

The effect of space allowance and cage size on laying hens housed in furnished cages, Part II: Behavior at the feeder

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ABSTRACT Standards for feeder (a.k.a. feed trough) space allowance (SA) are based primarily on studies in conventional cages where laying hens tend to eat simultaneously, limiting feeder space. Large furnished cages (FC) offer more total space and opportunities to perform a greater variety of behaviors, which may affect feeding behavior and feeder space requirements. Our objective was to determine the effects of floor/feeder SA on behavior at the feeder. LSL-Lite hens were housed in FC equipped with a nest, perches, and a scratch mat. Hens with SA of either 520 cm² (Low; 8.9 cm feeder space/hen) or 748 cm² (High; 12.8 cm feeder space/hen) per bird resulted in groups of 40 vs. 28 birds in small FC (SFC) and 80 vs. 55 in large FC (LFC). Chain feeders ran at 0500, 0800, 1100, 1400, and 1700 with lights on at 0500 and off at 1900 hours. Digital recordings of FC were scanned at chain feeder onset and every 15 min for one h after (5 scans × 5 feeding times × 2 d) to count the number of birds

with their head in the feeder. All occurrences of aggressive pecks and displacements during 2 continuous 30-minute observations at 0800 h and 1700 h also were counted. Mixed model repeated analyses tested the effects of SA, cage size, and time on the percent of hens feeding, and the frequency of aggressive pecks and displacements. Surprisingly, the percent of birds feeding simultaneously was similar regardless of cage size (LFC: 23.0 ± 0.9%; SFC: 24.0 ± 1.0%; $P = 0.44$) or SA (Low: 23.8 ± 0.9%; High: 23.3 ± 1.0%; $P = 0.62$). More birds were observed feeding at 1700 h (35.3 ± 0.1%) than any at other time ($P < 0.001$). Feeder use differed by cage area (nest, middle, or scratch) over the d ($P < 0.001$). The frequency of aggressive pecks was low overall and not affected by SA or cage size. Frequency of displacements was also low but greater at Low SA ($P = 0.001$). There was little evidence of feeder competition at the Low SA in this study.

Key words: laying hen, furnished cage, feeder space, behavior, aggression

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INTRODUCTION

Laying hens tend to eat synchronously (Webster and Hurnik, 1994; Collins et al., 2011; Nicol, 2015) and show a distinct diurnal feeding pattern with peak feeding behavior occurring at the end of the d (Savory, 1980). Therefore, adequate feeder space to allow simultaneous feeding is thought to be important for both the performance and welfare of laying hens (United Egg Producers, 2016). However, current standards for feeder space allowances (SA) are mainly based on data from conventional cages in which group sizes are small and

opportunities for activities other than feeding are few (e.g., Webster and Hurnik, 1994). During the evolution of conventional cage design, numerous studies indicated that shallow cage designs, which afforded more feeder space per unit area, increased egg-laying performance, improved feed efficiency, and reduced aggression compared with deep cage designs (Cunningham and Ostrander, 1981; Hughes, 1983; Adams and Craig, 1985). Furthermore, housing hens at higher density, and not just limiting feeder space by changing the cage dimensions, negatively affected both feeding behavior and egg production (Cunningham et al., 1987).

More recently, reducing feeder space below 10.9 cm/hen in conventional cages housing 5 hens was shown to decrease synchrony, reduce feeding times, and increase the variation in time spent feeding among individual hens (Thogerson et al., 2009a), as well as increase feed consumption (Thogerson et al., 2009b). In an epidemiological study on the effects of conventional cage designs on 165 layer houses in the United States, Garner et al. (2012) found that an increase in egg production was associated with increasing feeder space

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from 5 to 10.7 cm per hen, but not at feeder space allocations above that.

Considerably less is known about the use of feeder space in furnished cages (FC) where group sizes are larger and cage designs are more complex with the inclusion of nests and more opportunities for foraging on scratch mats. The current requirement for feeder space in Europe is 12 cm per bird (European Commission, 1999) and at least 7 cm per bird in Canada (National Farm Animal Care Council, 2017). It has been recommended that light hybrids should, at minimum, be given 12 cm and medium hybrids 14 cm, assuming that hens will feed synchronously (Appleby, 2004). However, these values are based on observations of hens in small furnished cages in which group sizes were 12 birds or less (see Albentosa et al., 2007). In small furnished cages, not all areas of the feed trough may be equally accessible to hens, especially around the nest area during peak nesting times (Albentosa et al., 2007). This may increase the demand for feeder space by decreasing the total amount of feeder space available, potentially leading to competition among hens for access to the feeder.

