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Nesting Behaviors and Egg Production Pattern of Laying Hens in Enriched Colony Housing

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ABSTRACT. *Alternative housing systems for laying hens are increasingly adopted by the US egg industry. However, information still lacks with regards to behavioral and production responses of the hens to resources allocation in such alternative housing systems. The objective of this study was to characterize the nesting behavior and the location of eggs laid in an enriched colony housing (ECH) system. The experiment was conducted in laboratory scale, involving an ECH commercial module with the capacity of 60 hens per colony. The nesting behaviors were evaluated using an ultra-high frequency radio-frequency identification (UHF RFID) system that consists of four antennas located inside the nest box, one reader, and 60 individual transponders (one per bird) attached to the hen legs. The following behaviors were quantified: time spent in the nest box, maximum number of hen occupancy, oviposition time and place, daily number of visits to the nest box, and number of visits per egg laid in the nest box. Preliminary results to date show that laying hens in the ECH spent on average 56 (±5) (mean ±SE) minutes inside nest box during laying or exploring visits and made an average of 17.8 (±1.4) visits per day. The number of visits per egg laid in the nest box was 21.3 (±0.6). The maximum occupancy averaged 11.0 (±0.5) birds, which occurred within 5-6 hours after the light was turned on. Most of the daily eggs (92.7 ±1.5%) were laid in the nest box, while 4.4 (±1.1) % eggs were laid in the scratch area, and 2.9 (±0.4) % in the perches area. Data collection and analysis is continuing. Information derived from this study is expected to provide insight into better design of nest box for laying hens.*

Keywords. *Animal welfare, egg production, RFID, alternative hen housing, individual behaviors*

Introduction

Transitioning of egg production systems from conventional cage to alternative housing (e.g., enriched colony, aviary cage-free) has been occurring and is anticipated to continue in various parts of the world, especially in Europe and the United States, toward meeting animal welfare requirements or legislation (Mench, 2008). At the same time, numerous questions about the design and operation remain to be addressed regarding the relatively new alternative hen-housing systems.

Animal welfare in production system environment has been evaluated by researchers (e.g., Alrøe et al., 2001; Te Velde et al., 2002; Bracke et al., 2006; Shao and Xin 2008; Gates and Xin 2008; Gocsik et al., 2015), and behavioral analyses are used to assess alterations in feeding and nesting patterns. The use of automatic measurement systems in livestock facilities has provided information to better understand animal well-being. However, the traditional method (e.g. visual analysis) used to assess animal behaviors is time-consuming and daunting for addressing individual behavioral characteristics.

Radio Frequency Identification (RFID) system has been used to study animal behaviors (Samad et al., 2010; Voulodimos et al., 2010; Brown-Brandl and Eigenberg, 2011; Maselyne et al., 2014a; Maselyne et al., 2014b; Cappai et al., 2014; Sales et al., 2015). It consists of a reader with a decoder to interpret the acquired data, scanning antenna and pre-programmed transponders. The RFID transponders can be active, when the power source is included, or passive, when the transponder is powered by the antenna (Sales et al., 2015). In animal behavior studies, the transponders are usually attached externally to animal's ear, neck, or leg.

Siegford et al. (2016) reviewed several tracking systems used to describe individual laying hens behaviors, addressing the strengths and weaknesses of each as well as the environment or conditions suitable for using them. Nakarmi et al. (2014) used image processing technique and passive RFID system to automate tracking and analyze laying hen behaviors. Recently, researchers have been interested in assessing animal welfare in order to provide insight into possible animal damage (Casey-Trott and Widowski, 2016). Although there are some studies relating the use of RFID system to evaluate animal behaviors, there is a lack of information regarding the nesting behaviors of laying hens in enriched colony housing (ECH).

Therefore, the aim of this work was to assess laying hen nesting behaviors using an Ultra High Frequency (UHF) RFID system followed by validation with video analysis. The behaviors quantified included time spent in the nest box, maximum occupancy, oviposition time and place, number of visits, and number of visits per eggs laid in the nest box.

