

# Laying-Hen Reactions to Artificial Light in a Floor Housing System

G. Gustafsson and E. von Wachenfelt

Swedish University of Agricultural Sciences,  
Department of Rural Buildings, S- 230 53 Alnarp, Sweden,  
[gosta.gustafsson@ltj.slu.se](mailto:gosta.gustafsson@ltj.slu.se)

## ABSTRACT

Investigations about laying-hen reactions to different artificial light conditions were carried out in a climate chamber equipped with a floor housing system for laying hens. The activity of the hens measured with activity sensors was about three times higher during light periods compared to dark periods. The light intensity had little influence on the total activity of the hens. Moisture production (MP) increased during light periods probably due to increased activity, thereby increasing respiration rate, but also due to increased scratching of the bedding material. The daily average MP varied between 6.9 and 7.0 g hen<sup>-1</sup>h<sup>-1</sup>. The level of light intensity seemed to have little influence on MP. Total heat production (THP) was slightly higher, between 20 to 30 %, during light periods compared to dark periods. Explanations can be increased bird activity as well as feed intake that led to increased metabolic rate during light periods. The daily average THP varied between 11.3 and 13.2 W per hen. Carbon dioxide production increased about 30 % during light periods compared to dark periods, probably due to increased activity and respiration.

The preference of light intensity was studied by varying the intensity between two parts of the housing system. The hens' preferences were measured by registration of the number of eggs laid and amount of manure produced in the two parts of the system. There was a tendency that the hens prefer a lower intensity for laying eggs but defecation occurred more at higher lighting intensity. Similar preferences occurred when the hens could choose between a bright light source and a dark area.

The preference of colour was studied by using coloured light in one part of the chamber and white light in the other part. The hens showed preference of white light, followed by green light for defecation but equal preference for laying eggs.

There were preferences for blue light compared to white light both for laying eggs and laying manure.

There was a small preference for red light compared to white light for laying eggs but equal preference for laying manure.

**Keywords:** Laying hens, artificial light, heat, moisture, carbon dioxide

## 1. INTRODUCTION

Lewis and Morris (2000) concluded that poultry perceive light from various types of lamps at a different intensity from humans because they are more sensitive to blue and red parts of the spectrum. They also concluded that turkey or chicken growth under red illumination is inferior to that under blue or green light, and this may be a result of birds exposed to red light being more active and showing more aggression than birds exposed to shorter wavelength radiation. Egg production traits appeared to be minimally affected by wavelength.

El-Husseiny et al (2000) evaluated the influence of coloured light (white-blue-red-green) on the performance of broiler and layer type chicks. A significant positive influence of green light on the final body weight, liveweight gain, feed consumption, feed conversion, dressing weight, liver weight and abdominal fat weight percentage was observed. A slightly positive influence of white and red light was observed on the the weight of pituitary gland and comb. Green light had a positively significant influence only on the weight of adrenal glands. Red or white light had a slightly positive effect on the egg production percentage. Blue and green light had no influence on egg weight, however, white and red light significantly improved ratio of feed consumed to egg produced, i.e., feed utilization efficiency.

Prescott et al (2003) proposed that dark periods should have a minimum duration of six hours and that bright light should be used in cases where pecking damage and cannibalism do not pose a problem. They also proposed that it is unlikely that the 100 Hz flicker associated with fluorescent light can be perceived by poultry. They suggested that ultraviolet-supplemented lighting may have some welfare benefits, and that very dim lighting may adversely affect ocular development.

A review by Lewis & Morris (1998) also had come to the conclusion that there was no evidence that fluorescent or high-pressure sodium lighting, regardless of intensity or spectral distribution, has any consistent detrimental effect on growth, food utilisation, reproductive performance, mortality, behaviour or live bird quality in either domestic fowl or turkeys, nor in the egg production of geese.

