ANALYSIS OF LIGHT PROPAGATION IN ENRICHED CAGES FOR LAYING HENS*

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The article is focused on the description of light intensity propagation in enriched cages for laying hens. The main aim of this work is to establish the relationship between measured data with numerical calculation and to evaluate an influence of cage construction on the light intensity of the working plane. A special attention was paid to the difference light intensity in both tiers. The measurement was done with two different light sources. This relation can have an important influence on the quality of hens breeding and quantity of eggs production. The obtained results should increase the knowledge on technology and microclimatic conditions in egg production.

light intensity; cage; numerical calculation; light source; working plane

INTRODUCTION

There are over 300 million laying hens in the European Union (EU), over three quarters of which are currently housed in battery cages (European Commission, 2005). The 1999 Laying Hens Directive prohibits conventional battery cages since 1 January 2012 (Council Directive 1999/74/EC). All laying hens in the EU must therefore be housed in other systems since 2012. The Directive permits the use of 'enriched' cages and non-cage systems (Pickett, 2007).

Light intensity (LI) is an important management factor for breeder type poultry, which can influence animal behaviour and through it to influence the egg production. This relation can have an important influence on the quality of hens breeding (welfare) and quantity of egg production.

The measurement of light in this context is called photometry. The photometer, which displays intensity as footcandles, has a light receptor cell that perceives light with the same spectral intensity as the human eye. Maximum reception of light energy occurs at a wavelength of 555 nanometers (green light) and decreases to a minimum at the two extremes of the visible light spectrum (blue and red). This results in an uneven detection of the light energy measurement across the visible light spectrum (Wineland, Siopes, 1992).

A threshold light intensity (2 lx) is crucial for stimulating hypothalamic receptors responsible for photo sexual variables. In consideration of the welfare of hens and workers, the recommended light intensity is 10 lx (Morris, 2004).

Despite welfare concerns, case systems remain sustainable due to efficient use of land and labor. Cages are usually constructed in batteries of several tiers. As there is an unavoidable variation in light intensity among tiers in multi-tier case systems, a balance is needed between providing sufficient light at the bottom tier and avoiding excessive light intensity at the top tier (Awoniyi, 2003).

Light intensity affected sexual maturation and egg production, as layers had differential responses to lighting. LI of 1 lx and 500 lx were found to be limiting to the egg production efficiency of layers. Whereas the birds receiving 1 lx had a reduced rate of egg production, those receiving 500 lx had reduced egg size later in the production period in combination with reduced shell quality, which indicated that inadequate feed intake under high LI conditions may be a factor affecting layer stocks. Exposure to high LI reduced egg size and total egg mass-produced. Ultimately, the brown egg strains appeared to be more susceptible to the negative effects of low or high LI, indicating the importance of matching management practices to the particular hen genotype (Renema et al., 2001).

Opinion on the effect of light intensity on egg production in the literature is inconsistent. Although recommended light intensity ranges from 5 to 10 lx (Lewis, Morris, 1999), Abdelkarim and Biellier (1982) noted a significant improvement in egg production as light intensity was increased progressively from 32 to 40 lx up to 343 to 409 lx during the 8-month laying period. Skřivan et al. (2000) recommended light intensity from 3 to 10 lx, but main influence is caused by the light regime and not only by the intensity. Yildiz et al. (2006) noted provision of variable light intensity ranging from 35 to 55 lx improves egg production.

The aim of our research is to determinate and to evaluate light propagation in enriched cages of Czech production arranged in two-tier battery.

MATERIAL AND METHODS

The light intensity on a lighted area we calculated as an average value. The flow method by Harrison Anderson was the main concept used during the research. The following equations (Habel, 1991) for calculation were considered.

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Mean value of illumination E_n (lx):

$$E_n = \frac{\Phi_D}{S} \quad \text{(lx)} \tag{1}$$

where: Φ_D – luminous flux (lm)
S – illuminated area (m^2)

Luminous intensity I (cd) based on an information about light source from producer:

$$I = \frac{\Phi_s}{\Omega_s} \quad \text{(cd)} \tag{2}$$

where: Φ_s – luminous flux of light source (lm)
Ω_s – solid angle of light source (sr)

Solid angle Ω (sr) related to the working plane:

$$\Omega = arctg\left(\frac{a \cdot b}{h \cdot \sqrt{a^2 + b^2 + h^2}}\right) \quad \text{(sr)} \tag{3}$$

where: a, b – dimensions of the working plane (m)
h – distance of the light source (m)

Luminous flux Φ_D (lm) related to the working plane:

$$\Phi_D = I \cdot \Omega \quad \text{(lm)} \tag{4}$$

Average reflection factor ρ_m (–):

$$\rho_m = \frac{\sum_{i=1}^{n} S_i \cdot \rho_i}{\sum_{i=1}^{n} S_i} \quad (–) \tag{5}$$

where: S_i – area of internal surfaces (m^2)
ρ_i – reflection factor of internal surfaces (–)

