Laying hens reactions on artificial light in a floor housing system

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Abstract: Investigations about laying hens reactions on 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 was considerably higher during light periods compared to dark periods. The light intensity had no influence on the total activity of the hens. The release of moisture increased during light periods probably due to increased activity increasing respiration rate but also on increased scratching in the bedding material. The daily average was 6.29 g hen^{-1} h^{-1} at 4 lux and 5.97 g hen^{-1} h^{-1} at 93 lux which corresponded to a difference of 5%. The level of light intensity seemed to have little influence on the release of moisture. The total release of heat was slightly higher during light periods compared to dark periods. Explanations can be increased activity but also feed intake increasing the metabolic rate during light periods. The daily average of total heat production was 17.0 W per hen at 4 lux and 14.7 at 93 lux which corresponds to a difference of 16%. The release of carbon dioxide increased during light 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 and amount of manure laid in the two parts of the system. It was a small tendency to prefer a lower intensity for laying eggs but a higher intensity were manure was placed. 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 laid 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 were 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 laying manure. It was a small preference for red light for laying eggs but equal preference for laying manure.

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

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1 Introduction

It has not been clear which influence light intensity and colour have on reactions and behaviour of laying hens.

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 in turkey and 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 couloured 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

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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 the amount of feed consumed/egg produced.

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 were 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 were no evidence that that fluorescent or high pressure sodium lighting irrespectably 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 together 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’s 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 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, 1984) do not take into consideration the influence of light conditions.

The objective of these investigations has therefore been to determine variations in activity, release 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

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^2 and the area where the laying hens were kept was 47 m^2.

The housing system contained a bedding area, a manure bin area with two manure conveyors below a draining floor and laying nests which were placed close to one of the walls.

Between 333 and 392 Lohmann Selected Leghorn (LSL) layers were kept in the system during the investigations.

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 automatic feed conveyors. The metabolisable energy content of the feed was 11.2 MJ/kg. The average feed intake was 1.39 MJ/(hen · day) during the investigations. The layers had free access to water through water nipples.

2.2 Light and climate conditions

The period with artificial light was automatically controlled. The period with light was from 3.30 a.m. to 7.30 p.m. The intensity of the light was gradually decreased after 6 p.m. 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.

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 at 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.

