British Poultry Science Volume 45, Number 1 (February 2004), pp. 20–27

Pop hole passages and welfare in furnished cages for laying hens

H. WALL, R. TAUSON AND K. ELWINGER

Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences, Uppsala, Sweden

Abstract 1. This study included two designs of furnished cages for 16 hens; H-cages divided into two apartments by a partition with pop holes in the middle of the cage, and fully open O-cages, without a partition. The hypothesis was that in this rather large group of birds the pop hole partition would benefit the birds by allowing them to avoid or escape from potential cannibals, feather-peckers or aggressive hens. All cages had two nests, two perches and one litter box.

2. A total of 10 cages (5 H and 5 O) were stocked with Lohmann Selected Leghorn (LSL) and 8 cages (4 H and 4 O) with Hy-Line W36. No birds were beak-trimmed.

3. Heterophil/lymphocyte (H/L) ratios, duration of tonic immobility (TI) and exterior appearance (scoring of plumage condition and wounds at comb or around cloaca) were used as indicators of well-being. Total mortality and deaths due to cannibalism were also recorded.

4. Visits to nests and passages through partition pop holes were studied in samples of 35 and 21 birds, respectively, using a technique based on passive integrated transponder (PIT) tags.

5. Cage design (H- *vs* O-cage) had no effect on the welfare traits chosen.

6. Hy-Line birds showed higher H/L ratios, longer duration of TI and better plumage condition than LSL birds. These differences are discussed in terms of stress thresholds and copying strategies.

7. On days when a hen made visits to nests, the visiting frequency was 1·4 and the total time in the nest was 41 min on average. Hens made use of the pop hole passages between 1 and 8 times per hen and day.

8. Overall low levels of aggression, lack of injuries or deaths due to cannibalism, and plumage condition indicating moderate feather pecking, together imply a low need to escape. The pop holes were used frequently and birds distributed well between compartments showing that the system worked well. However, at this group size there was no evidence in the measured traits that H-cages provided a better housing environment.

INTRODUCTION

To improve the welfare of laying hens, conventional cages will not be allowed in European Union countries from 2012 (European Commission, 1999). From then on cages will be permitted only if furnished with nests, perches and litter baths. In Sweden, conventional cages were banned in 1999, but the phase-out was delayed for another 4 years due to the fact that furnished cages that had been approved by compulsory testing were not available at that time.

The first approved models of furnished cages in Sweden are for groups of 8 or 10 birds (Tauson and Holm, 2002). Larger group sizes would benefit the birds by providing a larger total cage area, leading to enhanced exercise and probably, in turn, improved bone strength. In a larger cage it is also possible to incorporate two nests, two perches and a larger litter bath. Thereby, opportunities for birds to inspect and choose more than one nest site and for several birds to dust bath together are provided. Furthermore, larger group sizes imply an economic benefit due to a decrease in capital cost per hen housed. However, group size is one of the factors that has impact on the risk of problems with feather pecking (Bilčík and Keeling, 2000), cannibalism (Fiks-van Niekerk *et al.*, 2001) and aggressive interactions (Al-Rawi and Craig, 1975; Hughes and Wood-Gush, 1977; Bilčík and Keeling, 2000). The risk is important to consider especially in countries where beak-trimming is prohibited, like in Sweden, Finland and Norway, or where such prohibition is under way. Feather pecking is an animal welfare problem due to the pain it causes. Also, it may

Correspondence to: Dr Helena Wall, Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences, SE-755 97 Uppsala, Sweden. Tel: +46-(0)18674575. Fax: +46-(0)18674501. E-mail: helena.wall@huv.slu.se
Accepted for publication 1st August 2003.

ISSN 0007–1668(print)/ISSN 1466–1799(online) © 2004 British Poultry Science Ltd
DOI: 10.1080/00071660410001668815

develop into cannibalism if the pulling of large feathers results in bleeding. Poor feather cover is also an economic problem implying higher energy maintenance and thus higher feed consumption (Tauson and Svensson, 1980; Peguri and Coon, 1993). If the ability to avoid or escape from potential cannibals, feather-peckers as well as aggressive hens, could be improved in furnished cages it may allow larger groups of hens to be housed together.

Passive integrated transponder (PIT) tags are an identification system widely used to mark animals of different species. The technique has been used to identify individuals in studies where feeding activity has been measured, in fish (Brännäs and Alanärä, 1993) or in laying hens (Brännäs *et al*., 2001). From the high proportions of eggs laid in nests in furnished cages, reported in earlier studies (Appleby, 1998; Wall and Tauson, 2002), it is evident that most hens visit nests regularly. An interesting question is whether the nest-visiting pattern of a hen (visiting frequency or length of visits) is correlated to her welfare. For example, which hen in a group spends the longest time in the nest—the one showing signs of inferior welfare or the one with apparently good welfare? When assessing the welfare of layers, there are an almost infinite number of approaches available. This paper focuses on duration of tonic immobility (TI), heterophil/lymphocyte (H/L) ratio, exterior appearance, feather pecking and aggressive pecking. The duration of TI is considered a reliable measure of fearfulness in domestic fowls (Jones, 1986). The more fearful a bird is when TI is being induced, the longer it will remain immobile. During mild to moderate stress an increase in birds' H/L ratios is expected (Maxwell, 1993).

