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Abstract

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Keywords

Perch utilization, Perch preference, Alternative housing, Behavior and welfare, Automated monitoring

Disciplines

Agriculture | Bioresource and Agricultural Engineering | Poultry or Avian Science

Comments

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Perch-Shape Preference and Perching Behaviors of Young Laying Hens

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Abstract

Provision of perches in enriched colony or cage-free hen housing facilitates birds' ability to express natural behaviors, thus enhancing animal welfare. Although considerable research has been conducted on poultry perches, further investigation is needed of perching behavior and preference of laying hens to perch exposure and perch types. This study aimed to assess preference of young laying hens for round *vs.* hexagon perches and to characterize temporal perching behaviors of the young hens brought to an enriched colony setting from a cage pullet-rearing environment. A total of 42 Lohmann white hens in six equal groups, 17 weeks of age at the onset of the experiment, were used in the study. Each group of hens was housed in a wire-mesh floor pen equipped with two 120 cm long perches (one round perch at 3.2 cm dia. and one hexagon perch at 3.1 cm circumscribed dia., placed 40 cm apart and 30 cm above the floor). Each group was monitored continuously for 9 weeks. Perching behaviors during the monitoring period, including perching time, perch visit, and perching bird number, were recorded and analyzed daily using an automated perching monitoring system. Results revealed that the laying hens showed no preference between the round and hexagon perches ($P = 0.59$-0.98). Young laying hens without prior perching experience showed increasing use of perches over time ($P < 0.01$). It took up to five to seven weeks of perch exposure for young hens to show consistent perching behaviors in the enriched colony setting. This study also found that laying hens spent about 10% of daytime on the perches and over 75% of hens perched at night after approaching consistent perching behaviors. In general, the results supplemented to the existing knowledge base for the quantitative behavior study on laying hens' temporal perch use.

Keywords: Perch utilization, Perch preference, Alternative housing, Behavior and welfare, Automated monitoring.

1. Introduction

Laying hens are highly motivated to perch, thus provision of perches in hen housing can accommodate hen's natural behavior needs, enhancing animal welfare (Olsson and Keeling, 2002; Cooper and Albentosa, 2003; Weeks and Nicol, 2006). To improve laying hen welfare, the EU Directive banned conventional cages from 2012 and set forth the minimum standards that perches must have no sharp edges and perch space must be at least 15 cm per hen in alternative hen housing systems (Council Directive 1999/74/EC, 1999). Because of the EU's ban on conventional cages, enriched colony housing (**ECH**) became a popular alternative hen housing system. In 2014, 58% of the laying hens in the EU were housed in ECH systems (Windhorst, Personal Communication). Although laying hens are mostly housed in conventional cages in the United States (approximately 85%) and many other major egg-producing countries (e.g., China, Mexico, Japan, Indian, Brazil), ECH systems have been adopted by some egg producers in these countries. In the ECH systems, the perch is one of the most essential enrichments for the hens.

Many studies have investigated the effects of perch provision on production performance, health, and well-being of laying hens over the past four decades (Struelens and Tuyttens, 2009; Hester, 2014). Benefits of providing perches to laying hens include stimulating leg muscle development and bone mineral deposition (Enneking et al., 2012; Hester et al., 2013a), increasing volume and strength of certain bones (Hughes et al., 1993; Appleby and Hughes, 1990; Barnett et al., 2009), reducing abdominal fat deposition (Jiang et al., 2014), and reducing fearfulness and aggression (Donaldson and O'Connell, 2012). On the contrary, detrimental effects associated with perches include keel bone deformities, foot disorders, and bone fractures (Appleby et al., 1993; Tauson and Abrahamsson, 1994; Donaldson et al., 2012). Studies have also shown inconsistent results related to the impact of perches on feather condition or mortality of laying hens. For example, Duncan et al. (1992), Glatz and Barnett (1996), and Wechsler and Huber-Eicher (1998) reported beneficial impacts, whereas Tauson (1984), Moinard et al. (1998), and Hester et al. (2013b) reported detrimental impacts. These inconsistent results, to a large extent, could be attributed to differences in perch design, spatial arrangement of perches, or timing of birds' introduction to perches in the studies (Struelens and Tuyttens, 2009; Hester, 2014).

The EU Directive has required that perches must have no sharp edges (Council Directive 1999/74/EC, 1999). Pickel et al. (2011) found that peak force on the footpads of hens was greater when standing on the perches with sharp edges (square perch) as compared to round perches. This finding provided certain scientific evidence for the requirement of no sharp edges because the extra force on the footpads may lead to severe foot disorders such as bumble foot and toe pad hyperkeratosis. Consequently, round perches are most commonly used in alternative housing systems. However, the peak force on the keel bone of hens was much greater when resting on round *vs.* square perches (Pickel et al., 2011), which could contribute to development of more keel bone deformity. It should be noted that the pressure peaks on the keel bone were approximately 5 times higher compared with the pressure peaks on a single footpad (Pickel et al., 2011). In addition, round perches might be less adequate in terms of providing the stability necessary to accommodate the hen's landing or long-term roosting. For instance, Duncan et al. (1992) found that hens' feet slipped back and forth on round perches but not on square perches. Therefore, a hexagon perch, combining the shape features and advantages of both square and round perches, might prove to be more attractive to hens because of its potential to improve hens' ability to grasp the perch and reduce the chance of peak pressure on the keel bone and footpads. A review of literature did not reveal research information regarding hen's comparative use of round *vs.* hexagon perches.