Methodology

Sixty laying hens (Dekalb White, 50 weeks of age) were procured from a commercial farm with cage-free housing and were assigned to an ECH module (Big Dutchman, Vechta, Germany) in our research laboratory at Iowa State University. The ECH module (Figure 1) featured an average space allocation of 976 cm^2/bird of floor area, nest box (85.4 cm^2/bird), scratch area, perches, nipple drinkers, manure belt, along with room heating and humidification. After the hens had been fully acclimated to the housing environment, the behavioral data were collected for five consecutive days.

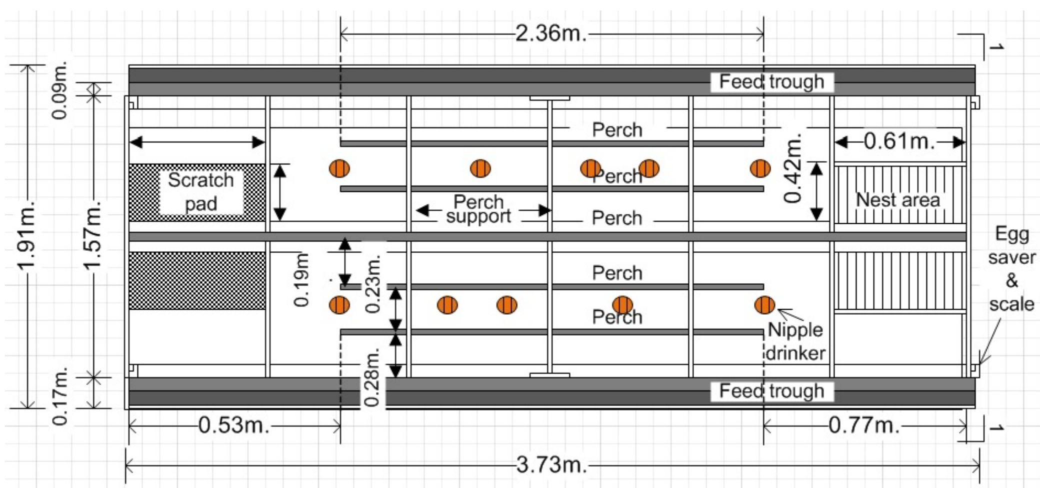


Figure 1. Top-view schematic of the enriched colony module used in the experiment.

The nesting behaviors were evaluated using UHF RFID system (ThingMagic Mercury M6 - TransTech Systems, Aurora, OR) that consisted of four antennas located on both sides of the nest box, one reader, and 60 individual passive transponders (one per bird). The transponder was attached to hen's leg (Figure 2); and from the contact of transponders with the antennas, the presence of birds in the next box was registered and stored in a computer. The number of eggs laid in the nest box was recorded via two load cell scales (Rice Lake Weighing Systems, Rice Lake, WI) – one on each side. Eggs laid outside the nest box were counted manually once a day. A more detailed description of the lab, ECH module and RFID system setup and its operational characteristics can be found in the paper by Li et al. (2016).

Two video cameras (IP Pro 3 Megapixel Bullet, DSS-BFR3MP, Backstreet Surveillance, Salt Lake City, UT) were installed on the ceiling and used to record the hen behaviors at 0.5 frame per second (fps). The two cameras were wired to an 8-port power-over-Ethernet (POE-108, Backstreet Surveillance, Salt Lake City, UT) injector. The video files were stored in 8-terabyte storage (two hard drives) of a NVR system (DSS-NVR5816, Backstreet Surveillance, Salt Lake City, UT).

Data were processed by a developed algorithm to achieve the registration table (table which shows if in a given time the transponders were registered). The results obtained from the algorithm in terms of the number of birds simultaneously in the nest box was compared against the traditional method (camera system) with 78 different time points.

