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

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Abstract
Quantitative measurement of animal welfare continues to be a challenging task for both the animal agriculture industry and the scientific community. Characterization of animal feeding behavior provides a comparative elucidation of the animal’s behavioral deviation from its norms and thus carries implications for its welfare. This study examines the effects of cage stocking density (348, 387, 426, and 465 cm²; or 54, 60, 66, and 72 in.² cage floor space per hen) on feeding behavior of W-36 White Leghorn laying hens kept in groups of six hens. The study employed a specialized instrumentation system and computational algorithm. The results revealed no significant difference among the stocking densities under thermoneutral conditions with regard to the following: daily feed intake (97 to 101 g/hen, p = 0.37), daily feeding time per hen (3.0 to 4.0 h/day, p = 0.32), number of meals ingested per day per cage (117 to 181 meals/day, p = 0.18), meal size (1.6 to 2.6 g/meal-hen, p = 0.09), meal duration (174 to 258 s/meal, p = 0.40), ingestion rate (0.47 to 0.77 g/min-hen, p = 0.06), and number of hens feeding per meal (1.9 to 2.0 hens/meal, p = 0.72). However, there was a trend that hens under the 465 cm² (72 in.²) stocking density displayed a greater meal size and ingestion rate. A field-scale study further investigating the effects of conventional vs. newly recommended (and voluntarily adopted) stocking densities on commercial egg layers seems warranted.

Keywords
Animal welfare, Ingestion, Poultry housing

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Comments
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EFFECTS OF CAGE STOCKING DENSITY ON FEEDING BEHAVIORS OF GROUP-HOUSING LAYING HENS

R. N. Cook, H. Xin, D. Nettleton

ABSTRACT. Quantitative measurement of animal welfare continues to be a challenging task for both the animal agriculture industry and the scientific community. Characterization of animal feeding behavior provides a comparative elucidation of the animal's behavioral deviation from its norms and thus carries implications for its welfare. This study examines the effects of cage stocking density (348, 387, 426, and 465 cm$^2$; or 54, 60, 66, and 72 in.$^2$ cage floor space per hen) on feeding behavior of W-36 White Leghorn laying hens kept in groups of six hens. The study employed a specialized instrumentation system and computational algorithm. The results revealed no significant difference among the stocking densities under thermoneutral conditions with regard to the following: daily feed intake (97 to 101 g/hen, p = 0.37), daily feeding time per hen (3.0 to 4.0 h/day, p = 0.32), number of meals ingested per day per cage (117 to 181 meals/day, p = 0.18), meal size (1.6 to 2.6 g/meal-hen, p = 0.09), meal duration (174 to 258 s/meal, p = 0.40), ingestion rate (0.47 to 0.77 g/min-hen, p = 0.06), and number of hens feeding per meal (1.9 to 2.0 hens/meal, p = 0.72). However, there was a trend that hens under the 465 cm$^2$ (72 in.$^2$) stocking density displayed a greater meal size and ingestion rate. A field-scale study further investigating the effects of conventional vs. newly recommended (and voluntarily adopted) stocking densities on commercial egg layers seems warranted.

Keywords. Animal welfare, Ingestion, Poultry housing.

Issues surrounding farm animal welfare or well-being, such as definitions, measurements, interpretation, and perception, continue to be controversial both in the U.S. and abroad. The animal welfare debate has spawned governmental actions in Europe, and the issue has been brought to the fore in the U.S. through recent implementation of welfare standards by certain consumer companies such as McDonald’s. The U.S. interest in these issues has increased because of the international developments, 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” (Bell and Weaver, 2002). But how do we measure the impacts of stocking density on the welfare of caged layers in a truly scientific manner? One possible indicator of welfare in poultry is comparative feeding behavior. Continuous measurement of feeding behavior has been used to differentiate the impacts of different environments or management practices on poultry. At the same time, use of specialized instrumentation for continuous measurement of feeding behavior has proven to be less time consuming, tedious, costly, and error-prone than direct human observation or video analysis (Gates and Xin, 2001; Persyn et al., 2002, 2003, 2004; Puma et al., 2001; Xin and Ikeguchi, 2001; Xin et al., 2002).

