

Effect of Nest Design, Passages, and Hybrid on Use of Nest and Production Performance of Layers in Furnished Cages

H. Wall,¹ R. Tauson, and K. Elwinger

Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences, S-755 97 Uppsala, Sweden

ABSTRACT Production performance, including egg quality, and proportion of eggs laid in nests were studied in furnished experimental cages incorporating nests, litter baths, and perches. The study comprised a total of 972 hens of two genotypes: Lohmann Selected Leghorn (LSL) and Hy-Line White. The birds were studied from 20 to 80 wk of age, and conventional four-hen cages were included as a reference. In furnished cages for six hens, the effects of 30 or 50% vs. 100% nest bottom lining (Astroturf®) were studied with LSL hens. Nest bottom lining had no significant effect on egg production or proportions of cracked or dirty eggs, but the use of nests was significantly higher in cages incorporating nests with 100% lining, compared with 50 or 30%. The two hybrids were compared when housed in large, group-furnished cages

for 14 or 16 hens of two designs; with a rear partition with two pop holes or fully open, i.e., no rear partition. LSL birds produced significantly better and had a significantly lower proportion of cracked eggs. There was no difference between H- and O-cages, either in production or in egg quality. LSL birds laid a significantly lower proportion of eggs in the nests, especially in O-cages, implying a significant hybrid × cage interaction. When housed in conventional cages, the hybrids did not differ in proportion of cracked eggs but differed in production traits. It was concluded that with the present nest design, the proportion of nest bottom lining cannot be reduced without affecting birds' use of nests, but the proportion did not affect exterior egg quality. The effect of genotype should be considered in the further development of furnished cages.

(*Key words:* egg production, exterior egg quality, use of nests, furnished cage, passage)

2002 Poultry Science 81:333–339

INTRODUCTION

A change to housing systems to improve the possibilities for hens to perform behaviors such as nesting, dust bathing, perching, and wing flapping is currently taking place in Europe. In Sweden, the Animal Welfare Ordinance from 1997 (Statens jordbruksverk, 1997) states that, in 1999, hens in cages should have access to a nest, a perch, and a litter bath (furnished cages); in 2012, conventional cages will be banned in Sweden as well as in all other European Union countries (European Commission, 1999). In the development of furnished cages, several aspects must be taken into account. The facilities should be designed to benefit expression of the behaviors mentioned above and, at the same time, maintain good levels of livability, health, and production traits.

The fact that laying hens are willing to work to gain access to a suitable nest (Smith et al., 1990; Cooper and Appleby, 1994) proves that nesting is essential to laying

hens. Enclosure and an appropriate substrate are important nest attractants, and nests lacking these qualities tend to be used to a lesser extent (Appleby and McRae, 1986; Appleby, 1990). Besides improving the welfare, nests may also lead to improved egg quality. Smith et al. (1993) found lower proportions of cracked and dirty eggs with nests present, and Abrahamsson and Tauson (1997) recorded similar or lower proportions of dirty but higher proportions of cracked eggs in small group-furnished cages compared with conventional cages.

The hygienic consequences of birds defecating in nests may depend on nest bottom substrate (lining). From hygienic points of view, the optimal situation would probably be a material that allows manure to pass through, e.g., some kind of wire floor. However, several studies have shown that nests with wire floor or plastic netting are less attractive to birds than are nests with lining (Hughes, 1993; van Niekerk and Reuvekamp, 1995; Abrahamsson et al., 1996). Reed and Nicol (1992) found that in rollaway nests, an artificial-grass pecking strip mounted on the rear wall encouraged the performing of nesting behaviors measured as time spent in the nest.

©2002 Poultry Science Association, Inc.

Received for publication April 5, 2001.

Accepted for publication October 18, 2001.

¹To whom correspondence should be addressed: HelenaWall@huv.slu.se.

Abbreviation Key: LSL = Lohmann Selected Leghorns.

Their findings indicate that a smaller amount of substrate, e.g., artificial turf, present only in one part of the nest, may be sufficient to enable nesting behavior in laying hens. Less artificial turf in the nests may improve the nest hygiene as well as making cleaning between batches less time consuming.

One benefit of furnished cages for larger groups of hens is the larger total cage area that enhances bird exercise and, thereby, improves bone strength and escape from aggressive birds. Birds in larger cages are also given the option to choose between at least two nests and two perches. The Get-away cage, with two perch levels, was first developed by Bareham (1976) and Elson (1976) for groups of 15 to 25 hens. However, compared with small group-furnished cages, the Get-away cages have disadvantages, such as poor inspection possibilities, soiling of plumage, and poor egg quality regarding cracked and dirty eggs (Abrahamsson et al., 1995).

