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Relation between social order and use of resources in small and large furnished cages for laying hens

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Abstract 1. The objective was to determine the relation between social rank and use of resources in a small furnished cage with sufficient resources per hen (SF) and a commercial large one with less adequate allowance of facilities per hen (LF).
2. Ninety-two cross layers were used. At the age of 16 weeks, the hens were divided at random into two groups. There were 4 furnished cages with 5 birds per cage and 4 large furnished cages with 18 birds per cage. The dominance hierarchy was determined, in which highest, medium and lowest ranking hens in each cage were identified. Behaviour, use of facilities and physical conditions of these hens were measured (one in each rank category in SF, two in each in LF).
3. Dustbathing and litter scratching were more frequent in the high ranking hens than the medium and low ranked hens in LF, while no significant difference was found between them in SF.
4. No significant difference between SF and LF was found in use of nest boxes. However, pre-laying sitting tended to be less frequent in low ranking than medium and high ranking hens in LF (Social order × Cage design). In the nest box most of time was spent in pre-laying sitting by SF hens, LF high and medium ranked hens (average 94·9%). However, LF low ranking hens spent their time escaping (33·1%), pre-laying sitting (27·7%) standing (25·7%) and moving (13·5%) in the nest.
5. In the large furnished cages with less facilities per hen, high ranking hens may be expected to have priority using the dust bath. In contrast, low ranking hens rarely performed nesting behaviour fully, and spend more time using the nest box as a refuge than for laying.

INTRODUCTION

Concepts of animal welfare have spread rapidly all over the world. For example, while conventional battery cages have become the most common housing system for laying hens, this is now recognised as a problem for poultry welfare because layers in cages are subject to behavioural restriction (Tauson, 2005). Jungle fowl evolved behaviour that increased their survival rate and/or the number of offspring surviving to the next generation, and these natural behaviours were preserved strongly in laying hens domesticated from Jungle fowl (Appleby *et al*., 2004). It used to be thought that because the eggs laid by hens kept commercially are not fertile and are removed every day, and the hens are protected from predators and extremes of cold, they do not need to perform these behaviour patterns (Appleby *et al*., 2004). However, a large body of scientific research has demonstrated the importance of hens being able to perform these behaviour patterns for their welfare (Keeling, 2004). In addition, there are physical effects. Thus, it was reported that hens' claw length is affected by scratching behaviour, such as litter scratching (Appleby *et al*., 2002; Shimmura *et al*., 2007*a*). Hens kept in conventional cages have welfare problems such as claws breaking due to over-growth and being unable to perform litter scratching or dustbathing (Appleby *et al*., 2004).

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Conventional cages will be banned in the European Union in 2012, where most development of alternative housing systems for laying hens has occurred. These comprise furnished cages and non-cage systems such as deep-litter, aviaries and free range. Furnished cages contain a perch, a nest box and a littered area, and provide more height and area per hen, and will be the only legal form of cage in the European Union from 2012. According to the 1999 EU Directive, from 2012 these cages will have to provide 750 cm^2/hen including nest and litter facilities (Blokhuis, 2004). Furnished cages provide most of the economic advantages of conventional cages while removing many behavioural restrictions (Appleby *et al*., 2002). Today, about 40% of layers in Sweden are kept in furnished cages (Tauson, 2005) and other countries in the European Union where this system is used are the United Kingdom, Norway, Germany and Denmark. Attention is also being given to furnished cages in Asia including Japan, because they can increase welfare while keeping good performance, indeed some farmers already use furnished cages in Japan.

An early model of furnished cage, the Edinburgh Modified Cage, was for groups of 4 birds (Appleby and Hughes, 1995). Small group size has the benefit of lower incidence of aggressive interaction, but if group size is increased this may minimise egg production cost per hen. Therefore, more recently the size of furnished cages has become larger, for example, 16 hens (Wall *et al*., 2004) and 40 hens per cage (Weitzenburger *et al*., 2005). Large furnished cages would benefit the birds by providing a larger total cage area, leading to enhanced exercise and probably, in turn, improved bone strength. However, this means that more hens share the nest box and litter area. In a previous study, we studied the differences in use of resources between dominant and subordinate hens in a small furnished cage (Shimmura *et al*., 2007*b*). We reported that dominant hens had priority using the dust bath, resulting in subordinate hens not being able to use the facility fully. It was suggested that hens' use of resources would generally be affected by social order, and this phenomenon was observed even in medium sized furnished cages with enough resources (Shimmura *et al*., 2007*c*). Therefore, in large furnished cages, only a small number of high ranking hens may have priority using resources such as the dust bath, even if those resources seem to be used fully by many hens. Also, in some cage designs the dust bath area is smaller than the nest, which may mean that competition for the dust bath is increased and that only a small number of high-ranking hens can use the dust bath. It would be difficult to conclude in these situations that furnished cages have an unequivocal advantage, removing behavioural restrictions.