The welfare 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 floor space per hen to increase over a five-year period ending in 2008 from the U.S. industry standard of 348 cm$^2$ (54 in.$^2$) per bird to a range of 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). In comparison, the European Union’s regulations for conventional cages require 550 cm$^2$ (85 in.$^2$) per hen (Hy-Line, 2003).

As a result of her studies, Dawkins (1999) asserts that there are no universal indicators of poultry welfare, and proposes that scientists investigate specific responses of poultry to particular situations. Previous studies of cage space have focused on many possible indicators of animal welfare and methods of measurement (Carmichael et al., 1998; Dawkins, 1981; Dawkins and Hardie, 1989; Goodling et al., 1984; Hann and Harvey, 1971; Mench et al., 1986; Nichol, 1987; Patterson and Siegel, 1998; Roush and Cravener, 1990).

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 on the birds. 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. The system was used to study the effects of drinking water temperature on ingestion behavior 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.

The objectives of this research were: (1) to adapt and expand the existing special cage system and data analysis algorithm developed to characterize individual bird feeding behavior for measurements of group-housed bird feeding behaviors, and (2) to assess the effects of cage stocking density on the feeding behavior of group-housed laying hens.

**MATERIALS AND METHODS**

**EXPERIMENTAL EQUIPMENT AND SETUP**

This study was conducted in environmentally controlled testing rooms (4.6 L × 2.7 W × 2.6 H m; 15 L × 9 W × 8.5 H ft) at the Livestock Environment and Animal Physiology (LEAP) Lab II at Iowa State University. Environmental conditions in the rooms were monitored and recorded every minute using portable dataloggers (HOBO H8 Pro Series RH/Tmp, Onset Computer Corp., Pocasset, Mass.). Room conditions were kept at an average temperature of 22.7 °C and relative humidity of 45% to 60%. Proper ventilation rate was used to maintain good air quality (i.e., CO₂ concentration <1000 ppm and NH₃ concentration <5 ppm). Fluorescent illumination of 10 lux at the bird level was provided for a 16 h lighting period each day (5:30 a.m. to 9:30 p.m.).

The testing room held four cages, each having a different stocking density: 348 cm² (54 in.²) per bird (SD54), 387 cm² (60 in.²) per bird (SD60), 426 cm² (66 in.²) per bird (SD66), and 465 cm² (72 in.²) per bird (SD72). All cages were constructed to have the same depth of 46 cm (18 in.) and same height of 40.6 cm (16 in.). The width determined the difference among the cages: 46, 51, 56, and 61 cm (18, 20, 22, 24 in.), respectively, for the SD54, SD60, SD66, and SD72 cages. This variation in cage width led to an average feeder space of 7.6, 8.4, 9.4, and 10.2 cm (3.0, 3.3, 3.7, and 4.0 in.) per hen for the SD54, SD60, SD66, and SD72 cages, respectively.

Each cage housed 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 precision nipple drinkers and a feed trough spanning the front width of each cage. Each opening equipped with an infrared (IR) sensor pair to detect the presence of a feeding hen at that particular location. This setup allowed the recording of the number of hens feeding simultaneously at any given time. These sensor pairs consisted of an IR light-emitting diode (LED) below the opening and an IR phototransistor above the opening (models OP165A and OP505A, Optek Technology, Inc., Carrollton, Texas) (fig. 1).

The 24 pairs of IR sensors with an output of 0 to 2.5 VDC were connected to the CR10X module via a 32-channel multiplexer (model AM416, CSI, Logan, Utah). Data from both the balances and from the IR sensor pairs were recorded every 2 s. The data were automatically downloaded to the hosting PC every 10 min via the datalogger’s companion PC208W software, and the files were retrieved and saved once every 24 h.