There have been few studies on feeding behavior in large furnished cages (a.k.a. enriched colony cages) where group sizes may be upwards of 60 hens (Blatchford and Mench, 2014) and in which there is more total space and furnishings for hens to perform a variety of activities, in addition to feeding. Social dynamics in these larger group sizes, in general as well as in relation to feeding, may be considerably different as hens may adopt a strategy of social tolerance rather than social hierarchy, especially because food is abundant and feeder space is not defensible (Estevez et al., 2007).

The study reported here was part of a larger project that compared the effects of 2 different SA in 2 sizes of large furnished cages on productivity, behavior, and welfare of laying hens (Widowski et al., 2017, *submitted*). Our objective here was to compare the effects of feeder SA (8.9 vs. 12.8 cm) on feeder use and aggressive behavior at the feeder. We hypothesized that SA would affect feeder use and predicted that there would be competition for feeder space in low SA FC, as indicated by the frequency of aggressive pecks and the number of displacements at the feeder.

METHODS

Animals and housing

Lohmann-selected Leghorn Lite hens were beak trimmed at the hatchery, reared in conventional cages, and housed in 24 Farmer Automatic Enrichable (Furnished) Cages (Clark Ag Systems, Ontario, Canada) at wk 18. A total of 1,218 hens was used as part of a larger experiment (see Widowski et al., 2017, *submitted*). In a 2 × 2 factorial experiment, 2 cage sizes (Large or LFC: 41,296 cm²; Small or SFC: 20,880 cm², custom built) and 2 SA (Low, 520 cm²/bird; High,

Table 1. Experimental treatments and resulting cage measurements and group sizes created by the 2 × 2 factorial (space allowance and cage size).

Floor space (cm ² /bird)	Cage size	Feeder space (cm/bird)	Hens housed per cage	Total # birds
Low (520)	Large N = 6	9	80	480
	Small N = 5	9	40	200
High (748)	Large N = 5	13.1	55	275
	Small N = 6	12.9	28	168

750 cm²/bird) were combined to create 4 treatment combinations and therefore 4 group sizes of 28, 40, 55, and 80 birds/cage (Table 1). Each treatment had 6 replicates, distributed among 3 tiers and 2 rooms; based on the placement of the cameras, only 5 replicates were visible for 2 treatments (see Table 1). For additional details on housing and management, see Widowski et al. (2017, *submitted*).

Each furnished cage was equipped with a nest area proportional to cage size (yellow plastic mesh surface and red plastic curtains), a middle area with perches (smooth white plastic), and a scratch area (smooth red plastic surface) located opposite to the nest (Figure 1). Every h, a small amount of feed was delivered onto the scratch mat via the internal feed auger. Nipple drinkers with cups were located above the auger down the middle of the cage, and over the scratch mat in small cages. Hens were fed a layer crumble diet from wk 18 to 72; feed was provided ad libitum and delivered every 3 h starting at 0500 h (see Widowski et al., 2017, *submitted* for nutritional details). The feed trough was accessible from both sides of the cage, extending from the scratch corner area to the nest corner area. The photoperiod was 14L:10D, with a 15-minute sunrise at 0500 h and a 15-minute sunset at 1845 hours. Animal use was approved by the University of Guelph Animal Care Committee (Animal Utilization Protocol #1947).

Video recording

Twelve ceiling-mounted video cameras (Panasonic Super Dynamic 5 Day/Night Camera, Panasonic Systems Networks Co. Ltd., Fukuoka, Japan) were focused on the feed trough located along the outside of the furnished cage doors. Half of the cages were recorded during wk 49 (6 cages in each of 2 rooms), and the cameras were moved to record the second half of the cages in wk 51 (6 cages in each of 2 rooms). Large cages required 4 camera angles to capture the whole cage (2 per side) while small cages required 2 (one per side; Figure 2). The entire light period (14 h) was recorded over 2 d and stored on a digital video recorder (16 Channel DVR, i3International; Toronto, Ontario, Canada) for later analysis.