The objective of the present study was to determine the relationship between social rank and use of resources such as the nest box and dust bath in a small purpose-made furnished cage with enough resources per hen and a large commercial one with smaller allowance of facilities per hen. Therefore, we investigated resource use, behaviour and physical condition in high, middle and low ranking hens in large and small furnished cages.

MATERIALS AND METHODS

Animals and housing arrangement

Ninety-two medium hybrid layers (White Leghorn/Rhode Island Red cross bred) were used. All birds had their beaks trimmed at one-day-old and were raised in pens with wood shavings on the floor. At the age of 16 weeks, the birds were individually marked using a combination of coloured leg rings, divided at random into two groups and moved to furnished cages in a laying house. One group was housed in 4 small furnished cages with 5 birds per cage and the other in 4 large furnished cages with 18 birds per cage.

The house was ventilated with three ceiling fans. Average daytime temperature (±SD) during the observation period was 26·8 ± 1·5°C at the centre of the house. Lighting was provided by miniature ceiling bulbs, adjusted to give an intensity of 10 lux at the food troughs, with the light period from 05:00 to 19:00 h. The birds had *ad libitum* access to water and feed. The feed contained more than 185 g CP and 11·88 MJ ME/kg. Feeding and any other routine work such as supplying wood shavings was done from 09:00 to 09:30 h and collecting eggs from 16:00 to 16:30 h.

Housing systems

Small furnished cage (SF)

Laying cages 65 × 46·5 × 47 cm (wide × deep × high) at the rear were used, the same as in our previous study (Shimmura *et al*., 2006). Following Appleby and Hughes (1995), each cage was equipped with a nest, a dust bath and a perch. The main cage area was 604·5 cm^2 per hen, with a floor of 2·5 × 5·0 cm wire mesh. The nest box was added on one side of the cage, 25 × 46·5 × 21 cm (wide × deep × high) at the rear. Nest area was 232·5 cm^2 per hen, so that total space allowance (excluding dust bath) was 837·0 cm^2 per hen. The nest was enclosed on all sides with wooden board, except for a floor lined with artificial turf,

an 8-cm space under the front so that eggs would roll out, and an entrance 13 × 23 cm (wide × high) (with a threshold 1·8 cm high so that eggs would not roll out of the side of the nest) which hens readily stepped through. Most eggs (95%) were laid in the nest box. Above the nest was a dust bath 4·5 cm deep, which was supplied with wood shavings. All wood shavings were removed and replaced with fresh shavings in the morning. A wooden perch (4 × 3 cm, deep × high, with chamfered top edge) was fitted across the width of the cage with its centre 10 cm from the cage floor and 18 cm from the rear of the cage. Perch, feeder and drinker space per hen were 13·0 cm.

Large furnished cage (LF)

A commercial large furnished cage (Meller, Germany) 240 × 62·5 × 47 cm (wide × deep × high) at the rear were used. Each cage was equipped with a nest, a dust bath and two perches. The main cage area was 658·3 cm^2 per hen. On one side was the nest box 60 × 35 × 47 cm (wide × deep × high) at the rear. Nest area was 116·7 cm^2 per hen. On the front of the nest box, a hanging red plastic sheet covered the entrance; otherwise, the nest was solid-walled and lined with artificial turf. Most eggs (99%) were laid in the nest box. Next to the nest box was a dust bath 30 × 35 cm (wide × deep), lined with artificial turf and supplied with wood shavings on the turf. The wood shavings were changed every morning. The litter area was 58·3 cm^2 per hen, so that total area for litter and nest box was 150 cm^2 per hen and total cage area was 833·3 cm^2 per hen. Two plastic perches (4 × 3 cm, deep × high, with chamfered top edge) were fitted across the width of the cage, 9 cm above the floor, one 20 cm and one 40 cm from the rear of the cage. Perch space per hen was 16·7 cm. Feeder space was 13·3 cm per hen, and each cage was equipped with 6 water nipples.