The objective of this study was to evaluate the use and effect of a partition with pop holes on some selected health, behavioural and physiological welfare traits in a furnished 16-hen cage. Furthermore, the PIT tag technique was adjusted and evaluated as a means of measuring passages through pop holes in the partition and into and out of nest boxes. As far as the authors are aware, this is the first paper where use of facilities in furnished metal cages has been studied by transponder technique.

MATERIALS AND METHODS

Birds, housing and light

The study included 160 Lohmann Selected Leghorn (LSL) and 128 Hy-Line White W36 birds. The pullets were reared in conventional rearing cages and were not beak-trimmed (prohibited in Sweden). At 16 weeks of age the birds were transferred to the experimental building, where they were housed in furnished three-tier experimental cages for 16 hens. The cages were constructed by making two back-to-back 8-hen metal cages into one 16-hen cage, either by taking away the rear metal partition (O-cage) or by providing the partition with pop holes (H-cage), see Figure 1. There were 9 cages of each design of which 5 were stocked with LSL and 4 with Hy-Line W36. The cages, 45 cm high in the centre, 100 cm deep and 96 cm wide, fulfilled the Swedish Animal Welfare Directives for a minimum of 600 cm^2 cage floor area per bird, with areas of nests and litter bath not included (SJVFS, 2003). At one end of the cage, two nest boxes, each measuring 25 × 50 cm (w × d), were positioned back-to-back (Figure 1), extending the total cage width by 25 cm. The nest size allowed more than one bird to use the nest simultaneously (Wall, 1998). The nests were 27·5 cm high in the front and had two openings (experimental design), one close to the feed trough and one close to the centre of the cage. Nests were lined with brown artificial turf (Astroturf®). Nest openings and pop holes were equipped with circular antennas (70 mm long and 150 mm in diameter). A litter box, measuring 50 × 50 cm (w × d) was placed on top of the roof area of the nests in adjacent cages, placed side by side.

Feed was distributed by an automatic flat chain feeder and eggs were collected daily by hand. The light was successively increased to 15 h at 24 weeks and was dimmed during 6 min in the evening before lights-out at 18 : 00 h, to imitate

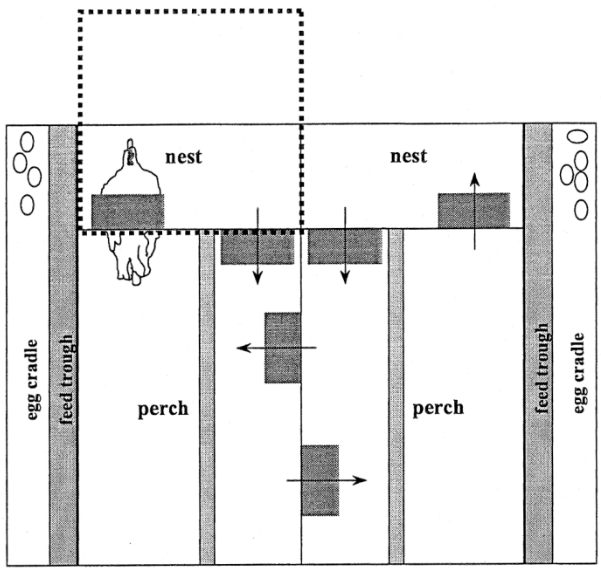

Figure 1. *Furnished cage for 16 hens with rear partition (H-cage), view from above. Antennas, illustrated by rectangles, were placed in nest openings and in rear partition pop holes. Each antenna had a swing door that enabled passage in only one direction (direction indicated by arrow). A litter bath (dotted lined rectangle) was positioned on top of the nest.*

dusk, and increased over the same period of time in the morning, dawn, at 03 : 00 h. Management of litter baths and content of feed were described by Wall *et al.* (2002).

Recording and statistical analysis of data

H/L ratios, duration of TI, exterior appearance and bird live weight were measured on 5 randomly chosen birds per cage, 90 birds in total. Coloured leg rings made it possible to identify each of these 5 focal birds. Mortality was recorded for all 16 birds per cage between 20 and 80 weeks. Hens that died during the study were subjected to autopsy and were not replaced.

