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Keywords

Light intensity, laying hens, light preference, behavior, circadian rhythm

Disciplines

Agriculture | Bioresource and Agricultural Engineering | Statistics and Probability

Comments

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ASSESSMENT OF LIGHTING NEEDS BY LAYING HENS VIA PREFERENCE TEST

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Introduction

Lighting and its properties (e.g., wavelength, intensity and duration) are a crucial factor affecting hen's growth, production, behavior, and welfare (Lewis, 2010; Perry, 2003). Light intensity can affect egg size, feed intake and mortality. The recommended light intensity for commercial hen houses is 10-20 lux (Lewis & Morris, 1999; Tucker & Charles, 1993). Some studies showed that lower light intensity could reduce the occurrence of cannibalism and feather pecking (Boshouwers & Nicaise, 1987; Williams, 1984). However, improper low light intensity (i.e. 1.1 lux) could cause issues such as adrenal overweight (Siopes, Timmons, Baughman, & Parkhurst, 1984), body underweight (Hester et al., 1987), leg problems (Davis et al., 1986; Deep et al., 2010; Hester et al., 1985), and partial or complete blindness due to eye morphology change (Blatchford et al., 2009; Deep et al., 2010; Harrison et al., 1968). Photoperiod is considered as one of the most critical environment factors affecting bird production (Lewis, 2006; H. A. Olanrewaju et al., 2006). Lewis et al. (2007) compared the performance of breeders reared in 11L: 13D and 16L: 8D, and found that birds under 11L: 13D had better feed conversion. Some intermittent lighting regimens have been reported to improve feed conversion (Lewis & Perry, 1990; Ma et al., 2013) and reduce mortality by reducing duration of daytime lighting (Lewis et al., 1996; Ma et al., 2013; Morris & Butler, 1995). In commercial farms, light intensity and photoperiod are designed mainly towards achieving high production, instead of considering actual light needs by hens, which may cause some welfare issues (Davis et al., 1986; Harrison et al., 1968; Hester et al., 1985; Prescott et al., 2003). Furthermore, desired light intensity and photoperiod from the hen's perspective are not fully understood and thus require investigation as concerns about animal welfare intensify.

Preference test is one of the best ways to assess the animal's biological or physiological demand. Some studies have been conducted on birds' light preference in several aspects. Davis et al. (1999) conducted a light intensity (6, 20, 60, and 200 lux) preference study using 2- and 6-week-old chickens and found that the birds preferred the brighter light at 2 weeks of age, but they spent more time under 6 lux at 6 weeks of age. Sherwin (1998) found that the light preference of male turkey was affected by the light intensity under which they were pre-acclimatized. Prescott and Wathes (2002) studied feeding preference under different light intensities (<1, 6, 20 or 200 lux) of ISA Brown hens and found that the birds chose to eat most of the time in the brightest condition (200 lux) and the least in the dimmest (<1 lux). Some other lighting preference studies have been done on color (Bateson & Wainwright, 1972; Ham & Osorio, 2007; Khosravinia, 2007; Prayitno et al., 1997; Salzen et al., 1971; Taylor et al., 1969), light source (Gunnarsson et al., 2008; Kristensen et al., 2002; Kristensen et al., 2007; Mendes et al., 2013; Vandenberg & Widowski, 2000; Widowski & Duncan, 1996; Widowski et al., 1992), and interaction between light intensity and temperature (Alsam & Wathes, 1991). In general, light preference of poultry is diversified with different strains and ages. No study was found on light intensity preference of W-36 hens, the most popular laying breed in USA.

The objective of this study was to investigate the preference of fluorescent light intensity by W-36 white laying hens by subjecting the birds to a range of light intensity (<1, 5, 15, 30 or 100 lux). An environmentally-controlled light tunnel, as described below, was constructed and used to address the objective.

Materials and methods

System description

The systems for this study included a 5-interconnected compartment preference test light tunnel and a 2-interconnected compartment acclimation chamber. Both were located in an environmentally-controlled room at Iowa State University, Ames, Iowa, USA.

The light-proof preference test system, or light tunnel (LT) (Figure 1), was constructed with an angle iron frame. The LT was 366 cm long, 91 cm wide and 198 cm high. It was divided into five side-by-side compartments (identical in dimension, i.e., 61 cm L x 91 cm W x 198 cm H each) using plastic panels. The LT had white internal walls and black external walls. Each compartment had a perforated ceiling and a cage (61 cm L x 61 cm W x 91 cm H). A height-adjustable nipple drinker was installed at the back of the cage, and a feed trough was mounted on a load-cell weighing platform in front of the cage. Two fluorescent tube lights (GE, 15W) partially covered by aluminum foil were installed on top of the perforated ceiling to create different light intensities in each compartment. A LED rope light was fixed at 30 cm above the feed troughs along the LT. This arrangement was made so that all compartments or light intensity regimens had the same lighting intensity at the feed trough, except for the < 1 lux one (no feeder light). To eliminate the interference of the LED rope light with the main light intensity treatment, the LED rope light was covered to confine the light to the feeder area. The partition walls between two adjacent compartments had black rubber-strip curtains (36 cm H x 20 cm W each), allowing the hens to easily pass through. Access to the LT was done through the movable front plastic panel of each

compartment. The five compartments shared a common hand-crank egg belt and a manure belt at the bottom of the LT, allowing eggs and manure collected at the end of the LT (Figure 1b) without opening the LT or disturbing the birds.

A push-pull ventilation system was installed to provide 60 air changes per hour (ACH) to the LT. It used two 10.5-cm diameter pushing fans (4WT47, Dayton Electric Mfg., Niles, IL, USA) at the end inlets of a perforated air duct, and one 10.5-cm diameter pulling fan at one end outlet of the perforated air duct. Similar ventilation rate was achieved among all the compartments through design of size and distance of the air duct holes. Use of 60 ACH was to ensure that no accumulation of bird heat in the LT to affect the indoor temperature and thus potentially cause bias in the data.