Measurements

Dominance hierarchy

Observations of aggression were conducted for a total of 24 between 16 and 30 weeks of age. Aggressive interactions were counted in all cages, in a period of 10 min per cage with one observer in SF and of 20 min per cage with two observers in LF. This observation was repeated twice in a day, morning (10:00–12:00 h), and afternoon (13:00–15:00 h). The total observation time was therefore 8 h per cage in SF (10 min × 2 × 24 d) and 16 h per cage in SF (20 min × 2 × 24 d). The agonistic behaviours recorded were aggressive pecking, displacing, chasing and threatening, with both aggressor and recipient noted. Aggressive pecking was to the head of the recipient, and excluded both severe feather pecking (forceful pecks, sometimes with feathers being pulled out and with the recipient bird moving away) and gentle feather pecking (careful pecks, not resulting in feathers being pulled out and usually without reaction from the recipient bird). The average total number (±SD) of agonistic interactions observed per cage was 57·8 ± 24·1 in SF and 357·3 ± 71·7 in LF. From these data, the dominance value of individual hens was calculated (Clutton-Brock *et al.*, 1979, 1986):

$$\text{Dominance value} = \frac{B + \Sigma b + 1}{L + \Sigma l + 1}$$

where B is the number of hens that the individual beat; Σb is the total number that they beat excluding the subject; L is the number of hens that it lost to; and Σl is the total number that they lost to excluding the subject. This index takes into account the success of opponents, so that the score of an individual is determined by the scores of the individuals it defeated and of those defeating the individual. The formula is especially effective in the case of a linear and fixed hierarchy such as domestic hens (Boyd and Silk, 1983). The linearity in each cage was also calculated, using Landau's index (Lehner, 1996). Normalised index values (h) range from 0 (nonlinear) to 1 (linear), and $h \geq 0{\cdot}9$ is a reasonable (although arbitrary) criterion for "strong", nearly linear hierarchies.

The mean (±SD) index values of linearity (h) were 0·93 ± 0·10 in SF and 0·97 ± 0·05 in LF, confirming that hierarchies within cages were nearly linear. So dominance values were used to identify highest, middle and lowest ranked hens in each cage for observation: one in each category in SF and two in LF. Mean (±SD) dominance value of high, middle and low were 7·8 ± 1·3, 0·8 ± 0·1 and 0·1 ± 0·0 in SF, and 32·3 ± 16·4, 0·9 ± 0·1 and 0·03 ± 0·0 in LF, respectively. As expected, there was significant variation in dominance value among rank categories (Friedman's test with replication, $P < 0{\cdot}001$) and significant differences were found between each category (Steel-Dwass' multiple comparison test, all $P < 0{\cdot}01$), while there was no effect of cage design ($P = 0{\cdot}74$).

Behavioural observations

Observations were conducted at 31, 35 and 39 weeks of age (3 d/week). Direct visual scans at 10 min intervals were conducted to record the location and behaviour of individual birds in all cages at the same time for 6 h/day: 2 h in each of

the early morning (06:00–08:00 h), the late morning (10:00–12:00 h) and the afternoon (13:00–15:00 h). Locations were recorded by functional position (nest, dust bath, perch, cage floor, feeder) and by horizontal position. The latter was categorised in SF as front (feeder, front cage floor) or rear cage floor, and in LF as front (feeder, front cage floor, front perch), middle cage floor or rear (rear cage floor, rear perch). The location ''feeder'' was recorded when a hen had her head in the feeder. For behaviour, the following activities were recorded: eating, drinking, resting, comfort behaviour (dustbathing, preening, body shaking, wing flapping, tail shaking, head rubbing, bill wiping), exploring (pecking litter, scratching litter, pecking cagemate (gentle feather pecking), pecking object), aggression (aggressive pecking, escaping), severe feather pecking, sham dustbathing, moving, prelaying sitting and others. Comfort behaviours listed above excluding dustbathing and preening were grouped as other comfort behaviour, because these behaviours were important for welfare evaluation but were seldom observed (Nicol, 1987; Dawkins and Hardie, 1989). Prelaying sitting was recorded when a hen was sitting in the nest box.

Physical condition

Body weight, feather damage and claw length were recorded at 31 and 39 weeks of age, before and after the behavioural observation. Feather damage was scored from 0 (no damage) to 5 (denuded) for 8 parts of the body (head, neck, breast, back, legs, belly, wings, tail), giving a total score from 0 to 40 (Bilčik and Keeling, 1999). Slightly different criteria were used for scoring flight feathers than for the rest of the plumage, because of the different types of feathers and damage. The assessment of feather damage was carried out by at least two people working together. The centre front and rear claws of the right foot were measured with a digital vernier calliper, which can measure by 0·01 mm, by recording the straight length from the root to the claw tip.