Behavior observation

Feeding behavior. The number of birds feeding in each area (nest, middle, or scratch; Figure 1) was

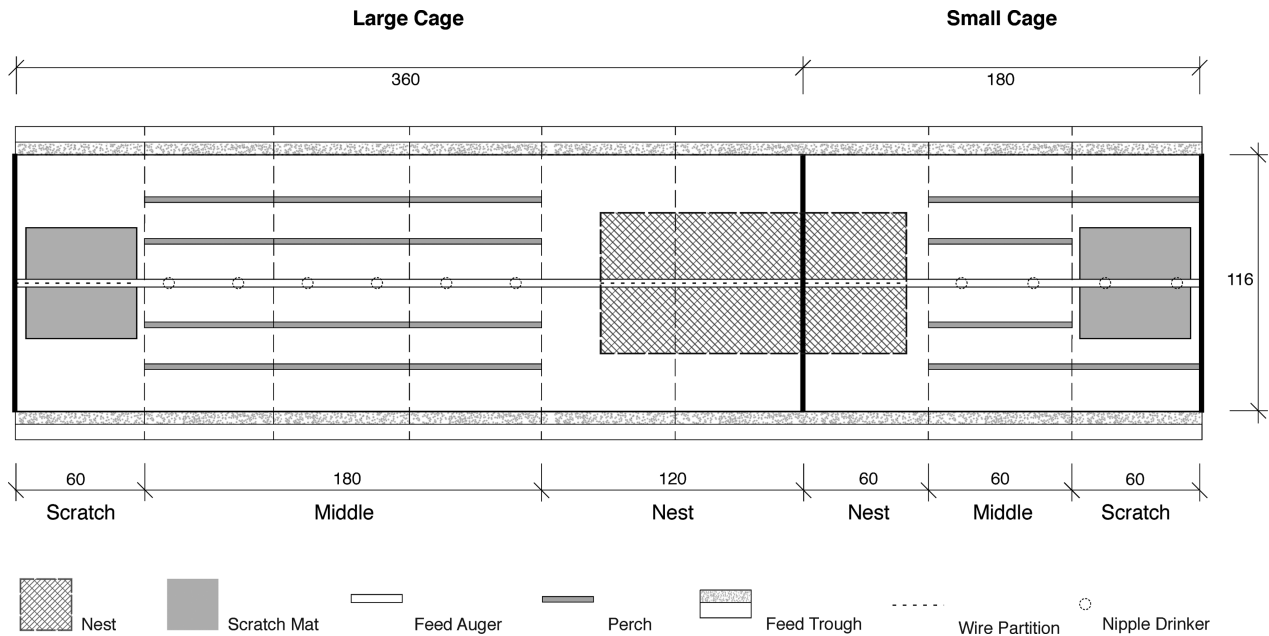


Figure 1. Top view of one tier of furnished cages: large on the left and small on the right. The cage sections have been highlighted by dashed lines: areas are equal in size in small cages (each one section), but vary in size in large cages (1, 2, and 3 sections for scratch, nest, and middle areas, respectively). The legend indicates each resource. Measurements are in cm.

Large Cage: View 1



Large Cage: View 2



Small Cage



Figure 2. Still images taken from the video recordings depicting examples of the 3 camera views: the nest area and first section of the middle area in a large cage (A), the second 2 middle sections and the scratch area (consisting of 1 section) in a large cage (B), and the whole side of a small cage (C). The same camera views were used on both sides of the cage and were filmed simultaneously.

counted from video recordings using an instantaneous scan sample. Each area was scanned immediately after each of 5 feeding periods (0500, 0800, 1100, 1400, and 1700 h) and every 15 min for the following h (5 scans/h). Feeding was defined as when a hen's head was located over the feeder, through the bars of the cage wall. The

observer recorded the number of hens feeding in each area separately; a hen was defined to be located in the nest, middle, or scratch area if her head was over the feeder within that cage area (Blatchford and Mench, 2014). Each cage consisted of multiple structural units referred to here as "sections," and each section was

60 cm long. In small cages, the nest, middle, and scratch areas were each one section long. In large cages, the nest was 2 sections, the middle was 3 sections, and the scratch area was one section (see Figure 1). Data were adjusted for differences in linear feed trough space between areas in the different cage sizes by dividing the number of birds feeding in each area by the number of cage sections in that area prior to statistical analyses.