Some studies showed that early access to perches had positive effects on musculoskeletal health of pullets as well as subsequent long-term health of hens (Hester et al., 2013a; Yan et al., 2014; Habinski et al., 2016). Similarly, research found that rearing pullets without early access to perches could impair the spatial cognitive skills of hens (Gunnarsson et al., 2000), thus may be detrimental to their subsequent perching ability and long-term welfare. However, raising pullets in conventional cages without perches is the most typical management practice in current commercial ECH systems. Thus there is still a need to further investigate and characterize perching behaviors of young laying hens (without perch exposure) introduced to ECH systems.

The objectives of this study were a) to assess hens' preference for perch shape between round and hexagon perches, and b) to quantify and characterize temporal perching behaviors of young laying hens after transfer from pullet-rearing cages into an enriched colony setting. The results contribute to scientific information on laying hen perch design and responses of novice birds to perch introduction.

2. Materials and Methods

The study was conducted in an environment-controlled animal research laboratory located at Iowa State University, Ames, Iowa, USA. Before the onset of the experiment, the experimental protocol was approved by the Iowa State University Institutional Animal Care and Use Committee (Log # 5-12-7364-G).

2.1. Experimental Birds and Management

A total of 42 Lohmann white laying hens in two successive batches (21 hens per batch) were used in the study. The birds were reared in a commercial pullet-rearing cage house (six pullets per cage) until the commencement of the experiment when they were at 17 weeks of age (**WOA**). All the birds had similar physical conditions, including body weight (1200 - 1250 g), feather coverage (no damage/loss), feet and keel bone conditions (no abnormal sign), and no prior perching experience at the onset of the experiment. For each batch, the birds were randomly assigned to three groups, with seven birds per group.

Three identical enriched experimental pens (P1, P2, and P3) were used in the study. These experimental pens (Fig. 1), each measuring 120 × 120 × 120 cm (L×W×H), had a wire-mesh floor (2.5 × 2.5 cm wire-mesh, 2057 cm^2/bird space allowance), a 120 × 30 × 40 cm elevated nest box (45 cm above floor, 514 cm^2/bird), two 60 × 15 × 10 cm rectangular feeders (installed outside of the left and right sidewalls), two nipple drinkers (on the rear wall at 40 cm above floor), and two parallel 120 cm long metal perches (a 3.2 cm dia. round perch and a 3.1 cm circumscribed circle dia. hexagon perch, each giving a minimum of 17 cm perch space per bird). Both perches were installed on adjustable brackets, 30 cm above the floor and

40 cm away from each respective sidewall, with a horizontal space of 40 cm between the two perches. The adjustable brackets allowed for quick relocation and placement of perches. The hexagon perches were oriented to present a flat surface on the top (Fig. 2a). All resource allowances, including perch, floor, feeder, nest, and nipple drinkers met or exceeded those in the legislation or recommendations for the hens. The experimental room was equipped with mechanical ventilation and heating/cooling to maintain the desired temperature of 21ºC and relative humidity of 40-60% throughout the experiment.

The lighting scheme applied in the study followed the commercial management guidelines (Table 1), including light, dim (dawn and dusk), and dark periods. Artificial light was the only light source throughout the experiment, and light was provided with compact fluorescent lamps for the daytime (20 lux) and light-emitting diode lights for the dim period (1-2 lux). Light intensity was measured and adjusted using a light meter (Model EA31, FLIR Systems Inc., Wilsonville, OR, USA[1]), and lighting was maintained at comparable levels at the same spot of the respective perch.

All birds underwent a 9-week test period (17-25 WOA). During this test period, the round and hexagon perches were continuously provided, and the birds had free access to both. The locations of the two perches were swapped once a week (at the end of each week) to avoid potential location effects (Table 2). The nest box door was blocked to restrict hen access during the dark period, i.e., the door was closed and reopened an hour before the onset of dusk and dawn periods, respectively. Feed (commercial corn and soy diets) and water were available *ad-libitum* for the hens throughout the test. Feeders were replenished and eggs were collected once a day at 17:00 h. The experimental pens were cleaned each week right after relocation of the perches. Wood shavings were placed under the wire-mesh floor to absorb the manure moisture and for easier cleaning.

[1] Mention of product or company name is for presentation clarity and does not imply endorsement by the authors or Iowa State University, nor exclusion of other suitable products.

2.2. Automated Perching Monitoring System

A real-time, sensor-based perching monitoring system was built by incorporating six pairs of load-cell sensors (Model 642C, Revere Transducers Inc., Tustin, CA, USA) supporting six metal perches (two perches per pen, Fig. 2a), coupled with a LabVIEW-based data acquisition system (version 7.1, National Instrument Corporation, Austin, TX, USA). This monitoring system consisted of a compact FieldPoint controller (NI cFP-2020, National Instrument Corporation) and two 8-channel thermocouple input modules (NI cFP-TC-120, National Instrument Corporation), collecting data at 1 Hz sampling rate. Each pair of load-cell sensors was fitted with the adjustable brackets and coupled to a metal perch, forming the weighing perch (Fig. 2a). For each weighing perch, an equation was developed by establishing relationship between a series of standard load weights (i.e., 0, 1500, 3000, 4500, 6000, and 9000 g) and the corresponding analog voltage outputs (Fig. 2b). The data acquisition system automatically read analog voltage outputs of the weighing perches and converted the electronic signals to load weight using the pre-defined equations, thereby providing real-time measurement of load weight on the perches (Fig. 2c). The load weight of perching birds on each perch was then converted to the number of perching birds on the corresponding perch (Fig. 2d) by using a series of determined weight thresholds (Table 3). This monitoring system was validated by comparing results with human observations and had been applied in a previously published perch study (Liu and Xin, 2017). Using this system, perching behaviors of the birds were continuously monitored throughout the test period, covering the first day to nine weeks of perch exposure (**WPE**).