Statistical analysis

The proportions of time spent by each individual bird at each location and in each behaviour were calculated, which calculated by the following formula: (total number performing a behaviour/ total number of observation point) × 100. Data for each week were pooled. In LF, data from the two hens of highest rank (1 and 2), middle rank (8 and 9) and lowest rank (17 and 18) in LF were averaged, resulting in one data unit for each rank category. In SF, data from hens ranked 1, 3 and 5 were used. Rank categories (high, middle and low) are hereafter referred to as ''ranks''. There were 4 replicate cages of each design, giving 4 replications for each rank in both SF and LF. As the data of each rank in a cage were linked, a repeated measures ANOVA was used to evaluate the effects of social rank, cage design (SF *vs*. LF) and interaction between them on the use of facilities, behaviour and physical condition. Each measurement thus involved 24 data units in the analysis (three social ranks × two cage designs × 4 replications). Significances of individual effects were evaluated by multiple comparison using the Tukey test. When significant interactions between social rank and cage design occurred, the dual data were unified and then compared using one-way ANOVA followed by the Tukey test. Some behavioural data (x; resting, litter scratching, aggressive pecking, escaping, severe feather pecking, sham dust-bathing) were $\log(x+1)$ transformed to produce a normal distribution (Martin and Bateson, 1993).

RESULTS

Use of facilities

The proportions of the total number of observation points spent by each ranked hen at each facility are shown in Table 1. Considering functional position, LF hens used the cage floor more and perch less than SF hens ($P<0{\cdot}01$ and $P<0{\cdot}05$, respectively). High ranking hens used the cage floor and the perch less than low ranking hens ($P<0{\cdot}05$ and $P=0{\cdot}05$, respectively). Significant interaction between social order and use of dust bath was found: high ranking hens used the dust bath more than medium and low ranking ones in LF (both $P<0{\cdot}05$), while no significant difference was found between SF ranks. There was no significant effect of rank and cage design on use of nest and feeder [s1]. Considering horizontal position, significant interactions between social order and use of the front and rear of the cage floor were found. Low ranking hens used the rear of cage floor more than high ($P<0{\cdot}01$) and medium ($P<0{\cdot}05$) hens in LF, while no difference was found between SF hens.

Behaviour

The proportions of the total number of observation points spent by each-ranked bird in each behaviour are shown in Table 2. There was significant interaction between social order and cage design in aggressive pecking or escaping. In LF, significant differences between social ranks were found in aggressive pecking and escaping (all $P<0{\cdot}01$), but significant differences between

Table 1. *Mean proportion ± standard deviation of total number of observation points spent by hens of each rank in each location in small and large furnished cages.*

Location	Cage design[†]	Social order			*F* value[‡]		
		High	Medium	Low	Cage design (C)	Social order (S)	C × S
Functional position							
Feeder	SF	39·1 ± 7·2	37·9 ± 14·8	32·3 ± 5·4	4·7	1·7	0·2
	LF	31·6 ± 5·0	35·5 ± 5·5	26·1 ± 4·7			
Cage floor	SF	13·6 ± 5·1	10·1 ± 5·4	15·8 ± 9·6	27·9**	4·6*	3·5
	LF	30·9 ± 7·2	39·1 ± 10·1	42·5 ± 6·3			
Perch	SF	28·0 ± 11·1	28·2 ± 7·4	32·3 ± 8·8	10·5*	3·6	0·6
	LF	11·4 ± 1·5	16·1 ± 4·5	21·6 ± 6·1			
Dust bath	SF	14·0 ± 5·6	17·7 ± 10·8	14·6 ± 11·9	4·1	5·0*	7·8**
	LF	18·9 ± 2·7	2·8 ± 0·7	1·4 ± 0·4			
Nest	SF	5·2 ± 2·8	6·0 ± 3·2	5·0 ± 3·6	1·4	0·1	0·8
	LF	7·1 ± 3·8	6·5 ± 2·0	8·4 ± 1·6			
Horizontal position							
Front	SF	9·4 ± 0·4	5·2 ± 2·6	8·7 ± 7·7	191·3***	0·9	4·3*
	LF	38·4 ± 4·9	46·1 ± 6·8	35·8 ± 5·8			
Rear	SF	4·2 ± 5·0	4·9 ± 4·0	7·1 ± 8·1	53·6***	15·6***	9·4**
	LF	13·9 ± 3·7	23·5 ± 3·6	37·8 ± 6·9			

*$P < 0·05$; **$P < 0·01$; ***$P < 0·001$.
[†]SF, small furnished cages; LF, large furnished cages.
[‡]Degrees of freedom of the effect of cage design (C) was 1, social order (S) was 2 and S × C was 2 in each location. *N* was 24 in each location.

