Effects of light on bird activity and carbon dioxide emissions from laying hens housed in an experimental building

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Abstract

Illumination is important in poultry houses since it affects production and it may also influence bird behaviour and wellbeing. Different types of light sources as well as their illuminance level may affect the birds differently. Experiments were made with the aim to study three different light sources, 1) conventional light bulbs, 2) common strip lights, and 3) daylight strip lights as light sources for laying hens and the effect of their illuminance levels on bird activity and CO₂ emissions. About 400 laying hens of the hybrid LSL (Lohmann Selected Leghorn) were housed in a small poultry house (climate chamber) at the SLU research station Alnarps Södergård. The total area of the chamber including walking alleys is 87 m² and the laying hens were kept on a 47 m² large area. The housing system (Fienhage GmbH, Germany) included a bedding area with sand and a manure bin area with a drainable floor above which drinking nipples, automatic feed conveyors, and perches were placed. The manure belts below the drainable floor were running once every day. Laying nests were placed close to one of the walls. Since the chamber is surrounded by an air conditioned indoor space it was possible to keep the poultry house temperature constant at about 20 °C. The air flow rate was manually adjusted with a damper in an exhaust air duct and calculated from air velocities measured in 5 points in a circular duct. It was kept at 1.2-1.6 m³ hen h⁻¹ during the experiments. Temperatures were recorded by thermocouples; RH was recorded by Rotronic Hygrometer®-C80 sensors, and carbon dioxide concentration was measured by an optical analyzer (RI-221, Riken Keiki Co). Animal activity was measured by sensors developed at Research Center Bygholm, Denmark. Illuminance was varied in the experiments and calculated from values measured by a hand holding Lux meter at 18 different places in the chamber. The range of illuminance levels for conventional light bulbs (LB), common strip lights (SL), and daylight strip lights (DSL) were 8-52, 5-63, and 4-93 lux respectively. The experiments started in November when the hens were about 20 weeks old and ended in June the year after.
In the experiments the illuminance for LB, SL and DSL were on average 15.7, 24.0, and 40.8 lux. Corresponding values for activity and CO₂ emissions were 0.28, 0.51, and 0.76 for activity and 3.78, 4.20, and 4.12 g hen⁻¹ h⁻¹ for CO₂ emissions respectively. Pearson correlations showed a significant positive relationship between illuminance and activity (p<0.01), and also between day after start of the experiments and activity (p<0.001). A higher R²-value (79.9%) was found in a regression where both illuminance and day after start of experiments were predictors for activity, while a small R²-value was found when using just illuminance as predictor. The data in the study did not reveal any significant differences in bird activity or CO₂ emissions for the three studied light sources. The increased activity by age (or season) was unexpected since the hens had no light from outside.

Keywords: Poultry, illumination, activity, carbon dioxide

1 Introduction

Illumination is important in poultry houses since it affects production and it may also influence bird behaviour and wellbeing. There are fundamental structure differences between human and avian eyes (Perry, 2004). It has been claimed that a very large amount of poultry behaviour is mediated by their highly specialized visual system (Mendes et al., 2013).

A highly important parameter in poultry production is the number of hours of light and darkness in the barn during a day. Thus, the photo period for laying hens and its influence on production parameters has been investigated in a large number of studies (Mohammed et al., 2010), and standard recommendations have been developed. Further, it is stated that higher light intensities seem to increase bird activity and it may also lead to increased frequency of feather pecking and higher mortality (Perry, 2004). Also type of light source seems to influence bird performance, at least to some extent. In studies of production performance of laying hens with supplemental lighting of about 11 lux for keeping 17 h light per day, it was found that feed conversion was higher for incandescent light (light bulbs) compared to illumination with fluorescent light, while no differences was found for feed consumption, bird weight and mortality (Ahmad et al., 2010). Increased intensity of both incandescent and fluorescent light has been found to increase bird activity and in a study, the activity (at illuminance levels above 5 lux) under fluorescent light was higher than that under incandescent light suggesting a perceived difference in quality of light from the different sources (Boshouwers and Nicaise, 1993). In a review of light versus performance and welfare of broilers it was found that fluorescent light lower the electricity use compared to incandescent light without negative impact on bird performance (Buyse et al., 1996).