The objective of the present study was to evaluate effects on birds' use of nests and on egg quality when using different hybrids or different proportions of artificial turf as nest bottom lining. Furthermore, experimental cages for 14 and 16 hens at one perch level were also included in the study. These studies were designed mainly for the purpose of another study on group dynamics, but interesting findings regarding egg position and egg quality were found and are reported in this paper. Conventional cages were used mainly for basic genotype studies and not for statistical comparison with the furnished cages.

MATERIALS AND METHODS

Housing

The study was carried out from November 1997 until January 1999, comprising the time from 20 to 80 wk of age. Three furnished cage models and one conventional model, all installed in three vertical tiers, were included in the study. All systems were placed in the same experimental building and fulfilled the Swedish Animal Welfare Directives of a minimum of 600 cm² cage floor area per bird, with nest and litter bath excluded. The furnished cages were placed in two batteries, and the conventional cages were in one battery. An overview of the experimental layout is given in Table 1.

FC-6. FC-6 is a furnished cage for six hens (72 cm wide, 50 cm deep, and 45 cm high at the rear). A nest box measuring 25 × 50 cm (width × depth) and 27.5 cm high at the front was positioned at one end of the cage (at right angles to the feed trough). A litter bath, 23.5 cm high, was placed on top of the nest box. The front and rear of the litter bath were made of transparent material (Plexiglass®) to make it lighter and to improve inspection possibilities. The nest box and litter bath had the same area, 1,250 cm², with 208 cm² per hen. A perch was placed parallel to the feed trough, 20 cm from the rear partition and 8 cm above the cage floor. The cage was designed as described by Abrahamsson and Tauson (1997), except

for the design of the nest opening. Because the cages in the present study were also used to investigate individual use of nests in another study, the nest box had two openings, one near the feed trough and one near the rear of the cage, both equipped with circular plastic tubes (8 cm long and 15 cm diameter). The tubes had doors that enabled passage in only one direction. The doors were positioned so that birds entered the nest through the front opening and left through the rear. The nest boxes were lined with brown artificial turf (Astro turf®) with small holes covering 30, 50, or 100% of the nest-bottom welded-wire area. In nests with less turf, the lining was positioned at the rear of the nest, with the wire floor left uncovered in the front.

FC-14. FC-14 was a furnished cage constructed by making two 7-hen cages into one 14-hen cage, either by removing the rear metal partition or by providing the partition with pop holes (Figure 1). An open space above and underneath the partition enabled hens on opposite sides to see each other. The cage was 84 cm wide, 100 cm deep, and 45 cm high at the center of the cage, and each cage had two nest boxes (width × depth × height as in FC-6). Each nest had two openings and full covering of brown artificial turf (Astro turf®). Nest boxes in adjacent cages were placed side by side, providing a roof area of 50 × 50 cm on top of which large litter baths (50 × 50 × 23.5 cm; width × depth × height) were situated (Figure 1). Each 14-hen cage incorporated one of these large litter baths. Nest openings and pop holes were designed the same as the nest openings in FC-6.

FC-16. FC-16 housed 16 hens and was of a design similar to FC-14 but 96 cm wide to provide 600 cm² per hen.

Conventional Cage. The conventional cage was a four-hen metal cage measuring 48 × 50 × 38 cm (width × depth (height)). The cage had horizontal metal bars at the rear.

All systems had horizontal front bars and solid side partitions. Because FC-14 and FC-16 had feed troughs on both sides of the battery, all systems provided 12 cm feed trough length per bird. In the furnished cages, a perch length of 12 cm per hen was provided.

Birds, Rearing, Management Routines, and Feeding

A total of 376 Hy-Line White W36 and 596 Lohmann Selected Leghorn (LSL) hens were used. The pullets were reared in conventional rearing cages and were not beak-trimmed (prohibited in Sweden). At 16 wk of age, the birds were transferred to the experimental building, where they received 10 h of light per day. The light was successively increased to 15 h at 24 wk of age and was dimmed for 6 min in the evening before lights-out at 1800 h, to imitate dusk, and increased for 6 min in the morning, dawn, at 0300 h. Twice each week, manure was removed with belts, and litter baths were manually filled with sand. Litter baths had a time-controlled closing mechanism that enabled birds to enter between certain hours. After the door closed, birds inside could leave by pushing the door