Table 2. *Mean proportion ± standard deviation of the total number of observation points spent by hens of each rank in each behaviour in small and large furnished cages.*

Behaviour	Cage design[†]	Social order			*F* value[‡]		
		High	Medium	Low	Cage design (C)	Social order (S)	C × S
Eating	SF	39·0 ± 7·2	37·9 ± 14·8	32·3 ± 5·4	5·0	1·7	0·2
	LF	31·7 ± 4·8	35·5 ± 2·6	25·9 ± 5·0			
Drinking	SF	5·2 ± 1·5	5·9 ± 1·9	5·6 ± 0·9	7·7*	1·6	0·1
	LF	3·3 ± 0·4	4·5 ± 1·2	4·0 ± 0·6			
Resting	SF	7·8 ± 5·8	10·3 ± 4·5	9·8 ± 1·7	3·4	0·5	0·1
	LF	5·8 ± 2·2	6·4 ± 1·6	6·8 ± 3·7			
Comfort							
Dust bathing	SF	2·9 ± 1·9	1·8 ± 1·2	2·5 ± 1·3	2·8	17·3***	8·7**
	LF	4·2 ± 0·8	0·1 ± 0·1	0·0 ± 0·1			
Preening	SF	20·4 ± 1·7	19·9 ± 6·6	22·5 ± 4·5	0·0	0·6	0·2
	LF	19·5 ± 4·7	21·4 ± 4·4	21·9 ± 7·1			
Other comfort	SF	1·6 ± 0·8	2·1 ± 0·7	1·5 ± 0·9	0·6	0·9	2·7
	LF	2·0 ± 0·6	1·1 ± 0·5	1·3 ± 0·6			
Exploring							
Litter pecking	SF	5·6 ± 3·4	5·3 ± 3·5	5·7 ± 2·1	10·3*	2·8	2·7
	LF	5·6 ± 1·6	1·4 ± 1·4	0·4 ± 0·3			
Litter scratching	SF	0·1 ± 0·2	0·1 ± 0·2	0·0 ± 0·0	8·1*	11·9**	9·8**
	LF	0·9 ± 0·5	0·1 ± 0·2	0·0 ± 0·1			
Object pecking	SF	0·3 ± 0·2	0·1 ± 0·1	0·3 ± 0·2	10·2**	0·5	0·4
	LF	0·4 ± 0·1	0·5 ± 0·2	0·5 ± 0·2			
Mate pecking	SF	0·3 ± 0·3	0·0 ± 0·1	0·2 ± 0·1	0·6	2·0	3·7
	LF	0·1 ± 0·1	0·1 ± 0·1	0·2 ± 0·0			
Aggression							
Aggressive pecking	SF	0·1 ± 0·2	0·0 ± 0·0	0·0 ± 0·0	30·2***	18·7***	17·6***
	LF	5·2 ± 2·2	0·6 ± 0·3	0·0 ± 0·0			
Escaping	SF	0·0 ± 0·0	0·1 ± 0·2	0·2 ± 0·3	64·1***	23·5***	21·1***
	LF	0·0 ± 0·0	1·1 ± 1·1	5·0 ± 1·4			
Severe feather pecking	SF	0·0 ± 0·0	0·0 ± 0·0	0·0 ± 0·0	11·9**	1·6	1·6
	LF	0·8 ± 0·8	0·3 ± 0·6	0·0 ± 0·0			
Sham dust-bathing	SF	0·4 ± 0·6	0·0 ± 0·0	0·0 ± 0·0	39·9***	7·4**	10·5***
	LF	0·2 ± 0·1	2·1 ± 0·5	4·4 ± 2·2			

(*continued*)