It has been suggested that poultry may experience the flicker from low frequency (LF) fluorescent lamps aversive since their vision is different from human vision. A number of studies have suggested this, however, in other studies different results were found. Laying hen behaviour under light from high frequency (HF) lamps and under light from low frequency (LF) fluorescent lamps was studied at an illumination level of 14 lux by Widowski & Duncan (1996). Hens were able to choose between staying in rooms with high frequency lamps and low frequency lamps, and Widowski and Duncan (1996) concluded that the hens in the study did not prefer the light under high frequency lamps when compared to the light under the low frequency lamps.

The choice of light sources may affect the amount of electricity used, being of economic importance for the producers. However, limited knowledge exists about how different light spectra in combination with different light intensities influence laying hen behaviour and wellbeing, i.e. different types of light sources as well as their illuminance level may affect the birds differently. In order to improve animal welfare and possibly save money in the production it is important to gain more knowledge about this issue.
1.1 Aim of the study

A hypothesis of the study was that light spectra from different types of light sources will influence laying hens differently when regarding different light intensities, and that bird activity and carbon dioxide (CO₂) production in a poultry shed will vary due to this.

Thus, experiments were made for laying hens with the aim to study three different light sources, 1) conventional light bulbs (incandescent light) 2) common strip lights (HF fluorescent light), and 3) daylight strip lights (HF fluorescent light) as light sources for laying hens in a loose housing system and the effect of their illuminance levels on bird activity and CO₂ emissions.

2 Materials and methods

2.1 Laying hens, housing and egg production

About 400 laying hens of the hybrid LSL (Lohmann Selected Leghorn) were housed in a small poultry shed (climate chamber) at the SLU research station Alnarps Södergård. The total area of the chamber including walking alleys was 87 m² and the laying hens were kept on a 47 m² large area. The housing system (Fienhage GmbH, Germany) included a bedding area with sand and a manure bin area with a drainable floor above which drinking nipples, automatic feed conveyors, and perches were placed. The manure belts below the drainable floor were running once every day. Laying nests were placed close to one of the walls. The hens were fed ad libitum and had free access to water. Eggs produced were counted and weighed daily.

2.2 Light sources, light schedule and illuminance

The conventional light bulbs (LB) providing incandescent light were placed in armatures with transparent globe formed plastic covers. The common strip lights (SL) of the type (Osram L 18W/32-930, LUMILUX deLuxe Warm white), and the daylight strip lights (DSL) of the type (Osram L 18W/12-950, LUMILUX deLuxe Daylite) providing high frequency (HF) fluorescent light were placed in about 1 m long armatures (Thorn PMII AKR 218W) with plastic covers.

The only light source in the chamber is artificial light, since no windows are present. The light schedule was 16 h light and 8 h darkness per day.

Illuminance was varied in the experiments and calculated from values measured by a hand holding Lux meter at 18 different places in the chamber at a height of 0.3 m above the floor, i.e. roughly at the height of the eyes of the hens. The range of illuminance levels for LB, SL, and DSL were 8-52, 5-63, and 4-93 lux respectively.

2.3 Climate and measurements

Since the chamber is surrounded by an air conditioned indoor space it was possible to keep the poultry house temperature constant at about 20 °C. The chamber was provided with supply air from the climate controlled space surrounding the chamber via two rows of air inlets in the ceiling. The air flow rate was manually adjusted with a damper in an exhaust air duct and calculated from air velocities measured in 5 points in a circular duct. It was kept at 1.2-1.6 m³ hen h⁻¹ during the experiments. Temperatures in supply and exhaust air were recorded by thermocouples; RH was recorded by Rotronic Hygromer®-C80 sensors, and carbon dioxide concentration was measured by an optical analyzer (RI-221, Riken Keiki Co). Animal activity was measured by sensors developed at Research Center Bygholm, Denmark (Pedersen and Pedersen, 1995).

2.4 Measurement period

The measurements started in November when the hens were about 20 weeks old and ended in June the year after that.
2.5 Data collection and statistic evaluation

Data regarding temperatures, humidity, CO₂ and activity was recorded each minute and average values for every 10 minutes were stored on a computer. For further analyses day average values were calculated, i.e. daily average values for the various parameters when the light was on. Only periods between 8 am and 6 pm were used to calculate these average day values for a certain light source and illuminance level. Further analysis of these daily average values was made by the statistic software package Minitab. Descriptive analysis, correlations and regressions were used in the evaluation.

