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

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Abstract

Although quantification of animal welfare continues to be a challenging task for both the animal agriculture industry and the scientific community, characterization of feeding behavior has been shown to be a good indicator of animal welfare. This study quantifies the effects of cage stocking density (348, 387, 426, and 465 cm2 cage floor space per hen; 54, 60, 66, and 72 in2 cage floor space per hen) on the feeding behavior of W-36 White Leghorn laying hens. Feeding behavior was characterized using a specialized instrumentation system and computational algorithm for each cage of six hens during four (24-hen) trials. Statistics show no significant difference among the stocking densities under thermoneutral conditions with regard to daily feed intake (97-101 g/hen, p=0.37), hen-hours spent feeding per cage (17.8-24.0 hen-hours/day, p=0.32), average daily feeding time per hen (3.0-4.0 h/day, p=0.32), number of meals ingested per day per cage (117-181 meals/day, p=0.18), meal size (1.6-2.6 g/meal-hen, p=0.09), average meal duration (174-258 sec/meal, p=0.4), ingestion rate (0.47-0.77 g/min-hen, p=0.06), and number of hens feeding per meal (1.9-2.0 hens/meal, p=0.72). Other characteristics measured and reported include simultaneous feeding behaviors and diurnal group 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.

Keywords

animal welfare, ingestion, poultry housing

Disciplines

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Comments

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

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Abstract. *Although quantification of animal welfare continues to be a challenging task for both the animal agriculture industry and the scientific community, characterization of feeding behavior has been shown to be a good indicator of animal welfare. This study quantifies the effects of cage stocking density (348, 387, 426, and 465 cm^2 cage floor space per hen; 54, 60, 66, and 72 in^2 cage floor space per hen) on the feeding behavior of W-36 White Leghorn laying hens. Feeding behavior was characterized using a specialized instrumentation system and computational algorithm for each cage of six hens during four (24-hen) trials. Statistics show no significant difference among the stocking densities under thermoneutral conditions with regard to daily feed intake (97-101 g/hen, p=0.37), hen-hours spent feeding per cage (17.8-24.0 hen-hours/day, p=0.32), average daily feeding time per hen (3.0-4.0 h/day, p=0.32), number of meals ingested per day per cage (117-181 meals/day, p=0.18), meal size (1.6-2.6 g/meal-hen, p=0.09), average meal duration (174-258 sec/meal, p=0.4), ingestion rate (0.47-0.77 g/min-hen, p=0.06), and number of hens feeding per meal (1.9-2.0 hens/meal, p=0.72). Other characteristics measured and reported include simultaneous feeding behaviors and diurnal group 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.*

Keywords. animal welfare, ingestion, poultry housing

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" (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 specific indicator of 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. At the same time, this method 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). Using this method allows an objective, quantitative, and non-invasive means of measuring an indicator of animal welfare.

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 floor space per hen to increase from the US 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). These new recommendations are similar to those of the European Union, which require 452 cm^2 (70 in^2) per hen (Hy-Line, 2000).

As a result of her studies, Dawkins (1999) asserts that there are no universal indicators of poultry welfare, and proposes that researchers investigate specific responses of poultry to particular situations. Previous studies on 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 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. The system was used 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.

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 individual bird measurement only to also include measurements for group-housed birds, and b) to investigate the effects of cage stocking density on the feeding behavior of group-housed laying hens.

Materials and Methods

Equipment and Setup

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 rooms 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 used in the rooms. Fluorescent illumination at 10 lux (1.0 fc) throughout the rooms was provided 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). 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, 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 led to a feeder space of 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 holding six hens 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) with the base secured to the balances with Velcro strips. The balances had automatic response adjustment to compensate for vibration and drafts, with 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, with each opening equipped with an infrared (IR) sensor pair to detect the presence of a hen eating at that particular location. This setup 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. (See Figure 1 for IR sensor circuit diagram.) 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) with an output between 0-2.5 VDC. Data from both the balances and from the IR sensor pairs 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.