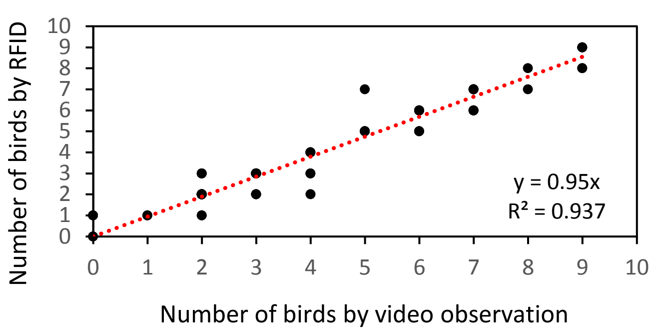
Figure 2. The RFID transponder (left) and its attachment to a hen's leg (right).

The processed data were analyzed statistically via JMP (Version Pro 12, SAS Institute, Cary, NC). A linear regression from camera and RFID observations was performed, and the pairwise difference was summarized. For the observations from behavioral data, the ANOVA procedure was executed, applying the means comparisons using Tukey-Kramer HSD (honest significant difference) at a level of 5% of significance. The following behaviors were quantified: time spent in nest box, maximum occupancy, oviposition time and place, number of visits to next box, and average number of visits per egg laid in the nest box. All the values of the response variables are presented as means ± standard error (SE) in this paper.

Results and Discussion

Validation of RFID Readings with Video Observations

The results provided by the RFID system were compared against the video, in which 78 random time points were selected. The differences between the number of birds registered by the camera and RFID systems were calculated, and the histogram of the differences was generated to assess the accuracy of the RFID system. In addition, a regression analysis was performed to measure the relationship between the results from the two measurement systems (Figure 3).



Summary statistics of difference between video observation and RFID measurement, in number of birds.

Mean	0.167
Median	0
Std Dev	0.633
Std Err Mean	0.072
Upper 99% Mean	0.356
Lower 99% Mean	-0.023
N	78

Figure 3. Regression of number of hens in the next box between video observation and RFID system and summary statistics of the difference.

The difference in number of hens detected with the two systems (Camera – RFID) had a mean of 0.167, median of 0, and 99% confidence interval of -0.023 to 0.356. Hence, we can conclude that there was no statistical difference in the number of birds registered between the RFID and camera systems at a significance probability level of 1%. The slope from the regression model was 0.95 while the coefficient of determination was 0.937, reflecting a good relationship between the two measurement systems.

The accuracy of the RFID system was 91.4 (±1.7) %, which infers that the RFID system may be adopted as a reasonable alternate or supplement to the camera system. The benefits of assessing behaviors with the RFID system include reduced time from data analysis, assessment of individual hen behavior, and extended period of monitoring and quantification.

In a choice-test study, Sales et al. (2015), using a passive low-frequency RFID system, presented detection rates on bird presence (mean ± SD) of 91.0% ± 2.6% for trials with groups of birds, and 85.8% ± 8.0% for trials with individual birds when measuring total compartment occupancy. When measuring frequency of compartment entries, the detection rates were 62.6% ± 11.2% for trials with groups, and 51.3% ± 18.4% for trials with individuals.

Time spent in nest box

No significant difference was detected in the time spent in the nest box by the hens among the monitored days (*p*=0.1569). Therefore, data from the five days of monitoring were pooled to analyze variability in the time spent among the individual birds. The average time that each bird spent in the nest box per day was determined and is shown in Figure 4.

