Effects of Cage Stocking Density on Feeding Behaviors of Group-Housed Laying Hens

Rachel N. Cook
Iowa State University

Hongwei Xin
Iowa State University, hxin@iastate.edu

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Abstract
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Keywords
Stocking density, laying hen, ingestion, animal welfare, poultry housing

Disciplines
Bioresource and Agricultural Engineering

Comments
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R. N. Cook, EIT, graduate research assistant1 H. Xin, Ph.D., professor2

ABSTRACT

This study quantifies the effects of cage stocking density (348, 387, 426, and 465 cm² per hen; 54, 60, 66, and 72 in² per hen) on the feeding behavior of the W-36 White Leghorn laying hen. Feeding behavior was characterized using a specialized instrumentation system and computational algorithm for each cage of six hens during four 24-hn trials. Statistics show no significant difference among the stocking densities under thermoneutral conditions for daily feed intake, hen-hours spent feeding per cage, average feeding time per hen, number of meals ingested per day per cage, meal size in g/meal-hen, average meal duration in sec/meal, ingestion rate in g/min-hen, and average number of hens feeding per meal. Other characteristics measured and reported include simultaneous feeding behaviors and diurnal feeding patterns. Quantification of specific responses such as feeding behavior to potential stressors (i.e. cage stocking density) may yield better housing design and management decisions based upon scientific data to improve animal welfare.

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INTRODUCTION

The issue of farm animal welfare or well-being continues to be a controversy both in the United States and abroad. Outcry from animal rights groups has focused the public eye on the animal production industry, resulting in the implementation of regulations meant to improve animal welfare with meager scientific evidence. The animal welfare debate has spawned governmental actions in Europe, and the issue has been brought to the fore in the US by recent minimum welfare standards imposed by private companies such as McDonald’s. International pressures have also increased US interest in these issues, such as the European Union’s request that animal welfare be included in future international trade talks (Estevez, 2003).

Cage floor space requirements for layers have been described as “the basis of more research than any other cage management factor” (North and Bell, 1990). So how do we measure animal welfare as it relates to the stocking density of caged layers in a truly scientific manner? One specific indicator of potential stress or welfare in poultry is feeding behavior. Continuous, automated measurement of feeding behavior has proven to be a useful tool for differentiating and quantifying the impacts of different environments or management practices on poultry while also proving to be less time consuming, tedious, costly, and error-prone than direct human observation or video analysis. Using this method allows an objective, quantitative, and non-invasive means of measuring an indicator of animal welfare.

The objectives of this research were a) to adapt and expand the feeding behavior measurement system and analytical algorithm used by Persyn et al. (2002, 2003, 2004) from the previous use for individual birds to also include group-housed birds, and b) to investigate the effects of cage stocking density on the feeding behavior of group-housed laying hens.

1 ASAE Student Member, Agricultural and Biosystems Engineering Department, Iowa State University, Ames, Iowa.
2 ASAE Member, Agricultural and Biosystems Engineering Department, Iowa State University, Ames, Iowa.
LITERATURE REVIEW

The guidelines established in 2000 by the United Egg Producers (UEP) and McDonald’s made a significant impact on the housing and husbandry of laying hens (Armstrong and Pajor, 2001). The UEP guidelines call for cage space per hen to increase from the US industry standard of 348 cm$^2$ (54 in$^2$) per bird to a range from 432 to 555 cm$^2$ (67 to 86 in$^2$) (UEP, 2000). McDonald’s Recommended Welfare Practices call for 465 cm$^2$ (72 in$^2$) of floor space per bird (McDonald’s, 2000). These new recommendations are similar to those of the European Union, which require 452 cm$^2$ (70 in$^2$) per hen (Hy-Line, 2000).

Xin and Ikeguchi (2001) developed a measurement system and analysis protocols to quantify feeding behavior of individual poultry in order to study effects of biophysical factors such as light, ration, noise, and thermal variables. Gates and Xin (2001) developed and tested algorithms for determining individual feeding statistics and pecking behavior from time-series recordings of feed weight. Puma et al. (2001) developed an instrumentation system to study dynamic feeding and drinking behaviors of individual birds. They used the system to investigate the effects of drinking water temperature on ingestion behavior and performance of laying hens subjected to heat challenge (Xin et al., 2002). Persyn et al. (2002, 2003, 2004) used the measurement system and computational algorithm developed by Xin and Ikeguchi (2001) to quantify feeding behaviors of pullets and laying hens with or without beak trimming.