H/L ratios

On 5 consecutive days at 37 and 72 weeks, one focal hen per cage was caught each day. Each focal hen was sampled once at each age. Blood was drawn from the wing vein using a 2 ml syringe and 0·8 mm gauge needle. The blood, approximately 1·5 ml, was gently ejected into tubes coated with lithium heparin anticoagulant and stored chilled. Blood collection took place in the poultry house and the procedure from catching the bird until blood was in the tube averaged 2 min. Blood smears were prepared in the laboratory. After drying, the smears were stained using May–Grunewald–Giemsa stain. Two hundred leukocytes, including heterophils, eosinophils, basophils, lymphocytes and monocytes were counted at ×40′ (oil immersion lens) and the H/L ratios were calculated.

Exterior appearance and live weight

Recording of bird live weight and scoring of external appearance were carried out at 52 weeks on the 5 focal birds in each cage. The traits scored for were: condition of plumage (neck, breast, back, wings, tail and cloaca) and wounds on the comb and around the cloaca. The scoring system assigned values of 1 to 4 points for each trait (Tauson *et al.*, 1984), where 4 represents no damage and 1 represents severe damage. The 6 variables for plumage condition were summarised; implying a total score ranging from 6 to 24 points.

TI test

Tonic immobility (TI) was assessed at 90 weeks. Testing took place between 09 : 00 and 13 : 00 h. All birds were tested within a period of 9 consecutive days. TI was induced by restraining the bird on its back for 15 s in a V-shaped wooden cradle covered with a dark towel, with the head hanging outside as described by Jones and Faure (1981). The operator held one hand over the bird's breast while the other hand covered the head. Testing took place in a separate room and the time from catching until the bird was placed in the cradle was approximately 60 s. The bird had to remain immobile for a minimum of 10 s in order to consider TI to have been induced. The duration of TI, latency to self-righting, was recorded. Maximum duration time was set to 1800 s.

Feather pecking and aggressive pecking

Feather pecking and aggressive pecking were studied by direct observations on 8 consecutive days at 35 weeks. Each cage was studied during one day for four 20 min periods, two of the periods between 08 : 00 and 10 : 00 h and two between 12 : 30 and 14 : 30 h. Feather pecks were classified as gentle or severe (Keeling, 1994), while aggressive pecks were defined as rapid, vigorous pecks directed to the head in a downward direction. The depth of the cages required two observers, one on each side of the cage battery. Statistical analyses were performed on the sum of pecks from the 4 periods.

Visits to nests and use of pop holes measured by PIT tag technique

The PIT tag technique has been described in detail by Prentice *et al.* (1990). In the present study the design and choice of antenna characteristics were based on experiences made in a pilot study, where different models of experimental antennas were constructed and evaluated (Wall, 1998). The final choice of design was an antenna of thin insulated copper wire coiled around a tube of PVC, 70 mm long and 150 mm in diameter. The desired inductance of approximately 0·38 mH was obtained when the wire was coiled about 44 loops around the tube.

Following a local anaesthetic, a PIT tag (ID 100, System Trovan®, AEG Identifications-systeme GmbH, Ulm, Germany) was implanted subcutaneously on the back of each hen at 28 weeks. The transponders were implanted approximately 50 mm from the rump and as parallel to the backbone of the bird as possible. The antennas, connected to decoders (LID 604, System Trovan®, AEG Identificationssysteme GmbH), were placed in the nest openings and pop holes and carried doors with a swing mechanism that enabled passage in one direction only, either in or out of the nest, see Figure 1. This enabled date and time for passages into or out of each nest to be recorded and stored in separate data files: a nest entrance file and a nest exit file. Passages through the pop holes were stored in separate data files as well. Each cage was recorded by the transponder technique for a 13-d period during 70 to 89 weeks. The position of all eggs was recorded during the same period.

Before the statistical analysis could be performed, the crude data had to be sorted and interpreted. Regarding the nests, data from the nest entrance file were matched with data from the exit file of the two nests, respectively. Because hens sometimes stood still in the antenna area, numerous records in sequence were generated. Hence, successive records within a period of 60 s and from the same antenna were assumed to originate from the same passage, either a hen entering or leaving the nest. Hence, in further analyses only the first recording of such a sequence was used. Direct observations showed that the one-way doors did not completely prevent hens from passing in the 'wrong' direction. When it appeared most likely that a hen had passed in and out through the same antenna, through the same nest opening, the passages were treated as an ordinary nest visit.

Each day that a hen was recorded by at least one of the antennas in the nests was categorised as either 'successful', in the meaning that the records could be interpreted into nest visits, or as 'unsuccessful' because visits to nests could not be identified. Hens for which at least two-thirds of the days with records were 'successful', were selected for further analysis. By this criterion 35 of the 90 focal hens were accepted and from now on are referred to as 'transponder hens'. In the majority of cages there was either one (6 cages) or two (7 cages) transponder hens. In the remaining 5 cages there were 0 or 3, 4 or 5 transponder hens. Total time spent in nests per day, number of visits to nests per day and distribution of visits between nests were calculated for each transponder hen.