3 Results

Average values of temperatures, humidity, CO₂ concentrations and ventilation rates for the periods with different light sources are shown in Table 1. Average values of the number of hens, egg production, CO₂ production per hen, illumination and activity for these periods are shown in Table 2. Due to instrument failures some days had to be excluded from the evaluation. This lead to variations in the average illumination levels for the different light sources. In the experiments the illuminance for LB, SL and DSL were on average 15.7, 24.0, and 40.8 lux.

Table 1: Average of daily values of temperature, relative humidity, carbon dioxide concentration and ventilation rate during periods with illumination.

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Relative Humidity, RH Inside the House</th>
<th>CO₂</th>
<th>Ventilation Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exhaust Air</td>
<td>Supply Air</td>
<td>Exhaust Air</td>
<td>Exhaust Air</td>
</tr>
<tr>
<td>Mean, °C (SD)</td>
<td>N</td>
<td>Mean, °C (SD)</td>
<td>N</td>
</tr>
<tr>
<td>Conventional light bulbs (LB)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19.1 (0.92)</td>
<td>22</td>
<td>9.6 (1.21)</td>
<td>22</td>
</tr>
<tr>
<td>Common strip lights (SL)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19.0 (0.95)</td>
<td>29</td>
<td>10.5 (1.64)</td>
<td>29</td>
</tr>
<tr>
<td>Daylight strip lights (DSL)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19.5 (0.72)</td>
<td>25</td>
<td>10.3 (0.94)</td>
<td>25</td>
</tr>
</tbody>
</table>

¹ N = No. of days with measurements

Table 2: Average No of hens, egg production, carbon dioxide production per hen, illuminance and activity during periods with illumination.

<table>
<thead>
<tr>
<th>No. of Hens</th>
<th>Eggs per Hen</th>
<th>CO₂ per Hen</th>
<th>Illuminance</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily production</td>
<td>Exhaust Air</td>
<td>Exhaust Air</td>
<td>Exhaust Air</td>
<td>Exhaust Air</td>
</tr>
<tr>
<td>Mean, No (SD)</td>
<td>N</td>
<td>Mean, No hen⁻¹ (SD)</td>
<td>N</td>
<td>Mean, g hen⁻¹ h⁻¹ (SD)</td>
</tr>
<tr>
<td>Conventional light bulbs (LB)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>392 (0.5)</td>
<td>22</td>
<td>0.93 (0.15)</td>
<td>20</td>
<td>3.78 (0.29)</td>
</tr>
<tr>
<td>Common strip lights (SL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>382 (4.6)</td>
<td>29</td>
<td>0.95 (0.09)</td>
<td>29</td>
<td>4.20 (0.22)</td>
</tr>
<tr>
<td>Daylight strip lights (DSL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>373 (3.6)</td>
<td>25</td>
<td>0.91 (0.16)</td>
<td>25</td>
<td>4.12 (0.14)</td>
</tr>
</tbody>
</table>

¹ N = No. of days with measurements
Laying hen activity and CO₂ production versus illumination for the different types of light sources studied are shown in Figure 1. As can be seen the measured activity for incandescent light (LB) was lower than for the fluorescent light from DSL. A large spread was observed both for activity and for CO₂ production.

Pearson correlations (Table 3) showed a significant positive relationship between illuminance and activity (p<0.01), and also between day after start of the experiments and activity (p<0.001). Laying hen activity versus illumination for all types of light sources is shown in Figure 2. Also at low light intensities a higher activity was observed during some days.

Table 3: Correlations between illuminance, day after start of the experiments, and laying hen performance parameters for the whole data set.