MATERIALS AND METHODS

Equipment and Set-up

This study was conducted in environmentally controlled testing rooms (4.6L x 2.7W x 2.6H m; 15L x 9W x 8.5H ft) at the Livestock Environment and Animal Physiology (LEAP) Lab II at Iowa State University. Environmental conditions in the room were monitored and recorded every one minute using portable data loggers (HOBO H8 Pro Series RH/Temp. Onset Computer Corp., Pocasset, MA, USA). Conditions were maintained at an average temperature of 22.7°C (72.8°F) and relative humidity between 45-60%. Minimum ventilation rate was enabled in the rooms. Portable lamps were used to provide approximately 10 lux (1.0 fc) of light throughout the rooms for a 16-hour lighting period each day (5:30 AM to 9:30 PM). Room lighting values were checked periodically using a digital light meter (model DLM2, Cole Parmer Instrument Company, Vernon Hills, IL, USA).

The testing room held four cages with a stocking density of 348 cm$^2$ (54 in$^2$) per bird (SD54), 387 cm$^2$ (60 in$^2$) per bird (SD60), 426 cm$^2$ (66 in$^2$) per bird (SD66), or 465 cm$^2$ (72 in$^2$) per bird (SD72). The cages had the same depth of 46 cm (18 in) and the same height of 40.6 cm (16 in). The difference among the cages was the width, being 46, 51, 56, and 61 cm (18, 20, 22, 24 in), respectively, for the SD54, SD60, SD66, and SD72 cages. This variation in width caused the feeder space to vary between cages at 7.6, 8.4, 9.4, and 10.2 cm (3, 3.3, 3.7, and 4 in) per hen for the SD54, SD60, SD66, SD72 cages, respectively.

Each cage held six hens and was equipped with two nipple drinkers and a feed trough spanning the front width of the cage. Each feed trough rested across two electronic balances (2200 ± 0.1 g, model GX 2000, A&D Company Limited, Tokyo, Japan) placed in front of the cage and was secured with Velcro strips. The balances had automatic response adjustment to compensate for vibration and drafts, and had an analog output of 0-2.2 VDC corresponding to the weighing capacity. The eight balances were connected to an electronic data logger (model CR10X, Campbell Scientific Inc., Logan, UT, USA).

Six access openings were available for feeding across the front of each cage, and each of these was equipped with an infrared (IR) sensor pair to detect the presence of a hen eating through a particular opening. These sensor pairs allowed the recording of the number of hens feeding at any given time. These sensor pairs consisted of an IR light emitting diode (LED) (model OP165A, Optek Technology, Inc., Carrollton, TX, USA) below the opening and an IR phototransistor (model OP505A, Optek Technology, Inc., Carrollton, TX, USA) above the
opening. The 24 pairs of IR sensors were connected to the CR10X datalogger via a 32-channel multiplexer (model AM416, Campbell Scientific, Inc., Logan, UT, USA) and had an output between 0-2.5 VDC. Both balance data and IR sensor data were recorded every two seconds. The data were automatically downloaded to a computer every ten minutes via the datalogger’s associated PC208W software, and the files were retrieved and saved once every 24 hours.

One video camera (Panasonic wv-CP410) was mounted directly above each cage to monitor the feeding behavior for the purposes of bird monitoring outside the testing room and validating the data acquisition system and the computational algorithm. The images from the four cameras were recorded during the lighting hours using a time-lapse videocassette recorder (model AG-6730, Panasonic, set to 72 hr/tape recording mode) and were viewable on a color monitor simultaneously using a quad-system (model WJ-420, Panasonic). See Figure 1 for photos of the experimental setup.

![A](image1)
![B](image2)
![C](image3)
![D](image4)

**Figure 1.** Photo views of the experimental setup: testing room (A); close-up view of feeder access openings with IR sensor pairs above and below each opening (B); hens feeding through instrumented feeder openings (C); video display and recording system (D).