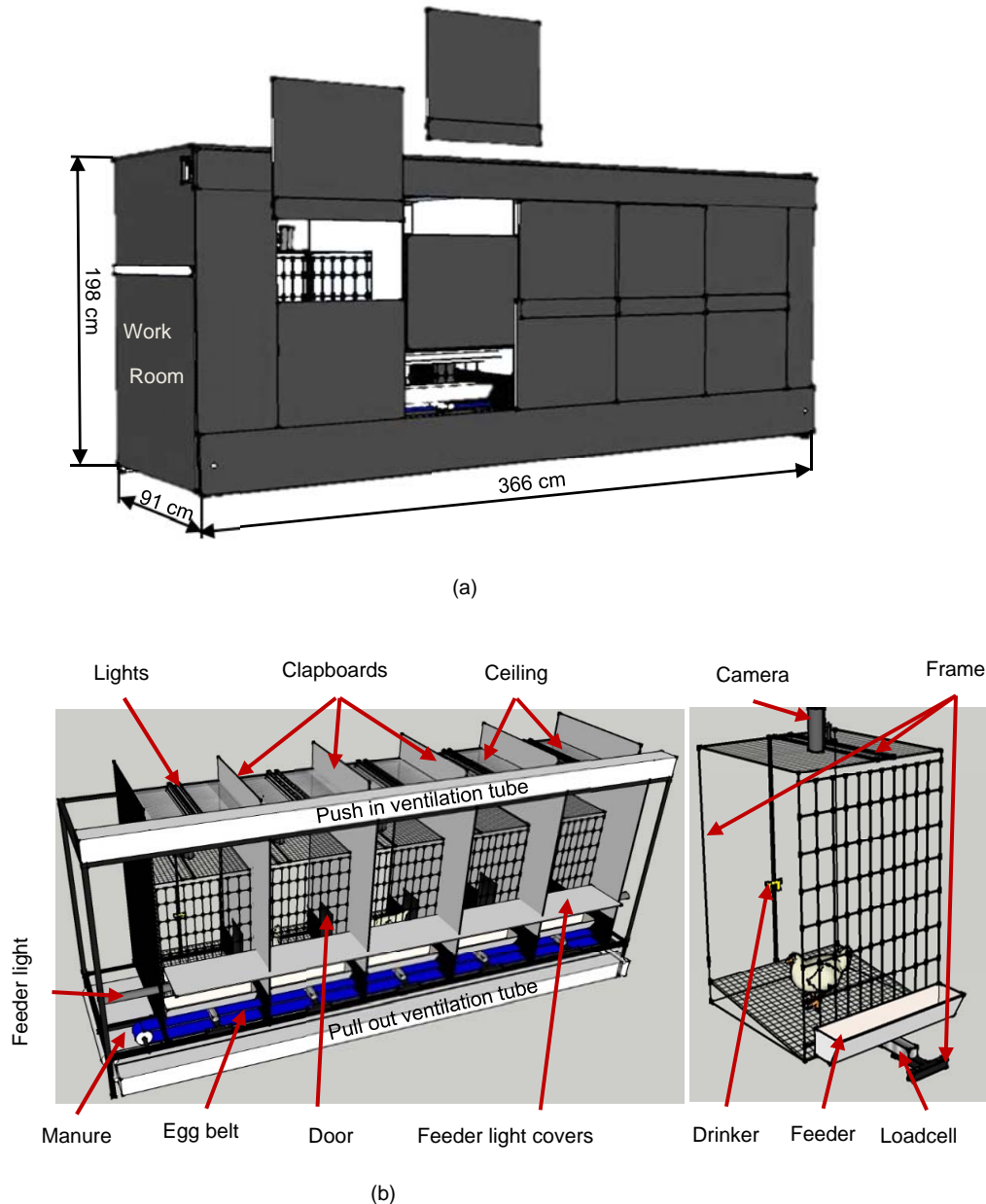


Figure 1. Schematic drawing of the light tunnel (LT) for preference test: (a) outside view, (b) inside view, and (c) an individual compartment.

A separate acclimation chamber (216 cm L × 89 cm W × 159 cm H) was constructed and used to acclimate the hens to the different light intensities under evaluation and to train the hens in passing the curtain door before they were transferred to the LT. The acclimatization system was also constructed using angle iron and black/white plastic panels. The system was divided into two identical compartments (74 cm L × 64 cm W × 46 cm H each) with a black rubber-strip curtain door (same as those used in the LT) in between. Each compartment

had a feed trough and a nipple drinker. A plastic board was placed under the wire-mesh floor to catch manure. Eight fluorescent tube lights (GE, 15W) in pairs of two were installed overhead along the length direction of the chamber at the same height as those in the LT. Through partially covering the light tubes and operating proper light combination, four different light intensities of 5, 15, 30 and 100 lux were achieved inside the chamber.

Experimental design

General information

Four batches of eight 23 week-old laying hens (Hy-Line W-36) procured from local commercial farms were used for preference test. After brought back to the laboratory, the eight hens of each batch were kept for 8 days in the acclimation chamber, where they were acclimated and exposed to the five light intensities under evaluation. Following acclimation, four hens were randomly chosen and transferred to the preference test LT, where they remained for 27 (for trial 1) or 33 days (for trials 2 - 6). Prior to the first trial and between trials, both LT and training/acclimation chamber were cleaned, disinfected and left empty for 3 days. The LT was maintained at 24.9 ± 0.5 °C and $30 \pm 5\%$ relative humidity (RH) during the test periods. Feed and water were provided *ad-libitum* in the acclimation chamber and LT. Feeding and egg collection were performed at 8:30 AM every day, and manure was removed once a week.

