Effect of Intermittent Lighting on Production Performance of Laying-Hen Parent Stocks

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Abstract
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Keywords
Intermittent lighting, lighting intensity, egg production, energy efficiency

Disciplines
Agriculture | Bioresource and Agricultural Engineering

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Abstract. The objective of this observational field study was to investigate the effect of an alternative intermittent lighting program (13L: 5D: 1L: 5D – Trt) vs. standard lighting program (16L: 8D – Ctrl) on production performance of laying-hen parent flocks. Two houses of 15,000 Hy-Line brown parent-stock hens each were used for the comparative study. Hen-day egg production (HDEP), eggs per hen housed (EHH), hen-day hatchable egg production (HDHEP), hatchable eggs per hen housed (HEHH), percentage of crack eggs, feed use, and hen mortality were recorded from 18 to 58 weeks of age. At 35 weeks of age, distributions of egg-laying time within the day and egg weight were monitored for three consecutive days. Light intensities at three (top, middle, and bottom) tier levels were measured at 36 weeks of age. HDEP of Ctrl and Trt regimens (mean ±SD) was 65.4±4.5% and 67.5±5.6%, respectively; and EHH was 146 and 153, respectively. HDHEP of Ctrl and Trt was 43.8±4.8% and 44.4±7.19%, respectively; and HEHH was 70 and 74, respectively. Crack eggs were 0.97±0.38% under Ctrl and 0.87±0.38% under Trt. Feed intake was similar for Ctrl (109±8 g hen\(^{-1}\) d\(^{-1}\)) and Trt (105±9 g hen\(^{-1}\) d\(^{-1}\)). Weekly mean mortality was 0.282±0.185% for Ctrl and 0.119±0.053% for Trt. Light intensities were significantly different among the top (18.7 ± 5.8 lux), middle (13.7 ± 5.0 lux) and bottom (11.3 ± 6.4 lux) tiers (P<0.01). Egg weight for the bottom tier was closer to the standard egg weight and was greater than that for the top or middle tier (P<0.05) in the Trt house, although significant difference was not observed in the Ctrl house. These field observational results indicate that the Trt lighting regimen has the potential to save lighting energy without compromising egg production performance of the hens. However further studies are needed to verify the findings.

Keywords. Intermittent lighting, lighting intensity, egg production, energy efficiency
Introduction

Lighting is a powerful exogenous factor in control of many physiological and behavioral processes. For laying birds (including breeders) light can influence the laying age, egg production and feeding behaviors (Morris et al., 1998; Lewis et al., 2006; Lewis et al., 2010; Lardner et al., 2012). Photoperiod allows the bird to establish circadian rhythmicity (Dawson et al., 2001).

Intermittent lighting was first used in studying photoperiodic induction of poultry (Dobie et al., 1996), and then research purpose turns to application because intermittent lighting can not only reduce illumination time but also keep similar even better performance of laying hens compared with traditional continuous lighting. Zahoor et al. (2011) studied effects of intermittent light on production of Japanese quail and found that properly designed intermittent lighting (8L:6D:2L:8D) could increase egg production (57.3%), improve feed conversion and reduce mortality (8.33%) compared to conversional (16L:8D) (50.5% and 1.04%). Classen et al. (2004) investigated photoperiods of 1 (12L: 12D), 2 (6L: 6D) and 12 (1L: 1D) on/off cycles within the day and found that the latter two light photoperiods (intermittent light) could improve feed conversion and decrease mortality. Meanwhile, studies have also reported that proper intermittent lighting programs could increase survival rate, reduce leg problems, improve vision, and increase anti-stress ability of younger broilers while saving energy (Abreu et al., 2011; Lewis et al., 2010; Baser et al., 2010). Tienhoven et al. (1984) compered energy consumption of laying hens under different lighting programs, and reported that the average daily oxygen consumption decreased 15% under 4×(1L: 3.5D): 1L: 5D photoperiod as compared with 14L: 10D. Lewis et al. (1986) found that when laying hens was kept under a lighting schedule of 14h light separated by a 4h dark + 6h dark, their feeding activity was decreased by 26%. Intermittent lighting may be better than single photoperiod days in the alleviation of heat stress. Francis et al. (1991) reported that the insertion of a 4h period of darkness in the middle of a 14h light period, when the ambient temperature was artificially raised from 25°C to 35-40°C, significantly reduced the rise in rectal temperature of 28-35 day old female broiler chicks. Midgley (1984) and Abbas et al (2007) also reported that birds subjected to intermittent lighting were quieter, less cannibalistic, and appeared to have less stress during hot weather. Lewis et al. (1992) summarized the effect of 36 different lighting programs on laying hens and concluded that intermittent light could decrease mortality, vice, obesity and heat stress. Similar results were reported by Gewehr et al. (2007), Freitas et al. (2011) and Shen et al. (2012).