Marosicevic et al (1990) examined the influence of combined natural and artificial light with that of red, blue and yellow light on the health and productive abilities of broilers. Their tests showed that the lighting regime applied had no effect on the chick health. The greatest weight gain was registered in chicks exposed to blue light, and the least in chicks exposed to combined natural and artificial light. The least consumption and optimal conversion of food were recorded in chicks exposed to blue light while the poorest food conversion was registered in chicks exposed to the combined lighting.

Heat and moisture production from poultry are greatly influenced by lighting conditions (Riskowski et al., 1978; Zulowich et al., 1987; Xin et al. 1996). About 25 % reduction in moisture, sensible and total heat production can be expected when switching from light to dark conditions for chickens (Xin et al. 1996). Mc Quitty et al. (1985) found during measurements in commercial farms with layers in cages that the carbon dioxide production was higher during light than during dark periods.

Standard equations for estimation of animal heat, moisture and carbon dioxide production (CIGR, 2002) do not take into consideration the influence of light conditions.

The objective of the investigations described in this paper was to determine variations in activity, production of sensible, latent and total heat, carbon dioxide and hens' preferences influenced by different intensities and colours of artificial light in a floor housing system for laying hens.

## 2. MATERIALS AND METHODS

### 2.1 Housing system

The investigations were carried out in a climate chamber equipped with a floor housing system for laying hens (Figure 1). The chamber was surrounded by a temperature-controlled air space where the inlet and surrounding air temperatures could be kept constant. The ventilation rate could therefore be kept constant. The total area of the chamber including walking alleys was 87 m<sup>2</sup> and the area where the laying hens were kept was 47 m<sup>2</sup>. The housing system contained a bedding area, a manure bin area with two manure conveyors below a perforated floor and laying nests which were placed close to one of the walls.

Between 392 and 396 Lohmann Selected Leghorn (LSL) layers with an age between 114 and 197 days (average weight 1.7 kg) were kept in the system during the study. The manure was removed from the two conveyors once a day. Part of the floor was covered with bedding of gravel with a depth of approximately 40 mm.

The layers were fed ad libitum from two automatic feed conveyors located 0.73 and 2.21 m from the nests above the manure bin area. The metabolisable energy content of the feed was 11.2 MJ kg<sup>-1</sup>. The average feed energy intake was 1.39 MJ hen<sup>-1</sup> day<sup>-1</sup> during the study period. The layers had free access to water through nipple drinkers.

### 2.2 Light and climate conditions

The period with artificial light, 3.30 a.m. to 7.30 p.m. was automatically controlled. The intensity of the light was gradually decreased after 6 p.m. Periods when the light conditions changed were avoided. The night period was defined as 8 p.m. to 3.30. a.m. and the day period from 8 a.m. to 6 p.m.

The "outside air temperature" surrounding the climate chamber was kept constant during each trial. The ventilation rate could thereby also be kept constant, 0.62 and 1.04 m<sup>3</sup> per hen and hour which correspond to 1.01 and 1.67 air exchanges per hour at two different ventilation rates. The target air temperature inside the climate chamber was 20 °C. Inlet air was sucked into the chamber through two inlets at the ceiling which each created 12 horizontal air jets. The outlet air was exhausted at a height of 2.5 m at one gable. No extra heat was added to the system except the heat generated from the artificial light during daytime. The maximum effect from the light sources was 845 W. Work operations in the system were mainly carried out from 8 a.m. to 1 p.m.