2.3. Characterization of Temporal Perching Behaviors

With the knowledge of the time-series (one sample per second) numbers of perching birds on each perch, perching behaviors of birds were quantified daily using an automated VBA program in Excel (Microsoft Office 2016, Redmond, WA, USA). Three primary perching behavior responses were determined, including a) perching time (**PT**) – time spent perching, min/bird; b) perch visit (**PV**) – number of jumps onto and off perch, number/bird; and c) perching birds number (**PBN**) – number of simultaneously perching birds. From these three primary responses, three types of derived behavior parameters were obtained, including 1) perching time ratio (**PTR**) – proportion of perching time for a given period (i.e., light, dim, dark period, or entire day), %; 2) perching frequency (**PF**) – perch visit per hour for a given period (i.e., light, dim, dark period, or entire day), times/bird-h; and 3) perching bird proportion (**PBP**) – proportion of simultaneously perching birds relative to the group total during the dark period, %. In this study, birds were not individually identified; thus all behavior variables were presented as group averages.

2.4. Statistical Analysis

All statistical analyses of the perching behavior variables were performed using SAS Studio 3.5 (SAS Institute, Inc., Cary, NC, USA). The group of hens was considered experimental unit, leading to six replicates in the study. Proportion values of daily PT, daily PV, and dark-period PBN for the respective perch were first analyzed to assess preference between round and hexagon perches. Then data of all the behavior variables for both perch types were pooled to characterize temporal perching behaviors of the young hens. All analyses were implemented with generalized linear mixed models using GLIMMIX procedure. A Gaussian distribution was specified for the analyses of PF, whereas a beta distribution was specified for all the proportion data. Evaluation of the perch preference was accomplished by testing the null hypothesis that the proportion of daily PT, daily PV, or dark-period PBN on respective perch equaled 0.5. Data at 1 WPE were excluded from the analysis of perch preference due to the infrequent perch use (acclimatization). In addition, Tukey-Kramer tests were used for pairwise comparisons among different WPEs for all the behavior variables. Effects were considered significant at $P < 0.05$. Normality and homogeneity of variance of data were examined by residual diagnostics. Unless otherwise specified, data are presented as least squares means along with the standard error of the mean (**SE**).

3. Results

3.1. Preference of Laying Hens between Round and Hexagon Perches

The laying hens showed no preference for round *vs*. hexagon perches based on daily perching time (PT), daily perch visit (PV), and dark-period perching bird number (PBN). Specifically, the hens showed a daily PT of 50.1 ± 4.3% for the round perch and 49.9 ± 4.3% for the hexagon perch ($P = 0.98$), daily PV of 49.7 ± 1.0% (round) and 50.3 ± 1.0% (hexagon) ($P = 0.74$), and dark-period PBN of 47.7 ± 4.1% (round) and 52.3 ± 4.1% (hexagon) ($P = 0.59$). Because the birds showed no preference for perch shape, the response variables were pooled in the presentation and analysis of diurnal and temporal perching behaviors in the following sections.

3.2. Diurnal and Temporal Perching Behavior of Laying Hens

3.2.1. Diurnal Perching Pattern

A representative diurnal perching pattern of laying hens at 9 WPE (25 WOA) is illustrated in Figure 3. Six out of the seven hens perched simultaneously during the dark period, with all perching hens continuously roosting on perches throughout the dark period (23:15 h - 6:45 h, Fig. 3a). In contrast, only one, two, or three hens (occasionally, four or five hens) perched simultaneously during the light period, with hens jumping on and off the perches frequently throughout the light period (7:00 h - 23:00 h, Fig. 3a). During the transition of light to dark period (started at 23:00 h until total dark at 23:15 h), hens jumped on and off the perches frequently (Fig. 3b). Immediately following lights off, hens' activity ceased. During the transition of dark to light period (started at 6:45 h until full light at 7:00 h), hens got off the perches in the early part (first 2-3 min) (Fig. 3c).

3.2.2. Temporal Perching Time Ratio and Perch Frequency

Perching time ratio (PTR) and Perching frequency (PF) of laying hens at 1-9 WPE for each period are shown in Table 4. PTR for all the periods increased over time during the 9-week period of perch exposure ($P < 0.01$). PF for all the periods also increased over time ($P < 0.01$), with the exception that the PF during the dark period was consistently low ($P = 0.75$). In general, it took about 6-7 WPE for the young hens to show consistent perching behaviors (i.e., no significant difference in perching behavior from any of the following WPEs). Specifically, PTR for the dark period approached stabilization at 6 WPE ($P = 0.74$-1.00), and PTR for the light period approached stabilization at 7 WPE ($P = 0.53$-1.00), whereas the rest variables approached stabilization at 2-3 WPE.