TABLE 1. Description of the experimental layout of housing systems, treatments, hybrids and replicates¹

Housing system	Treatment	Replicates per treatment (n)	Cages per replicate	Birds per cage
FC-6	30% nest bottom lining	4 (4 LSL)	3	6
	50% nest bottom lining	4 (4 LSL)	3	6
	100% nest bottom lining	4 (4 LSL)	3	6
FC-14	Rear partition with pop holes	3 ² , 9 ³ (5 HY, 4 LSL)	3 ² , 1 ³	14
	Without rear partition	3 ² , 9 ³ (5 HY, 4 LSL)	3 ² , 1 ³	14
FC-16	Rear partition with pop holes	3 ² , 9 ³ (4 HY, 5 LSL)	3 ² , 1 ³	16
	Without rear partition	3 ² , 9 ³ (4 HY, 5 LSL)	3 ² , 1 ³	16
CO	-	6 (3 HY, 3 LSL)	9	4

¹FC-6 was a furnished six-hen cage; FC-14 and FC-16 were furnished cages for 14 and 16 hens, respectively; and CO was a conventional four-hen cage. Lohman Selected Leghorn (LSL) and Hy-Line (HY) birds were used.

²Three vertical cages were always of the same treatment; hence, when comparing treatment three cages together were treated as one replicate.

³Hybrids were alternated within vertical cages and therefore each cage was treated as one replicate when comparing hybrids.

open. At 16 wk of age, the bath opened 5 h after lights-on and was open for 4 h and 30 min. Thereafter the opening period was successively increased to 6 h and 30 min at 24 wk of age, when final hours open were reached. The litter bath then became open 8 h after lights-on and remained so until 30 min before dark.

The furnished cages had automatic flat chain feeders, whereas hens in conventional cages were manually fed once a day. The pullets were fed a crumbled grower diet during rearing. From 17 wk of age until slaughter, all hens received a crumbled layer diet with a calculated content of 2,700 kcal/kg (11.2 MJ) metabolizable energy, 159 g crude protein, 35 g Ca, and 6 g P.

Recording and Statistical Analysis of Data

All eggs were collected manually each day. Production and mortality were recorded daily per group from 20 until 80 wk of age. The weight of eggs was recorded once every week. Hens that died during the experiment were subjected to autopsy and were not replaced. The position of all eggs in the furnished cages was recorded once every fourth week, before egg collection. The location of all birds in furnished cages was recorded 1 h after lights-out once every eighth week.

On six occasions (at 31, 40, 49, 59, 68, and 80 wk of age) eggs were collected on 5 consecutive d and analyzed for proportions of cracked and dirty eggs in a small version of a commercial egg candling machine. At 60 wk of age, five eggs from each 16-hen cage were collected and analyzed for shape index, breaking strength (The Canadian Egg Shell Tester²), and shell thickness.

Shell thickness was calculated as an average of three measurements across the egg equator with the shell membrane removed before the measurement. Recording of live weight and scoring of hygiene regarding plumage and feet were carried out at 52 wk of age on all hens in FC-16 and FC-6 and on all hens in three randomly selected

cages per replicate in conventional cages. The scoring system assigned 1 to 4 points (Tauson et al., 1984) for each trait, where a higher score indicated a cleaner condition. Before statistical analysis, traits given in proportions (mortality, cracked and dirty eggs, egg position, and bird location) were subjected to arcsin transformation (Snedecor and Cochran, 1989). Statistical analyses were performed using the mixed procedure (Littell et al., 1996) of SAS software (SAS Institute Inc., 1996). To analyze individual differences between treatments, Fisher's protected least-significant difference test was used.

The following models, where Y refers to the response variable, were used for the different housing systems, respectively.