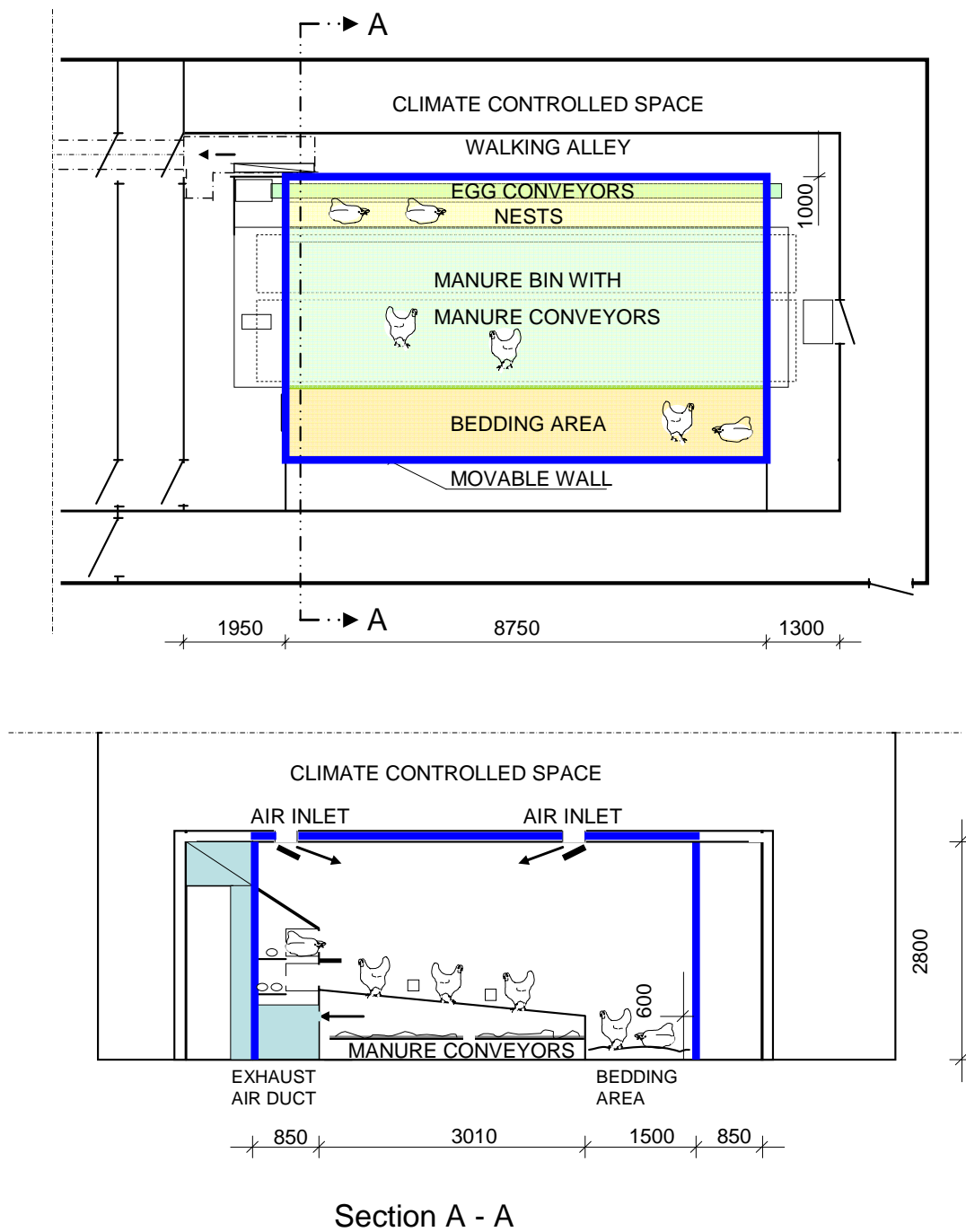


Figure 1. The climate chamber equipped with a floor housing system. Units are in mm.

## 2.3 Measurements

The hens' activity and production of sensible heat, moisture and carbon dioxide were determined at different light intensities and different light sources. Sensors for measurements of dry bulb air temperature, relative humidity (RH), ventilation rate, carbon dioxide concentration and activity were connected to a computer. Data were recorded each minute and average values for every 30 minutes were stored on the computer and used for evaluation.

Dry bulb air temperatures were measured with thermocouples type T (Cu/Cu-Ni) with five sensors in the inlet and four in the outlet air, respectively. Dry bulb air temperatures were also measured in six other locations in the airspace around the climate chamber for the determination of heat transmission losses. The air temperatures at different locations inside the climate chamber differed very little from the outlet temperature because of the mixing of the indoor air by the air jets created by the air inlets. The average indoor dry bulb air temperature was therefore defined as the average of the measured outlet dry bulb temperatures. The accuracy of the temperature measurements in individual locations is assumed to be better than 0.4 °C.