3.2.3. Temporal Proportion of Hens Perching during the Dark Period

Perching bird proportion (PBP) of laying hens during the dark period at 1-9 WPE is shown in Figure 4. Dark-period PBP increased over time during the 9-week period of perch exposure ($P < 0.01$). Specifically, from 1 to 9 WPE, dark-period PBP averaged 34.8 ± 7.4%, 49.7 ± 4.8%, 58.2 ± 4.7%, 67.4 ± 2.3%, 69.9 ± 1.9%, 73.3 ± 1.5%, 75.6 ± 1.5%, 76.0 ± 1.6%, and 78.7 ± 1.9%, respectively. Dark-period PBP approached stabilization at 5 WPE ($P = 0.06$-0.89).

4. Discussion

According to our literature review, this study is the first effort to assess preference between round and hexagon perches and to continuously monitor and characterize temporal perching behaviors of young laying hens (17-25 WOA) after transfer to enriched colony housing from a cage-rearing pullet house (no perches). By taking advantage of the automated sensor-based perching monitoring system, perch utilization by the hens was continuously recorded at 1-9 WPE. The young hens without prior perching experience were found to use the perches increasingly with WPE. It took them up to 5-7 weeks to get used to or maximize the use of the perches. These hens did not show preference between the round perch and the hexagon perch.

4.1. Perch-Shape Preference of Laying Hens

Limited published studies existed regarding perching behavior and preference of laying hens subjected to different shapes of perches (Struelens and Tuyttens, 2009); and no information was found about behavioral responses of hens to hexagon perch in the literature. In the current study, laying hens showed no preference between the round and hexagon perches with regards to perching time, perch visit, and the number of perching birds on the respective perch. This outcome coincides with the finding of an earlier study by Lambe and Scott (1998) who reported that hens showed no difference in time spent on round *vs.* rectangular perches or single *vs.* double wooden perches. Likewise, an earlier study found that hens showed no perch size preference (1.5, 3.0, 4.5, 6.0, 7.5, 9.0, or 10.5 cm perch width) as judged by the perch use at night (Struelens et al., 2009). In contrast, several earlier studies found certain perch features being preferred by laying hens. For instance, Struelens et al. (2008) found hens like to roost on high perches at night when given the opportunity to do so. Appleby et al. (1992) found that a perch with a slightly rough surface was preferred by hens. Studies have found detrimental impacts of using perches, including keel bone deformities, foot disorders and bone fractures (Appleby et al., 1993; Tauson and Abrahamsson, 1994; Donaldson et al., 2012). To overcome these detriments, Scholz et al. (2014) and Stratmann et al. (2015) investigated soft-surface perches that were shown to provide the most stable footing on perching and reduce the risk of perch-related keel bone injury. The benefit of the soft-surface perches arose from the compressible materials absorbing kinetic energy during collisions and increasing the spread of pressure on the keel bone during perching. Future research may focus on improving the perch surface materials as opposed to perch shape.

4.2. Diurnal and Temporal Perching Behavior of Laying Hens

The diurnal perching patterns of laying hens observed in the current study agreed well with observations in earlier studies. The times when birds went up to perches in the evening and came down from perches in the morning were associated with the changes in light intensity (Yeates, 1963; Lambe and Scott, 1998; Olsson and Keeling, 2000; Struelens et al., 2008). These cited studies found that much more movement of the hens on and off perches during the light period as compared to the dark period and hens frequently became very active, jumping on and off perches as dark period approached. In addition, more than 90% of the hens were on perch within 10 min. In comparison, little information was reported regarding when and how birds got off the perch upon lights-on in the morning. In the current study, the majority of the hens were observed to get off the perches at the beginning of the dawn-transition period, which could be attributed to the intrinsic motivation of feeding and drinking of the birds after a relatively long period of resting/sleeping in the dark period.

Laying hens are highly motivated to perch at night (Weeks and Nicol, 2006). Studies have shown that perching-experienced birds in cages/pens roosted on perches to a very high degree (80-100%) after dark when perch space was sufficient (Tauson, 1984; Appleby et al., 1993; Tauson and Abrahamsson, 1994;

Wall and Tauson, 2007; Pickel et al., 2010). In the current study, on average 78.7% of the hens perched during the dark period at 9 WPE, which was consistent with the findings from the cited studies. Although the novice young hens (without prior perching experience) increased perching at night in the current study, some birds always remained on the floor during the dark period. This result paralleled the findings of several earlier studies. A large variation in time spent perching among individual birds at night (dark period) has been reported (Lambe and Scott, 1998) and some individual birds did not use the perches at all (Appleby and Hughes, 1990; Appleby et al., 1992; Lambe and Scott, 1998). Moreover, Appleby et al. (1992) found that the birds roosted on the floor tended to be the same individuals. The perch monitoring system utilized in the current study was not designed or intended to determine or discern perching behavior of individual birds. The birds roosting on the floor at night in the current study and the cited studies might have been attributed to the dominance hierarchy among group-housed hens. Dominance hierarchy influences spatial distribution of birds on perches (Lill, 1968), and the subdominant birds may not be allowed to use perch at night. Floor-roosting may also be associated with the antipredator behavior of chickens (Hu et al., 2016). Hu et al. (2016) found that the degree of vigilance behavior of hens has decreased during domestication, which might have contributed to the reduced proportion of hens perching at night. However, this is not always the case. Laying hens in commercial aviary were found to prefer rooting in the highest enclosure levels, leading to crowing on upper perches and ledges while perch space remained available on lower levels (Brendler and Schrader, 2016; Campbell et al., 2016).

