 11 h, respectively. Feed consumption and body weights were recorded during the experimental period. On the 35th day, leg weakness in the chickens was assessed by measuring the walking ability and by scoring the gait; moreover, the risk of footpad dermatitis and ankle injuries was determined. The results indicated that wavelength conversion can induce increased locomotor activity in chickens. Moreover, when using wavelength conversions, fewer cases of leg lesions were found, suggesting that the overall well-being of the chickens was enhanced.
[Chen WJ, Sheng ST. **The Effect of Wavelength Conversions on Broiler Growth and Leg Disorders**. *Life Sci J* 2013; 10(2): 2488-2492]. (ISSN: 1097-8135). http://www.lifesciencesite.com 344

Keywords: body weight; feed consumption; gait scoring; wavelength conversions

1. Introduction

In commercial chicken farming, the most common goals are to increase the rates of feed conversion and growth. However, the environment that offers the optimal output with regards to these two aims may compromise animal welfare (Bessei, 2006).

Within a chicken coop, light is a controllable environmental factor, and chickens are affected by the photoperiod, illuminance, and the wavelength of light, both behaviorally and physiologically (Manser, 1996). The wavelength of light can affect the growth of broilers, and green light generally enhances the bodyweight of broilers (Halevy et al., 1998; Rozenboim et al., 1999; Cao et al., 2008). However, in the study by Rozenboim et al. (2004), which, unlike previous studies, focused on a single wavlength, chickens of various ages were exposed to several wavelengths, and the results showed that chickens grew more efficiently when exposed to multiple wavelengths than to a single wavelength. The increased growth has been suggested to be due to stronger stimulation of testosterone secretion in chickens by shorter than longer wavelengths (Cao et al., 2008). Other studies have suggested that such an effect is likely related to the different behavioral effects on the chickens in which short wavelengths reduce activity in the birds and affect their energy input and output balance (Prayitno et al., 1997).

Leg disorders in chickens, which are serious economic problems and an animal welfare concern, can result from genetic causes or from the effects of growth rates, activity levels, nutrition, and stocking density (Bradshaw et al., 2002). In Taiwan, lameness and contact dermatitis are the most common leg disorders in chickens, and chickens with these disorders may grow poorly and die, leading to economic losses for the owners.

When chickens sit for extended periods, the breast bears much of the body's weight, and the skin remains in contact with wet litter, which can lead to foot pad dermatitis (FPD) or ankle injuries (Harms and Simpson, 1975; Greene et al., 1985; Martland, 1985); however, increasing the chickens' activity can reduce these leg problems (Leterrier et al., 2001). Newberry et al. (1988) demonstrated that increasing the intensity of light can enhance activity levels and reduce the incidence of leg lesions among broilers. In low light (1 lux) environments, chickens move less and spend more time resting, which increases the possibility of developing FPD and, therefore, has a negative effect (Deepa et al., 2012; 2010). FPD incidence is currently used as a criterion for evaluating the wellbeing of poultry. Rearing broilers with light-dark cycles rather than with continuous light increases synchronous activity among the chickens and reduces leg lesions (Sanotra et al., 2002). A short photoperiod can affect the walking ability in chickens (Sorensen et al., 1999), whereas intermittent lighting increases feed intake and promotes weight gain in chickens (Ohtani and Leeson, 2000). Prayitno et al. (1997) conducted 2 experiments: In the first experiment, chickens were reared under either red or blue light at 3 intensity levels each to compare the effects of red light with that of blue light, as well as the effect of light intensities, on the activity of chickens. In the second experiment, chickens were exposed to red light either in the first or second half of the experiment to investigate the association between leg lesions and activity levels.

The majority of studies examining how certain wavelengths of light affect chickens have focused on single wavelengths, and few studies have examined the influence of wavelength conversion. In this study, the effects of daily wavelength conversion were investigated to ascertain whether the use of short wavelengths promotes growth in chickens, and whether the use of long wavelengths can induce increased movement in chickens. The experiments were designed to ensure that any observed positive effects are due to the stimulation from wavelength conversion. The results showed that wavelength conversion increased activity levels among the chickens (causing them to expend more energy), promoted flock behavior, and reduced the incidence of leg lesions, thereby enhancing the well-being of the chickens.

2. Material and Methods

Animals, Housing and Feeding

The 180 broilers, which were all Arbor Acres and 1 d old when purchased, were obtained from a commercial hatchery. During the 5-wk test period, the chickens were fed a commercial diet, which consisted of prestarter mash for 0 to 3-wk-old birds (22.5% CP 3060 kcal ME/kg) and early broiler feed after the 3-wk mark (20.5% CP 3075 kcal ME/kg). Groups of 10 chicks were each randomly assigned to 6 experiments, each of which was repeated 3 times. Birds were housed in approximately 1 m × 1.5 m cages and given free access to the same amount of water and food.