Aggressive behavior. From the video recordings, all occurrences of aggressive pecks and displacements were counted using continuous 30-minute observations at 0800 h and 1700 h (representing peak nesting, from Hunniford et al., 2014; and peak feeding time, from a preliminary analysis of feeding behavior, respectively). Aggressive pecks were defined as pecks directed at the head or neck region of another hen and delivered with a forceful downward motion. Aggressive pecks were counted when both hens had their heads in or over the feed trough, when just the recipient's head was in or over the feed trough, and when an aggressive interaction began with a hens' heads in or over the feeder but the peck was delivered just inside the cage. Aggressive pecks occurring within the cage were not visible on the camera and were not recorded. Displacements occurred in 2 situations, as described by Albentosa et al. (2007): either a hen was unsuccessful at reaching the feed trough by being blocked by other hens, or she was displaced backwards or sideways from the feeder and prevented from returning for at least 3 seconds. Similar to when assessing feeding behavior, each area of the cage was watched separately, and a hen was defined to be within the nest, middle, or scratch area when the aggressor or victim was within the boundaries of that area. Only 12 of the 24 FC in the middle ($n = 8$) and top tiers ($n = 4$) were adequately illuminated to reliably count aggressive and displacement behavior (6 cages in each room, 3 small and 3 large per room). Cages also were balanced for size and SA.

Statistics

Before analyses, all data were averaged over the 2 observation days. For all dependent variables, the experimental unit was cage and feeding period as a repeated measure. The model consisted of SA, cage size, feeding period, cage area, and their interactions plus room

and tier. Prior to mixed model analysis using SAS (SAS Institute Inc.; Cary, NC), data were tested for normality and transformed using square root when necessary. The raw means and standard errors are presented and statistical significance was set at $P = 0.05$.

Feeder use was statistically analyzed using the mean number of birds feeding averaged over all 5 scans within a feeding period, as well as the maximum number of birds feeding at any one scan during each feeding period. These values also were divided by the number of birds in the cage (adjusted for mortality) to test for any effects of the independent variables on the percentage of birds in the group observed feeding. Aggressive pecks and displacements were expressed as the frequency of behavior performed per hen per 30-minute observation period. Values were adjusted for mortality.

RESULTS

Feeding behavior

As expected, more hens fed simultaneously in low SA cages compared to high (mean: $P < 0.0001$; max: $P < 0.0001$), but there was no difference in the percentage of hens feeding in cages with different SA ($P = 0.56$; Table 2). Similarly in large cages, more hens fed simultaneously than in small cages (mean: $P < 0.0001$; max: $P < 0.0001$). However, there was no difference between cage sizes for the percentage of birds feeding ($P = 0.47$; Table 2). There was no interaction between SA and cage size for the average number ($P = 0.31$), maximum number ($P = 0.0809$), or the percentage of birds ($P = 0.85$) feeding simultaneously.

There was a significant effect of feeding period on the maximum number of hens feeding per cage ($P < 0.0001$; Figure 3); the last feeding period (1700 h) had a significantly greater maximum number of birds feeding than the other 4 time periods. Both the average number ($P < 0.0001$) and the percentage of hens feeding ($P < 0.0001$) increased during the afternoon period, peaking at 1700 h (Figure 3). Interestingly, the greatest percentage of hens feeding at any one time did not exceed 63% for any cage size/SA combination SFC: high SA 63%, low SA 55%; LFC: high SA 54%, low SA 49%.

Most hens fed in the scratch area, when correcting for the size of the area ($P < 0.0001$). There was also an interaction between feeding time and area ($P < 0.0001$).

Table 2. Mean number, maximum number, and percentage of hens feeding per cage per scan (\pm standard error) in low vs. high space allowances and large vs. small cage sizes.

	Space allowance		Cage size	
	Low $n = 11$	High $n = 11$	Large $n = 11$	Small $n = 11$
Mean	13.6 \pm 0.83 ^a	9.3 \pm 0.54 ^b	14.7 \pm 0.7 ^a	7.9 \pm 0.37 ^b
Maximum	20.0 \pm 0.99 ^a	14.8 \pm 0.7 ^b	22.0 \pm 0.78 ^a	12.3 \pm 0.44 ^b
% Group	23.9 \pm 0.92	23.2 \pm 0.92	23.0 \pm 0.91	24.0 \pm 0.98

All feeding periods are combined. Different letter superscripts indicate a significant main effect within row and variable ($P < 0.0001$). The interaction between cage size and space allowance was not statistically significant for any variable.