Perch utilization during the light period observed in this study (10% of the light period at 9 WPE) was much lower than that reported in earlier studies (ranging between 25-50%). Tauson (1984) reported hens perching 25-50% of the daytime, while others reported hens spending about 25% of the daytime on perches (Appleby et al., 1992; Valkonen et al., 2009). Yet, some studies reported that hens spent about 32-38% of the daytime on perches (Newberry et al., 2001; Barnett et al., 2009). More studies reported that hens spent about 47-51% of the daytime on perches (Appleby & Hughes, 1990; Struelens et al., 2009). For all these cited studies, the results were derived from manual observations, i.e., live observation or off-site observation of recorded videos, which covered limited parts of the light period (daytime) at certain ages (e.g., a couple of hours a day at each age). As a result, these results might not be inclusive enough to represent the actual daily usage, especially considering variations observed in perching behavior through the light period. When comparing the results in the current study with our earlier study that investigated perching behavior of hens as affected by horizontal space between parallel perches using the same automated perching monitoring system (Liu and Xin, 2017), hens in the current study spent much lower proportion of the daytime on perches (i.e., 10% *vs.* 21%) but had much higher perching frequency (8.0 *vs.* 1.9 times/bird-h). It should be noted that there were three distinct differences between the earlier study and the current study that may have influenced the perch utilization. First, hens in the earlier study were chosen from a commercial aviary house and were experienced in using perches, whereas pullets used in the current study came from pullet-rearing cages and had no prior perching experience. Second, birds in the earlier study were older (68 WOA), whereas birds in the current study were much younger (17-25 WOA) that were presumably more energetic. Third, stocking density was higher in the earlier study than in the current study (11 hens/m^2 *vs.* 5 hens/m^2).

In terms of the temporal perching behavior, the results of the current study agreed well with the findings of earlier studies. In general, perch use increased significantly with WPE within the first 1-2 weeks after the birds were introduced to perches. Hens tended to use the perch consistently throughout the subsequent WPE. Newberry et al. (2001) found that daytime perch utilization varied with bird age, with the total proportion of birds perching increasing from 27.5% in the youngest birds (3-6 WOA) to 47.4% when the birds were at 12-15 WOA. Faure and Jones (1982a) found that White Leghorn birds without perching experience took two days to get used to using perch when the perch was first introduced at 17 WOA. In addition, Duncan et al. (1992) found that overall time spent in daytime perching was relatively consistent over the laying cycle. In contrast, Faure and Jones (1982b) found when providing perches to 15-week old pullets, repeated perch exposure increased the time spent on perches in daytime by the perching birds but did not affect the non-perching birds. However, individual variance of perch use was not determined in the current study. Therefore, we were unable to tell perching or lack thereof by individual birds nor could we determine perching variance among the individual birds.

5. Conclusion

This study revealed that Lohmann white laying hens showed no preference between the round and hexagon perches during a 9-week perch exposure after transfer into an enriched colony setting. Young laying hens without prior perching experience showed increasing use of perches over time and it took them up to five to seven weeks of perch exposure to show consistent perching behaviors in the enriched colony setting. This study also found that laying hens spent about 10% of daytime on the perches and over 75% of hens perched at night after they approached consistent perching behaviors.

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Table Captions

Table 1. Light schedule for laying hens used in the study

Table 2. Perch arrangements in the study

Table 3. Determination of number of birds on each weighing perch based on the threshold values

Table 4. Perching time ratio and perching frequency for light, dim, dark periods and the entire day during a 9-week perch exposure of laying hens

Figure Captions

Figure 1. A schematic representation of the experimental pens. (a) side view, (b) top view.

Figure 2. An automated perching monitoring system. (a) weighing perches, (b) an example of linear response of loadcell scale output to load weight on the weighing perch, (c) load weight of perching hens on each perch, (d) number of perching birds on each perch.

Figure 3. Diurnal perching pattern of hens at nine weeks of perch exposure: (a) diurnal pattern, (b) during dusk transition period, and (c) during dawn transition period.

Figure 4. Proportion of birds perching during the dark period. Data are presented as least squares means ± SE. Values with different superscripts are significantly different at $P < 0.05$.

Table 1. Light schedule for laying hens used in the study

WOA [1]	WPE [2]	Dawn (1-2 lux)	Light (20 lux)	Dusk (1-2 lux)	Dark (0 lux)	Light hour (h/day)
17	1	08:45-09:00	09:00-21:00	21:00-21:15	21:15-08:45	12
18	2	08:15-08:30	08:30-21:30	21:30-21:45	21:45-08:15	13
19	3	07:45-08:00	08:00-22:00	22:00-22:15	22:15-07:45	14
20	4	07:30-07:45	07:45-22:15	22:15-22:30	22:30-07:30	14.5
21	5	07:15-07:30	07:30-22:30	22:30-22:45	22:45-07:15	15
22	6	07:15-07:30	07:30-22:45	22:45-23:00	23:00-07:15	15.25
23	7	07:00-07:15	07:15-22:45	22:45-23:00	23:00-07:00	15.5
24	8	07:00-07:15	07:15-23:00	23:00-23:15	23:15-07:00	15.75
25	9	06:45-07:00	07:00-23:00	23:00-23:15	23:15-06:45	16