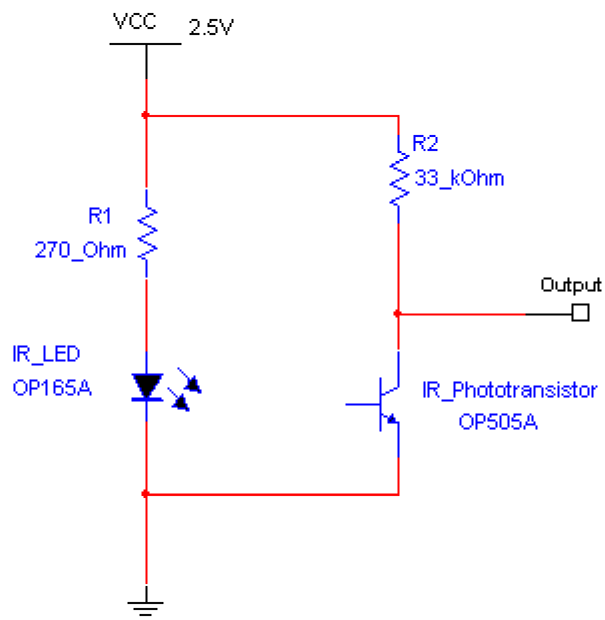
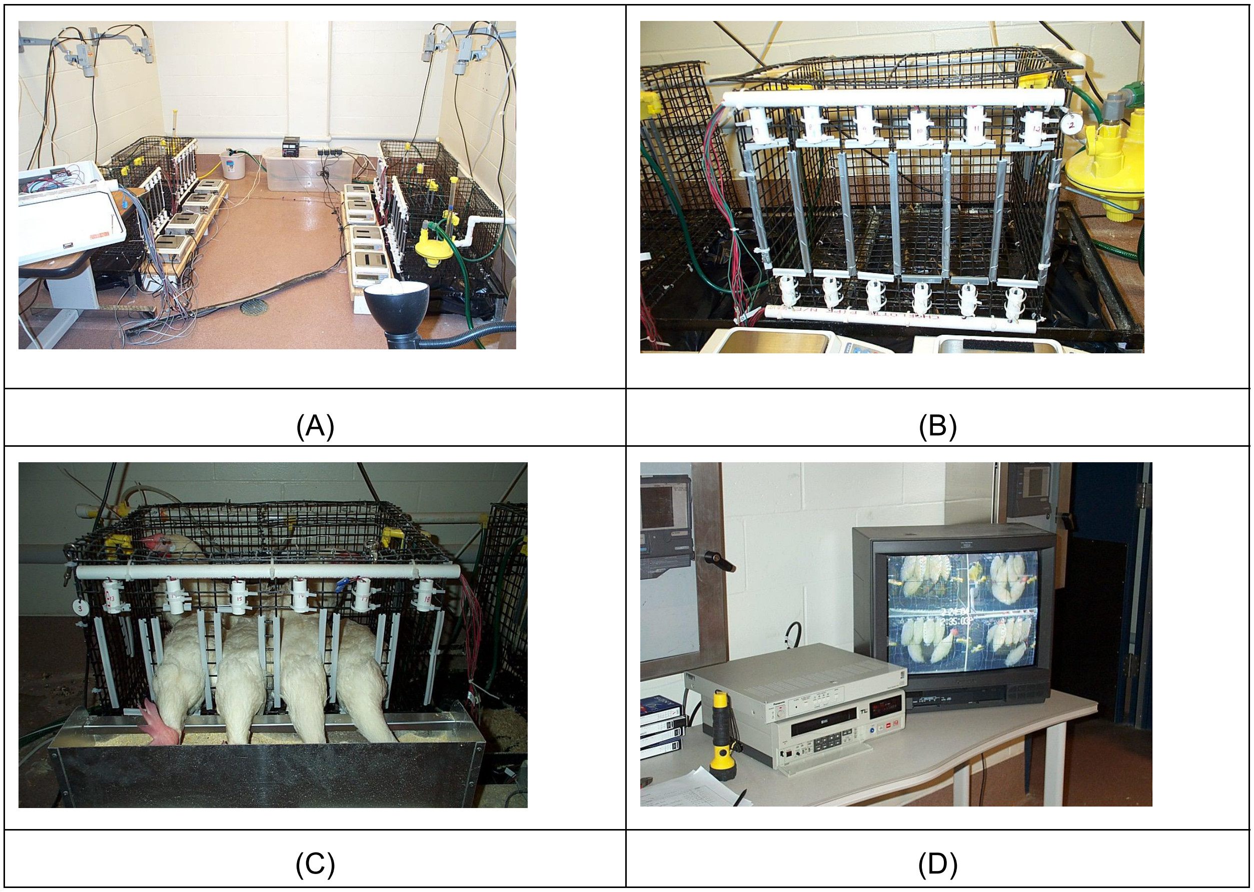


Figure 1. Circuit diagram of infrared emitter detector pairs used to detect bird presence at a feeder opening.