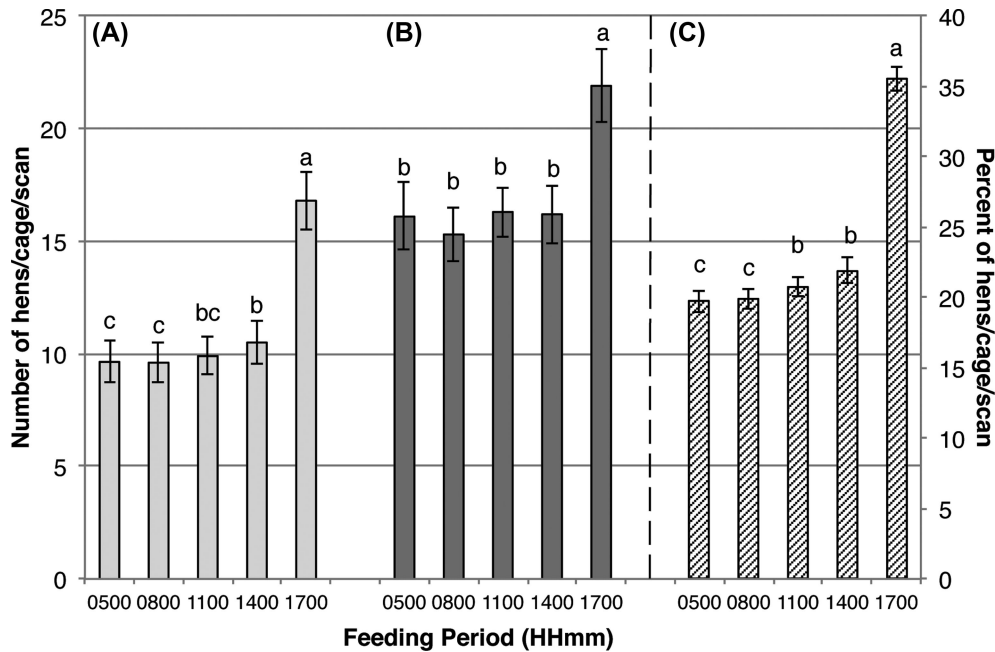


Figure 3. The mean number (A), maximum number (B), and percentage (C) of hens feeding per cage per scan. Different letter superscripts within each dependent variable are statistically different ($P < 0.05$). Error bars represent standard error of the mean.

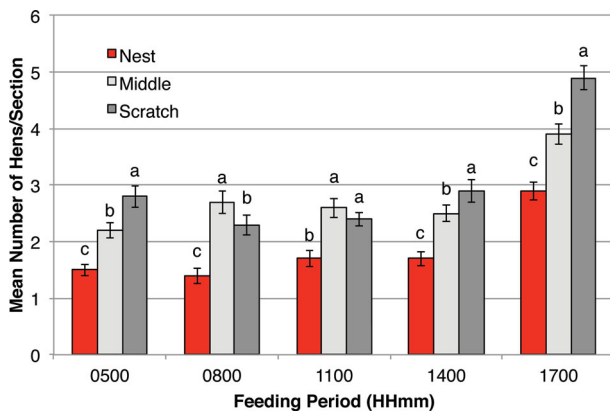


Figure 4. Feeder use by cage section (location) over time. Different letter superscripts within location indicate statistical differences across time periods ($P < 0.001$). Error bars represent standard error.

The nest area was used the least during all feeding periods. There were significantly more hens feeding in the middle area than either the scratch area or nest area during the 0800 h time period, coinciding with peak laying time (Hunniford et al., 2014). In 3 of the 5 feeding periods (0500, 1400, and 1700 h), most hens were observed feeding in the scratch area, followed by the middle and then nest areas (Figure 4).