[1] WOA = weeks of age
[2] WPE = week(s) of perch exposure

Table 2. Perch arrangements in the study

WOA [1]	WPE [2]	Batch 1						Batch 2					
		P1 [3]		P2		P3		P1		P2		P3	
		L [4]	R	L	R	L	R	L	R	L	R	L	R
17	1	C [5]	H	H	C	H	C	H	C	C	H	C	H
18	2	C	H	H	C	H	C	H	C	C	H	C	H
19	3	H	C	C	H	C	H	C	H	H	C	H	C
20	4	H	C	C	H	H	C	C	H	H	C	C	H
21	5	C	H	H	C	C	H	H	C	C	H	H	C
22	6	C	H	C	H	H	C	H	C	H	C	C	H
23	7	H	C	C	H	H	C	C	H	H	C	C	H
24	8	C	H	H	C	C	H	H	C	C	H	H	C
25	9	H	C	H	C	C	H	C	H	C	H	H	C

[1] WOA = weeks of age
[2] WPE = week(s) of perch exposure
[3] P1, P2, and P3: testing pen 1, 2, and 3, respectively
[4] L, R: left and right side of the testing pen, respectively
[5] C, H: circular (round) and hexagon perch, respectively

Table 3. Determination of number of birds on each weighing perch based on the threshold values

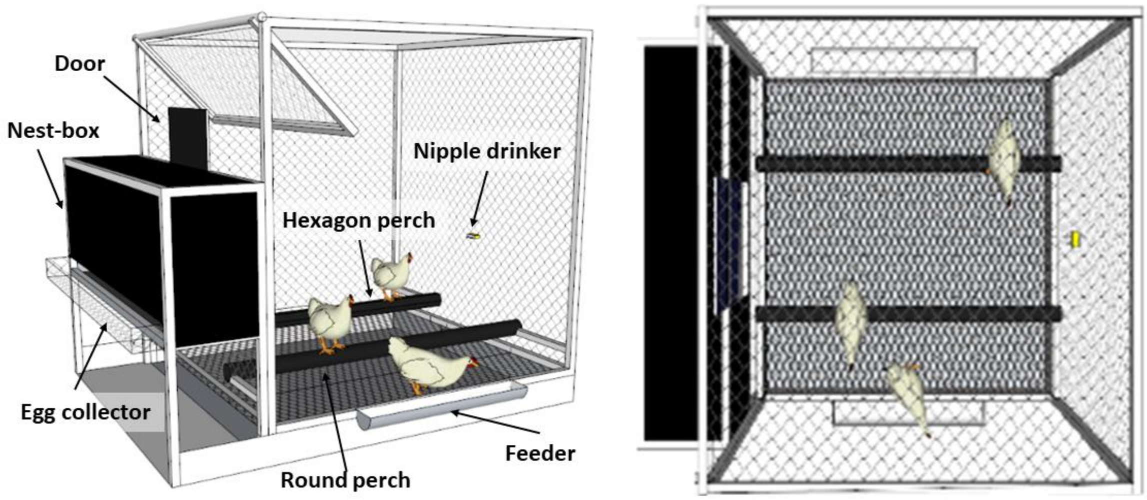
PBN [1]	Threshold values for load weight [4] (g)	
	Period 1 [2]	Period 2 [3]
1	1000 - 1550	1150 - 1750
2	2200 - 2900	2500 - 3300
3	3400 - 4300	3850 - 4850
4	4600 - 5600	5200 - 6400
5	5800 - 6950	6500 - 7900
6	7050 - 8250	7950 - 9400
7	8250 - 9600	9400 - 11000

[1] PBN = perching bird number, i.e., number of simultaneously perching birds.
[2] Birds at 17-19 weeks of age (WOA) with body weight ranging from 1200 g to 1350 g.
[3] Birds at 20-25 WOA with body weight ranging from 1350 g to 1550 g.
[4] Threshold values for determining the number of simultaneously perching birds on each weighing perch. For example, if the measurement from the weighing perch shows a load weight of 1300 g, then there is one bird perching on the weighing perch.

Table 4. Perching time ratio and perching frequency for light, dim, dark periods and the entire day during a 9-week perch exposure of laying hens [1]

WPE [2]	PTR [3] (%)				PF [4] (number/bird-h)			
	light	dim	dark	daily	light	dim	dark	daily
1	2.8 ± 0.7[c]	6.3 ± 1.8[b]	26.2 ± 6.9[d]	14.6 ± 3.2[b]	4.9 ± 0.5[b]	10.5 ± 2.0[b]	0.1 ± 0.0	2.6 ± 0.3[c]
2	5.8 ± 1.9[bc]	12.5 ± 3.1[ab]	39.4 ± 6.7[d]	23.7 ± 3.8[ab]	6.8 ± 0.5[ab]	15.4 ± 1.0[ab]	0.2 ± 0.0	3.8 ± 0.3[bc]
3	5.8 ± 0.9[bc]	12.3 ± 2.3[ab]	50.6 ± 4.5[cd]	25.5 ± 2.7[ab]	7.6 ± 0.6[a]	16.8 ± 1.6[ab]	0.1 ± 0.0	4.5 ± 0.4[ab]
4	5.4 ± 0.4[bc]	15.0 ± 1.4[ab]	62.1 ± 2.1[bc]	27.6 ± 1.4[a]	8.3 ± 0.3[a]	18.9 ± 0.8[a]	0.2 ± 0.0	5.3 ± 0.2[a]
5	6.4 ± 0.4[b]	16.5 ± 1.2[a]	65.0 ± 1.6[bc]	28.1 ± 0.8[a]	8.4 ± 0.4[a]	18.3 ± 1.0[a]	0.1 ± 0.0	5.5 ± 0.2[a]
6	6.3 ± 0.4[b]	19.9 ± 2.4[a]	70.4 ± 1.7[ab]	29.0 ± 0.8[a]	8.4 ± 04[a]	17.7 ± 0.8[a]	0.1 ± 0.0	5.6 ± 0.2[a]
7	7.3 ± 0.7[ab]	18.1 ± 2.1[a]	72.8 ± 1.5[a]	29.5 ± 0.8[a]	8.6 ± 0.5[a]	20.5 ± 1.4[a]	0.1 ± 0.0	5.9 ± 0.4[a]
8	9.4 ± 0.7[a]	19.9 ± 2.0[a]	73.3 ± 1.6[a]	30.3 ± 0.8[a]	8.4 ± 0.3[a]	20.4 ± 0.8[a]	0.1 ± 0.0	5.9 ± 0.2[a]
9	9.7 ± 1.1[a]	19.8 ± 1.3[a]	75.5 ± 1.6[a]	30.7 ± 1.3[a]	8.0 ± 0.5[a]	22.2 ± 0.9[a]	0.2 ± 0.0	5.7 ± 0.4[a]