Lighting environment

Light spectra at the five light intensities were measured using a spectrometer (Once Innovations, Inc., Plymouth, MN, USA). Because the spectral sensitivity of poultry is different from that of humans (Prescott & Wathes, 1999), the light intensity perceived by poultry (referred to as “plux” here) may differ from that perceived by human (in lux) under the same lighting condition. Light intensity (lux) is usually tested based on human eye. Therefore, both plux and lux were measured under the five light intensities in this study, and their relationship is shown in Figure 2a. Spectra of all different light intensities had the same shape, which means foil covers did not change the spectral profiles but only the irradiance (Figure 2b).

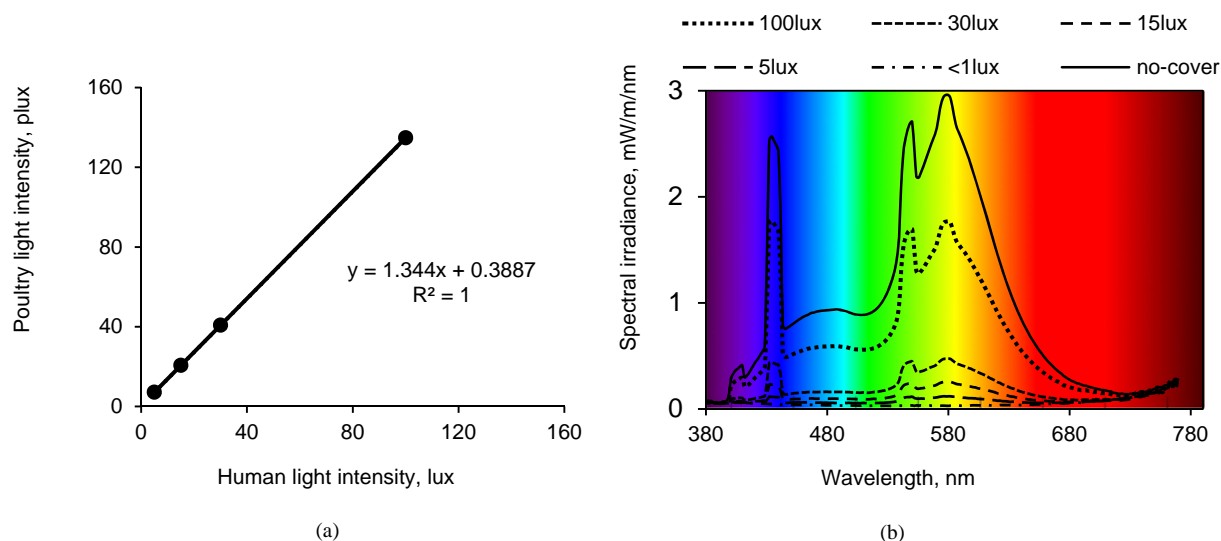


Figure 2. Relationship of light intensity of the fluorescent light for poultry vs. human (a), and spectral profiles of the fluorescent light at different light intensities (b).

Acclimation

The curtain door was fully open on the first acclimation day, then the curtain strips were gradually let down in the next four days (1/4 every day). From day 5 to 8, the curtain was fully down. This arrangement trained the hens to freely pass through the curtain doors in the LT during the preference test that followed. The hens were also exposed to multiple light intensities that were used in the LT. During the 8-day acclimation period, the photoperiod within the day was 16L: 8D. The 16 lighting hours of each day were divided into four equal-length periods (4 h/period) of 5, 15, 30 and 100 lux, respectively. The order of light intensities was based on a 4×4 Latin Square arrangement (Table 1), such that each time period received a given light intensity twice during the 8-day acclimation period.

Table 1. Lighting intensities assigned to different periods (P) on acclimation days

Day	Light intensity (lux)				
	P1 (0830 -1230, 4h)	P2 (1230 -1630, 4h)	P3 (1630 – 2030, 4h)	P4 (2030 – 0030, 4h)	P5 (0030 – 0830, 8h)
1	5	15	30	100	0
2	15	5	100	30	0
3	30	100	5	15	0
4	100	30	15	5	0
5	5	15	30	100	0
6	15	5	100	30	0
7	30	100	5	15	0
8	100	30	15	5	0

Preference test

After acclimation, four birds were randomly selected and transferred to the LT for preference test. The five intensity levels of <1, 15, 30 and 100 lux were randomly assigned to the five compartments following a Latin Square design (Table 2), so that each compartment received a light intensity the same number of times per trial (balanced-randomized design). It should be mentioned that the <1 lux light intensity was always assigned to either of the two side compartments in trial 1. Nine or ten episodes were involved per trial. In trial 1, each episode lasted for 3 days (27 consecutive days of testing overall). For trials 2, 3, 4, 5 and 6, the first episode lasted for 6 days to give the birds more time to be acclimatized to the LT, and then lights were re-assigned every 3 days (33 consecutive days of testing overall). Between episodes, feed left in the trough of all compartments was replaced and new feed added. Light intensity at the feeder level was 30 lux for all but the < 1 lux compartment (no feeder light).