Of the 35 transponder hens, 21 were housed in cages with a partition and pop holes (H) and the rest in fully open cages (O). In the pop hole data files, records in a sequence within 5 s were assumed to have arisen at the same passage and hence, in further analyses, only the first recording of such a sequence was used.

At 90 weeks, when the study ended, the back of each hen was manually scanned with an antenna in order to detect birds in which the PIT tag was lost, had moved out of position, or did not work.

Statistical analysis

Statistical analyses were performed using the statistical system SAS (SAS Institute Inc., 1999–2001, SAS System for Windows, release 8·02 TS Level 02M0). The study was a split-plot design (Snedecor and Cochran, 1989), in which the main plot corresponds to three vertical cages and subplot to one single cage. Three vertical cages were always either pop hole cages (H) or open (O). Hence, when comparing H- *vs* O-cages, the experimental unit was made up of three cages. Hybrids were alternated within vertical cages and therefore, when comparing hybrids, each cage was an experimental unit. The total number of cages was 18, implying 6 main plots and 18 subplots. To satisfy assumptions of normality, data were transformed where necessary. Mortality rates were transformed to arcsines (Snedecor and Cochran, 1989) and the number of feather pecks and aggressive pecks were log transformed. Analysis of variance was performed using the MIXED procedure with the following model, where *Y* refers to the response variable:

```
PROC MIXED;
CLASSES V D H;
MODEL Y = D H D×H;
RANDOM V*D;
```

where V = three vertical cages, D = cage design (H- or O-cage) and H = hybrid. Calculation of partial correlation between the recorded traits was performed.

The traits regarding nest visits and pop hole passages did not satisfy assumptions of normality, even after being transformed and hence, analysis of variance was not performed. Calculation of Spearman partial rank-order correlation was performed between the traits regarding nest visits and passages and welfare traits. The analyses included only the transponder hens and these were treated as independent observations.

RESULTS

During the observations of pecking, severe feather pecking was seen in only two of the cages, and this trait was therefore not included in the statistical analyses. Neither hybrid nor cage design had any significant effect on gentle feather pecks or aggressive pecks. During the total of 80 min that each cage was observed, the average number of gentle feather pecks and aggressive pecks were 68 (minimum 16, maximum 176) and 16 (minimum 0, maximum 35), respectively. The majority of aggressive pecks occurred at the feed trough.

The scoring of external appearance revealed that none of the hens had wounds on the comb or around the cloaca, implying that all groups received the highest possible score for the trait (not in the tables). Plumage condition, bird live weight, H/L ratios and TI duration were all affected by hybrid but not by cage design

Table 1. *Plumage condition, bird live weight, H/L ratios and duration of TI as affected by cage design and genotype*

	Cage design		Hybrids		*P*-value		
	H-cage	O-cage	Hy-Line	LSL	Cage design	Hybrids	Cage design*Hybrid
Plumage condition[1]	18·8	18·6	20·3	17·1	0·78	0·001	0·97
Bird live weight (kg)	1·75	1·78	1·69	1·85	0·56	0·001	0·40
H/L ratio at 37 weeks of age	0·57	0·55	0·69	0·44	0·81	0·018	0·11
H/L ratio at 72 weeks of age	0·62	0·69	0·91	0·40	0·61	0·001	0·39
Duration of TI (s)	774	613	936	450	0·18	0·001	0·85

[1]Score from 6 to 24 points: the higher scores indicate better plumage.

Table 2. *Means of traits regarding nest visiting patterns*

	Cage design		Hybrids	
	H-cage	O-cage	Hy-Line	LSL
Number of hens observed	21	15	16	20
Total time spent in nests/hen and day, min[1]	41·7 (10·5–86·4)[2]	39·6 (13·1–57·2)	40·3 (21·7–70·8)	41·2 (10·5–86·4)
Number of visits to nest/hen and day[1]	1·35 (1·0–2·4)	1·5 (1·0–1·9)	1·5 (1·1–2·4)	1·3 (1·0–1·8)
Consistency in nest choice regarding nest visits, proportion[3]	0·90 (0·54–1·0)	0·90 (0·69–1·0)	0·86 (0·54–1·0)	0·93 (0·67–1·0)

[1]Only days when a hen made visits to nests are included in calculated means.
[2]Values in parentheses represent min and max.
[3]Ranges from 0·5 (both nests visited to equal extent) to 1·0 (all visits to the same nest).