Lighting Schedule

To compare the effects of wavelength conversion, the entire test used the same photoperiod, namely 23L:1D. The light intensity of the horizontal plane had a measurement of 25 cm according to the photoreceptor sensor of a light meter (TES-1339, TES CORP Inc., Taipei, Taiwan), and the average light intensity in each cage was 40 lux. The wavelength conversions that the birds of each group were exposed to were as follows: **Group A**: green light for the first 10 d, and blue light from the 11th day onward; **Group B**: a cycle of green light for 3 h, red light for 1 h, then blue light for 3 h; **Group C**: alternating green and blue light, 3h each; **Group D**: green light for 11 h, followed by blue light for 12 h; **Group E**: green light for 10 d, and a cycle of blue light for 3 h and red light for 1 h from the 11th day onward; **Group F**: a cycle consisting of green, red, and blue lights for 11 h, 1 h, and 11 h, respectively. Electronic timers were used to control the changes between different lights. To avoid alarming the chickens, new light sources were switched on 1 min before turning off the preceding light sources.

Production Data and Gait Abnormalities

Each chicken in every group was weighed once every 5 d, the daily feed consumption in each cage was recorded, and the feed conversion rate of each bird was calculated. The chickens' gait was observed during the first 35 d and each bird was given a score (Dawkins et al., 2004). The chickens' risk of developing FPD and ankle injuries was also measured. To interpret the results, the collected data were subjected to statistical analysis using a one-way analysis of variance with a completely randomized design.

3. Results and Discussion

The weights of chickens are displayed in Table I. Compared with the control group (Group A), increasing the daily wavelength conversion frequency did not increase the weight of the chickens. There was no statistically significant difference in body weight between the chickens of Group A and Groups D, E, and F, but chickens in Groups B and C were significantly lighter. Moreover, the data showed that the frequency of wavelength conversion had a significant effect on the feed-conversion rate (Table II), which was better in Group A.

Studies have suggested that the wavelength of light affects the behavior of chickens rather than their growth in the environment of a single wavelength. Red light increases the activity of chickens, which causes the birds to lose weight and reduces the probability of the birds to develop leg lesions (Prayitno et al., 1997). In this study, multiple wavelength conversions were tested, the growth of chickens in different groups was compared, and the gait and the incidence of leg lesions among the chickens were periodically measured.

Analysis of the data from Groups A, C, and D showed that blue-green wavelength conversion alone does not enhance the growth of chickens (Table I), and that Group A chickens had the best body weight and feed-conversion ratio (Table II). However, switching wavelengths to a higher frequency could cause the chickens to lose weight because chickens become active when they sense a change in the ambient light, and the increased activity leads to higher energy expenditure. The data from Group B showed that exposure to red, blue, and green light led to the maximal loss of weight in the chickens, likely because the extra red light increased activity in the chickens and caused them to expend more energy. The observed effects of red light on body weights and feed-conversion ratios (Group C had the lightest chickens) are consistent with the findings of Prayitno (1997).

Table I. Differences in Optical Wavelength and Body Weight

Age(d)	Light color					
	GB10 (A)	g3r1b3 (B)	g3b3 (C)	g11b12 (D)	GBr (E)	g11r1b1 (F)
0	42.2 ± 0.4	42.2 ± 0.4	42.2 ± 0.4	42.2 ± 0.4	42.2±0.4	42.2±0.4
5	98.6±0.8[a]	94.2 ± 1.4[b]	98.2 ± 1.4[a]	97.2 ± 1.2[a]	98.2±1.2 [a]	98±1.6 [a]
10	246 ± 4.2[a]	228 ± 2.2[c]	240 ± 3[b]	244 ± 3.7[ab]	238±5.1 [ab]	233±6 [b]
15	440 ± 6.6[a]	398 ± 4.2[bc]	422 ± 8.2[b]	436 ± 7[a]	442±12 [a]	426±10 [b]
20	776 ± 12[a]	706 ± 8.2[c]	732±10.2[bc]	760±12.3[ab]	774±16 [ab]	753±18 [ab]
25	998 ± 26[a]	866 ± 16[c]	922 ± 21[b]	962 ± 22[a]	1002±25 [a]	986±30 [a]
30	1302 ± 40[a]	1198 ± 22[c]	1241± 32[bc]	1278± 30[ab]	1312±36 [a]	1298±24[ab]
35	1688 ± 36[a]	1507 ± 26[b]	1578 ± 37[b]	1632 ± 32[a]	1692±78 [a]	1680±42[a]

[a–c] Values not marked with the same letters differ significantly ($P < 0.05$).
Data are means ± SE.