Table 2. Light intensity in compartment (C1 – C5) of the light tunnel during test period

Episode	Day	Light intensity (lux)										
		Trial 1					Day	Trial 2 - 6				
		C1	C2	C3	C4	C5		C1	C2	C3	C4	C5
1	1-3	100	30	15	5	<1	1-6	5	30	<1	100	15
2	4-6	<1	30	100	5	15	7-9	<1	5	30	15	100
3	7-9	15	5	100	30	<1	10-12	30	100	15	5	<1
4	10-12	<1	5	15	30	100	13-15	15	<1	100	30	5
5	13-15	<1	100	30	15	5	16-18	100	15	5	<1	30
6	16-18	30	100	5	15	<1	19-21	5	30	<1	100	15
7	19-21	<1	15	5	100	30	22-24	<1	5	30	15	100
8	22-24	5	15	30	100	<1	25-27	30	100	15	5	<1
9	25-27	100	30	15	5	<1	29-30	15	<1	100	30	5
10							31-33	100	15	5	<1	30

Data collection

The compartment occupancy of hens was monitored using five infrared video cameras (GS831SM/B, Gadspot, Inc. Corp., Tainan City, Taiwan) mounted on the top of the respective compartments. The five cameras were connected to a video capture card (GV-600B-16-X, GeoVision Inc., Taipei, Taiwan) with Surveillance System software (Ver 8.5, GeoVision Inc., Taipei, Taiwan). Images of each compartment were continuously captured at 2-s intervals throughout the experiment period. The number of hens was determined using image analysis in Matlab (R2013a, MathWorks, Inc., Torrance, CA, USA) and Excel 2013 (VBA program). Image processing in Matlab is shown in Figure 3. Original images were analyzed through cropping, binarization (with a black & white scale threshold of 0.75), boundary closing, hole filling, and spot removing to obtain the final image of white hen area and black background. The total hen area, number of white regions, area of each region and number of compartments occupied by hens at a given moment were further analyzed in Excel to calculate the number of hens in each image. The process of hen number calculation is illustrated in Figure 4. The program output on hen

number was validated by human observation of the images. For each trial, four days of data were chosen, and data associated with the first and last minutes of each hour were used in the validation. Results by the human observation and program calculation were compared and the agreement was 98% or better. The hen number data were analyzed in Excel to determine time spent and times of inter-compartment movement. Time spent was calculated by summarizing hen number over a time period (hour or day) and inter-compartment movements were calculated by counting times of a hen entering the compartments (Table 3).

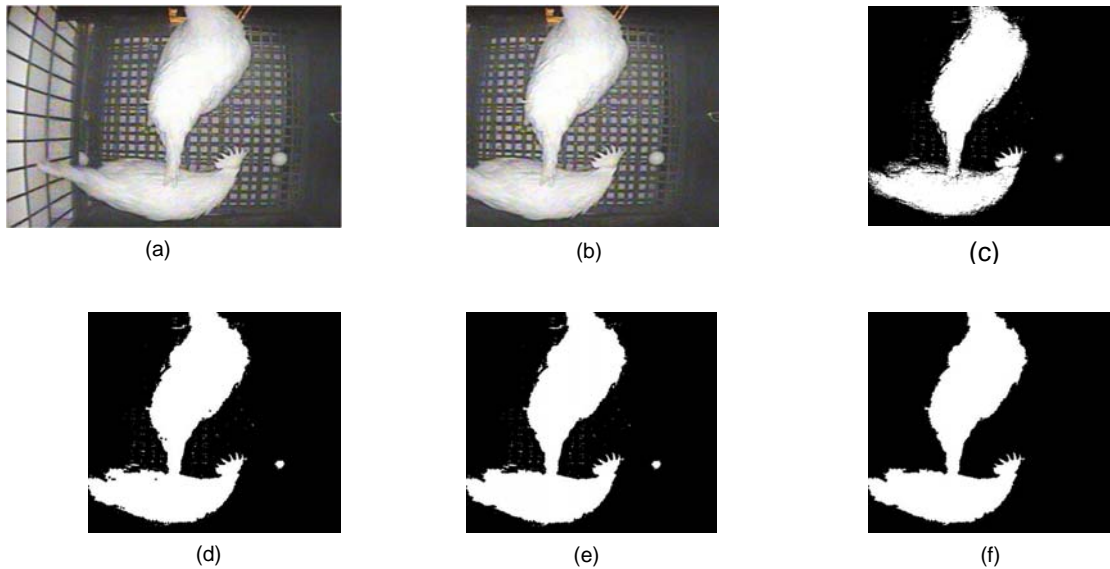


Figure 3. Image processing in Matlab: (a) original image; (b) cropped image; (c) binary image; (d) boundary-closed image; (e) hole-filled image; (f) noise-spot-removed image (final image).