Although much research has shown the improved performance and welfare of broilers, broiler breeders and laying hens under intermittent lighting programs, the effects of intermittent lighting on performance of laying-hen parent stocks are less known or studied. The objective of this study was to investigate effect of alternative (intermittent) vs. conventional lighting programs on the performance of laying-hen parent stock on a commercial farm. The effect of light intensity in different tiers on hen’s performance was also examined.

Materials and Methods

Housing, Animals and Management

The field study was conducted using two tunnel-ventilated, light-proof hen houses, each measuring 90.25m long and 12.75m wide (fig. 1). Air entered the house through box inlets on both sidewalls. An evaporative cooling pad was installed on one end wall, and was used to cool the house in summer, as needed. Eight fans (1.4 m dia.) were installed on the other end wall of the house. Indoor temperature was automatically controlled according to the production guidelines.

Each house had 15,000 hens and 750 roosters (Hy-Line Brown parent stock) allocated in four rows of triple-tier cages (fig. 1), with a stocking intensity of 400 cm²/bird and 5 birds per cage. Travel feeders and nipple drinkers were used. The cages were arranged in half-stair steps with shallow manure pit that was cleaned daily. Feed and water were provided ad libitum. Artificial insemination was performed daily between 14:00h and 18:00h from 31 weeks of age. Daily management schedule is shown in table 1.
Table 1. Daily Management Schedule of Laying-Hen Parent Breeder Stock

<table>
<thead>
<tr>
<th>Daily Management</th>
<th>Time</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>5:00-5:10</td>
<td>Feeding</td>
<td>13:50-14:00  Feeding</td>
</tr>
<tr>
<td>8:00-8:10</td>
<td>Feeding</td>
<td>14:00-18:00  Artificial insemination</td>
</tr>
<tr>
<td>8:10-8:30</td>
<td>Cleaning, pick up mortality</td>
<td>15:30-15:40  Feeding</td>
</tr>
<tr>
<td>8:30-9:30</td>
<td>Removing manure</td>
<td>16:00-17:00  Collecting eggs</td>
</tr>
<tr>
<td>9:30-10:00</td>
<td>Collecting eggs</td>
<td>18:00-18:10  Feeding</td>
</tr>
<tr>
<td>10:00-10:10</td>
<td>Feeding</td>
<td>18:10-18:30  Cleaning</td>
</tr>
<tr>
<td>11:00-11:30</td>
<td>Disinfecting</td>
<td>19:00-19:10  Feeding</td>
</tr>
<tr>
<td>11:30-11:40</td>
<td>Feeding</td>
<td></td>
</tr>
</tbody>
</table>

Prior to the experiment, the pullets had been provided 23 h light at 1 week of age, which gradually decreased to 9 h light at 18 weeks of age. After week 18, the illumination time in the two houses increased 0.5 h every week till 16 h lighting in one house (Ctrl) and 13 h lighting in the other (Trt), thereafter keeping the photoperiods at 16L:8D in the Ctrl house and 13L:5D:1L:5D the Trt house. The illumination period was 4:00-20:00h in the Ctrl house, and 6:00-19:00h and 00:00-1:00h in the Trt house. The lights (7W fluorescence bulbs) were hung in a staggering manner 2.5 m above the floor in the service aisles, 29 in the odd lines and 30 in the even lines. All lights were automatically controlled. Other environmental conditions in both houses were maintained to be identical by an automatic control system.

Data Collection, Measurement, and Data Analysis

Egg production, mortality, feed use in both Ctrl and Trt houses were recorded daily from 18 weeks of age. Starting from 31 weeks of age (onset of artificial insemination), eggs were categorized into hatchable and abnormal ones. Hatchable eggs must not have abnormal shape, sand shell, cracking, dirt, double-yolk or overweight. At 35 weeks of age, hatchable and abnormal eggs from half of the 2nd cage row were recorded every hour during light periods for 3 consecutive days, and 42 randomly-selected eggs were weighed with an electronic balance three times a day.
Light intensity at three tiers was measured at 8:00h, 12:00h and 16:00h for two consecutive days at 36 weeks of age using a digital lux meter (TES-1332A, TES Electrical Electronic Corp, Taipei, China). Fifteen (15) locations (fig. 1) were measured: under the lights and between two lights, at the bird level of each tier. Three locations along each aisle: 6 measurement points per location (i.e., under lights + between lights) × (top + middle + bottom tiers).