One video camera (Panasonic wv-CP410) was mounted directly above each cage. 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). 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. (See Figure 2 for photos of the experimental setup.)



(A) (B) (C) (D)

Figure 2. 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 hens

The experimental hens were Hy-Line W-36 between 32-40 weeks of age and approximately 1.5 kg (3.3 lbs.) body weight at procurement. All experimental hens had been housed at 348 cm^2 (54 in^2) cage floor space per bird at the farm. The hens were acclimated to their new environment in the testing room for at least four days before data collection began on a trial and lasted seven to nine days. Four days of stabilized feeding behavior data were analyzed from each replicate. 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.

Analysis of Feeding Characteristics

Feeding behaviors of the laying hens and the effects of stocking density were evaluated by an analysis protocol adapted from that 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 3. 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 4.

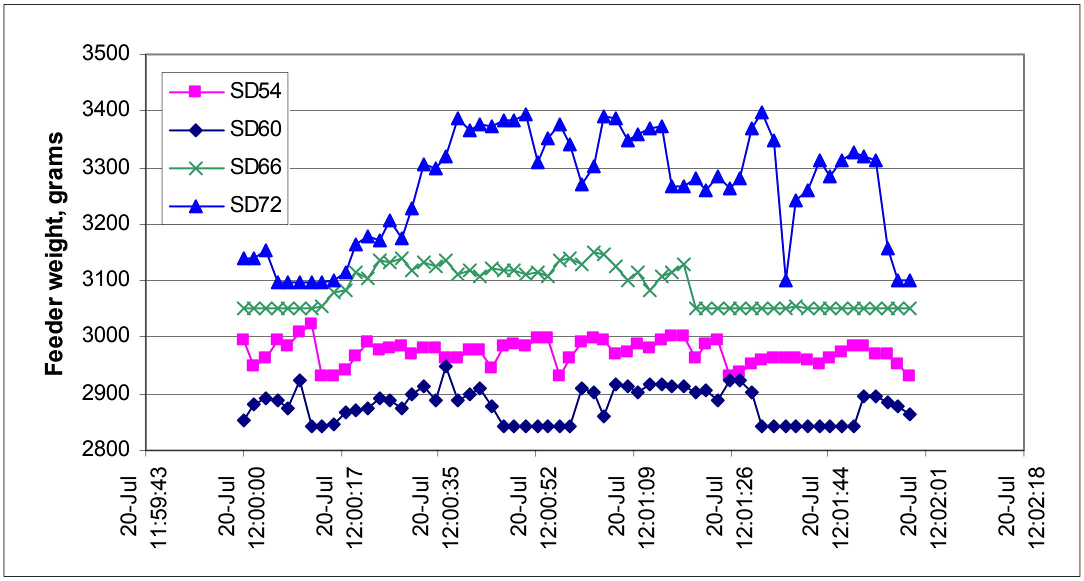


Figure 3. Two-minute time series of raw feeding event signals from the electronic balances of different stocking density (SD) indicating the dynamic feeder weight in grams.