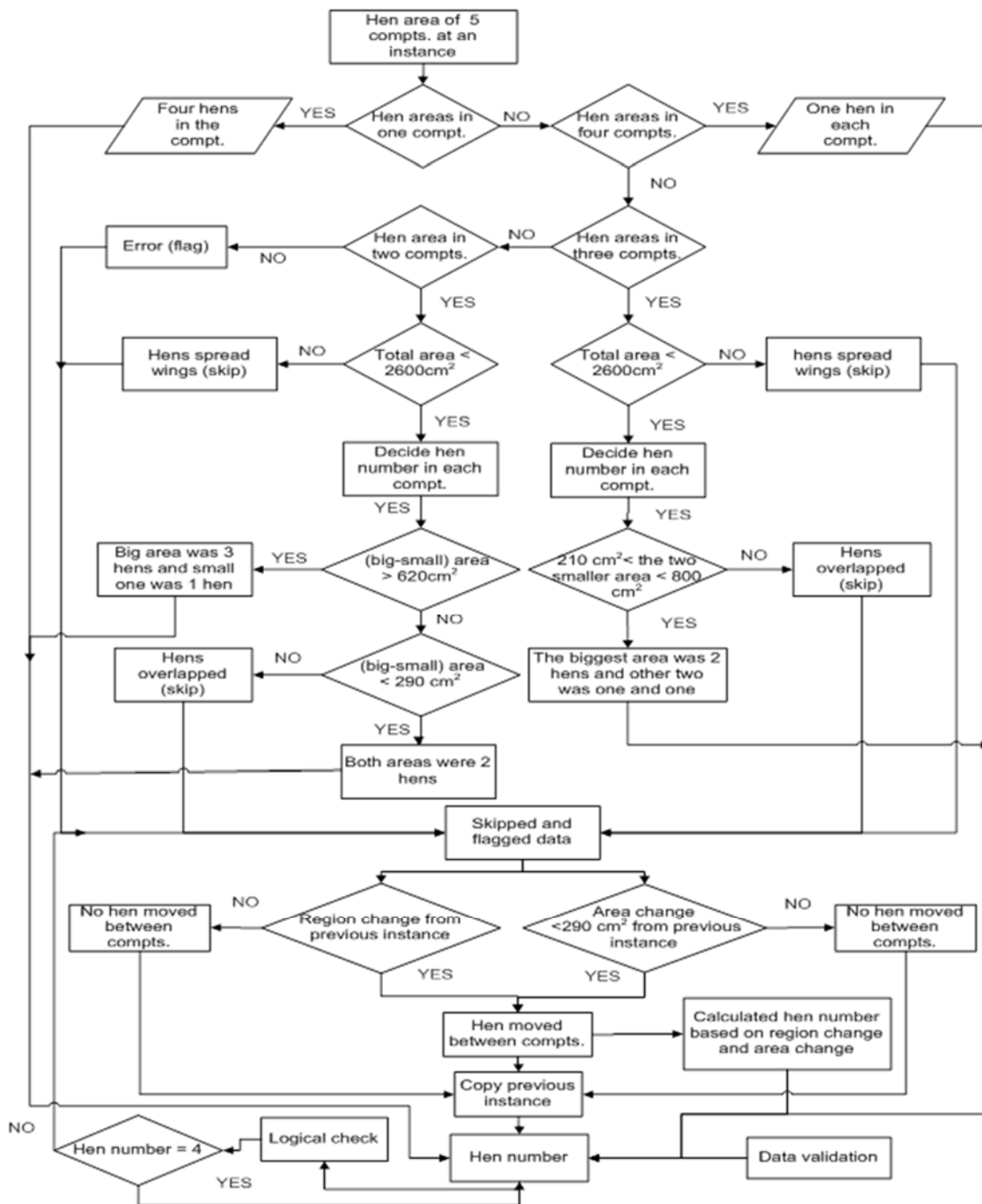


Figure 4. Process of determining hen number in each compartment using the VBA program in Excel.

Load-cell sensors (RL1040-N5, Rice Lake Weighing Systems, Rice Lake, WI, USA) were used to monitor and measure feeding activities and feed intake. Outputs of these sensors were continuously recorded every second through a LabVIEW program (version 7.1, National Instrument Corporation, Austin, TX, USA). An algorithm (in Matlab 2014a) was developed to calculate time at feeder, feeding time, feeding rate, feeding time distribution and feeding time relative to total time spent in each compartment (Table 3). Eggs laid in each compartment were recorded daily (Table 3).

Temperature and RH inside the LT were continuously measured during the experiment using thermocouples ($\pm 0.5^\circ\text{C}$, Type-T, OMEGA Engineering, Inc., Stamford, CT, USA) and a RH sensor (HMT100, Vaisala, Inc., Woburn, MA, USA). Room temperature was also monitored using the same type of thermocouple.

Table 3. Hen behavior and production parameters of concern and definitions

Parameters	Unit	Definition
Time spent (TS)	h/hen-day	Average time spent in one compartment (under a light intensity)
Percentage of time spent (PTS)	%	Time spent ÷ 24 hours × 100 %
Inter-compartment movement (ICM)	times	Times of hens moving from a compartment to an adjacent one (i.e., 15 lux to 5 lux counted as movement to 5 lux)
Visit duration (VD)	min/time	Time spent ÷ inter-compartment movement
Feed intake (FI)	g/hen-day	Daily feed use per hen
Time at feeder(TAF)	h/hen-day	Overall time spent at the feeder (with or without feed consumption)
Feeding time (FT)	h/hen-day	Time spent on eating
Feeding rate (FR)	g/h-hen	Feed intake ÷ feeding time
Egg laid (EL)		Number of eggs laid

Statistical analysis

The first four days of each trial and the first day of each remaining test episode were considered as acclimation periods. As such, only data on the last two days of each test episode were used for subsequent data analysis. Therefore, 16 days (trial 1) or 20 days (trials 2, 3, 4, 5 & 6) of data were summarized in the statistical analysis. The percentage of time spent (pts) was transformed using a log transformation [$\log_e(\text{pts}/(1 - \text{pts}))$] to stabilize the variance, allowing statistic model to be performed. All data were analyzed using PROC MIXED model in SAS 9.3. The model included light intensity, compartment and their interaction as fixed effects. Trial and the 3-way interaction among trials, day and compartment were considered as random effects. Finally a blocked-diagonal matrix for the error term was used, where block correspond to the interaction between trial and day. Effects were considered significant at $p < 0.05$. The statistical model was of the following form:

$$Y_{ijkd} = \mu + L_i + C_j + (LC)_{ij} + T_k + (CTD)_{jkd} + \varepsilon_{ijkd}$$

where Y_{ijkd} represents the response variable on day d of trial k in compartment j with light intensity i , μ is the intercept, L_i is the light intensity (<1, 5, 15, 30, and 100 lux) effect, C_j is the compartment (1, 2, 3, 4 and 5) effect, $(LC)_{ij}$ is the interaction effect of light intensity and compartment, $T_k \sim N(0, \sigma^2)$ and $CTD_{jkd} \sim N(0, \tau^2)$ is the random effect. Let $\varepsilon_{kd} = (\varepsilon_{11kd}, \dots, \varepsilon_{55kd})$ the error vector for day d and trial k , then $\text{Var}(\varepsilon_{kd}) = R$ a positive-semidefinite and symmetric matrix. Effects of light intensity, compartment, and their interactions on the response variables are shown in Table 4.