One video camera (model WV-CP410, Panasonic) was mounted directly above each cage. The images from the four cameras were recorded during the lighting hours using a time-lapse VCR (model AG-6730, Panasonic, set to 72 h/tape recording mode). Video output signals from the four cameras were connected to a quad-system (model WJ-420, Panasonic) so that they were simultaneously viewable on a color monitor (fig. 2). Real-time viewing allowed undisturbed monitoring of the birds from outside the testing room, and the recorded images were used to validate the data acquisition system and computational algorithm.

**EXPERIMENTAL HENS**

Laying hens used in this study were Hy-Line W-36 at 32 to 40 weeks of age and approximately 1.5 kg body weight at procurement. All the experimental hens had been housed in groups of six at 348 cm² (54 in.²) cage floor space per bird at the farm, and they were kept in the same groups while being transferred to the lab and during the tests. The hens were acclimated to their new environment and stocking density in the testing room for at least four days before data collection began in a trial. The hens were considered to have been acclimated and ready for testing when daily feed intake became stabilized at 90 to 100 g/hen-day. Data collection lasted 7 to 9 days, and four days of stabilized feeding behavior data were analyzed from each replicate. Eggs were collected once a day during data collection. Feed troughs were refilled every other day with the same diet that the hens had been fed at the farm.
Figure 2. Photos of: (a) experimental setup in testing room, (b) feeder access openings with IR sensor pairs above and below each opening, (c) hens feeding through instrumented feeder openings, and (d) video display and recording system.

ANALYSIS OF FEEDING CHARACTERISTICS

Feeding behaviors of the laying hens and the effects of stocking density were assessed using an analysis protocol that had originally been developed by Xin and Ikeguchi (2001). The characterized feeding behaviors included the following: 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 3. The IR sensor signals were used to determine the presence of a hen feeding at a particular feeder opening. A high sensor signal, defined as readings within 5% of the maximum output for a particular sensor, indicated the presence of a hen. Based on review of the recorded video images, a hen fully obstructed the IR sensors to reach the feed trough, leading to a high sensor output reading. The readings falling between full high or low signals seem to result from partial obstruction of the sensors during other activities, such as a hen entering or exiting a feeder opening, tail feathers protruding into the

![Figure 3. Two-minute time series of raw feeding event signals from the electronic balances of different stocking density (SD), indicating the dynamic feeder weight in grams.]()
opening when a hen turned around, etc. A sample of IR sensor signals is shown in figure 4.

Based on trial and error optimization, a change in total feeder weight exceeding 2 g between two adjacent feeder weight readings was chosen to signal a feeding event, i.e., allowing 1 g of variation in the signal output from each balance during a period of no feeding activity. Daily feed intake values determined from the algorithm were within 4% of the values obtained from the daily beginning and ending feeder weights. A time span of at least 16 s (eight readings) during which the feeder weight remained stable (<2 g 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 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 a change in stocking density and group size; consequently, these data points were excluded from the analysis.

RESULTS AND DISCUSSION

The statistics of hen feeding characteristics for each stocking density are summarized in table 1. The p-values shown correspond to a mixed linear model 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 indicates a significant difference between the stocking densities for each parameter. Results of the statistical analyses revealed that no significant differences could be detected among the stocking densities for any of the feeding behavior parameters recorded during these four trials (p > 0.05). However, differences in meal size and ingestion rate among the stocking density regimens were on the borderline of being significant (p = 0.09 for meal size, and p = 0.06 for ingestion rate). Specifically, hens in the SD72 regimen tended to have greater meal size and ingestion rate.

Data reported by Persyn et al. (2002, 2004) for individually housed hens at 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 feeding time of 3.3 ± 0.4 h per day. The group-housed hens (32 to 42 weeks old) in the current study tended to consume more feed and spend more time at the feeder. The hens in the current study were near their production peak; hence, higher feed intake was expected. Diurnal feeding patterns are shown in figure 5, where anticipatory feeding before lights off is apparent. The data points represent the portion of each hour spent feeding by a particular cage of hens throughout a 24 h period, and were averaged over all the days of data collection. Simultaneous feeding behavior data are shown in figure 6 as the percentage of total feeding time that different numbers of birds were present at the feeder for each cage. This information is useful for determining 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 stressful for the hens. Although feeder space was not the focus of this study, the results indicate that the variation in feeder space did not have a statistically significant impact on the feeding behaviors studied.