Aggressive behavior

The frequency of aggressive pecks per hen counted in a 30-minute observation period was the same regardless of SA ($P = 0.58$) or cage size ($P = 0.54$; Table 3) with no interactions ($P = 0.47$). Significantly more aggressive pecks were performed in the nest area at 0800 h, co-

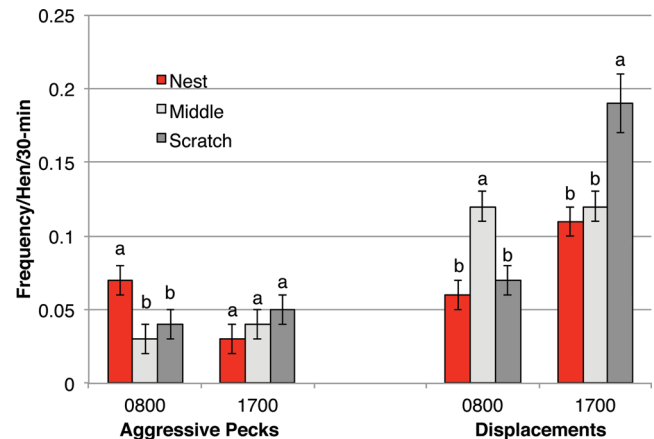


Figure 5. The frequency of aggressive pecks and displacements per hen per 30-minute observation period (either 0800 or 1700 h). Different letter superscripts represent statistical differences within behavior and time period ($P < 0.05$). Error bars represent standard error of the mean.

inciding with peak lay; there were no differences among areas at 1700 h (Figure 5).

There was no statistical difference in the frequency of displacements between large and small cages ($P = 0.62$); however, there were significantly more displacements in low SA cages compared to high ($P = 0.0005$; Table 3). There was also no interaction between SA and cage size ($P = 0.19$). There was a significant interaction between feeding period and area ($P < 0.0001$). Most displacements occurred in the middle of the cage during the 0800 h time period and in the scratch area during the 1700 h time period (Figure 5), coinciding with where most hens were feeding during those time periods (see also Figure 3).

Table 3. Frequency of aggressive pecks and displacements per hen per 30-minute observation period (\pm standard error) averaged over the 0800 and 1700 observations periods.

	Space allowance		Cage size	
	Low n = 6	High n = 6	Large n = 6	Small n = 6
Aggressive pecks	0.05 \pm 0.01	0.04 \pm 0.01	0.04 \pm 0.01	0.05 \pm 0.01
Displacements	0.14 \pm 0.01 ^a	0.09 \pm 0.01 ^b	0.10 \pm 0.01	0.12 \pm 0.02

Different superscripts indicate significantly different main effects within a row ($P < 0.0005$). There were no interactions between space allowance and cage size.

DISCUSSION

In agreement with other studies, the feeders were most occupied during the last feeding period of the d (e.g., Savory et al., 1978; Savory, 1980; Blatchford and Mench, 2014). This result is consistent with the need for hens to increase their feed intake and calcium load prior to the onset of the scotophase, during which the bulk of eggshell for the following day's egg is laid down (Etches, 1996; Leeson and Summers, 2008).

Hens used feeders in different areas of the cage depending on the time of day. Based on the description of the timing of egg laying for these birds provided by Hunniford et al. (2014; measured at 54 to 55 wk), the distribution of hens feeding in different cage areas during the 0800 h time period coincides with the hens' preferred laying locations in the nest and scratch mat. The increased use of the nest and scratch areas for nesting in the morning subsequently re-directed hens' feeding behavior to less occupied feeders in the middle of the cage. This finding is consistent with Blatchford and Mench (2014) who also found that feeders in the nest area were used least in the morning. During the first time period (0500 h) and the last 2 time periods (1400 h and 1700 h), hens occupied the scratch area the most for feeding. This area was more open, which may have allowed more hens to congregate and access the feeder more easily. Even though the feed trough was accessible throughout the cage, activity related to other priority behaviors, such as nesting, may have impeded access, potentially limiting feeder space, similar to what Albertosa et al. (2007) observed in SFC.