Temperature and relative humidity (RH) were continuously measured at five locations per house (one per aisle, fig. 1) at 30-min intervals from 36 to 43 weeks of age using portable sensors (THERMO RECORDER RS-11, ESPEC Corp., Osaka, Japan). The T/RH measurements were taken at 3 m above the floor.

Hen-day egg production (HDEP, %) is defined as daily eggs produced divided by the number of hens in the house ×100%. Eggs per hen housed (EHH) is the cumulative eggs produced divided by the initial number of hens placed. Hatchable hen-day egg production (HHDEP, %) is daily hatchable eggs produced divided by the number of hens in the house ×100%. Hatchable eggs per hen housed (HEHH) is cumulative hatchable eggs produced divided by the initial number of hens placed.

Statistical analysis was performed with SPSS17.0 (Statistical Program for Social Sciences, Beijing, China), using ANOVA procedure. LSD method was used to adjust the multiple comparisons between treatments. Significant differences between treatments were identified at P <0.05. Data were presented as Mean ± SD.

Results and Discussion

Indoor Temperature and Relative Humidity (RH)

Daily average temperature and RH of Ctrl and Trt are shown in Figures 2, respectively. It can be seen that the temperature and RH were very similar in the two houses. Daily mean, maximum and minimum temperature was 26.1°C, 30.9°C and 14.0°C, respectively, for the Ctrl house; and 25.4°C, 30.2°C and 12.7°C, respectively, for the Trt house. Daily mean, maximum and minimum RH was 86%, 94% and 46%, respectively, for the Ctrl house; and 83%, 95% and 47%, respectively, for the Trt house (P₁=0.713 and P_RH=0.504).

Figure 2. Daily mean temperature and daily mean relative humidity (RH) of Ctrl and Trt houses during 36-43 wk of age. The Ctrl hens had a 16L:8D lighting regimen while the Trt hens had a 13L:5D:1L:5D regimen. Mean temperature of the Ctrl and Trt houses was 26.1°C and 25.4°C, respectively (P=0.713). Mean RH of the Ctrl and Trt houses was 86% and 83%, respectively (P=0.504).
Hen Production Performance

Weekly average HDEP is shown in Figure 3 and table 2. From 18 to 23 wk, HDEP of both groups showed gradual increase and reached a peak at 23 wk (80.1% for Ctrl and 83.0% for Trt), with the mean HDEP during this period being 25.9±3.4% for the Ctrl hens and 28.8±3.3% for the Trt hens. However, HDEP of both groups decreased at 24-26 wk because of bird flu. The Ctrl group had 7.11% more reduction than the Trt. After the bird flu, HDEP increased again then maintained at a relative stable level. The mean HDEP of Ctrl and Trt (18-58wk) hens were 59.7±19.3% and 60.8±19.2%, respectively. For HHEP (fig. 4), the Trt hens produced 7 more eggs per hen than the Ctrl hens as of 58 wk of age. Our results were consistent with the literature reports that hens under intermittent lighting had better performance than under continuous lighting (Morris et al., 1995; Lewis et al., 1997; Classen et al., 2004; Zahoor et al., 2011).

Artificial insemination started from 31wk of age in both groups, and weekly HDHEP is shown in Figure 5. From 31 to 58 wk, mean HDHEP of the Ctrl and Trt hens was 43.8±4.8% and 44.4±7.1%, respectively. The proportion of hatchable eggs relative to total eggs of Crtl and Trt was 66.8±7.2% and 66.5±7.7%, respectively. As can be seen from the data in Figure 6, Trt produced 4 more hatchable eggs per hen housed than Ctrl.

Percentage of crack eggs (Table 2) in Trt was higher than that in Ctrl, 0.97±0.38% and 0.87±0.38%, respectively, for the period of 18-58 wk of ages. Feed intake (fig. 7) was similar between the two groups. Since Trt produced more eggs which means that feed conversion of intermittent lighting group tend to be higher than that of conventional lighting group, which is consistent with that had been reported (Lewis et al., 1986; Morris 1987; Classen et al., 2004; Zahoor et al., 2011). Mortality (fig. 8) in Ctrl was 0.156% higher than that in Trt at 24-25wk during bird flu period, and the mean mortality of Ctrl and Trt were 0.282±0.185% and 0.119±0.053%, respectively. Lewis et al. (1996) analyzed mortality rates in domestic fowl under many kinds of intermittent and conventional lighting treatments and reported that intermittent lighting program with shorter daily illumination time could reduce mortality. In this experiment, similar result was obtained in that intermittent lighting tended to reduce hen mortality.