RH was measured with electronic humidity sensors (Hygromer®-C80) in the inlet (two sensors) and outlet air (two sensors). The sensors were calibrated against Li-Cl solutions corresponding to 30, 60 and 90 % RH. The accuracy of the RH sensors was estimated to be ±3%.

Ventilation rate was continuously measured with a free running impeller measuring fan (FANCOM), located in the exhaust air duct. The impeller had been calibrated at the Research Center Bygholm, Denmark, before and after the installation. The accuracy of the impeller was better than 3 % of the measured value.

Carbon dioxide concentration in the outlet air was measured with an optical analyser (RI-221) manufactured by Rieken Keiki Co. The analyser was calibrated frequently against calibration gases with the concentrations of 0 and 1830 ppm respectively. The accuracy of the analyser was better than ±25 ppm.

The density of the exhausted air was corrected according to the average outlet air temperature measured with thermocouples.

The activity in the chamber was measured with four activity sensors developed at the Research Center Bygholm (Pedersen and Pedersen, 1995). The measuring system was based on infrared motion detectors, of which four were in use. The levels of the signal from the four activity sensors differed considerably depending on the location of the sensors inside the chamber, where two were placed above the perch area close to the animals and the other two above the floor area. The signals were weighted individually and expressed relative to the daily mean, expressed as following:

$$a(t) = \frac{u(t)}{u_{\text{average}}} \quad (1)$$

## 2.4 Balance equations and evaluation

The sensible heat production (SHP) was calculated from the following equation:

$$\text{SHP} = \frac{q \cdot \rho_a \cdot C_p}{3.6} \cdot (T_{\text{out}} - T_{\text{in}}) + U_f \cdot A_f \cdot (T_{\text{out}} - 7) + U_{w,c} \cdot A_g \cdot (T_{\text{out}} - 18) + U_{w,c} \cdot A_{w,c} \cdot (T_{\text{out}} - T_{a,s}) - P_{\text{light}} \quad (2)$$

To determine SHP, it was necessary to determine the heat transmission losses from the building surfaces of the climate chamber according to the heat balance equation above. The transmission heat loss consists of heat loss to the floor, to an adjacent heated room at one gable and from the walls and ceiling to the surrounding air space. The ground temperature for the floor was set to 7 °C and the temperature in the adjacent room to 18 °C. The insulation of the walls and the ceiling was equal so their heat transmission coefficients (U-values) were assumed to be identical. The values  $U_f$  and  $U_{w,c}$  were determined at stationary conditions by heating the air inside the chamber with a 10 000 W electrical heater in two trials at low and high temperature levels, when there were no hens inside the chamber. The measurements were carried out both with and without bedding in order to evaluate the influence of floor insulation on the heat transmission losses. The U-values which satisfy two trials with bedding were calculated to  $U_f = 0.70 \text{ W m}^{-2} \text{ °C}^{-1}$  and  $U_{w,c} = 1.02 \text{ W m}^{-2} \text{ °C}^{-1}$  respectively. Without bedding the total heat transmission loss was approximately 5 % higher than that with bedding.

The mass balance of moisture gave the moisture production (MP) as:

$$\text{MP} = q \cdot \rho_a \cdot (X_{\text{out}} - X_{\text{in}}) \quad (3)$$

where

$$X = \left( \frac{\phi \cdot 622}{100} \right) \cdot \left( \frac{p}{1013 - \frac{\phi \cdot p}{100}} \right) \quad (4)$$

$$p = 10.0e^{\left( \frac{51.9171 - \frac{1350.4}{T} - 4.5453 \ln T}{1} \right)} \quad (5)$$

According to CIGR (1992) the latent heat production (LHP) was calculated as:

$$\text{LHP} = F \cdot 0.680 \quad (6)$$

The total heat production (THP) was determined as:

$$\text{THP} = \text{SHP} + \text{LHP} \quad (7)$$

The balance of carbon dioxide gave the carbon dioxide production as:

$$K = q \cdot \rho_c \cdot (C - 350) \quad (8)$$

The inlet (outdoor) concentration of carbon dioxide was checked with a hand instrument several times. 350 ppm seemed as a reasonable background concentration for the calculations.