Table 4. Effects of light intensity, compartment, and their interactions on total time spent, time at feeder, feeding time, feed intake and egg laid of hens in different light intensities.

Variables	L	C	L × C
Time spent (TS)	***	NS	NS
Inter-compartment movement (ICM)	***	**	**
Visit Duration (VD)	***	NS	NS
Time at feeder (TAF)	***	NS	NS
Feeding time (FT)	***	NS	NS
Feed intake (FI)	***	NS	NS
Feeding rate (FR)	NS	NS	NS
Egg laid (EL)	***	NS	NS

L = light intensity; C = compartment; * P < 0.05; ** P < 0.01; *** P < 0.001; NS = not significant (P > 0.05)

Results and discussion

Time spent

The time spent (TS) in the compartments was significantly affected by light intensity, but not by compartment or the interaction effect (Table 4), indicating a strong preference of the hens for certain light intensities. Since < 1 lux was considered as dark period, the total TS of hens in light period was 14 hours (Table 5). During light period, hens spent most of their time in 5 lux (6.4 ± 0.5 h/hen-day, 45.3 %) which was significantly higher ($P < 0.05$) than TS in 15, 30 or 100 lux. Hens spent similar time in 15 (3.1 ± 0.4 h/hen-day, 22.2 %) and 30 lux (3.0 ± 0.4 h/hen-day, 22.1 %) ($P = 0.988$). TS in 100 lux (1.5 ± 0.2 h/hen-day, 6.1 %) was the lowest ($P < 0.05$). Therefore, the light intensity of 5 lux was preferred by the hens over 15 or 30 lux, and 100 lux was least preferred. This result seems consistent with the report by Davis et al. (1999) who observed that older poultry preferred dimmer light.

Table 5. Effects of light intensity on total time spent (TS) (mean \pm s.e.)

	Light intensity level (lux)	TS (h/hen-day)	PTS (%)
Light period	5	6.4 ± 0.5^a	45.3 ± 2.0^a
	15	3.1 ± 0.4^b	22.2 ± 1.5^b
	30	3.0 ± 0.4^b	22.1 ± 1.6^b
	100	1.5 ± 0.2^c	10.4 ± 0.9^c
	Overall	14.0	100
Dark period	< 1 lux	10.0 ± 0.7	

^{a,b} Values within a column with different superscripts differ significantly at $P < 0.05$.

Animals generally behave to maximize their welfare and will preferentially choose the variant that is most likely to satisfy their requirements (Dawkins, 1990). The fact that the W-36 laying hens spent more time of their light period in the lower light intensity (5 lux) indicates that the low light intensity might better satisfy their welfare requirements. Low intensity light can reduce cannibalism and feather pecking and has been used in commercial farms (Boshouwers & Nicaise, 1987; Hughes & Duncan, 1972; Kjaer & Vestergaard, 1999; Williams, 1984). At the same time, some evidence also showed that birds reared in low light intensity at 0.5 or 1 lux result in heavier and larger eyes (Blatchford et al., 2012; Deep et al., 2010; Siopes et al., 1984). Blatchford et al. (2009) reported that broilers had heavier and larger eyes at 5 lux, whereas Olanrewaju et al. (2012) and Deep et al. (2013) found no difference in eye size under 5 lux as compared with higher light intensities. These studies used different light conditions (range from 0.1 to 220 lux), strains (laying hens, turkeys and broilers) and ages (from day-old to 46 week-old); therefore it is difficult to draw concrete conclusions. Also it should be noted that the light set-up in the present study, where five levels of light intensity were provided continuously, was not comparable with conventional poultry housing where birds are in consecutive light (e.g., 16) or dark (8) hours per day. Therefore, further work is needed to verify the welfare effects of the light intensities as preferred by the laying hen in the present study over an extended period.

Inter-compartment movement

Light intensity, compartment and their interaction had effects on inter-compartment movement (ICM) (Table 4). ICM and visit durations (VD) under different light intensities were shown in Figure 5. The only significant difference in ICM occurred between 5 lux (339 ± 23) and 100 lux (256 ± 25) ($P < 0.05$). VD in <1 lux (2.9 ± 0.3 min/time) was significantly greater than those of the other light intensities ($P < 0.05$). The ICM outcome confirmed that the hens experienced all the light intensities during the preference test. VD can provide information on an animal's motivation to exit or enter a specific environment, hence reflecting the natural exploratory behavior of most animal species (Kristensen et al., 2000). For this study, when laying hens were first transferred to different light environments they were observed to explore different light intensities, and then chose the ones they preferred to stay in.