(Table 1). Hy-Line hens had better plumage condition, lower body weight, higher H/L ratios and longer TI duration than LSL hens. No partial correlations of interest were found except for a negative correlation between bird live weight and TI duration (−0·81; $P<0{\cdot}001$). The mortality (from 20 to 80 weeks of age) was significantly affected neither by cage design, nor by genotype. The mortality was 2·8% in H-cages, 4·9% in O-cages ($P<0{\cdot}56$), and 3·1 and 4·4% in Hy-Line and LSL ($P<0{\cdot}61$), respectively. No birds were injured or died due to cannibalistic pecking.

During the 13-d recording period, Hy-Line hens laid 90·6% of the eggs in nests whereas in LSL this proportion was only 66·8% ($P<0{\cdot}05$). Cage design, H- or O-cage, did not significantly affect the proportion of eggs laid in nests. Eggs laid in nests were distributed approximately equally between the two nests in 12 of 18 cages—each nest containing more than 40 and less than 60% of all nest eggs. In the remaining cages, the distribution of eggs between nests was less equal, with up to 78% of eggs laid in the same nest. However, regarding nest visits (Table 2), most of the transponder hens visited one of the two nests far more frequently than the other nest—the average hen made 90% of her visits to the nest she visited most frequently. On days when a hen made visits to nests, the frequency was 1·4 visits and the total time in nests per day was 41 min on average (Table 2). Of the 35 transponder hens, one LSL and one Hy-Line hen, both housed in O-cages, stayed in the nest during the night twice during the 13-d period of recording. As examples, Figure 2 illustrates the distribution of visits to the two nests in two of the hens. No significant correlations were found between the traits regarding nest visits, pop hole passages and welfare traits.

The majority of the transponder hens housed in H-cages (16 of 21) passed through the pop holes on average one to three times a day. The remaining 5 animals passed between 5 and 8 times per day, on average. According to the research technician the birds were generally evenly distributed between the compartments. When hens were scanned at 90 weeks PIT tags could not be detected in 11·5% of the hens.

DISCUSSION

No differences between H- and O-cages were found in any of the welfare traits recorded. There were no signs of cannibalistic behaviour; none of the birds had wounds around the cloaca at the scoring of external appearance and no injuries or deaths due to cannibalism were detected. As a consequence, there was probably no urgent need for birds to escape in order to avoid cannibalistic pecking. At the behavioural observations at 35 weeks some aggressive pecking was observed but none of the birds had wounds on the comb when scored for external appearance at 52 weeks. It is not known whether the aggressive pecks did not result in wounds or if aggression declined with bird age. The absence of cannibalism together with the low level of aggression make it difficult to form an opinion on whether pop hole passages function as a way of escape when there is a need.

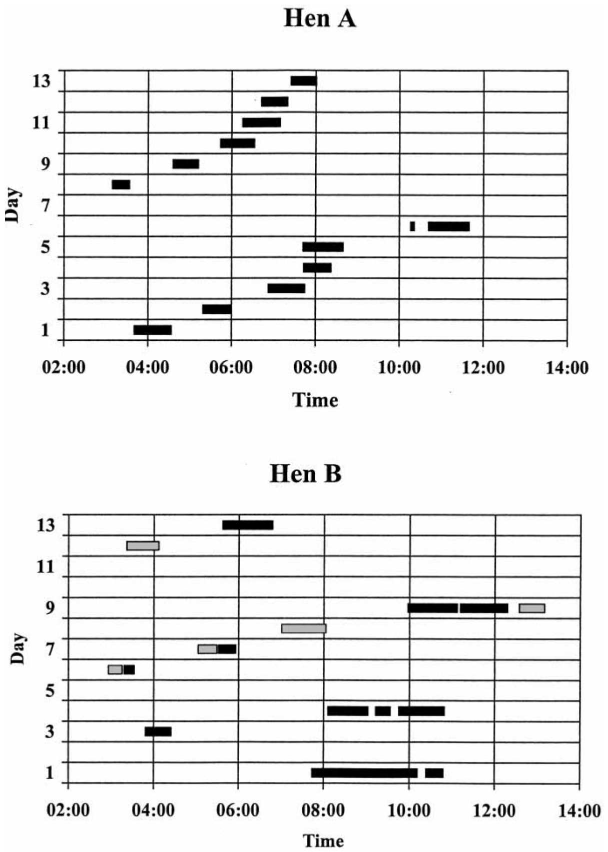

Figure 2. *Example of the time for and duration of visits of two hens to nests during the 13-d period of recording. Each rectangle symbolises a nest visit and visits to different nests are distinguished by colour, black vs grey. Hen A directed all visits to one of the nests whereas hen B made visits to both nests. The light was on between 03 : 00 and 18 : 00 h.*

However, it was obvious that birds alternated between compartments by using the pop holes and it would appear that some birds find it attractive to change compartments, perhaps appreciating the opportunity for variation. In even larger furnished cages without partition/pop holes, housing up to 54 non-beak-trimmed hens together, high mortality rates due to cannibalism have been reported (Fiks-van Niekerk *et al.*, 2001). It would be interesting in such large group sizes to study effects of similar partitioning devices as used in the present study.