[1] Data are least squares means ± SE. Within each column, values with different superscripts are significantly different at $P < 0.05$.
[2] WPE = weeks of perch exposure.
[3] PTR = perching time ratio – proportion of perching time for a given period, %.
[4] PF = perching frequency – perch visit per hour for a given period, number/bird-h.



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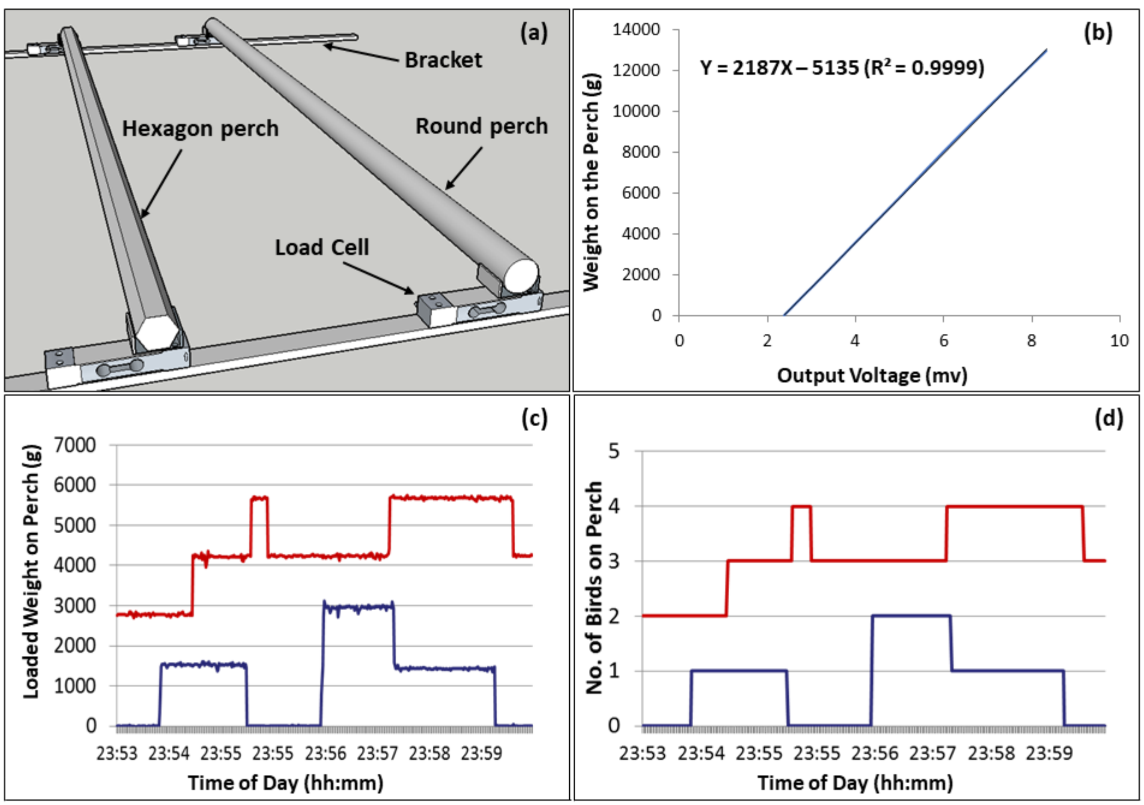