Although more hens fed simultaneously when groups were larger, the average maximum number of birds feeding did not differ among treatments, and the absolute maximum number of birds feeding simultaneously was never higher than 63% of birds in the cage. This finding contradicts anecdotal evidence that all hens feed at the same time when the feeders are running (Appleby, 2004), but agrees with the findings of Albertosa et al. (2007) who always observed fewer than the whole group of hens feeding synchronously in FC housing 6, 8, or 10 birds per cage. In Blatchford and Mench (2014), a maximum of 42 birds out of a 60-bird group (70%) housed in enriched cages was observed to feed simultaneously. Previous work on groups of 4 laying hens in pens (Collins et al., 2011) and commercial broiler chickens stocked at different densities

(Collins and Sumpter, 2007) indicated that chickens do feed synchronously more often than random expectation, confirming that social facilitation of feeding is important for domestic fowl. However, providing enough feeder space to allow members of the group to feed synchronously does not necessarily imply that all members of the group need to feed simultaneously, as long as each bird can access enough feed to support her individual nutrient requirements without experiencing undue levels of competition. As group sizes increase with commensurate access to resources, hens become less competitive and more socially tolerant towards each other (Estevez et al., 2007); hens evaluate the costs of aggressively competing for a desirable food source to outweigh the benefits (Estevez et al., 2002). Therefore, a high degree of synchrony (the number of individuals at a food source) might actually suppress aggressive behavior in larger groups (Estevez et al., 2002).

Providing ample feeder space does have consequences for production parameters in smaller group sizes (e.g., Garner et al., 2012). Diarra and Devi (2014) compared the feed intake and body weight of hens in floor pens (20 birds per group) with feeder spaces ranging from 5.6 to 16.8 cm per hen. Feed consumption and BW gain did not differ, but uniformity was poorer in groups with 5.6 and 8.4 cm compared to those with 11.2 cm or above. Not only was feeding behavior affected by feeder SA, but egg production also was influenced. Hen-day egg production was greatest when hens were given more feeder space; hens with 5.60 cm had a production rate of 30%, while hens given 11.20 cm had 72.2%, and hens with 14.00 cm had 69.1%. Hens with so little feeder space may have had to put more energy into competing for space, with clear consequences for their hen-day egg production. Thogerson et al. (2009b) did not find an effect of feeder SA on egg production, but decreased feeder space did decrease feed efficiency, which the authors anticipated was due to increased feed wastage. In our companion study, we did not find an effect of SA on BW uniformity, egg production, or feed consumption (Widowski et al., 2017, *submitted*).

Contrary to our expectation, the frequency of aggressive pecks was quite low, and not affected by SA. Much of the aggressive pecking we observed may have been more related to nesting than feeding because it was mainly performed outside the nest area, and it coincided with peak laying time and not with peak feeding (Hunniford et al., 2014). Most displacements were

performed in the middle area of the cage at 0800 h and in the scratch area at 1700 h, which coincides with the locations where the most hens were found feeding. However, the frequency of displacements was also relatively low, with 0.14/hen per 30 min translating into different numbers of displacements per group (11.2 if 80 hens/FC, 7.7 if 55 hens/FC, 5.6 if 40 hens/FC, 3.9 if 28 hens/FC). Although competition was not aggressive, these displacement patterns suggest that hens were still jostling for space at the feeder to some degree.

The observation that the average number of birds observed feeding was around 23 to 24% of birds, regardless of group size, is an interesting one. Spacing behavior is suggested to rely on the balance between social attraction and repulsion (Mench and Keeling, 2001). Meunier-Salaün and Faure (1984) found that feeding behavior and synchrony also were affected by the construction of the feeder itself; more birds fed simultaneously when the feeders were partitioned, but hens had longer and less frequent feeding bouts with non-partitioned feeders. Free access to a one m feeder (33 cm per bird) led to the best feeding conditions: long, infrequent feeding bouts; a high degree of synchrony; and low levels of aggression. The authors rightly recommend that “to determine the requirements of laying hens for feeding space, attention must be paid to social attraction as well as to competition at the feeder.” In the current study, the stable percentage of birds feeding simultaneously across group sizes may represent the balance to which Mench and Keeling (2001) were referring.

In conclusion, there appeared to be little competition for space at the feeders at the feeder space allowances (8.9 vs. 12.8 cm), or for the FC sizes and designs of the large FC used in this study. The use of the feed trough differed throughout the d, among different areas of the cage, and was apparently affected by other activities. There was little evidence to suggest that at these group sizes, 8.9 cm of feeder space was limiting or that all hens attempted to eat simultaneously. These data suggest that feeder space requirements may differ for large (enriched colony) vs. small (conventional or FC housing fewer than 15 hens) group sizes, but that access to the feeder during different times of d should be taken into consideration.

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