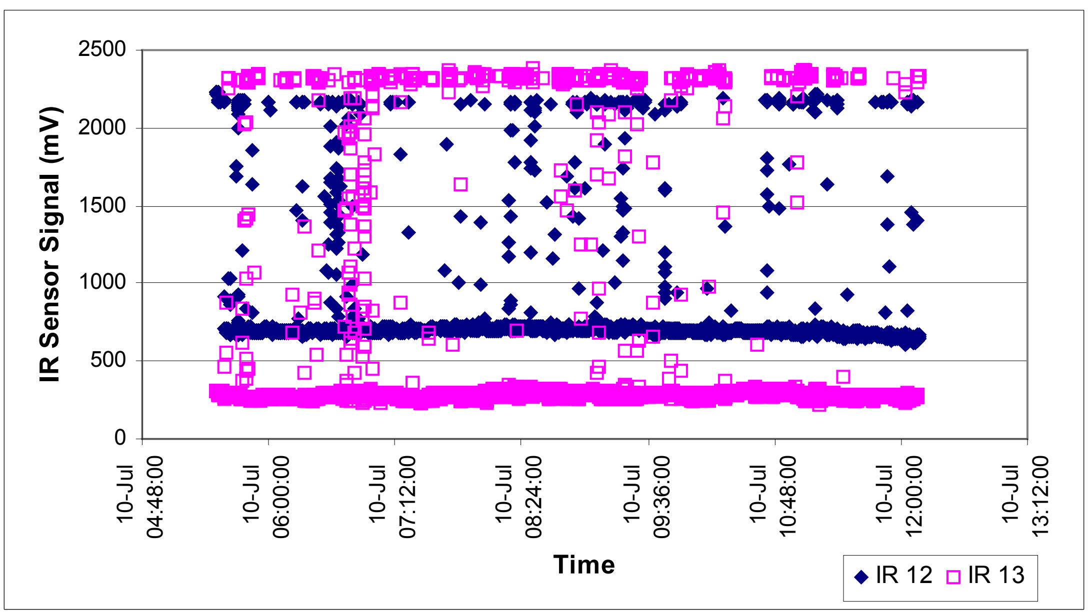


Figure 4. Sample of two raw infrared sensor signals used to determine the presence of a hen at a particular feeder opening.

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

Table 1 summarizes the feeding characteristics, where the mean and standard errors 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 among the stocking densities for any of the feeding behavior parameters recorded during these four trials.

Table 1. Statistics of feeding characteristics for the four stocking densities of 348, 387, 426, and 465 cm^2 (54, 60, 66, 72 in^2) per hen.

Feeding Characteristic	SD54		SD60		SD66		SD72		P-value
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	
Daily feed intake per hen (g)	100	4	97	4	98	4	101	4	0.37
Daily hen-hours spent feeding per cage	24.0	2.8	17.8	2.4	22.0	2.4	18.8	2.4	0.32
Average daily feeding time per hen, hr/hen-d	4.0	0.5	3.0	0.4	3.7	0.4	3.1	0.4	0.32
Number of meals per day per cage	144	22	181	22	170	22	117	22	0.18
Average meal size (g)	1.9	0.4	1.9	0.3	1.6	0.3	2.6	0.3	0.09
Average meal duration (sec/meal)	258	43	174	39	198	39	220	39	0.40
Average ingestion rate (g/min-hen)	0.47	0.08	0.63	0.07	0.50	0.07	0.77	0.07	0.06
Average number of hens feeding per meal	2.0	0.1	1.9	0.1	1.9	0.1	2.0	0.1	0.72

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 time spent feeding per day of 3.3 ± 0.4 hours per day. The group-housed hens 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 would be expected. Diurnal feeding patterns are shown in Figure 5, where anticipatory feeding before lights off was apparent. 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 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 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. Although feeder space in particular 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.