Internal reflection component e_i (–) of factor of luminous intensity:

$$e_i = e_{i\min} + \frac{3 \cdot x^2}{l^2} \cdot (e_{im} - e_{i\min}) \quad (–) \tag{6}$$

where: e_{im} – average value of internal reflection component (–)
$e_{i\min}$ – minimum value of internal reflection component (–)
x – distance of evaluated point to the off-side wall (m)
l – depth of cage (m)

Mean value of illumination E_d in not directly illuminated cage (lx):

$$E_d = E_n \cdot e_i \text{ (lx)} \tag{7}$$

Coefficient of internal light reduction c_c (–) by construction of cage:

$$c_c = \frac{E_m}{E_{m*}} \quad (–) \tag{8}$$

Measurements were performed under condition about 100 percent eclipsis and with a constant light intensity level of the light source. Two-tier enriched (furnished) battery of cages produced in the Czech Republic was used for this research work. The dimensions of the cage are shown in Table 2. Light intensity was measured in two working planes (SR). First and second working plane (SR1, SR2) were measured on upper edge of the feeder in the first and second tiers (see Fig. 2).

Table 1. Parameters of the incandescent bulb

Incandescent wattage (W)	Average lumens produced (lm)	Lumen range (lm)	Lumen of our incandescent bulb (lm)
40	408	320–495	475
100	1412	1075–1750	1100

Table 2. Basic dimensions of studied enriched cages

Cage	Length (mm)	Width (mm)	Height (mm)	Laying nest (L x W) (mm)
A	1950	1005	570–455	660 x 502

Measurements were done under various intensity of artificial light source. First light source was incandescent bulb with input of 100 W and second 40W. The basic parameters of our bulb see Table 1.

Illumination was measured with sensor PU 150 Metra Blansko. The instrument for the measurements has a measuring range and tolerance of: 10 lx – 10%; 40 lx – 20%; 200 lx – 10%; 1000 lx – 10%; 5000 lx – 10%; 100 000 lx – 20%. The measurement was provided in the laboratory conditions without housed laying hens.

The light source was situated 3 m above floor level. The dimensions of light location and working planes are shown in Fig. 3.

The readings of measurement were compared with theoretical calculated values, based on the following equations. The final results of comparison gave us an information about the influence of cage on illumination reduction. Fig. 3 shows working plane, in which is illumination calculated.

RESULTS AND DISCUSSION

Mean value of illumination obtained from measured values by 100-watt light bulb at first working plane (SR1) was 16.89 lx and at second working plane (SR2) it was 4.73 lx. By lightening 40-watt light bulb at first working plane (SR1) it was 4.76 lx and at second working plane (SR2) it was 1.81 lx.

The calculated results from analytical procedure has been at first working plane (SR1) 18,01 lx and at second working plane (SR2) 4,73 lx by 100-watt light bulb. By lightening 40-watt light bulb at first working plane (SR1) it has been 5,64 lx and at second working plane (SR2) 1,82 lx.

The results of light intensity measurement and comparison with calculated data are shown in Tables 3 and 4. The measured and calculated data were split into values influenced by cages construction and without it. Columns E_{m*} show measured data without the influence of the cage, columns E_m data with the influence of the cage, columns E_{n*} show calculated data without the influence of the cage and columns E_n data with the influence of the cage. Columns σ_*, σ show a mean-root-square error for E_{m*} and E_m. Columns v, v_* show a variation coefficient for values of light intensity with the influence factor of cages construction and without the influence factor.

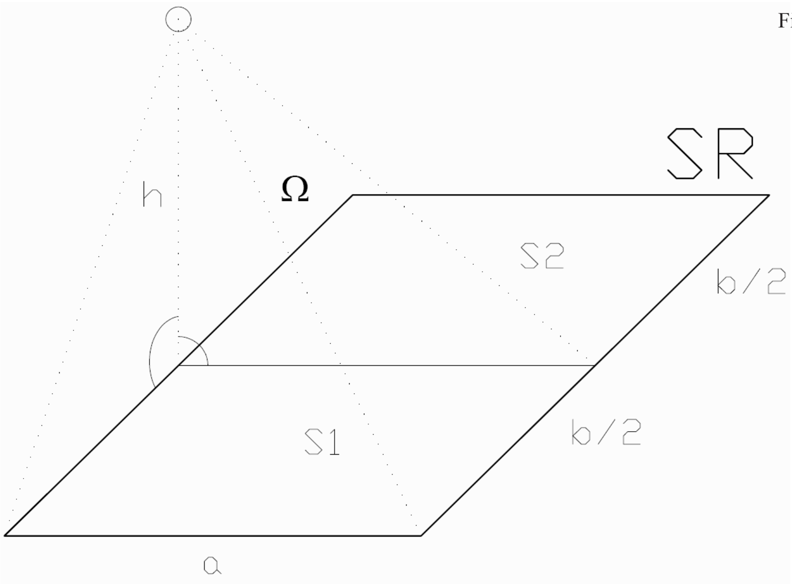

Fig. 1. Working plane (SR1, SR2, area of measurement)