<table>
<thead>
<tr>
<th></th>
<th>Laying hen activity</th>
<th>CO₂ production per Hen</th>
<th>Eggs per Hen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illuminance, lux</td>
<td>0.341 **</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
<tr>
<td>Day after start</td>
<td>0.888 ***</td>
<td>0.422 ***</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

N.S. = Not Significant;  
* = Significance level p≤0.05;  ** = Significance level p≤0.01;  *** = Significance level p≤0.001
Hen activity and CO₂ production versus day after start of the measurements are shown in Figure 3. As can be seen hen activity decreases from start of the measurement in November until about the 50th day of the measurements which represents mid winter. In order to further investigate this, 3D plots of hen activity, illuminance and day from start and day from midwinter (Figure 4). A higher R²-value (79.9%) was found in a regression where both illuminance and day after start of experiments were predictors for activity, while a small R²-value was found when using just illuminance as predictor. In regressions where illuminance and day from mid winter were used as predictors of hen activity for the whole data set, and for LB, SL and DSL separately calculated R² values were 89.5, 82.0, 95.5, and 79.5 respectively.

4 Discussions

When looking just for of the data of illuminance versus hen activity the recordings suggest that activity is lower from incandescent light (LB) than for HF fluorescent light, and that hen activity is especially high for light similar to daylight spectra (DSL). The data also suggest some increase of hen activity when increasing light intensity. Further, a very large spread in hen activity was found for the same light source and especially for HF fluorescent light from common strip lights (SL). The increase of hen activity by an increase in light intensity in a poultry shed is a common conclusion also in other studies e.g. Mohammed et al. (2010) and Perry (2004).

Although hen activity in the study was observed to be higher for HF fluorescent light than for incandescent light, a conclusion stating this may be wrong. A significant and strong relationship between day after start of experiments (or season) and hen activity interferes with data.
of hen activity observed under light from the different light sources. This time based or seasonal effect on hen activity in the data set rather much overshadowed the specific effect of a certain light source. However, the derived constants in regression equations for hen activity as a function of illuminance and start of measurements (season) indicate for the study a higher response to an increase of light intensity from HF fluorescent light than to an increase in light intensity from the incandescent light sources. In other words, hens may be more affected by light from fluorescent light than from light from incandescent light, and increasing light intensity from strip lights may lead to higher increase in hen activity than increasing light intensity from common light bulbs.

A question that should be raised concerns the unexpected strong increase in hen activity by days after start of the experiments or season. The first reflection concerns accuracy of measurements. However, there were no indications of errors in measurements. Another reflection concerns influence of light from outside. The chamber where the hens were housed is a chamber inside a house shielded from light outside by the lack of windows and double walls and the only indication of season outside which the hens possibly could notice relates to composition of and content of components in the supply air and maybe sounds from outside. Anyhow, a strong increase in hen activity by days after start of the experiments or season was observed in the study. Explanations are hard to find, and heritage might perhaps play an important role. Circadian rhythms might to some extent depend on factors influenced by heritage. Some studies indicate that such factors exist.

The found influence of season on observed hen activity in the study indicate that studies of light sources and light intensities for poultry should be designed to handle such seasonal variations in order to make a reliable interpretation of the response.

Overall the data in the study indicated that season combined with light intensity influenced hen activity to a large extent.

Regarding CO2 production in the poultry shed, the age of the laying hens seemed to have an influence which could be expected. A moderate increase in CO2 production expressed in amount of CO2 produced per laying hen was observed for increased age of the laying hens. No significant influence of light sources or light intensity could be found for CO2 production in the poultry shed. Differences in CO2 emissions from barns with different light sources may occur, however, conclusions concerning this could not be made when analysing data collected in the study.

5 Conclusions

The data set in the study is limited and only limited conclusions can be made. The following conclusions can be made:

- Bird activity seems to increase by light intensity, at least to some extent.
- When regarding the data collected in the study there were no sure indications of differences in bird activity or CO2 emissions for the three studied light sources with light from incandescent light and fluorescent light. However increases in HF fluorescent light seemed to influence hen activity more than incandescent light from conventional light bulbs.
- An increased activity by age (or season), unexpected in the study since the hens had no light from outside, might possibly be caused by circadian rhythms of the laying hens transferred by heritage.
- The found influence of season on observed hen activity in the study indicates that studies of light sources and light intensities for poultry should be designed to handle such seasonal variations facilitating the interpretation of the response.

Future studies should be made in order to determine the response of different light spectra on laying hen performance and to determine the importance of heritage on laying hen performance due to season.
6 Acknowledgements

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7 References