Figure 3. Weekly average hen-day egg production of parent stock hens in Ctrl and Trt houses. The Ctrl hens had a 16L:8D photoperiod and the Trt hens had a 13L:5D:1L:5D photoperiod. Overall mean HDEP of Ctrl and Trt was 59.7±19.3% and 60.8±19.2%, respectively.

Figure 4. Eggs per hen housed in Ctrl and Trt houses. The Ctrl hens had a 16L:8D photoperiod and the Trt hens had a 13L:5D:1L:5D photoperiod. EHH of Ctrl and Trt for the period was 146 and 153, respectively.
Table 2. Egg Production at Different Ages (mean ± SD)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Total egg production</th>
<th>Hatchable egg production</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>18-58wk</td>
<td>24-26wk*</td>
</tr>
<tr>
<td></td>
<td>16L:8D</td>
<td>13L:5D:1L:5D</td>
</tr>
<tr>
<td>HDEP, %</td>
<td>59.7±19.3</td>
<td>60.8±19.2</td>
</tr>
<tr>
<td>Crack Egg, %</td>
<td>0.97±0.38</td>
<td>0.87±0.38</td>
</tr>
<tr>
<td>Feed Intake, g hen⁻¹d⁻¹</td>
<td>109±8</td>
<td>105±9</td>
</tr>
<tr>
<td>Mortality, %</td>
<td>0.069±0.069</td>
<td>0.057±0.033</td>
</tr>
</tbody>
</table>

*Bird flu occurred in both houses at 24 weeks of age
Daily Distribution of Egg Laying Time

Daily distribution of egg-laying time is shown in Figure 9. Laying peak in the Ctrl regimen appeared at 8:00-9:00h, and eggs produced during this period accounted for 14.0% of the total egg production. Laying peaks also appeared at 8:00-9:00h in the Trt regimen, although the production during this period accounted for 9.45% of the daily total. The Trt hens also produced eggs during the dark period of 1:00-6:00h, which accounted for 13.82% of the daily total. On the other hand, cumulative egg production before 12:00h (fig. 10) was 87.84% of daily total egg production in Ctrl and 90.67% in Trt. More eggs were produced in dark period for the Trt hens, reflecting the effect of photoperiod on hen's oviposition (Bhatti et al., 1978). Since the daily artificial insemination was carried out in the afternoon, morning egg laying would increase the chance of egg fertilization. Based on the result of this study, the intermittent light schedule tended to stimulate 2.83% more eggs laid in the Trt prior to 12:00h, which could be beneficial to artificial insemination.

Effect of Light Intensity (of Different Tiers) on Production Performance

Light Intensity of Tiers

Light intensity of different cage tiers is shown in table 3. As expected, light intensity in different tires differed significantly (P<0.001). Average light intensity of two groups from top to bottom was 18.7, 13.7 and 11.3 lux, respectively. Light intensity of these two houses was not uniform and top and middle was little high.

Table 3. Light Intensity (lux) in different tiers (mean ± SD)

<table>
<thead>
<tr>
<th></th>
<th>Bottom Tier</th>
<th>Middle Tier</th>
<th>Top Tier</th>
</tr>
</thead>
<tbody>
<tr>
<td>16L:8D</td>
<td>12.4 ± 8.5</td>
<td>14.3 ± 6.5</td>
<td>19.5 ± 7.3</td>
</tr>
<tr>
<td>13L:5D:1L:5D</td>
<td>10.3 ± 2.9</td>
<td>13.1 ± 2.7</td>
<td>17.9 ± 3.6</td>
</tr>
<tr>
<td>Mean</td>
<td>11.3 ± 6.4</td>
<td>13.7 ± 5.0</td>
<td>18.7 ± 5.8</td>
</tr>
</tbody>
</table>

a,b,c means in the same row with different letters are significantly different (P<0.05).
**Effect on Egg Production**

HDEP and HHDEP of Ctrl and Trt are shown in Figures 11a and 11b, respectively. In both cases, the numerical values of HDEP followed the order (from high to low) of middle, top and bottom, although no statistical significance was found (P=0.132 and 0.712). In comparison, HHDEP followed the order (high to low) of top, middle and bottom, and once again no significant difference was detected (P=0.408 and 0.519). Similar findings were reported by Lewis et al. (2009) who showed no significant effects of 15-70 lux light intensity on egg production.