It has been shown that elevated perches improve escape possibilities for hens housed in pens (Cordiner and Savory, 2001). The Get-away cage, first developed by Bareham (1976) and Elson (1976), had different perch levels to facilitate birds' possibilities to escape. However, that cage design had disadvantages such as poor inspection possibilities, poor egg quality regarding cracked and dirty eggs (Abrahamsson *et al.*, 1995) and soiling of plumage (Abrahamsson *et al.*, 1996). The latter was caused by hens on the elevated perches defaecating on birds below, but also due to inferior hygiene in general. Although Wall *et al.* (2002) found slightly inferior plumage hygiene of birds in cages with pop hole passages the plumage hygiene was quite acceptable. Furthermore, as no effect of the pop hole partition was found on the proportion of dirty eggs in that study, the H-cage seems acceptable from the hygienic point of view in contrast to the Get-away cage.

The differences found in the present study were related to genotype. Thus Hy-Line birds had a lower live weight, better plumage condition, higher H/L ratios and longer TI reaction than LSL. Hy-Line is a small bird and the difference in bird live weight between Hy-Line and LSL was therefore expected. The plumage score of 20·3 (max. score 24·0) at 52 weeks found in the Hy-Line birds, implies that little severe feather pecking occurred. Although LSL birds had a lower plumage score (17·1) than the Hy-Line birds, the feather pecking was still moderate for non-beak-trimmed birds. Corticosterone, supplied through the diet (El-lethey *et al.*, 2001) or by infusion (Jones *et al.*, 1988) generates raised H/L ratios and prolonged duration of TI, indicating that TI as well as H/L is closely related to stress. El-lethey *et al.* (2000) suggested that stress is a factor that may enhance the development of feather pecking, but it may be that a certain stress threshold has to be overcome before such an abnormal behaviour appears. A possible difference in this threshold may explain why Hy-Line hens had such good plumage despite appearing to be more stressed than LSL, according to H/L ratios and TI durations.

However, differences in the stress response in lines of hens showing a high or low tendency to feather peck have been explained in terms of active and passive coping strategies (Korte *et al.*, 1997). These strategies are associated with different physiological and endocrine responses to stress (Korte *et al.*, 1997) and may also be related to birds' TI response (Beuving and Blokhuis, 1997). In the present study the LSL hens, performing more feather pecking but showing less fear, may have a more active coping strategy than the Hy-Line hens.

The negative correlation between bird live weight and TI duration agrees with associations found between growth and fearfulness in lines of quails divergently selected for either body weight (Jones *et al.*, 1997) or duration of TI (Minvielle *et al.*, 2002). However, no correlation was found between the traits in a quail line selected neither for body weight nor fear response (Minvielle *et al.*, 2002).

The proportion of eggs laid in nests was rather low for the LSL birds (66·8%) whereas the Hy-Line proportion (90·6%) was more in agreement with results from other studies on furnished cages at research stations (Wall and Tauson, 2002) or in surveys in commercial farms

(Tauson and Holm, 2002) where there are no experimental doors in nest openings. The birds in the present study were part of a study on egg quality reported by Wall *et al.* (2002). With twice as many replicates as in the present study and repeated measurements of egg position, Wall *et al.* (2002) found a significant interaction between cage design and hybrid because LSL birds laid fewer eggs in the nests (with experimental doors) when housed in O-cages compared with H-cages, whereas there was no difference regarding Hy-Line. It was suggested that LSL birds found it difficult to learn how to enter nests, and in H-cages learning was facilitated by use of the same experimental doors in the partition pop holes. Considering the substantial effort hens have proved willing to make in order to reach attractive nest sites (Smith *et al.*, 1990) it is surprising that the LSL hens did not learn how to reach the nest. It may be that the genotypes differed not only in capacity to use experimental doors but also in the perception of the nests (Cooper and Appleby, 1997). In the present study, no direct observations of hens' nesting behaviours were performed. However, providing cages with nests reduces birds' frustration prior to oviposition (Yue and Duncan, 2003) and in furnished small group cages for 4 to 6 birds, nesting behaviour has been reported to be settled (Appleby, 1998).