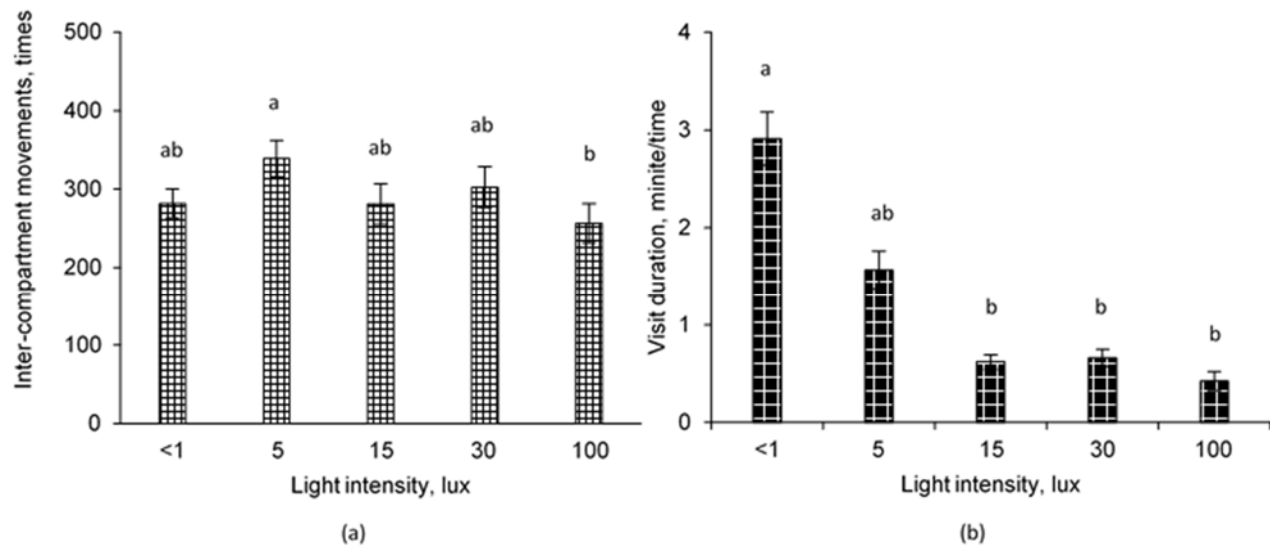


Figure 5. Daily inter-compartment movements (a) and visit duration (b) of hens for different light intensities (mean ± s.e.). n=116; ^{a,b}In each chart, bars with different letters differ significantly (P < 0.05).

Feed intake and feeding behavior

The distribution of feed intake (FI) in the five light intensities is shown in Table 6. FI in <1 lux and 5 lux was significantly higher than that in 15, 30 or 100 lux (P < 0.05). Similar FI occurred in 15 lux and 30 lux (P = 0.901). Hens had the lowest FI in 100 lux (P < 0.05). Time at feeder (TAF) and feeding time (FT) followed similar trend to FI. TAF averaged 4.4 ± 0.1 h and 3.4 ± 0.1 h of which was spent on actual feeding. This led to an average feeding rate (FR) of 25.6 ± 2.3 g/h-hen. No significant difference in FR was detected among the five light intensities (P = 0.057 - 0.998).

Table 6. Feed intake (FI), time at feeder (TAF), feeding time (FT), and feeding rate (FR) under different light intensities (n= 116) (mean ± s.e.m.)

Variable	Light intensity (lux)					Overall
	<1	5	15	30	100	
FI, g/hen-day	24.8 ± 2.4 ^a	28.4 ± 1.9 ^a	13.8 ± 1.5 ^b	14.5 ± 1.6 ^b	5.8 ± 0.9 ^c	87.3 ± 1.7
% of total FI, %	28.4 ± 2.7 ^a	32.5 ± 2.2 ^a	15.8 ± 1.8 ^b	16.6 ± 1.9 ^b	6.7 ± 1.0 ^c	100
TAF, h/hen-day	1.2 ± 1.1 ^a	1.4 ± 0.1 ^a	0.7 ± 0.1 ^b	0.8 ± 0.1 ^b	0.3 ± 0.1 ^c	4.4 ± 0.1
FT, h/hen-day	0.9 ± 0.1 ^a	1.1 ± 0.1 ^a	0.5 ± 0.1 ^b	0.6 ± 0.1 ^b	0.2 ± 0.0 ^c	3.4 ± 0.1
FR, g/h-hen	28.4 ± 2.5	25.5 ± 2.3	25.5 ± 2.4	24.3 ± 2.1	24.1 ± 2.0	25.6 ± 2.3

^{a,b} Values within a row with different superscripts differ significantly at P<0.05.

Prescott and Wathes (2002) studied feeding preference under different light intensities (<1, 6, 20 or 200 lux) of ISA Brown hens and found that the birds chose to eat the most time in the brightest (200 lux) and least in the dimmest (<1 lux) light intensity. Their conclusion was that hens might be averse to eating in very dim light, presumably because the process of eating is normally guided visually. In the present study, feeding light (30 lux) was provided to all compartments except for the < 1 lux regimen. The results showed that hens preferred to feed in the compartment in which they spent more time, which was somewhat contrary to the findings of Prescott and Wathes (2002). Moreover, the W-36 hen did not show aversion to feeding in <1 lux.

Malleau et al. (2007) found that broiler and layer chicks were very rarely recorded at the feeder or drinker during the lights-off period, but they spent the dark hours resting as a group. Kristensen et al. (2007) found no broilers feeding or drinking during an 8-hour uninterrupted dark (0 lux) at 2 or 6 weeks of age. Savory (1980) reported that fowl did not feed during 8 h periods of darkness, but they did feed during 6 h or shorter dark periods, suggesting that they perceive multiple periods of darkness differently.

Egg production and eggs laid

Throughout the experiment period, 4 hens laid 3 or 4 eggs daily and the hen-day egg production averaged $96.0 \pm 0.9\%$. Light intensity impacted the location of eggs laid (**EL**) in that the hens laid $61.9 \pm 3.6\%$ of the total eggs in <1 lux, which was significantly higher than that in 5, 15, 30 or 100 lux ($P < 0.05$) (Table 4). There was no difference among 5 lux ($12.5 \pm 2.3\%$), 15 lux ($11.0 \pm 2.3\%$), 30 lux ($7.6 \pm 1.6\%$) and 100 lux ($7.0 \pm 1.9\%$) ($P = 0.184 - 0.795$). Therefore, hens preferred to lay eggs in <1 lux (Figure 6).