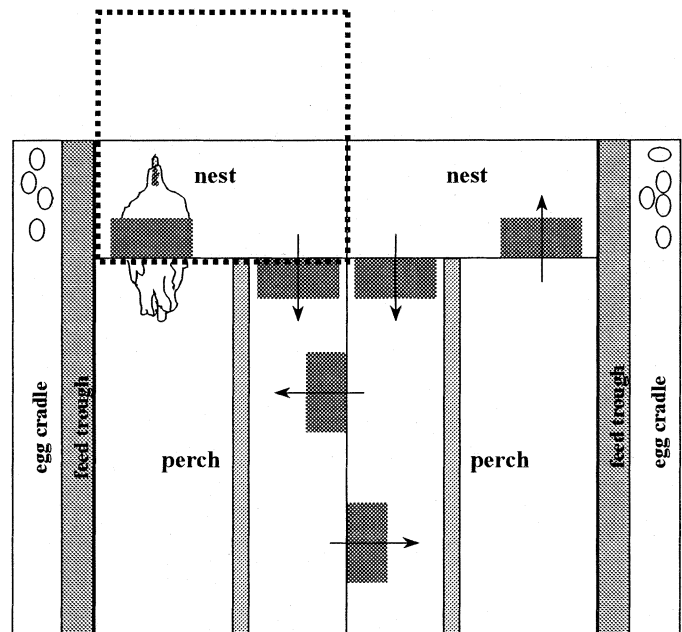


FIGURE 1. Furnished cage for 14 hens with rear partition, view from above. Rectangles with arrows symbolize one-way passages. Dotted lined rectangle symbolizes litter bath on top of nest.

²Otal Precision Company Limited, Ottawa Ontario, Canada K1G 3N3.

FC-6

```
PROC MIXED;
CLASSES R N A;
MODEL Y = N A N*A;
RANDOM R*N;
```

where R = replicate, N = proportion of nest bottom lining, and A = age. Traits not measured repeatedly were analyzed as above but with the age factor excluded.

FC-14 and FC-16

The experiment was a split-plot design (Snedecor and Cochran, 1989), in which main plot corresponds to three vertical cages and subplot to one single cage, see Table 1. Nonrepeated measures, e.g., production and scores of hygiene regarding plumage and feet, were analyzed as follows:

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

where V = three vertical cages, D = cage design, H = hybrid, and S = group size.

Traits measured repeatedly, e.g., egg position and bird location, were analyzed as follows.

```
PROC MIXED;
CLASSES V D H S C A;
MODEL Y = D H S A D*H D*S D*A H*S H*A S*A
D*H*S D*H*A H*A*S D*A*S D*H*A*S;
RANDOM V*D*S D*S*H*C;
```

where V = three vertical cages, D = cage design, H = hybrid, S = group size, C = one single cage, and A = age.

Group size, i.e., 14 or 16 hens, was not included in the model when analyzing hygiene, bird live weight, shape index, shell breaking strength, and shell thickness because these parameters were measured only in the 16-hen cages.

Conventional Cage

```
PROC MIXED;
CLASSES R H A;
Y = H A H*A;
RANDOM H*R;
```

where R = replicate, H = hybrid, and A = age. Traits not measured repeatedly were analyzed as above but with the age factor excluded.

As given in the statistical models above, all interactions were tested. However, three or four factor interactions were not found to be significant; therefore, they were excluded from the final statistical model. Furthermore, as the aim of the study was not to evaluate differences between different ages or group sizes, nonsignificant two-

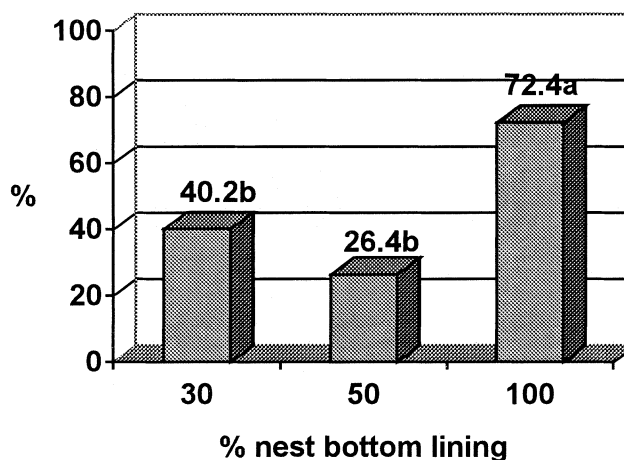


FIGURE 2. Percentage of eggs laid in nest boxes with 30, 50, or 100% nest-bottom lining in cages housing six hens. Columns with no common superscript differ significantly ($P \leq 0.01$).

factor interactions, including age or group size, were excluded from the final statistical models.