### Table 1. Statistics of feeding characteristics of laying hens kept under one of the stocking densities of 348, 387, 426, and 465 cm² (54, 60, 66, 72 in.²) per hen (SE = standard error of the mean).

<table>
<thead>
<tr>
<th>Feeding Characteristic</th>
<th>SD54 Mean</th>
<th>SD54 SE</th>
<th>SD60 Mean</th>
<th>SD60 SE</th>
<th>SD66 Mean</th>
<th>SD66 SE</th>
<th>SD72 Mean</th>
<th>SD72 SE</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily feed intake per hen (g)</td>
<td>100</td>
<td>4</td>
<td>97</td>
<td>4</td>
<td>98</td>
<td>4</td>
<td>101</td>
<td>4</td>
<td>0.37</td>
</tr>
<tr>
<td>Daily hen-hours spent feeding per cage</td>
<td>24.0</td>
<td>2.8</td>
<td>17.8</td>
<td>2.4</td>
<td>22.0</td>
<td>2.4</td>
<td>18.8</td>
<td>2.4</td>
<td>0.32</td>
</tr>
<tr>
<td>Daily feeding time per hen (h/hen-d)</td>
<td>4.0</td>
<td>0.5</td>
<td>3.0</td>
<td>0.4</td>
<td>3.7</td>
<td>0.4</td>
<td>3.1</td>
<td>0.4</td>
<td>0.32</td>
</tr>
<tr>
<td>Number of meals per day per cage</td>
<td>144</td>
<td>22</td>
<td>181</td>
<td>22</td>
<td>170</td>
<td>22</td>
<td>117</td>
<td>22</td>
<td>0.18</td>
</tr>
<tr>
<td>Meal size (g)</td>
<td>1.9</td>
<td>0.4</td>
<td>1.9</td>
<td>0.3</td>
<td>1.6</td>
<td>0.3</td>
<td>2.6</td>
<td>0.3</td>
<td>0.09</td>
</tr>
<tr>
<td>Meal duration (s/meal)</td>
<td>258</td>
<td>43</td>
<td>174</td>
<td>39</td>
<td>198</td>
<td>39</td>
<td>220</td>
<td>39</td>
<td>0.40</td>
</tr>
<tr>
<td>Ingestion rate (g/min-hen)</td>
<td>0.47</td>
<td>0.08</td>
<td>0.63</td>
<td>0.07</td>
<td>0.50</td>
<td>0.07</td>
<td>0.77</td>
<td>0.07</td>
<td>0.06</td>
</tr>
<tr>
<td>Number of hens feeding per meal</td>
<td>2.0</td>
<td>0.1</td>
<td>1.9</td>
<td>0.1</td>
<td>1.9</td>
<td>0.1</td>
<td>2.0</td>
<td>0.1</td>
<td>0.72</td>
</tr>
</tbody>
</table>
Due to the relatively small number of trials and the missing data from the SD54 regimen, some additional data analysis was conducted on the feeding characteristics to determine the precision obtained in the statistical analysis. If indeed there were differences among the stocking densities, then the responses would be expected to be progressive in nature. For example, if daily feed intake were affected, intake for the SD54 cage might be 5% lower than intake for the SD60 cage, which in turn might be 5% lower than that for the SD66 cage, and so on. Using these progressive differences as a model, a linear contrast was performed in SAS to estimate the slope of a line passing through the mean values for each feeding characteristic. This slope would indicate the effect of one additional square inch of space per hen on the response variable in question. The resulting estimated slopes are shown in table 2, along with a 95% confidence interval for each estimate. All of these confidence intervals include zero because no overall statistical differences could be detected;

Table 2. Estimates of stocking density (SD) effect on feeding characteristics per additional square inch of space per hen and for 18 additional square inches per hen (the maximum SD difference studied); 95% confidence intervals indicate the range of possible effects; all confidence intervals include zero, indicating the possibility of no effect.