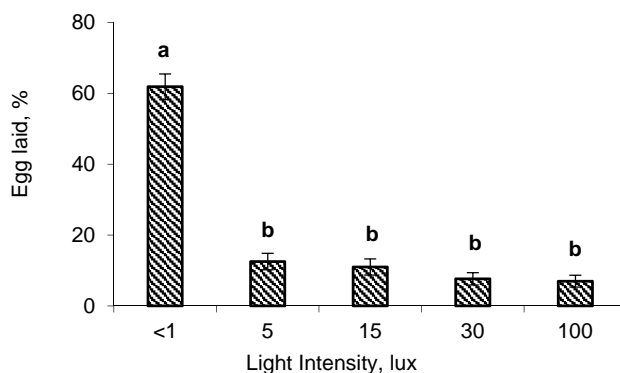


Figure 6. Percent of egg laid in different light intensities (mean \pm s.e.). n=116; Bars with different letters differ significantly at $P < 0.05$.

Millam (1987) found that hens preferred to nest in boxes at one end of a row compared to those in the middle. Appleby et al. (1984) found that some hens preferred brightly lit nest boxes (20 lux) while others preferred dimly lit nest boxes (5 lux), when given a free choice. When both situations were provided (compartments in a row and different light intensities) hens showed a strong motivation laying eggs in <1 lux rather than end compartments (<1 lux was moved from compartment to compartment). In conclusion, hens preferred to lay eggs in dim light (<1 lux) over locations.

Distribution of dark and light

Hourly mean TS in each light intensity is shown in Figure 7. TS in the dark (<1 lux) and light (sum of 5, 15, 30 and 100 lux) was intermittent in each hour. The hourly mean TS in the dark was 25.0 ± 0.4 min. Daily total mean TS in the dark (<1 lux) and light (sum of 5, 15, 30 and 100 lux) was 10.0 ± 0.7 h and 14.0 ± 0.7 h, respectively ($P < 0.001$).

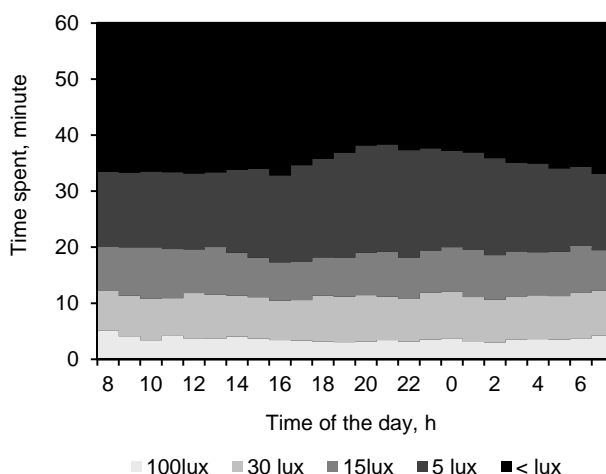


Figure 7. Distribution of time spent under different light intensity in each hour per day (n=116).

Light intensity associated with the darkness definition has been reported to range from 0 to 4 lux (Berk, 1995; Coenen et al., 1988; Malleau et al., 2007). Light intensity level of <1 lux was considered as dark in the present experiment. The laying hens showed circadian rhythm in the daily usage of the light and dark compartments with an overall light and dark distribution of 14L:10D. This light-dark pattern was different from the photoperiod of 16L:8D typically practiced in commercial operation in that the darkness was intermittently distributed in each hour of the day in the current study. The total dark period (10 h) was also longer than the typical 8 h used in commercial

practice. Within the 10 h dark period (< 1 lux), feeding activities (Table 6) and egg laying (Figure 6) were also noticed, which might have contributed to the longer dark period. TS of laying hen at feeder in < 1 lux was 1.2 h, but TS of egg laying and other behaviors (resting, drinking, walking, etc.) was not quantified. The underlying reason for the longer dark period remains to be better understood.

In investigating light intensity (6, 20, 60 and 200 lux) preference of layers and broiler at 2 or 6 weeks of age, Davis et al. (1999) found no significant circadian rhythm in using 6 or 200 lux by the broilers at 2 or 6 weeks, or the layers at 2 weeks. However, the pullets showed rhythm for perching behavior at 6 weeks. Savory and Duncan (1982) assessed motivation for light and darkness in broilers and layers by training them to peck on a panel to switch light on or off. When the room was lit, the birds worked to switch to darkness for only <1% of the time; whereas in a dark room, they worked to turn on the lights for about 80% of the time. In our study, when the laying hens were offered to choose freely between light and dark, they chose to spend 40% of the day intermittently in darkness (<1 lux).

Conclusions

The W-36 laying hen showed apparent preference when allowed to choose among a range of light intensities. Specifically, the following was observed.

1. The hen preferred to stay in dimer light (5 lux) during the light period, which made up 45.4 % (6.4 h/day) of the total light time budget.
2. The hen preferred to feed in < 1 lux (24.8 ± 2.4 g/hen-day, 28.4 %) without feeding light and in 5 lux (28.4 ± 1.9 g/hen-day, 32.5 %) with feeding light (30 lux) as compared with other light intensity levels.
3. The hens laid 61.9% of their eggs in < 1 lux compartment, reflecting their preference of laying egg in 'darkness' (< 1 lux).
4. Within a day the hens spent 10.0 ± 0.7 h (41.50 %) in darkness and 14.0 ± 0.7 h (58.5 %) in light. Time spent in darkness was intermittently distributed throughout the day.

Further study is needed to assess the range of light intensity preferred by the laying hen in the present study with regards to long-term welfare and production performance.

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