RESULTS

Nest Bottom Lining (FC-6)

Nest bottom lining (30 or 50% vs. 100%) had no significant effect on laying percentage, egg weight, egg mass, bird live weight, or proportions of cracked or dirty eggs. The proportions of cracked and dirty eggs with increasing nest bottom lining were 5.6, 5.7, and 4.2% and 3.9, 4.4, and 3.7%, respectively. The proportion of cracked eggs increased with bird age ($P \leq 0.001$), from 3.4% at 31 wk of age to 9.3% at 80 wk of age. No birds died in cages with 50 or 100% nest-bottom lining, whereas a total of six birds died in cages with 30% lining ($P \leq 0.05$), implying an average mortality of 2.8%. Lower proportions of eggs were laid in nests with 30 or 50% nest-bottom lining ($P \leq 0.01$) as compared with 100% coverage (Figure 2). No significant differences in hygiene regarding dirty plumage or feet were found. Observations of bird positions after lights-out showed that 83% roosted on the perch, 0.6% were in the nest box, and the rest of birds were on the floor. No birds were found in the litter baths during the dark period. Nest-bottom lining had no significant effect on where birds spent the night. The percentage of birds sleeping in the nests remained the same throughout the study, whereas use of perches increased with bird age ($P \leq 0.001$), reaching 88% at 80 wk of age.

Cage Design (FC-14 or FC-16) and Hybrid

Cage design, i.e., partition with pop holes vs. open cage, had no significant effect on production, mortality, live weight, or exterior egg quality (see Table 2). LSL had higher laying percentage, egg weight, and egg mass per hen housed as well as per hen day and live weight ($P \leq 0.001$). The proportion of cracked eggs increased with

TABLE 2. Production performance, mortality, and exterior egg quality parameters as influenced by cage design and hybrid in a furnished cage model (FC-14 and FC-16) and by hybrid in a conventional four-hen model (CO)¹

	FC-14 and FC-16						CO		
	Cage design		Hybrids		P-value		Hybrids		P-value
	H	O	Hy-Line	LSL ⁴	Cage	Hybrids	Hy-Line	LSL ⁴	Hybrids
Laying % (hen day)	85.4	84.6	81.6	88.4	0.40	***	82.5	89.8	**
Egg weight, g	61.6	61.9	60.8	62.6	0.43	***	62.6	64.4	**
Egg mass, kg /hen housed	21.9	21.4	20.4	22.9	0.35	***	21.7	23.7	**
Egg mass, g/hen day	52.6	52.3	49.6	55.4	0.71	***	51.6	57.8	***
Mortality, ² % of hen housed	1.8	4.8	3.4	3.2	0.29	0.92	0	5.6	**
Live weight, kg	1.72	1.77	1.65	1.84	0.36	***	1.63	1.87	*
Cracked eggs, ² %	10.3	9.7	14.2	5.8	0.67	***	3.4	3.3	0.99
Dirty eggs, ² %	2.8	2.5	2.5	2.8	0.61	0.33	4.9	3.4	0.06
Shape index, ³ %	73.4	73.7	74.2	72.9	0.51	*	—	—	—
Shell breaking strength, ³ kg	3.56	3.64	3.46	3.75	0.65	0.08	—	—	—
Shell thickness, ³ 10 ⁻² mm	30.5	30.5	29.8	31.2	0.99	**	—	—	—

¹H = cage with rear partition with pop holes; O = cage without partition.

²Presented as mean values instead of least-squares means because of the arcsin transformation.

³Measured only in FC-16 cages.

⁴Lohman Selected Leghorns.

* $P \leq 0.05$; ** $P \leq 0.01$; *** $P \leq 0.001$.

bird age ($P \leq 0.001$), from 6.3% at 31 wk of age to 15.0% at 80 wk of age (data not shown). Hy-Line hens had a higher proportion of cracked eggs compared with LSL hens ($P \leq 0.001$). Eggs laid by Hy-Line birds had a higher shape index ($P \leq 0.05$), indicating a more globular shape and a thinner eggshell ($P \leq 0.01$).

The proportions of eggs laid in the nests (data not shown in tables) were 89.6 and 69.4% for Hy-Line and LSL hens, respectively ($P \leq 0.001$). LSL laid a lower proportion in the nests, especially in cages without a rear partition (Figure 3), implying an interaction between cage design and hybrid ($P \leq 0.05$). The observations at the beginning of the dark period (data not shown) revealed that 89 vs. 80% of Hy-Line and LSL birds, respectively, roosted on the perches ($P \leq 0.001$), and use increased with age of bird ($P \leq 0.001$). The use of perches by LSL hens was higher in cages with a rear partition compared with