Table II. Differences in Optical Wavelength, Feed Conversion, GS and Mortality Rates

Parameters	Light color					
	GB10 (A)	g3r1b3 (B)	g3b3 (C)	g11b12 (D)	GBr (E)	g11r1b1 (F)
Feed Conversion ratio (FCR)	1.84±0.07[a]	2.3 ± 0.01[d]	2.14 ± 0.04[c]	1.96 ±0.02[b]	2.06±0.02[bc]	2.02±0.04[b]
Mortality (%)	13.33	6.66	0	6.66	3.33	0
Gait score 0 (%)	92.3	92.9	100	89.3	100	96.7
Gait score 1 (%)	0	3.57	0	7.14	0	3.33
Gait score 2 (%)	7.69	3.57c	0	3.57	0	0
Foot pad (%)	7.69	7.14	10	3.57	3.44	6.67
Lesions (%)	15.38	10.71	13.33	7.14	10.34	13.33

[a–d] Values not marked with the same letters differ significantly ($P \leq 0.05$).
Data are means ± SE.

Because Group F chickens received red light only 1 h/d, their weight was unaffected and showed no significant differences compared with the controls. However, 6 chickens in Group E had the highest average weight; although the weights of chickens in Groups E and A were not significantly different, the feed-conversion rate in Group A was better than in Group E. We believe that the effect of the wavelength conversion protocol used for Group E is similar to the effect of intermittent illumination, which affects activity among young chickens (Ohtani and Tanaka, 1998) and improves weight and production efficiency among chickens (Rahimi et al., 2005). Chickens eat when exposed to light and reduce activity in darkness to avoid unnecessary energy expenditure. Red light increases the activity of chickens, but when raised under a variety of wavelengths, chickens are more likely to eat under red than blue-green light (Rierson, 2008). In Group E, red light caused chickens to procure food, whereas blue or green light, like darkness, reduced activity among the chickens, causing them to gain weight. However, because the overall activity of the chickens also increased, the feed-conversion rate in Group E was not as good as that in Group A.

Throughout this study, deaths among the chickens were recorded and the gait and incidence of leg lesions in the chickens were measured. Mortality in Group A was higher than in other groups. Most deaths in Group A occurred when the chickens were approximately 20 days old; the birds had developed leg lesions that made standing impossible and, therefore, they could not be fed. Chickens in Group B died earlier than others, possibly because of a lack of familiarity with the environment and the frequent wavelength conversion, which made the chicks restless and, therefore, prone to peck at or trample one another.

Activity and exercise that improve leg health can stimulate skeletal muscle growth in the legs and improve the growth of chickens, but chickens that gain weight rapidly cannot bear the load of their own bodyweight; hence, a chicken's locomotor activity is an important indicator of leg health (Reiter and Bessei, 1995; Rutten et al., 2002). The gait scores of chickens measured in this study also reflected leg heath. The wavelength conversion in Group B disturbed the chickens and made them anxious, causing them to develop leg injuries. Chickens in Groups C and E had generally good gait scores, but the continuous presence of light gradually reduced locomotor activity in the birds as they aged. In addition, the chickens grew rapidly, which resulted in an increase in the incidence of leg lesions. The data from this study reveal the suitable wavelength conversion—and the degree of stimulation to a chicken's emotional state—that can induce the proper amount of exercise to reduce the incidence of leg lesions and strengthen the consistency of day-to-day behavior among the chickens.

FPD and ankle burns in chickens are caused by prolonged exposure to poor litter (Algers and Svedberg, 1989; Ekstrand et al., 1997; Dawkins et al., 2004). We attempted to increase activity among chickens and thereby reduce the time the birds spent sitting. However, our data show that chickens in all groups were affected by leg problems, and, therefore, an increase in activity does not appear to be directly correlated with a reduction in the prevalence of ailments like FPD and ankle injuries. We suspect that the dampness and the ammonia content of the litter are mainly responsible for causing leg ailments in the chickens.

4. CONCLUSION

Although increasing the frequency of wavelength change stimulated growth in chickens, the effect was not statistically significant. However, the use of suitable wavelength combinations can increase the locomotor activity of the chickens. In this study, one group of chickens was first exposed to green light for 10 d, and, thereafter, to a repeated cycle of blue and red light for 3 h each; this group, compared to other groups, showed less change in body weight but also had fewer cases of leg lesions. Using this gentle method, the lifestyle and health of broilers can be improved to raise the overall well-being of chickens.

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6/21/2013