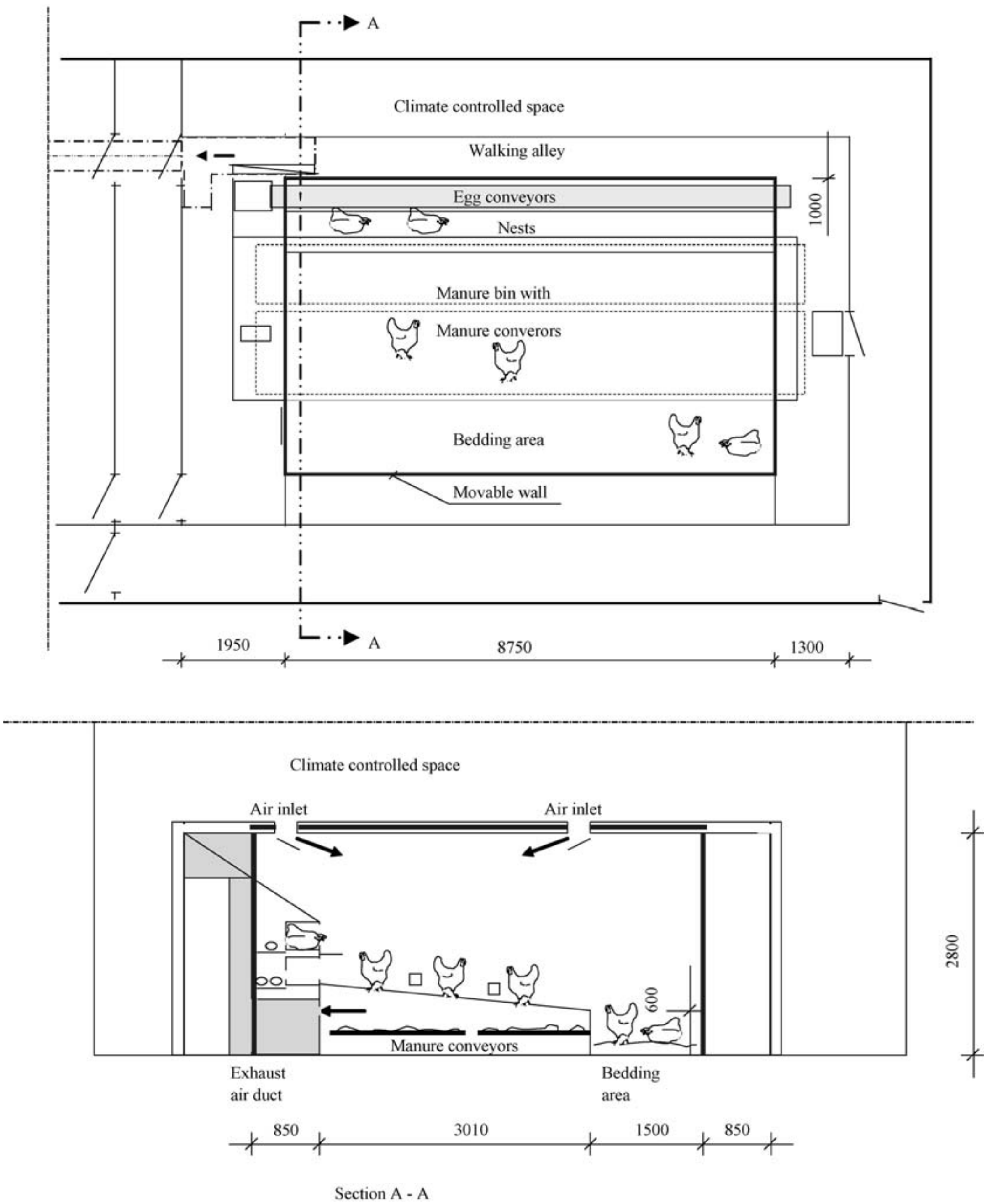


Figure 1 Climate chamber equipped with a floor housing system

2.3 Measurements

The hens´ activity, release of heat, moisture and carbon dioxide were determined at different light intensities and different light sources.

Sensors for measurements of dry bulb air temperatures, relative humidities, 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℃.

Relative humidities were 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% relative humidities. The accuracy of the humidity sensors is estimated to ±3%.

The 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 is 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 1,830 ppm respectively. The accuracy of the analyser is 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 is based on infra red motion detectors, of which four were in use. The level of the signal from the four activity sensors differs 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 two other above the floor area. The signals were weighted individually and expressed relatively to the daily mean, expressed with the ratio:

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

2.4 Balance equations and evaluation

The release of sensible heat was calculated from the below equation:

$$P_s = \frac{q \cdot \rho_a \cdot Cp}{3.6} \cdot (T_{out} - T_{in}) + U_f \cdot A_f \cdot (T_{out} - 7) + U_{w,c} \cdot A_g \cdot (T_{out} - 18) + U_{w,c} \cdot A_{w,c} \cdot (T_{out} - T_{a,s}) \tag{2}$$

To determine the release of sensible heat, 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℃ and the temperature in the adjacent room to 18℃. The insulation of the walls and the ceiling is equal so their heat transmission coefficients (U-values) are 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 satisfied two trials with bedding were calculated to U_f = 0.70 W/(m^2·℃) and $U_{w,c}$ = 1.02 W/(m^2·℃), respectively. Without bedding the total heat transmission loss was approximately 5% higher than with bedding.

The mass balance of moisture gave the production of moisture as:

$$F = q \cdot \rho_a \cdot (X_{out} - X_{in}) \tag{3}$$

where

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

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

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

$$P_l = F \cdot 0.680 \tag{6}$$

The total heat production was determined as:

$$P_{tot} = P_s + P_l \tag{7}$$

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

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

2.5 Accuracy of determinations

The maximum error of determinations of sensible heat production was estimated from:

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

The estimated maximum errors were 3% for ventilation rate, 0.003 kg/m^3 for the air density, 0.6℃ 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℃ the maximum error of sensible heat may be as high as 20% while it decreases to 11% at a temperature difference of 20℃.

The corresponding maximum error of latent heat production was:

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

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

The maximum error of carbon dioxide production was:

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

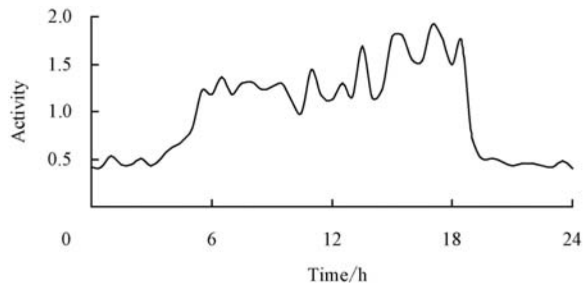
The maximum error in determination of outlet carbon dioxide concentration was estimated to be 25 ppm. The maximum error of carbon dioxide production was estimated to 7%, according to Equation (11).