## 2.5 Accuracy of determinations

The maximum error of determinations of SHP was estimated from:

$$\frac{\Delta \text{SHP}}{\text{SHP}} = \frac{\Delta q}{q} + \frac{\Delta \rho_a}{\rho_a} + \frac{\Delta (T_{\text{out}} - T_{\text{in}})}{T_{\text{out}} - T_{\text{in}}} + \frac{\Delta \text{UA}}{\text{UA}} \quad (9)$$

The estimated maximum errors were 3 % for ventilation rate, 0.003 kg m<sup>-3</sup> for the air density, 0.6 °C for the temperature difference and finally 5 % for the total heat transmission loss. According to Equation 9, the maximum error will be dependent on the temperature difference between outlet temperature and inlet/airspace temperatures. At a low temperature difference of 5 °C the maximum error of SHP may be as high as 20 % while it decreases to 11 % at a temperature difference of 20 °C.

The corresponding maximum error of LHP was:

$$\frac{\Delta \text{LHP}}{\text{LHP}} = \frac{\Delta q}{q} + \frac{\Delta \rho_a}{\rho_a} + \frac{\Delta (X_{\text{out}} - X_{\text{in}})}{X_{\text{out}} - X_{\text{in}}} \quad (10)$$

The maximum error in determination of difference in water content between outlet and inlet air was estimated to be 0.26 g kg<sup>-1</sup>. According to Equation 10 the maximum error of latent heat production will be 8 %.

The maximum error of carbon dioxide production was:

$$\frac{\Delta K}{K} = \frac{\Delta q}{q} + \frac{\Delta \rho_c}{\rho_c} + \frac{\Delta C}{C} + \frac{10}{350} \quad (11)$$

The maximum error in determination of outlet carbon dioxide concentration was estimated to be 25 ppm. The maximum error of carbon dioxide production was estimated to 7 %, according to Equation 11.

The hens' preference/choice of light intensity and colour was determined by dividing the chamber in two parts with a drapery so that different light conditions could be obtained. The hens could move between the two parts of the system. The hens' preferences were measured by registration of the number of eggs laid and amount of manure accumulated in the two parts of the system.

### 3. RESULTS

#### 3.1 Influence on activity

The measured variations in activity at 4 and 93 lux are presented in Figure 2. The activity of the hens measured with activity sensors was about three times higher during light periods compared to dark periods. The light intensity had little influence on the total activity of the hens.

#### 3.2 Influence on climate

##### 3.2.1 Moisture Production (MP)

Examples of typical daily variations in MP are presented in Figure 3 for 4 and 93 lux intensity. MP increased during the light period probably due to increased activity and thus respiration rate but also from increased scratching of the bedding material. The daily average MP varied between 6.9 and 7.0 g hen<sup>-1</sup>h<sup>-1</sup>. The level of light intensity seemed to have little influence on MP.