**Experimental Birds**

The experimental birds were W-36 white leghorn hens between 32-40 weeks of age and approximately 1.5 kg (3.3 lbs.) body weight at procurement that had been housed at 348 cm² (54 in²) per bird at the farm. The hens were acclimated to their new environment for at least four days before data collection began on a trial. The hens were checked and eggs were collected once each day during data collection. Feed troughs were refilled every other day with the same commercial diet the hens had been fed at the farm. The hens were housed in the testing room for 11-13 days, with the first three to seven days being an acclimation period. Four days of stabilized feeding behavior data were analyzed from each replicate.

**Analysis of Feeding Characteristics**

Feeding behaviors of the laying hens and the effects of stocking density were evaluated by an analysis protocol that was developed by adaptation from previous protocol used by Xin and Ikeguchi (2001) and Persyn, et al. (2002, 2003, 2004). The characterized feeding behaviors included average daily feed intake per hen, daily time spent feeding in hen-hours per cage and...
average hours per hen, number of meals per day, meal size, meal duration, ingestion rate, average number of hens feeding per meal, distribution of simultaneous feeding activity, and diurnal feeding patterns. To obtain these values, the start and stop time of each feeding event had to be determined as well as the recorded feeder weights at these moments. The feeder weight of each cage was spanned over two balances and the sum of their recorded values yielded the total feeder weight. A two-minute sample of feeding event signals is shown in Figure 2. The IR sensor signals were used to determine the presence of a hen feeding at a particular feeder opening. A high signal indicated the presence of a hen, with a high signal defined as any reading within 5% of the maximum reading for a particular sensor. Based on review of the video recordings, a hen fully obstructed the IR sensors to reach the feed trough, giving a full high reading during feeding. The readings that are in-between a full high or low signal seem to be a result of partial obstruction of the sensors during other activities, such as a hen entering or exiting a feeder opening, tail feathers protruding from the opening when a hen turns around, etc. A sample of IR sensor signals is shown in Figure 3.

![Figure 2. Two-minute sample of raw feeding event signals from the electronic balances indicating the dynamic feeder weight in grams.](image2)

![Figure 3. Sample of two raw infrared sensor signals used to determine the presence of a hen at a particular feeder opening.](image3)
Based on trial and error optimization, a threshold change in total feeder weight of 2 grams between two adjacent readings was chosen to signal a feeding event, allowing one gram of variation in the signal from each balance during a period of no feeding activity. This resulted in the feed intake values as determined from the algorithm being within 4% of the values obtained from the feeder weights at the beginning and ending of day. A time span of at least 16 seconds (8 readings) in which the feeder weight remained stable (<2 g in feeder weight change) was used to define the breaks between feeding events. Due to the absence of feeding activity during the dark hours of the day, the data from the dark period were excluded from the analysis of the feeding characteristics. All of the analyses were conducted on the pooled data from the four groups of birds with the exception of the SD54 cage. The loss of one bird in the SD54 cage during the first trial caused the change in stocking density and group size; thus, these data points were excluded from the analysis.

RESULTS AND DISCUSSION

The feeding characteristics of the hens are summarized in Table 1, where the mean values and standard error are shown for each stocking density. The p-value shown corresponds to a "mixed procedure" analysis using SAS that included factors for the fixed effect of stocking density and the random effects of trial and day of data collection within each trial. A p-value of 0.05 or less would indicate a significant difference between the stocking densities for a parameter. From the data shown, it can be concluded that no significant differences exist between the stocking densities for any of the feeding behavior parameters recorded during these four trials.