cages without, 84 vs. 76%, whereas the opposite was found with Hy-Line hens, 86 vs. 92%, resulting in an hybrid \times cage interaction ($P \leq 0.01$). Less than 1% of the birds spent the night in the nests, but this proportion increased with bird age ($P \leq 0.05$). The proportion of birds in the nests was higher in cages with 14 compared with 16 birds ($P \leq 0.01$), and there was an interaction between hybrid and group size ($P \leq 0.01$). This interaction occurred because the proportion of LSL hens spending the night in the nests was higher in cages with 14 hens than with 16 hens, whereas the opposite was the case for Hy-Line hens. Only six birds or 0.14% were found in the litter baths, and all of these were Hy-Line birds, resulting in a significant effect of hybrid ($P \leq 0.05$) for this trait. The average plumage hygiene score (data not shown) was 3.9 in open cages and 3.7 in cages with a partition ($P \leq 0.05$), where a higher score indicated cleaner conditions. There was no significant difference in plumage hygiene between hybrids. The average foot score was 3.8 in both hybrids (NS) and 3.7 and 3.9 in open and partitioned cages, respectively (NS).

Hybrid (Conventional Cage)

LSL had a higher laying percentage ($P \leq 0.01$), egg weight ($P \leq 0.01$), and egg mass per hen housed ($P \leq 0.01$) as well as per hen day ($P \leq 0.001$) (Table 2). No Hy-Line birds died, whereas a total of six LSL birds died, indicating an average mortality of 2.8% and a significant effect of hybrid ($P \leq 0.01$). There were no significant hybrid differences for cracked or dirty eggs, but the proportion of cracked eggs increased with bird age ($P \leq 0.05$), from 2.3% at 31 wk of age to 4.8% at 80 wk of age (data not shown). Plumage and foot hygiene (data not shown) did not differ between the hybrids, and the average scores were 4.0 for both traits, i.e., being the maximum possible score.

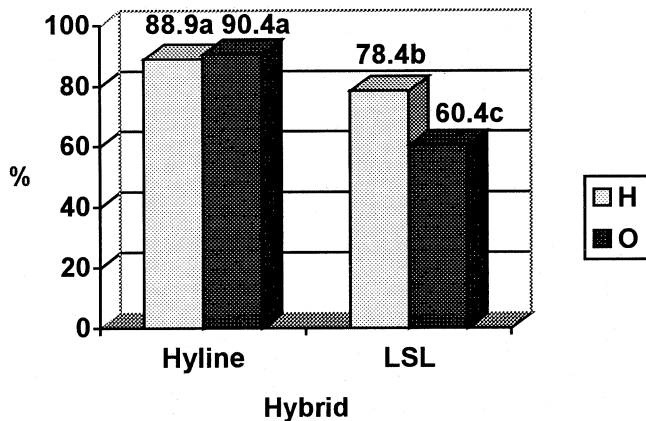


FIGURE 3. Percentage of eggs laid in nest boxes in cages housing 14 or 16 hens. The cages were open (O) without a rear partition or had a partition with pop holes (H). Columns with no common superscript differ significantly ($P \leq 0.05$). LSL = Lohman Selected Leghorns.

DISCUSSION

The furnished cages in this study were experimental cages, e.g., not constructed with special emphasis regarding egg quality. Hence, better results, especially regarding proportions of cracked eggs, have been reported by Wall and Tauson (2000) with designs that are more recent.

Significant differences regarding production and bird live weight were found only between hybrids. The overall low mortality agrees well with results by Abrahamsson and Tauson (1997). There is no known explanation of why only LSL hens died in conventional cages and why, in FC-6, mortality occurred only in cages with 30% nest-bottom lining, but these events are assumed to be random. Plumage and foot hygiene were good on the whole. The somewhat better plumage hygiene found in cages without a rear partition (FC-14 and FC-16) might have been due to the fact that already slightly soiled birds spread the dirt over a larger part of the body when passing through the tubes of the pop holes.

The proportions of eggs laid in nests with 100% nest-bottom lining were lower than reported by Abrahamsson et al. (1996), in which LSL birds in two trials laid 94 and 92% in nests, and by Abrahamsson and Tauson (1997), in which the proportion was 84% (LSL). The lower proportions in the present study, observed particularly with LSL, were probably due to the specially designed nest openings that made a bird's inspection of the nest, and also entering the nest, a bit more difficult. However, several studies have shown that hens are willing to work to get access to suitable nest sites (Smith et al., 1990; Cooper and Appleby, 1994), and, as the doors in the present study were easily pushed open, the motivation to use the nests was too low or some birds did not figure out how to get in and out. The latter is supported by the interaction between hybrid and cage design (Figure 3). This interaction indicated that LSL birds in cages with a rear partition might have learned how to enter the nests by use of the same door mechanism as in the pop holes in the partition. This observation shows the importance of using different hybrids in further studies on furnished cage design.