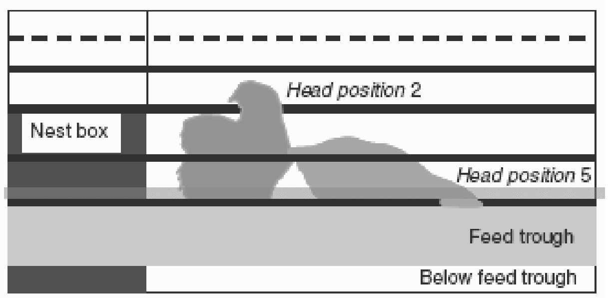

Fig. 2 The blue area corresponds with position of the measurement (SR1, SR2)

Measured values embody a high mean-root-square error, to this answers as well a high variable coefficient (see Tables 3 and 4). This high values are effected of cages construction, when were measured high differences of values in the nets and the cage. Then were measured and calculated great differences between each tier. The first (top) tier was directly illuminated from the light source and the only impediment here is produced by the roof of the cage, which is made of wire. This area has not an outstanding influence on the light intensity (1). The calculation on the top plan (SR1) was simplified for this reason. It was not speculated with a reflected nor absorbed component of light. During the calculation on the bottom plan (SR2) already gives out to high loss of light intensity, which causes the light reduction because of the non-transparent ceiling of the cage (manure belt conveyor and feeding trough) (7).

The measurement data without influence of the cage were used for the calculation of coefficient of internal light reduction by cage construction (8) (see Table 5). This coefficient implies that a decrease of light intensity on the first working plane (SR) is about 20 percent and on the second SR it is about 65 percent with each light source.

CONCLUSIONS

Our results confirmed that the propagation of the light in enriched cages is strongly influenced by the construction of cage, which causes the light reduction because of the non-transparent ceiling of the cage (manure belt conveyor and feeding trough). The proposed method of calculation enables to preliminary estimate expected artificial illumination in battery of enriched cages a several levels. The measured values confirmed calculated values. The

Table 3. Measured and calculated data for 100 W bulb

Working plane	100 W Incandescent bulb							
	E_{m*} (lx)	E_m (lx)	E_{n*} (lx)	E_n (lx)	σ_{m*}	v_{m*}	σ_m	v_m
SR1	20.39	16.69	18.01	18.01	8.56	41.98	7.13	42.23
SR2	12.96	4.33	10.67	4.73	2.96	22.81	6.36	147.04

Table 4. Measured and calculated data for 40 W bulb

Working plane	40 W Incandescent bulb							
	E_{m*} (lx)	E_m (lx)	E_{n*} (lx)	$E_{n\,(lx)}$	σ_{m*}	v_{m*}	σ_m	v_m
SR1	5.98	4.76	5.64	5.64	3.00	50.12	3.49	72.66
SR2	4.52	1.81	3.30	1.82	1.70	37.31	2.43	133.76