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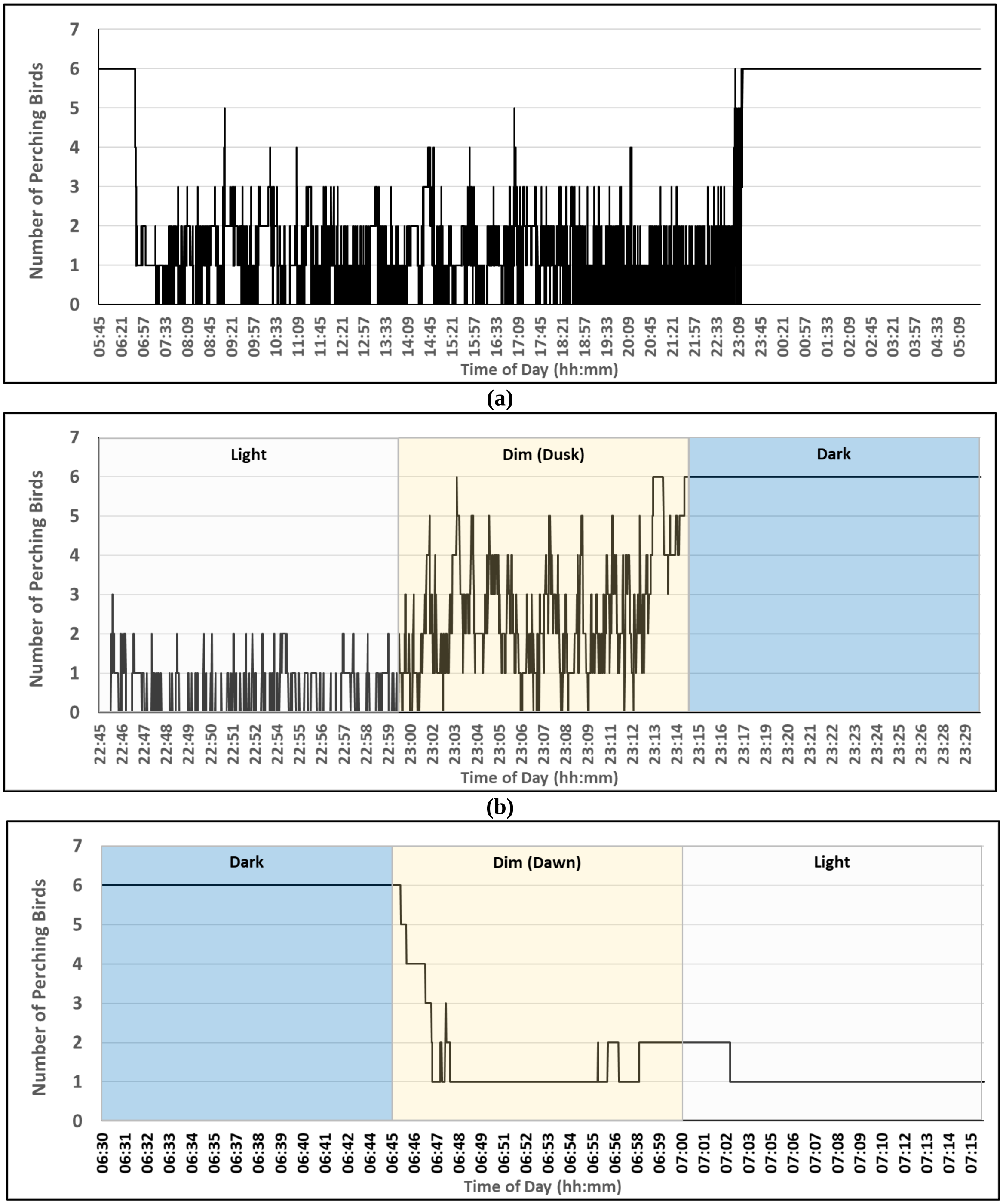

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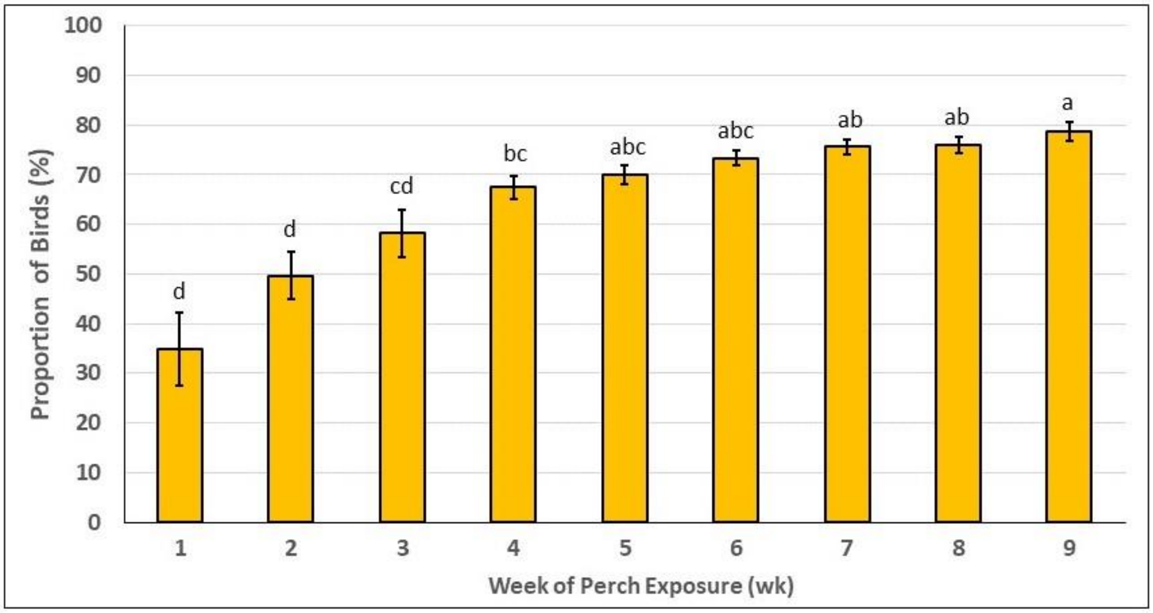

Figure 4. Proportion of birds perching during the dark period. Data are presented as least squares means ± SE. Values with different superscripts are significantly different at $P < 0.05$.