From a bird-welfare point of view, it seems important that the nest design attracts as many birds as possible. The lower proportions of eggs laid in nests with reduced nest-bottom lining clearly show that these nests did not provide an acceptable nesting environment. However, it should be noted that the lining was placed in the rear of the nest and was probably noticed only by hens that entered the nest. Perhaps more birds would have been attracted if the lining had been placed in the front, where the entrance was positioned, so that it could have been viewed from outside the entrance. Furthermore, the one-way doors also made inspection more difficult. As a majority of the eggs in cages with 30 or 50% nest-bottom lining were laid in the cage area, treatment effects regarding egg quality, i.e., due to lining, might not have been identified. Earlier studies have shown that nests with some kind of loose material (Huber et al., 1985) that can be molded (Duncan and Kite, 1989) are preferred when

hens are given a choice. However, enclosed nests with artificial turf as nesting material are accepted to a large extent when no other nesting substrates are present (Abrahamsson et al., 1996; Abrahamsson and Tauson, 1997; Appleby, 1998) and prelaying behavior has been reported to be normal (Appleby, 1998).

The considerable differences in cracked eggs between hybrids when housed in the large furnished cages (FC-14 and FC-16) might have been due to several factors. As shell thickness and shape index were measured only for FC-16 cages, it can only be assumed that Hy-Line eggs had thinner eggshells and a higher shape index compared with LSL eggs in conventional cages as well. If so, the thinner eggshell might have had a larger impact in the furnished cage because many eggs—on average 89.6% for Hy-Line and 69.4% for LSL—were laid in a nest of only 25 cm width. The accumulation of eggs increased the risk of collisions in the egg cradle and, hence, might have caused more cracks than in a conventional cage with three or four eggs in a cradle of about 50 cm length (Abrahamsson et al., 1995). The accumulation of eggs in the egg cradle outside the nests was higher in cages with Hy-Line birds, because of the hybrid difference in proportions of eggs laid in nests.

A tendency of lower proportions of cracked eggs in shallow-wide compared with deep-narrow conventional cages has been reported by Lee and Bolton (1976). A lower risk of two eggs colliding and a shorter distance between the rear and the egg collection area, leading to a decrease in the speed of rolling, were suggested as possible explanations of that difference. In the present study, the more globular shape of Hy-Line eggs might have affected the rolling characteristics, i.e., by enhancing the speed of eggs when rolling out of the nest. Furthermore, on several occasions, Hy-Line hens in different cages were observed moving eggs from the egg cradle back into the nest with their beaks by stretching their heads into the egg cradle, a behavior that probably affected the proportion of cracks. Sherwin and Nicol (1992) found that hens in cages incorporating nests were not randomly oriented when sitting in nests and that the orientation was dependent on whether the nest faced the cage with its long or short side. In deep nests, like those used in the present study, bird orientation as well as position in the nest (in the rear or front of the nest) may have a large impact on the proportion of cracked eggs, as the distance an egg has to roll may affect speed and thereby the risk of cracks.

Inferior hygiene resulting in dirty eggs has been reported to be a problem in earlier studies with cages incorporating nests lacking closing mechanism (Sherwin and Nicol, 1992; Smith et al., 1993). However, in those studies, the nest design enabled hens to roost on the nest edges, and, in the absence of perches, some birds did. In the present experiment, only a few hens stayed in the nests overnight, despite the fact that they were available round the clock, resulting in moderate proportions of dirty eggs. The difference in perch use after dark between the 14- vs. 16-hen cages (as well as the hybrid \times cage interaction) is difficult to explain, as perch length per hen was the

same in all cages. In earlier studies, the use of perches after dark has been greater than 90% (Abrahamsson et al., 1996; Abrahamsson and Tauson, 1997; Appleby, 1998), and it is not known why the proportions were lower in the present study, especially in LSL.

In conclusion, with the nest design used in the present study, the proportion of nest-bottom lining cannot be reduced to 30 or 50% without affecting the use of the nests by the birds. The outcome might, however, be different in nests with ordinary openings, lacking the specially designed one-way doors used in this study. The genotype differences in use of facilities and proportion of cracked eggs, as well as the genotype \times cage interactions, are important to consider in the further development of furnished cages.

ACKNOWLEDGMENTS

The Swedish Farmers' Foundation for Agricultural Research and the Swedish Board of Agriculture are thanked for financial support.