The PIT tag technique was considered to have worked reliably in only 35 out of the 90 focal birds. Some birds were never recorded by any of the antennas and one possibility is that these hens never passed through the antennas. As tags could not be detected in 11·5% of the hens it is likely that some hens were not recorded because they had lost their PIT tag, the tag had moved under the skin or malfunctioned. Furthermore, a few hens were probably wrongly classified as impossible to interpret and hence could in fact have been included in the analyses. The cage itself, being of metal, had a negative influence on the sensitivity of the antennas. However, although the number of 'transponder hens' was limited, they represented a sample of the flock. Hence, the study illustrates a large variation in the pattern of visits to nests and passages through pop holes in furnished cages, not shown before. The variation regarding nesting trait is clearly shown by the minimum and maximum levels, given in Table 2. Some hens' visits to nests showed a regular pattern, which most likely reflected their egg-laying pattern (for example, hen A in Figure 2), whereas other hens visited the nest at more irregular intervals (hen B in Figure 2). During the night, some hens in furnished cages may rest on the floor or in the nests, instead of on the perches, and the birds staying in nests may defaecate on the nest bottom lining, in turn causing dirty eggs. However, with the same experimental cage and genotypes as in the present study, Wall *et al.* (2002) found less than 1% of the birds in the nest after dark. In the present study, two transponder hens stayed in the nest overnight, but only for two nights. Obviously, some hens use different resting places during different nights.

In conclusion, no evidence that H-cages provided a better housing environment was found in the present study. On the basis of the few signs of aggression, lack of injuries or deaths due to cannibalism, and plumage condition indicating only moderate feather pecking, it is likely that the need to escape from aggressors, cannibals and feather-peckers was low. It is possible that the outcome would have been different if the need to escape had been more evident, for example, in an even larger group size or with other genotypes, such as medium heavy brown ones. If so, the furnished cage design used in the present study was shown to be working in so far as use of the pop holes is concerned.

ACKNOWLEDGEMENTS

The present studies were made possible by financial support from the Swedish Farmers' Foundation for Agricultural Research and the Swedish Board of Agriculture. The Department of Clinical Chemistry at the Swedish University of Agricultural Sciences is thanked for carrying out the blood cell counts. We also thank K.E. Holm for very valuable support in all matters regarding the PIT tag technique, R. Öberg for technical assistance and Bröderna Victorsson AB for providing the special designs of cages required.

REFERENCES

Abrahamsson, P., Tauson, R. & Appleby, M.C. (1995) Performance of four hybrids of laying hens in modified and conventional cages. *Acta Agriculturae Scandinavica, Section A, Animal Science*, **45**: 286–296.

Abrahamsson, P., Tauson, R. & Appleby, M.C. (1996) Behaviour, health and integument of four hybrids of laying hens in modified and conventional cages. *British Poultry Science*, **37**: 521–540.

Al-Rawi, B. & Craig, J.V. (1975) Agonistic behavior of caged chickens related to group size and area per bird. *Applied Animal Ethology*, **2**: 69–80.

Appleby, M.C. (1998) The Edinburgh Modified Cage: effects of group size and space allowance on brown laying hens. *The Journal of Applied Poultry Research*, **7**: 152–161.

Bareham, J.R. (1976) A comparison of the behaviour and production of laying hens in experimental and conventional battery cages. *Applied Animal Ethology*, **2**: 291–303.

Beuving, G. & Blokhuis, H.J. (1997) Effect of novelty and restraint on catecholamines in plasma in laying hens. *British Poultry Science*, **38**: 297–300.

Bilčík, B. & Keeling, L.J. (2000) Relationship between feather pecking and ground pecking in laying hens and the effect of group size. *Applied Animal Behaviour Science*, **68**: 55–66.

BRÄNNÄS, E. & ALANÄRÄ, A. (1993) Monitoring the feeding activity of individual fish with a demand feeding system. *Journal of Fish Biology*, **42**: 209–215.

BRÄNNÄS, E., WIKLUND, B.S., BUREL, C., CISZUK, P., LILJEDAHL, L.E. & KIESSLING, A. (2001) Note on a method for individual recognition in feed pecking in free running groups of hens. *Applied Animal Behaviour Science*, **70**: 239–243.

COOPER, J.J. & APPLEBY, M.C. (1997) Motivational aspects of individual variation in response to nestboxes by laying hens. *Animal Behaviour*, **54**: 1245–1253.

CORDINER, L.S. & SAVORY, C.J. (2001) Use of perches and nestboxes by laying hens in relation to social status, based on examination of consistency of ranking orders and frequency of interaction. *Applied Animal Behaviour Science*, **71**: 305–317.

EL-LETHEY, H., AERNI, V., JUNGI, T.W. & WECHSLER, B. (2000) Stress and feather pecking in laying hens in relation to housing conditions. *British Poultry Science*, **41**: 22–28.

EL-LETHEY, H., JUNGI, T.W. & HUBER, E. (2001) Effects of feeding corticosterone and housing conditions on feather pecking in laying hens (*Gallus gallus domesticus*). *Physiology and Behavior*, **73**: 243–251.

ELSON, H.A. (1976) New ideas on laying cage design—the 'get-away' cage. *Proceedings of the 5th European Poultry Conference*, Malta, pp. 1030–1041.