<table>
<thead>
<tr>
<th>Tier</th>
<th>Egg Production (%)</th>
<th>Hatchable Egg Production (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bottom</td>
<td>74.88</td>
<td>49.08</td>
</tr>
<tr>
<td>Middle</td>
<td>76.06</td>
<td>53.52</td>
</tr>
<tr>
<td>Top</td>
<td>73.01</td>
<td>54.45</td>
</tr>
</tbody>
</table>

*Figure 11a. Egg production and hatchable egg production of hens in the 16L: 8D regimen. There was no difference in egg production (P=0.132) or hatchable eggs (P=0.408) among the tiers. Vertical bars represent standard error.*

<table>
<thead>
<tr>
<th>Tier</th>
<th>Egg Production (%)</th>
<th>Hatchable Egg Production (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bottom</td>
<td>73.75</td>
<td>49.83</td>
</tr>
<tr>
<td>Middle</td>
<td>75.13</td>
<td>52.10</td>
</tr>
<tr>
<td>Top</td>
<td>73.34</td>
<td>54.86</td>
</tr>
</tbody>
</table>

*Figure 11b. Egg production and hatchable egg production of hens in the 13L: 5D: 1L: 5D regimen. There was no difference in egg production (P=0.712) or hatchable eggs (P=0.519) among tiers. Vertical bars represent standard error.*

**Effect on Egg Weight**

Egg weight of different tiers for Ctrl and Trt is shown in Figure 12. No difference in egg weight was detected among tiers in the Ctrl house (P=0.223); whereas eggs in the bottom tier were significantly heavier than those of middle (P=0.004) and top (P=0.001) tiers in the Trt house, although there was no difference between the middle and top tiers (p=0.434). It had been reported that heavier eggs were associated with lower light intensity, and as light intensity increased egg weight decreased exponentially (Renema et al., 2001; Lewis et al. 2009; Yildiz et al., 2006). The standard hatch eggs of Hy-Line Brown parent stocks (PS) average 62.4 g and the recommended light intensity for Hy-Line Brown PS during laying period is 15-30 lux (Hy-Line International, 2013). Egg weight in the bottom tier was closer to the standard value.

<table>
<thead>
<tr>
<th>Tier</th>
<th>Egg Weight, g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bottom</td>
<td>61.24</td>
</tr>
<tr>
<td>Middle</td>
<td>61.40</td>
</tr>
<tr>
<td>Top</td>
<td>61.05</td>
</tr>
</tbody>
</table>

*Figure 12. Egg weight of Ctrl (16L: 8D) and Trt (13L:5D:1L:5D) hens among different tiers. No difference in egg weight was found among tiers (P=0.223) in the Ctrl group; whereas egg weight of top tier was significantly different compared with middle (P=0.004) and bottom (P=0.001) but there was no difference between middle and top in the Trt group (p=0.434).*
Summary and Conclusions

Production performance of Hy-Line Brown parent stocks was monitored and compared under two lighting regimens: standard photoperiod of 16L:8D or control (Ctrl) vs. an alternative intermittent photoperiod of 13L:5D:1L:5D or treatment (Trt) in commercial production houses, one house of 15,000 hens per lighting regimen. The monitoring was conducted for 40 weeks, i.e., from 18 to 58 weeks of age. Vertical stratification of light intensity was also measured in both houses. The following observations were made:

1. Weekly hen-day egg production under Ctrl and Trt was 65.4±4.6% and 67.5±5.7%, respectively; and eggs per hen housed were 146 and 153, respectively. Hen-day hatchable egg production under Ctrl and Trt was 43.8±4.8% and 44.4±7.1%, respectively; and hatchable eggs per hen house were 70 and 74, respectively.

2. Percentage of cracked eggs under Ctrl and Trt was 0.97±0.38% and 0.87±0.38%, respectively. Feed intake was similar between the two lighting regimens. Mean mortality under Ctrl and Trt was 0.282±0.185% and 0.119±0.053%, respectively. The Trt hens laid more eggs in the dark period than the Ctrl hens. The Trt lighting tends to improve both overall egg production and hatch eggs while reducing energy use.

3. Light intensity was significantly different among the 3 tiers, Top > Middle > Bottom (P<0.001). Egg weight for the bottom tier (lower light intensity) was higher than that for the top or middle tier (P<0.05) in the Trt house; but not so in the Ctrl house.

It should be noted that the data reported here were from only one laying cycle with one control house and one treatment house. Further study should be carried out to consolidate the findings of this study by incorporating data from more flocks.

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