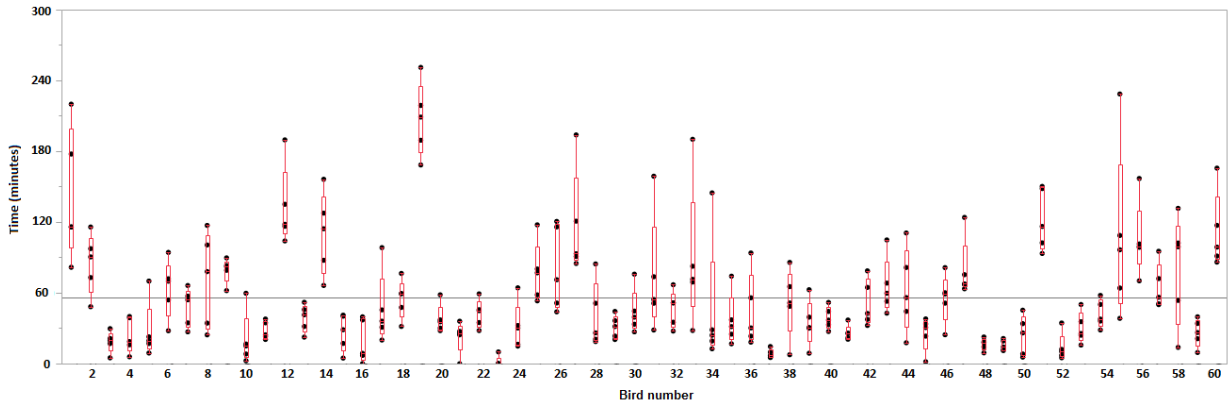


Figure 4. Daily time spent per bird in the nest box of the enriched colony housing. The horizontal line represents the overall mean. The scatter data points represent the daily time that each bird spent in the nest box for each of the five days; the upper and lower whiskers represent values outside the middle 50% that fall within the inter-quartile range.

As indicated by the data in Figure 4, the hens displayed considerable variations in their daily usage of the nest box. The variability was highly significant (*p* <0.0001), with the mean time spent being 56 (± 5) minutes per day. This result parallels the report by Stampfli et al. (2011) who found that birds can spend 10 to 90 minutes when laying an egg.

Daily frequency of nest box visits

All exploring and laying visits to the nest box by the hens were registered, for which the daily number of visits by each bird could be quantified for all 60 hens. The results are presented in Figure 5.

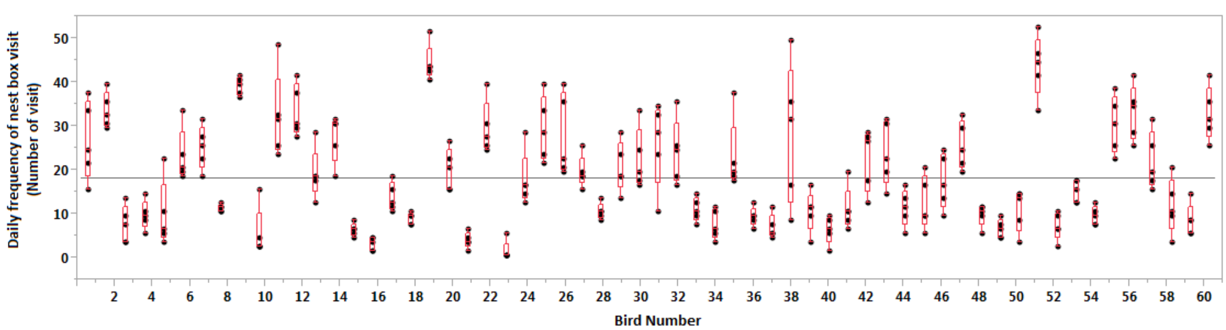


Figure 5. Registered visits to the nest box by each hen in the enriched colony housing. The scatter data points represent the daily number of nest box visits per bird for each of the five days; the upper and lower whiskers represent values outside the middle 50% that fall within the inter-quartile range.

There was no statistical evidence that the average daily number of visits to the nest box changed among the five days of monitoring (*p* = 0.8572). However, highly significant differences in daily number of visits were detected among the hens (*p* <0.0001), with an overall mean of 17.8 (± 1.4) visits per day. The number of visit per egg laid in nest box was 21.3 (±0.6). With the current setup of the housing and instrumentation systems, it is impossible to quantify hen-specific number of visits per egg laid.