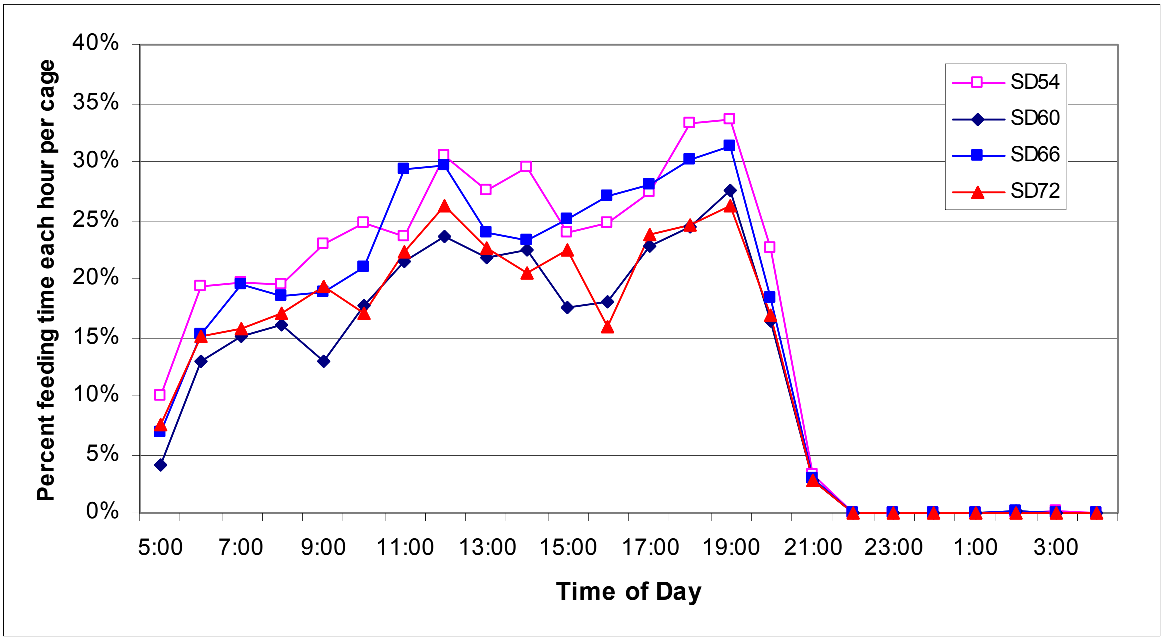


Figure 5. Diurnal feeding patterns of hens at four stocking densities (348, 387, 426, and 465 cm^2 per hen; 54, 60, 66, and 72 in^2 per hen). Chart displays average percent of time spent feeding in each hour. Based on averages from four days' feeding data from each group of 24 hens. Lighting schedule was 16h light (5:30AM-9:30PM) and 8h dark (9:30PM-5:30AM). Data for Group 1 of SD54 were omitted due to mortality.

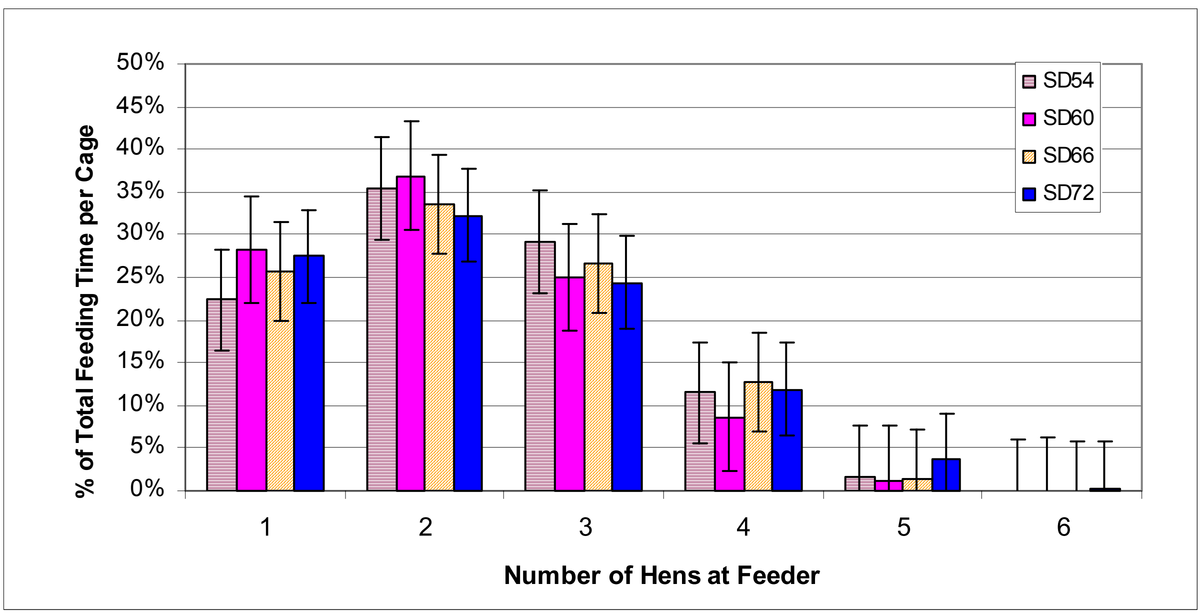


Figure 6. Distribution of simultaneous feeding behavior of hens under four stocking densities (348, 387, 426, and 465 cm^2 per hen; 54, 60, 66, and 72 in^2 per hen), expressed as the percentage of the total feeding time of the cage when a particular number of hens were at the feeder simultaneously. Standard error bars are shown. Based on pooled data from four replications except Group1 SD54 cage data omitted due to mortality.

Due to the relatively small number of trials and the missing data that occurred with the SD54 cage, some additional data analysis was conducted on the feeding characteristics of particular interest (daily feed intake, feeding time, and average number of hens feeding per meal). A program was developed in SAS to simulate additional datasets with covariance parameters equal to those present in the recorded datasets. Using these simulated datasets, the statistical power of the study conducted was evaluated, with statistical power defined as the probability of rejecting a false null hypothesis. In this case, the null hypothesis is that the response variables (feeding characteristics) are equal for all the stocking densities studied. If indeed there were differences among the stocking densities, it is expected that the responses would 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 the SD66 cage, and so on. Using these progressive differences as a model, the results of the analysis indicate that the four trials conducted would have been able to detect a progressive 4% difference in daily feed intake per hen with 99% power, a progressive 25% difference in feeding time per cage with 88% power, and a progressive 10% difference in the average number of hens feeding per meal with 87% power.

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.

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