Table 2. *Continued.*

Behaviour	Cage design†	Social order			*F* value‡		
		High	Medium	Low	Cage design (C)	Social order (S)	C × S
Moving	SF	2·3 ± 0·9	1·8 ± 0·5	2·5 ± 1·1	21·1**	2·1	1·9
	LF	3·6 ± 0·7	5·2 ± 1·1	5·8 ± 2·4			
Pre-laying	SF	5·1 ± 2·9	5·9 ± 2·9	5·1 ± 3·5	0·0	3·8	3·2
	LF	7·0 ± 3·6	5·6 ± 1·9	2·4 ± 0·9			

*$P<0·05$; **$P<0·01$; ***$P<0·001$.
†SF, small furnished cages; LF, large furnished cages.
‡Degrees of freedom of the effect of cage design (C) was 1, social order (S) was 2 and S × C was 2 in each location. *N* was 24 in each behaviour.

Table 3. *Mean proportion ± standard deviation of total number of observation time spent by hens of each rank in each behaviour in nest box in small and large furnished cages.*

Behaviour	Cage design†	Social order			*F* value‡		
		High	Medium	Low	Cage design (C)	Social order (S)	C × S
Pre-laying sitting	SF	96·1 ± 4·5	98·6 ± 2·0	91·3 ± 11·1	60·7***	88·5***	63·0***
	LF	99·3 ± 0·8	89·1 ± 2·7	27·7 ± 10·6			
Standing	SF	2·8 ± 3·5	1·4 ± 2·0	1·1 ± 2·2	14·1**	29·9***	36·3***
	LF	0·2 ± 0·5	3·6 ± 4·7	25·7 ± 7·7			
Escaping	SF	0·0 ± 0·0	0·0 ± 0·0	0·0 ± 0·0	26·3**	23·4***	23·4***
	LF	0·0 ± 0·0	1·7 ± 3·3	33·1 ± 13·0			
Moving	SF	0·0 ± 0·0	0·0 ± 0·0	7·6 ± 11·9	1·6	4·7*	0·4
	LF	0·4 ± 0·8	5·6 ± 5·9	13·5 ± 12·0			

*$P<0·05$; **$P<0·01$; ***$P<0·001$.
†SF, small furnished cages; LF, large furnished cages.
‡Degrees of freedom of the effect of cage design (C) was 1, social order (S) was 2 and S × C was 2 in each location. *N* was 24 in each behaviour.

ranks were not found in SF. While drinking was less frequent in LF than SF, feather pecking, moving and object pecking were all more frequent in LF than SF (all $P<0·01$). Significant interactions between social order and cage design were found in dustbathing and litter scratching. Dustbathing was more common in the high hens than the medium and low ones in LF (both $P<0·01$), while no significant difference was found between SF ranks. Litter scratching had similar tendencies to dustbathing, and litter scratching was more frequent in the high hens than the medium and low ranked ones in LF (both $P<0·01$), while no significant difference was found between SF ranks. Sham dustbathing also had significant interaction between social order and cage design. While no significant difference was found between SF ranks, in LF sham dustbathing was more frequent in the low and medium than the high ones (both $P<0·01$). A tendency interacted social order with cage design was found in pre-laying.

The proportion of the total number of observation points spent by LF low ranking hens performing pre-laying sitting tended to be lower compared with LF high ones ($P=0·06$), while no tendency was found between SF ranks (Table 2). The proportion of the total number of observation points spent in each behaviour in the nest is shown in Table 3. Significant interactions between social order and cage design were found in the proportion of time spent in pre-laying sitting, standing and escaping in the nest box. When in the nest box, most of time was spent in pre-laying sitting by SF hens and LF high and medium ranking hens. By contrast, LF low hens spent only 27·7% of time in the nest box in pre-laying sitting, and the rest of their time escaping, standing and moving.

Physical condition

Increments of body weight, feather damage and claw length from 31 to 39 weeks of age are shown in Table 4. Feather damage was worse in LF than in SF ($P<0·001$). No significant difference was found in the other physical measurements.