Although it was not expected that birds would keep visiting the nest box after having laid the eggs, this finding agreed with that by Buchwalder and Frohlich (2011) who found a high number of nest visit per egg (40.3±11.4). In addition, Ringgnberg et al. (2014) found in their experiment that the number of visits per egg laid was 34.9±3.7. The revisit can be explained as the exploratory behavior of the hens (Wood-Gush and Vestergaard, 1989), or an indication that the enrichments inside the colony were not enough to keep them attracted.

Maximum occupancy in the nest box and oviposition time

Occupancy of the next box changed with time throughout the day. The maximum occupancy, averaging 11 (± 0.5) birds, took place between 7:30 and 10:30 h, i.e., within 5-6 hours after the light came on at 5:00 h. After this peak time, the frequency of bird visiting the next box decreased and maintained at low levels until 21:30 h (Figure 6).

It was observed that most of the eggs were laid in the nest box between 7:30 and 11:30 h, which coincided with the period of maximum nest box occupancy. Lentfer et al. (2011) reported that the main laying period for hens in commercial aviary systems was 1 to 4 hours after lights were turned on.

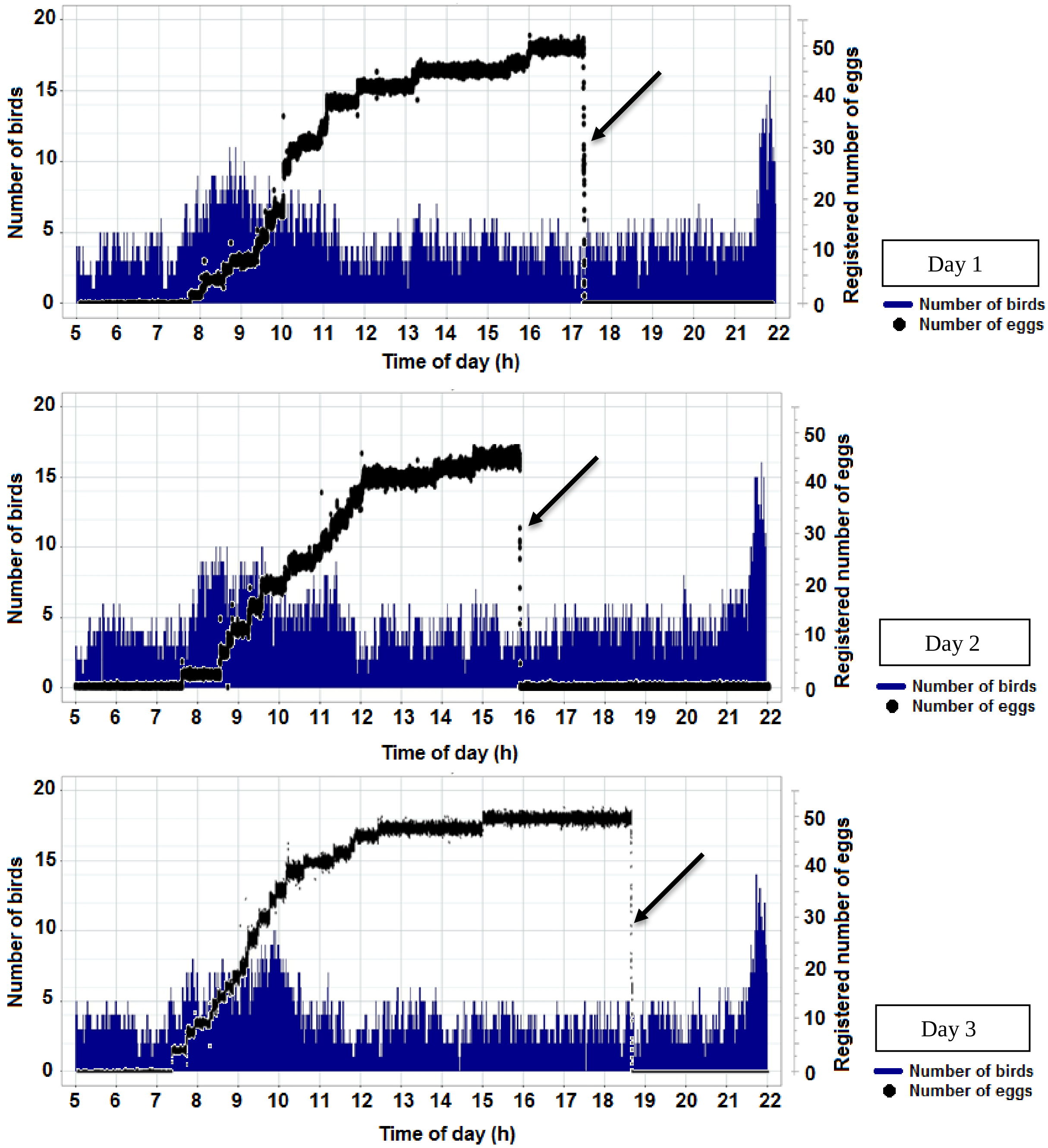


Figure 6. Examples of diurnal profile of nest box occupancy by the laying hens and registered number of eggs in egg collector (unfiltered raw data) in an enriched colony housing module (The arrow indicates the moment when eggs were removed out of the egg collector).

The concentration of hens in the nest box during the peak time may be explained by the phenomenon of gregarious nesting, also known as the preference for occupied nests (Appleby et al., 1984; Riber, 2010). In addition, Ringgenberg et al. (2014) found that laying hens preferred small group nests (7 birds max. occupancy) over larger group nests (9 birds in max. occupancy), attributing this behavior to the sense of protection.

Most of the daily eggs 92.7 (±1.5)% were laid in the nest box, while 4.4 (±1.1)% eggs were laid in the scratch area, and 2.9 (±0.4)% in the perches area. Hunniford et al. (2014) found similar results in small enriched cages, where 91.7% of the total eggs was laid in the nest box, 7.2% in the scratch area, and 1.1% in the perches area.