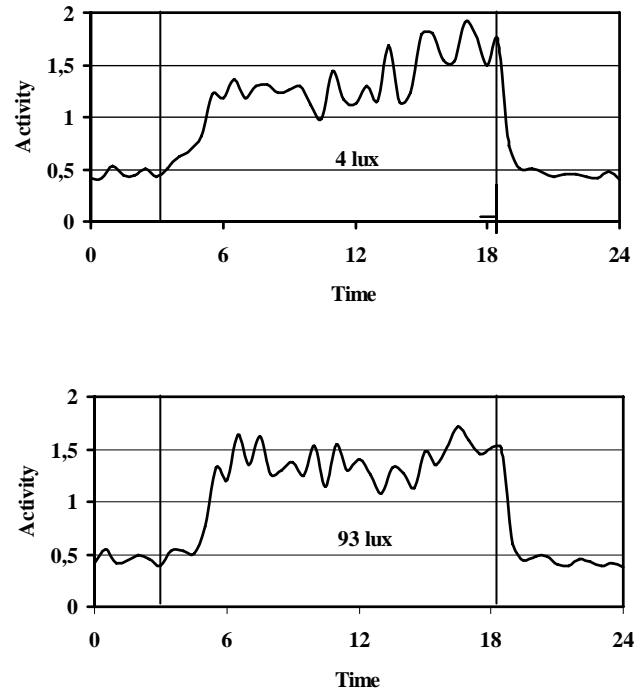
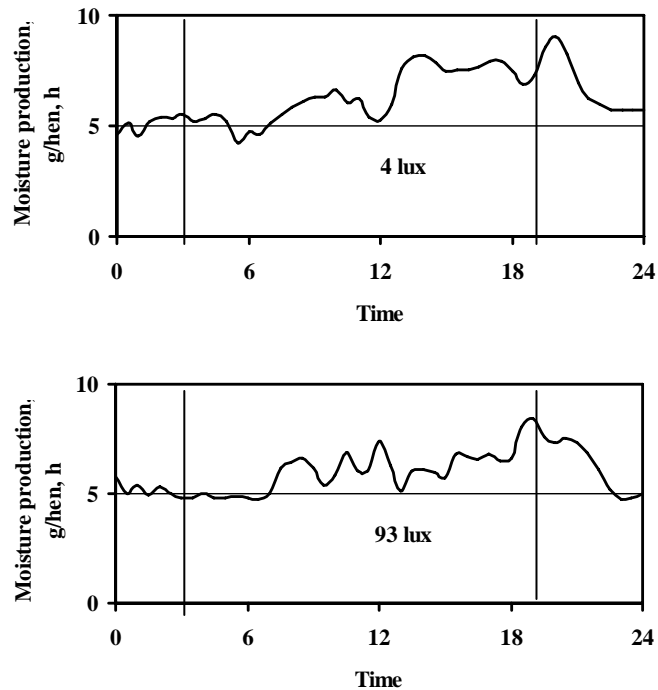


Figure 2. Examples of typical daily variations in activity at 4 and 93 lux. The daily average of activity is 1.0.



Figur 3. Examples of daily variations in moisture production at 4 and 93 lux.

### 3.2.2 Heat production

The partitioning of THP into SHP and LHP is presented in Figure 4. The THP was slightly higher, between 20 to 30 %, during the light period compared to the dark period. Explanations can be increased activity and feed intake which led to increased metabolic rate during the light period. The daily average THP varied between 11.3 and 13.2 W per hen. This level corresponds well with values reported by Chepete and Xin (2004) who reported THP in the range of 5.5 to 7.8 W per kg body weight.