<table>
<thead>
<tr>
<th>Feeding Characteristic</th>
<th>SD54 Mean (SE)</th>
<th>SD60 Mean (SE)</th>
<th>SD66 Mean (SE)</th>
<th>SD72 Mean (SE)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Daily feed intake per hen (g)</strong></td>
<td>100 (4)</td>
<td>97 (4)</td>
<td>98 (4)</td>
<td>101 (4)</td>
<td>0.37</td>
</tr>
<tr>
<td><strong>Daily hen-hrs spent feeding per cage</strong></td>
<td>23.96 (2.75)</td>
<td>17.84 (2.39)</td>
<td>22.00 (2.39)</td>
<td>18.82 (2.39)</td>
<td>0.32</td>
</tr>
<tr>
<td><strong>Average daily feeding time per hen, hr/hen-d</strong></td>
<td>4.00 (0.46)</td>
<td>2.97 (0.40)</td>
<td>3.67 (0.40)</td>
<td>3.14 (0.40)</td>
<td>0.32</td>
</tr>
<tr>
<td><strong>Number of meals per day per cage</strong></td>
<td>144 (22)</td>
<td>181 (22)</td>
<td>170 (22)</td>
<td>117 (22)</td>
<td>0.18</td>
</tr>
<tr>
<td><strong>Average meal size (g/meal-hen)</strong></td>
<td>1.9 (0.4)</td>
<td>1.9 (0.3)</td>
<td>1.6 (0.3)</td>
<td>2.6 (0.3)</td>
<td>0.09</td>
</tr>
<tr>
<td><strong>Average meal duration (seconds/meal)</strong></td>
<td>258 (43)</td>
<td>174 (39)</td>
<td>198 (39)</td>
<td>220 (39)</td>
<td>0.40</td>
</tr>
<tr>
<td><strong>Average ingestion rate (g/min-hen)</strong></td>
<td>0.47 (0.08)</td>
<td>0.63 (0.07)</td>
<td>0.50 (0.07)</td>
<td>0.77 (0.07)</td>
<td>0.06</td>
</tr>
<tr>
<td><strong>Average number of hens feeding per meal</strong></td>
<td>2.0 (0.1)</td>
<td>1.9 (0.1)</td>
<td>1.9 (0.1)</td>
<td>2.0 (0.1)</td>
<td>0.72</td>
</tr>
</tbody>
</table>

Table 1. Statistics for feeding characteristics among the four stocking densities.

Data reported by Persyn et al. (2002, 2004) for individually housed birds (77 weeks of age) showed a mean daily feed intake value of 87.4 ± 6.3 g/hen for beak trimmed birds and a mean time spent feeding per day of 3.3 ± 0.4 hours per day. The group-housed birds in the current study tended to consume more feed and spend more time at the feeder on average. Diurnal feeding patterns are shown in Figure 4. These points represent the percent of each hour spent feeding by a particular cage of hens throughout a 24-hour period, and were averaged over all the days of data collection. Simultaneous feeding behavior data are shown in Figure 5 as the percentage of total feeding time that different numbers of birds were present at the feeder for each cage. This information is useful to determine whether more birds tend to eat simultaneously if space at the feeder is available. Inability to feed with the rest of the group due to lack of space at the feeder could be a stressor for the hens.
Figure 4. Diurnal feeding patterns of hens at four stocking densities (348, 387, 426, and 465 cm$^2$ per hen; 54, 60, 66, and 72 in$^2$ per hen). Chart displays average percent of time spent feeding in each hour. Based on averages from four days’ feeding data from each group of 24 hens. Lighting schedule was 16h light (5:30AM-9:30PM) and 8h dark (9:30PM-5:30AM). *Data for Group 1 SD54 omitted due to mortality.

Figure 5. Distribution of simultaneous feeding behavior of hens under four stocking densities (348, 387, 426, and 465 cm$^2$ per hen; 54, 60, 66, and 72 in$^2$ per hen), expressed as the percentage of the total feeding time of the cage when a particular number of hens were at the feeder simultaneously. Standard error bars are shown. Based on pooled data from four replications except Group1 SD54 cage data omitted due to mortality.

CONCLUSION
This study successfully adapted and expanded the previously used instrumentation system and computational algorithm from its single-bird measurements to group-housed birds. This experiment also investigated the effects of cage stocking density on the feeding behavior of group-housed laying hens. The data revealed that daily feeding behaviors of hens subjected to stocking density of 54, 60, 66, or 72 in$^2$ per hen were not significantly different. Hence, from the standpoint of feeding behavior as an animal welfare indicator, the stocking densities examined in this study did not compromise the hens’ welfare under thermoneutral conditions.
ACKNOWLEDGEMENTS

We would like to thank Ham and Eggs, LLC for their cooperation in providing the experimental hens and feed. Funding for this research was provided in part by the multi-state research project NE-127 “Biophysical Models for Poultry Production” and by the Iowa Egg Council.

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