The hens´ preference/choice of intensity and colour was determined by dividing the chamber into 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 and amount of manure laid in the two parts of the system.

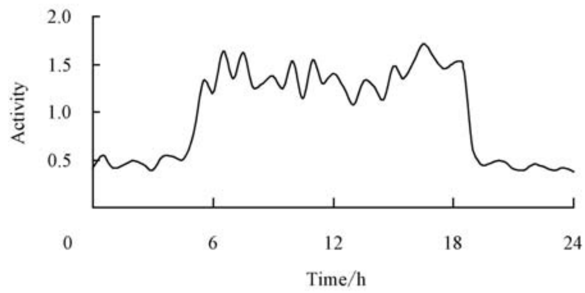
3 Results

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 was considerably higher during the light period compared to the dark period. The light intensity had no influence on the total activity of the hens.



a. 4 lux



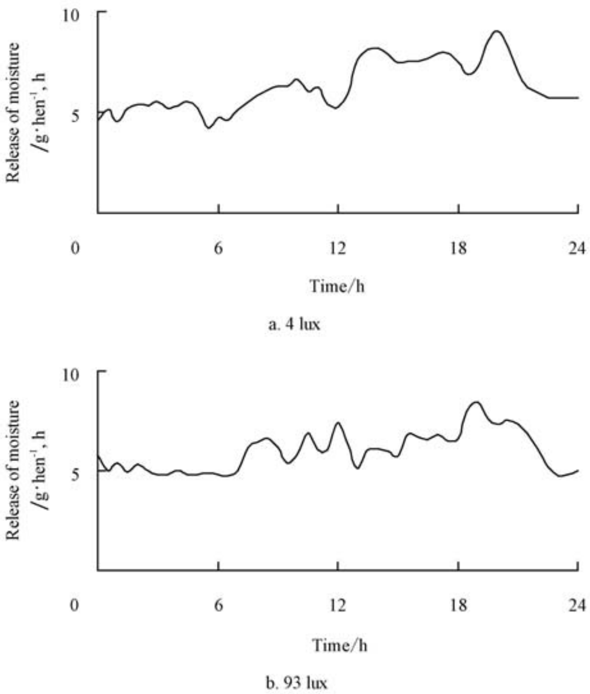
b. 93 lux

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

3.2 Influence on climate

3.2.1 Moisture

The daily variations in release of moisture are presented in Figure 3 at 4 and 93 lux intensity. The release of moisture increased during the light period probably due to increased activity increasing respiration rate but also on increased scratching in the bedding material. The daily average was 6.29 g/hen, h at 4 lux and 5.97 g/hen, h at 93 lux which corresponds to a difference of 5%. The level of light intensity seemed to have little influence on the release of moisture.



Figur 3 Daily variations in release of moisture at 4 and 93 lux

3.2.2 Heat production

How the total heat production is divided into sensible and latent heat production is presented in Figure 4. The total release of heat was slightly higher during the light period compared to the dark period. Explanations can be increased activity but also feed intake increasing the metabolic rate during the light period. The daily average of total heat production was 17.0 W per hen at 4 lux and 14.7 W at 93 lux which corresponds to a difference of 16%.

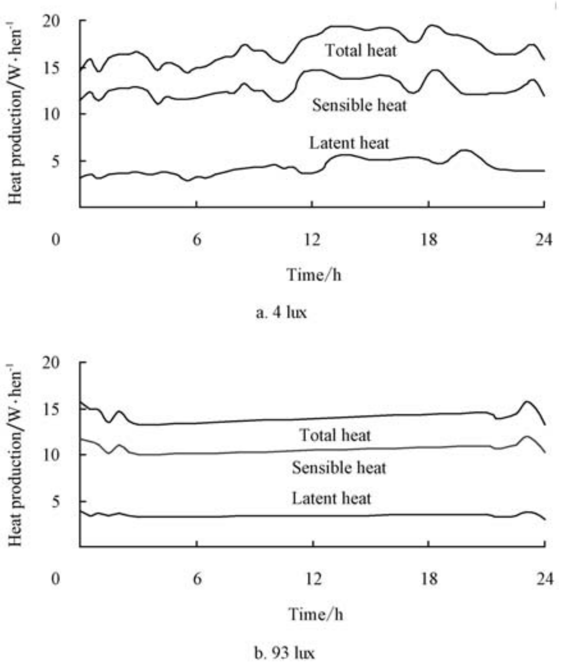


Figure 4 Daily variations in heat production at 4 and 93 lux

3.2.3 Carbon dioxide production

The release of carbon dioxide also increased during the light period probably due to increased activity and respiration which was shown in Figure 5.