<table>
<thead>
<tr>
<th>Feeding Characteristic</th>
<th>SD Effect per in.² of Additional Space per Hen</th>
<th>SD Effect for 72 vs. 54 in.² per Hen</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimated Effect</td>
<td>95% CI</td>
</tr>
<tr>
<td>Daily feed intake per hen (g)</td>
<td>0.08</td>
<td>−0.18 − 0.34</td>
</tr>
<tr>
<td>Daily hen–hours spent feeding per cage</td>
<td>−0.19</td>
<td>−0.61 − 0.23</td>
</tr>
<tr>
<td>Number of meals per day per cage</td>
<td>−1.5</td>
<td>−5.2 − 2.1</td>
</tr>
<tr>
<td>Average meal size (g)</td>
<td>0.029</td>
<td>−0.017 − 0.075</td>
</tr>
<tr>
<td>Meal duration (s/meal)</td>
<td>−1.5</td>
<td>−7.3 − 4.3</td>
</tr>
<tr>
<td>Ingestion rate (g/min-hen)</td>
<td>0.013</td>
<td>−0.0001 − 0.026</td>
</tr>
<tr>
<td>Number of hens feeding per meal</td>
<td>−0.004</td>
<td>−0.021 − 0.014</td>
</tr>
</tbody>
</table>

Figure 5. Diurnal feeding patterns of hens at four stocking densities (348, 387, 426, and 465 cm² per hen; or 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 16 h light (5:30 a.m. to 9:30 p.m.) and 8 h dark (9:30 p.m. to 5:30 a.m.). Data for group 1 of SD54 were omitted due to mortality.

Figure 6. Distribution of simultaneous feeding behavior of hens under four stocking densities (348, 387, 426, and 465 cm² per hen; or 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 was at the feeder simultaneously. Standard error bars are shown. Based on pooled data from four replications, except group 1 SD54 cage data were omitted due to mortality.
thus, the possibility of no effect cannot be ruled out. The confidence intervals are useful to see the range of possible values of the stocking density effect. For example, for the daily feed intake per hen in grams, the estimated effect is a 0.08 g/hen-day increase in feed intake for every additional square inch of space per hen. The confidence interval indicates that the effect could actually lie anywhere in the range of a decreased intake of 0.18 g/hen-day to an increased intake of 0.34 g/hen-day for each additional square inch of space per hen. These numbers translate to an estimated increased intake of 1.43 g/hen-day with a 95% CI range of −3.20 to 6.05 g/hen-day for the maximum difference in stocking density studied, i.e., 18 additional in.² per hen or 72 in.²/hen versus 54 in.²/hen. The magnitude of the effect on each feeding characteristic for 72 in.²/hen versus 54 in.²/hen is also shown in Table 2. Because no statistical differences could be detected, the confidence intervals allow us to consider whether or not differences of practical significance might exist at the extremes of the confidence interval range.

It should be noted that the current laboratory-scale behavioral study involved a small number of hens under thermoneutral conditions. A field-scale verification test under commercial production condition is thus warranted to further quantify the stocking density effects on hen behavior, microenvironment, and production performance.

CONCLUSIONS

This study successfully expanded an existing feeding behavior assessment system for individual birds to be applicable for group-housed birds. The system was used to examine the effects of cage stocking density of 348, 387, 426, and 465 cm² (54, 60, 66, or 72 in.²) per hen on the feeding behavior of group-housed laying hens. The data revealed no statistically significant differences (p > 0.05) in the behavioral responses among the four stocking densities under thermoneutral conditions. Further evaluation of conventional stocking density (54 in.²/hen) vs. the newly recommended stocking density (72 in.²/hen or greater) under commercial production conditions over extended (year-round) period is warranted.

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