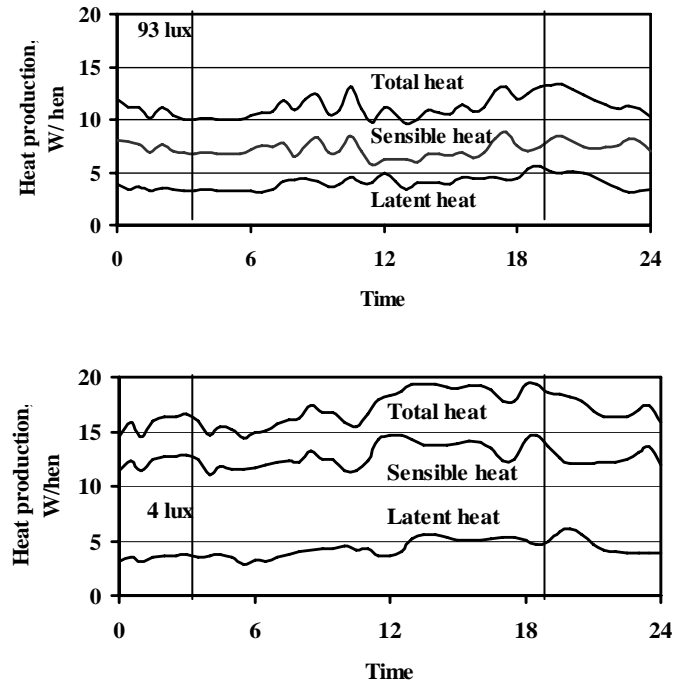


Figure 4. Examples of daily variations in heat production of LSH hens in cage-free housing at 4 or 93 lux light intensity.

### 3.2.3 Carbon dioxide production

The carbon dioxide production also increased during the light period probably due to increased activity and respiration (Figure 5). The release of carbon dioxide varied between 2.7 and 4.0 g/hen, h<sup>-1</sup>. Pedersen et al (2008) suggest from a literature review a provisional value of CO<sub>2</sub> production for layers of 0.180 m<sup>3</sup> h<sup>-1</sup> per W total heat produced. With a total heat production in the range of 11.3 to 13.2 W/hen it should correspond to a carbon dioxide production between 2.0 and 2.4 g h<sup>-1</sup>.

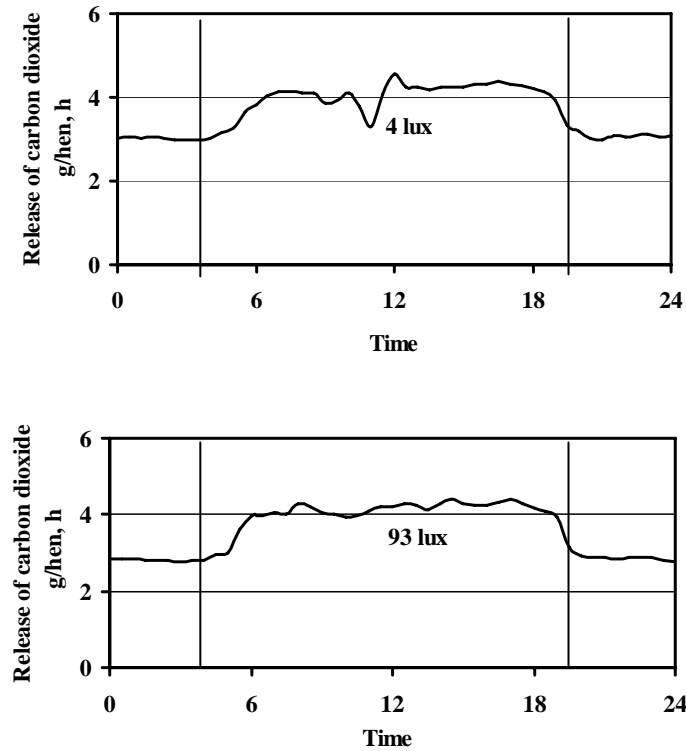


Figure 5. Examples of daily variations in carbon dioxide production at 4 and 93 lux.

### 3.3 Preferences

The preference of light intensity was studied by varying the intensity between the two parts of the housing system.

The hens' preferences were measured by registration of the number of eggs and amount of manure laid in the two parts of the system.

There was a small tendency ( $R^2=0,10$ ) for the hens to prefer a lower intensity for laying eggs but a higher intensity for defecation ( $R^2= 0,36$ ).