EUROPEAN COMMISSION (1999) Council Directive 1999/74/EC of 19 July 1999 laying down minimum standards for the protection of laying hens. Official Journal L 203, 03/08/1999.

FIKS-VAN NIEKERK, T.G.C.M., REUVEKAMP, B.F.J. & VAN EMOUS, R.A. (2001) Furnished cages for larger groups of laying hens. *Proceedings of the 6th European Symposium on Poultry Welfare*, Zollikofen, pp. 20–22.

HUGHES, B.O. & WOOD-GUSH, D.G.M. (1977) Agonistic behaviour in domestic hens: the influence of housing method and group size. *Animal Behaviour*, **25**: 1056–1062.

JONES, R.B. (1986) The tonic immobility reaction of the domestic fowl: a review. *World's Poultry Science Journal*, **42**: 82–96.

JONES, R.B. & FAURE, J.M. (1981) Tonic immobility ("righting time") in laying hens housed in cages and pens. *Applied Animal Ethology*, **7**: 369–372.

JONES, R.B., BEUVING, G. & BLOKHUIS, H.J. (1988) Tonic immobility and heterophil/lymphocyte responses of the domestic fowl to corticosterone infusion. *Physiology and Behavior*, **42**: 249–253.

JONES, R.B., SATTERLEE, D.G. & MARKS, H.L. (1997) Fear-related behaviour in Japanese quail divergently selected for body weight. *Applied Animal Behaviour Science*, **52**: 87–98.

KEELING, L.J. (1994) Feather pecking—who in the group does it, how often and under what circumstances? *Proceedings of the 9th European Poultry Conference*, Glasgow, pp. 288–289.

KORTE, S.M., BEUVING, G., RUESINK, W. & BLOKHUIS, H.J. (1997) Plasma catecholamine and corticosterone levels during manual restraint in chicks from a high and low feather pecking line of laying hens. *Physiology and Behavior*, **62**: 437–441.

MAXWELL, M.H. (1993) Avian blood leucocyte responses to stress. *World's Poultry Science Journal*, **49**: 34–43.

MINVIELLE, F., MILLS, A.D., FAURE, J.M., MONVOISIN, J.L. & GOURICHON, D. (2002) Fearfulness and performance related traits in selected lines of Japanese quail (*Coturnix japonica*). *Poultry Science*, **81**: 321–326.

PEGURI, A. & COON, C. (1993) Effect of feather coverage and temperature on layer performance. *Poultry Science*, **72**: 1318–1329.

PRENTICE, E.F., FLAGG, T.A. & MCCUTCHEON, C.S. (1990) Feasibility of using implantable passive integrated transponder (PIT) tags in salmonids. *American Fisheries Society Symposium*, **7**: 317–322.

SJVFS (2003) Statens jordbruksverks författningssamling 2003:6, L 100. Statens jordbruksverk, Jönköping, Sweden.

SMITH, S.F., APPLEBY, M.C. & HUGHES, B.O. (1990) Problem solving by domestic hens: opening doors to reach nest sites. *Applied Animal Behaviour Science*, **28**: 287–292.

SNEDECOR, G.W. & COCHRAN, W.G. (1989) *Statistical Methods*, 8th edn (Ames, Iowa State University Press).

TAUSON, R. & HOLM, K.E. (2002) Evaluation of Victorsson furnished cage for 8 laying hens according to the 7§ of the Swedish Animal Welfare Ordinance and according to the New-Technique Evaluation Program at the Swedish Board of Agriculture (in Swedish with English tables, figures and summary). Report 251, Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences.

TAUSON, R. & SVENSSON, S.A. (1980) Influence of plumage condition on the hen's feed requirement. *Swedish Journal of Agricultural Research*, **10**: 35–39.

TAUSON, R., AMBROSEN, T. & ELWINGER, K. (1984) Evaluation of procedures for scoring the integument of laying hens—independent scoring of plumage condition. *Acta Agriculturae Scandinavica*, **34**: 400–408.

WALL, H. (1998) Studies of transponder technique in monitoring laying hens' individual use of nests in furnished cages (in Swedish with abstract in English). Degree Project 96, Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences.

WALL, H. & TAUSON, R. (2002) Egg quality in furnished cages for laying hens—effects of crack reduction measures and hybrid. *Poultry Science*, **81**: 340–348.

WALL, H., TAUSON, R. & ELWINGER, K. (2002) Effect of nest design, passages, and hybrid on use of nest and production performance of layers in furnished cages. *Poultry Science*, **81**: 333–339.

YUE, S. & DUNCAN, I.J.H. (2003) Frustrated nesting behaviour: relation to extra-cuticular shell calcium and bone strength in White Leghorn hens. *British Poultry Science*, **44**: 175–181.