DISCUSSION

As suggested in the Introduction, large furnished cages should benefit the birds by providing a larger total cage area, leading to enhanced exercise and probably, in turn, improved bone strength. Evidence was obtained here to support this. Moving was observed more frequently in LF than in SF, which shows that exercise was

Table 4. *Mean increment ± standard deviation of physical condition from 31 to 39 weeks of hens of each rank in small and large furnished cages.*

Measurement	Cage design[†]	Social order			*F* value[‡]		
		High	Medium	Low	Cage design (C)	Social order (S)	C × S
Body weight (g)	SF	317·5 ± 35·7	290·0 ± 26·5	185·0 ± 14·4	0·3	1·5	2·3
	LF	298·8 ± 53·4	306·3 ± 106·8	313·8 ± 68·7			
Total feather score	SF	1·3 ± 0·8	1·0 ± 0·7	2·5 ± 0·3	64·6***	1·3	0·8
	LF	2·6 ± 0·9	4·9 ± 1·1	5·4 ± 0·4			
Claw length (mm)							
Front	SF	2·5 ± 0·4	3·7 ± 0·1	2·5 ± 0·9	0·3	1·0	0·4
	LF	2·5 ± 0·6	2·7 ± 0·6	2·4 ± 1·0			
Rear	SF	0·5 ± 0·7	2·1 ± 0·5	1·2 ± 0·9	0·2	0·2	0·6
	LF	0·0 ± 0·9	0·4 ± 0·5	−0·1 ± 0·6			

*$P < 0{\cdot}05$; **$P < 0{\cdot}01$; ***$P < 0{\cdot}001$.
[†]SF, small furnished cages; LF, large furnished cages. [‡]Degrees of freedom of the effect of cage design (C) was 1, social order (S) was 2 and S × C was 2 in each location. *N* was 24 in each measurement.

enhanced in LF. It was also confirmed that the hens' use of the perch decreased while the use of cage floor increased in the larger cages. However, large furnished cages also have the disadvantage of larger group size, which results in more aggression. In groups small enough for members to recognise each other individually, for example 4 or 5, aggression was generally rare once a hierarchy is established. However, when group size is large, aggression is more frequent. Published evidence suggests a positive correlation between group size and rate of aggression with more aggression per bird in larger groups (Hughes and Wood-Gush, 1997). Severe aggressive behaviour sometimes leads to cannibalism and high mortality, which is a serious welfare problem in laying hens (Hughes and Duncan, 1972). The LayWel Project also reported that large furnished cages had a higher risk of increased mortality (Blokhuis *et al*., 2007). In the present study, results of aggressive interactions were in accordance with those earlier studies. Thus, high ranking LF hens frequently performed aggressive pecking, while the behaviour was rare in high ranking SF hens. Severe feather pecking was also more frequent in LF than in SF, which probably contributed to the worse feather condition in LF. Large furnished cages are therefore associated with risk of aggressive interactions, cannibalism and mortality. It is also common in any large groups of hens kept moderately intensively that a small number of birds will be pecked continually by others (McBride, 1958). This has been described as the ''peck order effect'' and such birds as ''runts'' (Appleby, 1985). They have heads and combs scarred from pecking, poor body condition and posture, and spend most of the time trying to avoid interaction with others. This often makes them feed very little and remain at the rear of cage (Keeling and Duncan, 1989). The effect is less common in conventional cages or when hens are kept in small groups in furnished cages, but probably more frequent in larger caged groups including large furnished cages (Appleby *et al*., 2004; Shimmura *et al*., 2007*d*). This effect was also confirmed in a study investigating behaviour of individual hens in many types of furnished cages, where it was reported that social competition affected synchronisation at feeding and feeding bout (Albentosa *et al*., 2007). Although no significant differences were found in maintenance behaviour, such as eating, between social order in this study, the low ranking LF hens spent 5·0% of their time escaping and used the rear of the cage floor more frequently compared with higher ranking hens in this study. These results agreed with the previous studies mentioned above. Therefore, the low ranking LF hens might be ''runts'', and in this sense, they are at potential risk for acute stress such as competition for resources.

Dustbathing in poultry is a highly motivated behaviour which occurs even in the absence of salient stimuli as ''sham'' or ''vacuum'' dustbathing (Keeling, 2004). According to the 1999 EU Directive, only cages with 150 cm^2 area per hen for nest and litter facilities are allowed from 2012 (Blokhuis, 2004). However, providing the litter for hens in cages remains a problem. Compared to studies of aviaries, which have reported that litter areas are well used (Odén *et al*., 2002), in furnished cages dust baths seem to be less attractive and frequently remain unused by hens (Lindberg and Nicol, 1997). It was shown here in LF that high ranking hens spent more time in the dust bath than low ones. It was also observed that the categories of behaviours performed in the dust bath, such as dustbathing and litter scratching, were more frequent in the high ranking LF hens, while low ranking LF hens performed sham dustbathing more frequently. However, these rank effects were not observed in SF. These results imply that the high LF hens had priority using the dust bath, while the low LF hens could not use this resource fully, which is in accordance