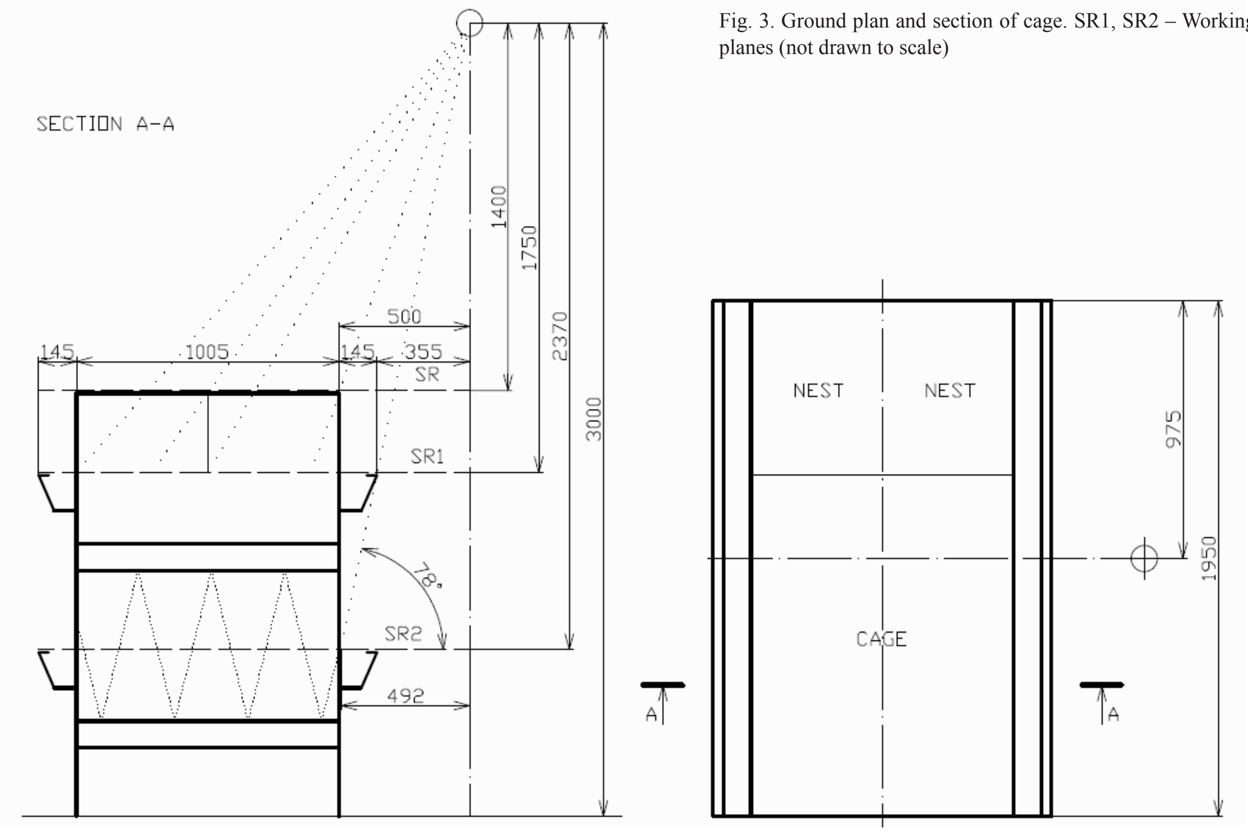

Fig. 3. Ground plan and section of cage. SR1, SR2 – Working planes (not drawn to scale)

Table 5. Coefficient of internal light reduction by construction of cage

Working plane	100W Incandescent bulb	40W Incandescent bulb
	c_c (–)	c_c (–)
SR1	0.818	0.796
SR2	0.334	0.400

comparison of the results obtained in measured level (SR1, SR2) with values measured without cages in the same level enables to determine the coefficient of internal light reduction by construction of cage c_c (–). The influence of cage on the internal light conditions in the housing area of the cage was determined by calculation as well as by the measurement. The bigger reduction was in the first tier of the cages.

As we can see from the results, the construction of the cage, placing and design of the light source have a great influence on the resulting value of light intensity. That is why during building design equipped with enriched cages the physiological demands of laying hens should be respected and the light sources must be situated in suitable positions of the hall. Too high illumination or insufficient light conditions can result in decreased production results.

From the available sources there are not known any similar measurements nowadays, which would investigate the influence of cage construction on the light intensity. For this cause it was not possible to compare the obtained data and method of calculation with other experiments. The future work will be focused on the research in the real farm in the battery of cages occupied by laying hens and polluted by the use during the breeding period.

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Analýza šíření světla v obohacených klecích pro nosnice.

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Příspěvek popisuje změnu intenzity osvětlení (IO) vlivem konstrukce klece. Hlavním cílem práce je odvození výpočtu pro stanovení intenzity osvětlení a porovnání těchto výsledků s naměřenými hodnotami a dále zhodnocení vlivu klece na intenzitu osvětlení v jednotlivých srovnávacích rovinách. Důraz byl kladen především na rozdílnou hodnotu IO v první a druhé etáži klece. Pro toto měření byly zvoleny dvě srovnávací roviny, na kterých byly naměřeny hodnoty intenzity osvětlení. Jsou označeny jako srovnávací rovina SR1 a SR2. Jejich výšková pozice byla zvolena přibližně v úrovni krmného žlabu, a to jak v první, tak i ve druhé etáži. Měření a výpočty byly provedeny s dvěma různými světelnými zdroji o rozdílném příkonu a světelném toku. Intenzita osvětlení a jeho rovnoměrnost mohou hrát důležitý vliv na kvalitu welfare nosnic a na snášku vajec. Z dostupných pramenů nejsou v současné době známa žádná podobná měření, která by se zabývala vlivem konstrukce klece na změnu intenzity osvětlení. Z tohoto důvodu nebylo možné získané výsledky a navržený postup výpočtu srovnat s jiným experimentem. Získané výsledky mohou přinést rozšíření znalostí o technologii a mikroklimatu v chovech nosnic.

intenzita osvětlení; klec; numerický výpočet; světelný zdroj; srovnávací rovina

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