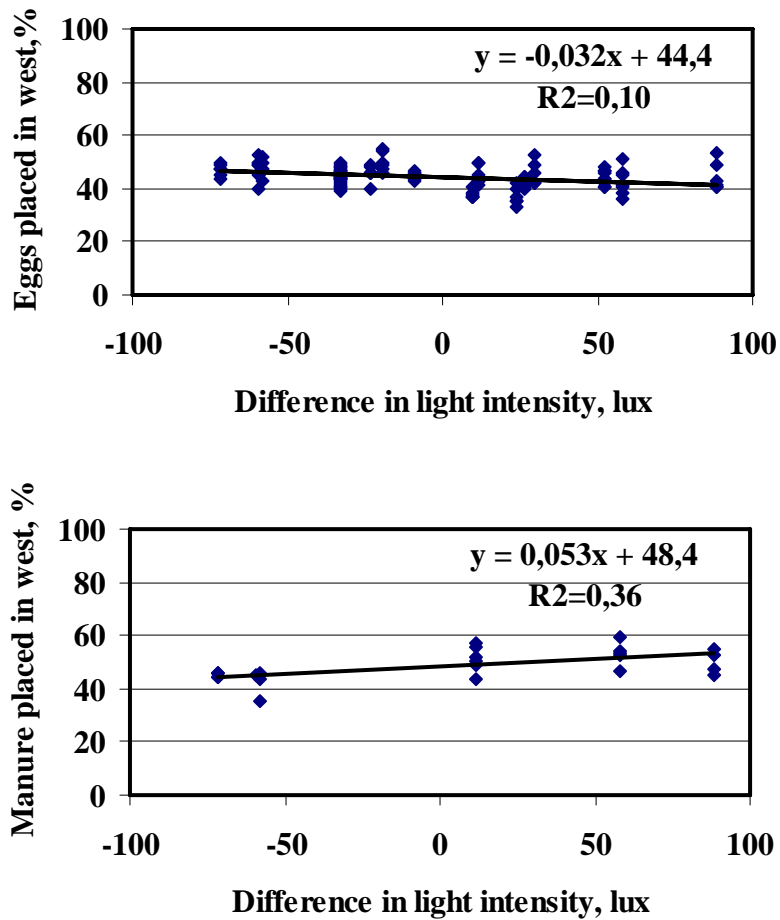


Figure 6. Preferences of differences in light intensity for laying eggs and defecation.

The preference to lay eggs was also studied when one part of the chamber just had one concentrated light source. The other part was nearly dark. Even in this case the hens preferred to lay eggs in the dark part. More manure was accumulated in the light part.

The preference of colour was studied by using coloured light in one part of the chamber and by using white light in the other part. Changes in amount of eggs and manure was measured and compared to the conditions with equal concentrations of white light.

The hens preferred white light before green light for the laying of manure but had equal preference for laying eggs.

There were preferences for blue light both for laying eggs and manure.

It was a small preference for red light for laying eggs but equal preference for laying manure.

#### 4. CONCLUSIONS

The investigations have shown that there are large differences in activity and production of moisture and carbon dioxide between light and dark periods for laying hens in a floor housing system for laying hens. These facts should be considered in design guidelines for climatisation of housing systems for laying hens in floor housing systems.

There were preferences for blue light both for laying eggs and manure.

It was a small preference for red light for laying eggs but equal preference for laying manure.

#### 5. ACKNOWLEDGEMENTS

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## Notations

$a$	normalised activity level
$C$	concentration of carbon dioxide, ppm
$C_p$	specific heat capacity of air, $\text{J kg}^{-1} \text{K}^{-1}$
$K$	production of carbon dioxide, mg/h
LHP	latent heat production, W
MP	moisture production, $\text{g h}^{-1}$
$p$	saturation pressure of air, mbar
$q$	ventilation rate, $\text{m}^3 \text{h}^{-1}$
SHP	sensible heat production, W
$T$	air temperature, $^{\circ}\text{C}$
THP	total heat production, W
$U$	heat transmission coefficient of building surfaces, $\text{W m}^{-2} \text{ }^{\circ}\text{C}^{-1}$
$u$	voltage from activity sensor, V
$X$	water content of air, $\text{g kg air}^{-1}$
$\Delta$	difference
$\phi$	relative humidity, %
$\rho$	density, $\text{kg m}^{-3}$

Indices:

a	air
as	surrounding airspace
c	carbon dioxide
f	floor
g	gable
in	inlet
l	latent
light	light sources
out	outlet

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s        sensible

tot      total  
w,c      wall, ceiling