with the other studies (van Rooijen, 1999; Shimmura *et al*., 2007*b*). Competition for the dust bath is also suggested by the fact that aggressive interactions were frequently observed in the litter area both in furnished cages and non-cage systems (Shimmura *et al*., 2006). Such competition will be increased if the dust bath area per hen is very small (Shimmura *et al*., 2007*d*). In the present study, LF had less dust bath area per hen (58·3 cm^2) than SF (232·5 cm^2). The low ranking LF hens therefore could not use the dust bath area fully because of competition with the higher ranking hens for the dust bath. Lundberg and Keeling (2003) suggested that a lack of attraction to the dust bath in furnished cages might be due to the effect of social order, observing that high ranking birds were stimulated to dustbathe by a video image of a bathing bird, but middle and low rank birds did not react to the image of a high ranking bird. Recently, the size of furnished cages is becoming larger and larger, as mentioned in the Introduction. The present results suggest that this has some potential disadvantages for hen welfare.

Domestic hens are also highly motivated to show nesting behaviour. Several studies have demonstrated that hens are motivated to lay their egg in a nest box (Duncan and Kite, 1989) and later work has confirmed this (Cooper and Appleby, 1995, 1996), showing that motivation to gain access to a nest site increases near the start of the sitting phase of pre-laying behaviour (Freire *et al*., 1997). In our study, the amount of time spent in the nest box was similar between each rank in SF and LF. However, the amount of time that LF low-ranking hens performed pre-laying sitting was lower than LF medium and high ranking hens. When in the nest box, most of the time was spent in pre-laying sitting by SF hens and LF high and medium ranking hens. By contrast, LF low hens spent much of their time in the nest escaping, standing and moving (Table 3). Two possible explanations may be given for these results. Firstly, the low ranking hens were apparently unable to perform nesting behaviour fully, as they spent less time in the sitting phase than the higher ranking hens. Medium hybrids such as those used in the present study usually sit before laying and often show ''vacuum'' nesting behaviour (Appleby *et al*., 2004). Mills *et al*. (1985) recorded the heart rates of hens performing ''vacuum'' nesting behaviour and concluded that birds are calm during both sitting and vacuum nesting. This calmer behaviour of medium hybrids in the pre-laying period is generally interpreted as showing better adaptation to the cage environment than light hybrids. The nest area per hen in LF (116·7 cm^2) was less than in SF (232·5 cm^2). This would result in the number of nest sites per hen being less in LF than in SF. Aggressive interactions may occur frequently if nests are limited (Meijsser and Hughes, 1989). In an occupied nest, dominant birds sometimes peck other birds entering the nest, which may result in subordinate birds leaving the nest box. This effect was confirmed in an experimental study, where Freire *et al*. (1997) reported that hens took longer to enter a pen where there was a dominant, while searching for a nest site. It was also observed in LF that higher ranked hens in occupied nests sometimes pecked other, low ranked hens in the nest. Therefore, low ranking LF hens could not perform a sitting phase in the nest box in a calm state. Appleby (2004) suggested that at least 300 cm^2 per nesting bird is needed for a nest site, because in groups of 5 or 6 hens, no more than 4 were seen in 1205 cm^2 nest boxes simultaneously (Appleby, 1998). On this basis, SF cages provided nearly 4 nest sites for 5 hens, but LF cages only provided 7 nest sites for 18 hens. In this respect, lower ranking hens have much greater behavioural restrictions when nest space per hen is insufficient, as in LF, due to the combination of stocking density and the provision of less nesting facilities.

The second explanation for behaviour in LF nest boxes is their use as a refuge by low ranking hens. In our previous study, we compared the use of resources by dominant and subordinate hens in a small furnished cage and reported a positive relation between aggressive pecking by dominant hens and use of nests by subordinates (Shimmura *et al*., 2007). Those results suggested that subordinate hens used the nest box for refuge. In the present study, LF low ranking hens spent more time escaping than pre-laying in the nest. Therefore, it was confirmed that low ranking LF hens used the nest for both laying and refuge, and especially for the latter.

In conclusion, in large furnished cages with a smaller allowance of dust bath per hen, higher ranking hens may have priority using the dust bath. Similarly, if nest space per hen is limited, low ranking hens may not perform nesting behaviour fully, spending more time in the nest box for refuge than for laying. These findings may be relevant for bird welfare.

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