REFERENCES

- Abrahamsson, P., and R. Tauson, 1997. Effects of group size on performance, health and birds' use of facilities in furnished cages for laying hens. *Acta Agric. Scand. Sect. A Anim. Sci.* 47:254–260.
- Abrahamsson, P., R. Tauson, and M. C. Appleby, 1995. Performance of four hybrids of laying hens in modified and conventional cages. *Acta Agric. Scand. Sect. A Anim. Sci.* 45:286–296.
- Abrahamsson, P., R. Tauson, and M. C. Appleby, 1996. Behaviour, health and integument of four hybrids of laying hens in modified and conventional cages. *Br. Poult. Sci.* 37:521–540.
- Appleby, M. C., 1990. Behaviour of laying hens in cages with nest sites. *Br. Poult. Sci.* 31:71–80.
- Appleby, M. C., 1998. The Edinburgh Modified Cage: Effects of group size and space allowance on brown laying hens. *J. Appl. Poult. Res.* 7:152–161.
- Appleby, M. C., and H. E. McRae, 1986. The individual nest box as a super-stimulus for domestic hens. *Appl. Anim. Behav. Sci.* 15:169–176.
- Bareham, J. R., 1976. A comparison of the behaviour and production of laying hens in experimental and conventional battery cages. *Appl. Anim. Behav. Sci.* 2:291–303.
- Cooper, J. J., and M. C. Appleby, 1994. The use of aversive barriers to quantify nesting motivation in domestic hens. Pages 11–24 *in*: Proceedings of the symposium Modified Cages for Laying Hens. Universities Federation for Animal Welfare, Potters Bar, UK.
- Duncan, I. J. H., and V. G. Kite, 1989. Nest site selection and nest-building behaviour in domestic fowl. *Anim. Behav.* 37:215–231.
- Elson, H. A., 1976. New ideas on laying cage design—the 'get-away' cage. Pages 1030–1037 *in*: Proceedings of the 5th European Poultry Conference. WPSA, Malta.
- 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)*:53–57.
- Huber, H. U., D. W. Fölsch, and U. Stähli, 1985. Influence of various nesting materials on nest site selection of the domestic hen. *Br. Poult. Sci.* 26:367–373.
- Hughes, B. O., 1993. Choice between artificial turf and wire floor as nest sites in individually caged laying hens. *Appl. Anim. Behav. Sci.* 36:327–335.
- Lee, D. J. W., and W. Bolton, 1976. Battery cage shape: the laying performance of medium- and light-body weight strains of hens. *Br. Poult. Sci.* 17:321–326.
- Littell, R. C., G. A. Milliken, W. W. Stroup and R. D. Wolfinger, 1996. SAS® System for Mixed Models. SAS Institute Inc., Cary, NC.
- Reed, H. J., and C. J. Nicol, 1992. Effects of nest linings, pecking strips and partitioning on nest use and behaviour in modified battery cages. *Br. Poult. Sci.* 33:719–727.
- SAS Institute Inc., 1996. System for Windows, Release 6. 12 TS Level 0020. SAS Institute Inc., Cary, NC.
- Sherwin, C. M., and C. J. Nicol, 1992. Behaviour and production of laying hens in three prototypes of cages incorporating nests. *Appl. Anim. Behav. Sci.* 35:41–54.
- Smith, S. F., M. C. Appleby, and B. O. Hughes, 1990. Problem solving by domestic hens: Opening doors to reach nest sites. *Appl. Anim. Behav. Sci.* 28:287–292.
- Smith, S. F., M. C. Appleby, and B. O. Hughes, 1993. Nesting and dust bathing by hens in cages: Matching and mis-matching between behaviour and environment. *Br. Poult. Sci.* 34:21–33.
- Snedecor, G. W., and W. G. Cochran, 1989. *Statistical Methods*. 8th ed. Iowa State University Press, Ames, IA.
- Statens jordbruksverk, 1997. Statens jordbruksverks författningssamling. SJVFS 1997:71, L 106. Statens jordbruksverk, 551 82 Jönköping, Sweden. (In Swedish).
- Tauson, R., T. Ambrosen, and K. Elwinger, 1984. Evaluation of procedures for scoring the integument of laying hens - independent scoring of plumage condition. *Acta Agric. Scand.* 34:400–408.
- van Niekerk, T. G. C. M., and B. F. J. Reuvekamp, 1995. Improving the welfare of laying hens in cages. *Misset World Poult.* 11:38–41.
- Wall, H., and R. Tauson, 2000. Exterior egg quality and use of nests in furnished cages. Poster Abstract. Proceedings of the XXI World's Poultry Congress. Available: <http://www.wpsa.com>