Comparing this egg-laying pattern with the individual time spent in the nest box, it was observed that a few birds did not visit the nest box on some days. This behavior could be related to social factors such as presence of dominant hens (Rietveld-Piepers et al., 1985), lack of interest in delaying oviposition to a less competitive time (Reynard an Savory, 1999), or specific preference from the scratch and perches areas over the nest box. Hunniford and Widowski (2016) reported that the rearing environment affects nest use, and individual laying hens might perceive nest sites differently.

The late peak can be explained by the fact that when the light started to go off at 21:45 h, the birds grouped in and around the nest box to rest during the dark period (Figure 7).

Figure 7. Nesting behavior of the hens in the enriched colony housing during light/day (left) and dark/night (right) periods. Red rectangular illustrates the next box.

From the nocturnal resting behavior, it was observed that most of birds preferred floor over the perches, which differed from the typical nocturnal behavior of hens in ECH. This outcome might have resulted from the fact that the hens used in this study were transferred from a cage-free house at 50 weeks of age, and the hens opted to keep their resting behavior. The room temperature was kept at 22-24ºC throughout the experiment period, which eliminates the cause for "huddling" of the hens due to lower-than-the-thermoneutral environmental temperature. Future trials will involve hens with ECH background.

Conclusions

An RFID system for assessing the nesting behaviors of laying hens was established and tested. The system was compared to the standard camera visualization method and the performance was quite favorable. Using the RFID system, the following nesting behaviors of individual laying hens in an enriched colony housing system were evaluated: time spent in the nest box, maximum occupancy, oviposition time and place, number of visits, and number of visits per eggs laid in the nest box. This new monitoring and quantification approach makes it possible to reduce labor requirement and assess behaviors of individual hens in a group setting for an extended period. The nesting behaviors for one set of laying hens have been characterized and presented in this paper, and more experiments are forthcoming. The resultant information will enable more efficient design, allocation of resources, and management of the hen-housing systems.

Acknowledgments

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