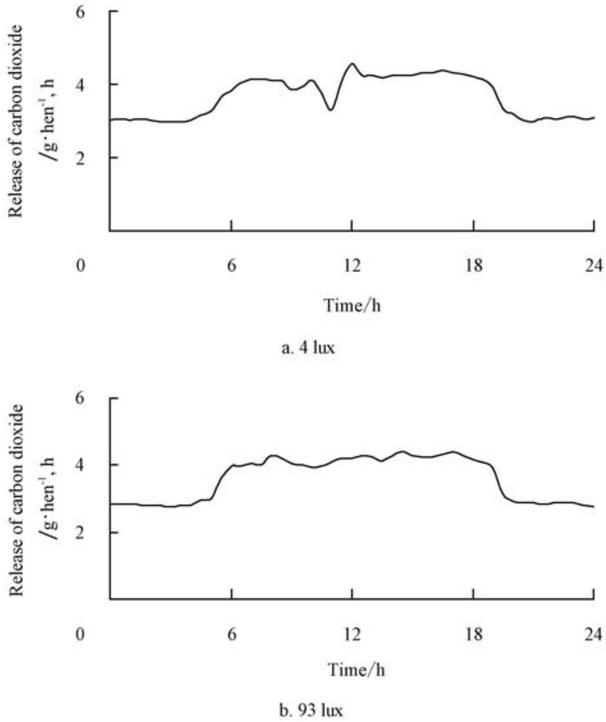


Figure 5 Daily variations in carbon dioxide production at 4 and 93 lux

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.

It was a small tendency to prefer a lower intensity for laying eggs but a higher intensity were manure was placed.

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 laid 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 were 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.

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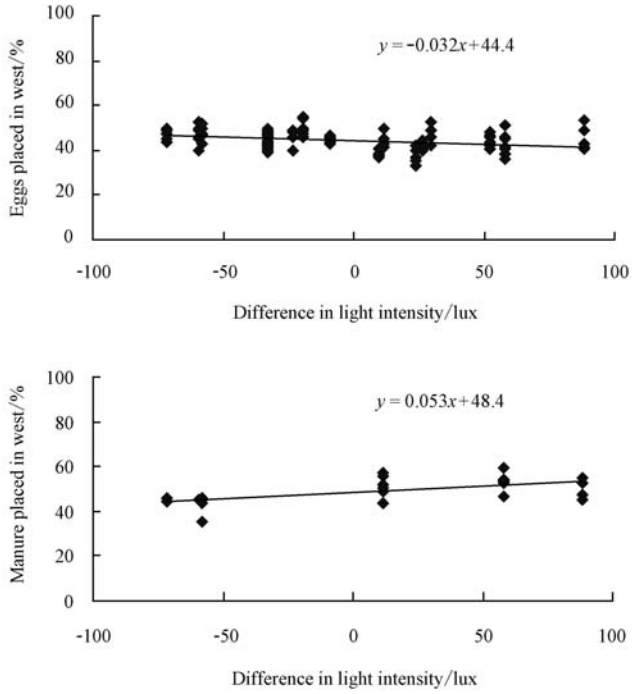

Figure 6 Preferences of differences in light intensity for laying eggs and manure

4 Conclusions

The investigations have shown that there are large differences in activity and release 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 climatization of housing systems for laying hens in floor housing systems.

Acknowledgements

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Eggs placed in west, %

Nomenclature

a normalised activity level

C concentration of carbon dioxide, ppm

Cp specific heat capacity of air, J/(kg·K)

F production of moisture, gh

K production of carbon dioxide, mg/h

P heat production, W

p saturation pressure of air, mbar

q ventilation rate, m^3/h

T air temperature, ℃

U heat transmission coefficient of building surfaces, $W/(m^2\cdot ℃)$

u voltage from activity sensor, V

X water content of air, g kg air^{-1}

Δ difference

ϕ relative humidity, %

ρ density, kg m^{-3}

Indices:

a air

as surrounding airspace

c carbon dioxide

f floor

g gable

in inlet

l latent

out outlet

s sensible

tot total

w,c wall, ceiling

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