Production performance and proportion of nest eggs in layer hybrids housed in different designs of furnished cages

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ABSTRACT The aim of the study was to compare use of nests, production performance, and egg quality in 4 designs of furnished cages (FC) housing 8 (T8), 10 (T10), 20 (T20), or 40 (T40) layers. The FC housing 8 and 10 hens were commonly used in commercial egg production in Sweden, whereas the cages housing 20 and 40 hens constituted new designs, at present not allowed in Sweden. The FC also differed in design and location of litter facilities. The study comprised 2 full production cycles (20–72 wk of age). Trial 1 included 588 Hy-Line White W98 and 460 Hy-Line Brown layers, and trial 2 used 572 Lohmann Selected Leghorn and 588 Lohmann Brown layers. In accordance with Swedish prohibition, beak treatment was not conducted. In both trials production parameters and mortality were considered normal and levels were unaffected by cage design. Deaths attributable to cannibalistic pecking were rare. Overall, exterior egg quality was superior in T8 compared with T20 and T40, whereas T10 generated intermediate results. Genotype differences were found in production performance, exterior egg quality, and use of nests. In T8 and T10 at least 95% of the eggs were laid in nest whereas in T20 and T40 a considerable percentage of eggs were laid on the litter mat, constituting the litter facility in those cage models. Additional lighting of litter mats (trial 2) had no effect on layers' choice of site for egg laying. Dividing T40 cages in 2 identical cage halves by a rear partition with pop holes had no effect on any of the traits measured. In conclusion, housing larger groups of non-beak-treated hens together in FC is possible, with acceptable levels of production and mortality, provided that cannibalism does not develop. The inferior egg quality in T20 and T40, likely caused by the large proportions of misplaced eggs, needs to be considered in the further development of those cage designs.

Key words: furnished cage, group size, production performance, exterior egg quality, nest use

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INTRODUCTION

Concern for the welfare of laying hens has led to a ban of conventional battery cages in the European Union countries (European Communities, 1999). Beginning in January 2012, cages must be furnished with nests and perches, and litter must be provided. According to the European Union directive, furnished cages (**FC**) should provide an area of 750 cm^2/hen but no stipulation exists regarding group size. Group size is a matter of high interest in Europe, and particularly in countries where national regulations restrict the maximum number of hens housed in the same cage (Blokhuis et al., 2007). Examples of countries with such restrictions are Sweden, where the maximum group size at present is 16 hens (Jordbruksverket, 2010), and Denmark, which allows only 10 birds together in the same FC (Fødevarestyrelsen, 2002). Irrespective of group size, several aspects must be considered when new designs of FC are developed. Besides providing hens in FC with good opportunities to perform nesting, perching, and litter-based activities, it is important that livability, health, and production traits are maintained at good levels.

Larger group sizes imply an economic benefit because of a decrease in capital cost per hen housed and benefit the layers by providing a larger total cage area, leading to enhanced exercise and possibly, in turn, a stronger skeleton. However, with increased number of hens housed together follows a higher risk for behaviors detrimental to bird welfare such as feather pecking, aggressive interactions (Bilčík and Keeling, 2000), and cannibalism (Fiks-van Niekerk et al., 2001). Especially in countries where all kinds of beak treatments are prohibited, such as in Finland, Norway, and Sweden, cannibalistic pecking may cause high mortality (Guesdon et al., 2006). Considering the potential risks followed by increased group size in FC, it is of interest to

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Table 1. Experimental layout of furnished cage models, genotypes, and replicates

Furnished cage model[1]	Replicates,[2] n Trial 1	Trial 2	Cages, n/replicate	Birds, n/cage
T8	8 (8 HyW)	15 (7 LSL, 8 LB)	2	8
T10	10 (5 HyW, 5 HyB)	10 (5 LSL, 5 LB)	2	10
T20				
No light upon litter turf	12 (6 HyW, 6 HyB)	6 (3 LSL, 3 LB)	1	20
Light upon litter turf	—	6 (3 LSL, 3 LB)	1	20
T40				
Free passage	6 (3 HyW, 3 HyB)	6 (3 LSL, 3 LB)	1	40
Pop hole passage	6 (3 HyW, 3 HyB)	6 (3 LSL, 3 LB)	1	40

[1] Furnished cages housed 8 (T8), 10 (T10), 20 (T20), or 40 (T40) layers.

[2] HyW = Hy-Line White W-98; HyB = Hy-Line Brown; LSL = Lohmann Selected Leghorn; LB = Lohmann Brown.

study whether minor alterations in cage design such as rear partitions with pop holes (Wall et al., 2004) can improve the possibility for potential victims to escape other hens without negative effects on production performance and egg quality.

A high use of nests implies that nest design is perceived attractive enough to motivate hens to enter and lay eggs there. Enclosure and an appropriate substrate (Appleby and McRae, 1986; Appleby, 1990), such as artificial turf lining (Wall and Tauson, 2002; Struelens et al., 2005), are important nest attractants. If the nest is of good design and used to a high extent, similar levels of cracked and dirty eggs as in conventional battery cages can be expected in small-group FC (Wall and Tauson, 2007). However, because FC for larger groups of hens is a more recently developed concept in housing, with other solutions for design as well as location of nest and litter facilities, studying use of the nest in relation to egg quality is of high importance.

The objective of the present study was to compare layers' use of nests, production performance, and egg quality in 4 designs of FC. The cages for 8 and 10 birds were models commonly used in commercial egg production in Sweden, whereas the cages for 20 and 40 hens constituted a new concept of FC design, likely with a potential for further development. In addition, one-half of the cages for 40 hens were divided into 2 identical cage halves by a rear partition with 2 pop holes. The study comprised 2 full production cycles and 4 genotypes.

MATERIALS AND METHODS

Housing

In 2 consecutive trials, 4 FC models were used in 3 vertical-tiers in the same experimental building. The cage models (Victorsson AB, Frillesås, Sweden) housed 8 (**T8**), 10 (**T10**), 20 (**T20**), or 40 (**T40**) hens. The models differed in aspects other than group size. All cages had horizontal front bars and solid side partitions. An overview of the experimental layout is given in Table 1. The study was approved by the Uppsala Local Ethics Committee.

The T8 (121 × 50 × 45 cm; width × depth × height) had a deep and narrow nest box (1,200 cm^2) positioned at one end of the cage and reaching all the way to the feed trough (Figure 1). In T10 (121 × 63 × 45 cm; width × depth × height) the nest (1,500 cm^2) was located along the rear partition (Figure 2). In T20 (242 × 79 × 45 cm; width × depth × height) the nest (3,600 cm^2) was positioned in one end of the cage (Figure 3). The T40 consisted of 2 T20 cages combined either by removing the rear partition in the perch area or by supplying the rear partition with 2 pop holes, each with a width of 20 cm. In T8 and T10, the litter facility was located on top of the nest (Figures 1 and 2), whereas in T20 and T40 the litter facility was a litter mat (i.e., a piece of artificial turf with perforated base fixed on the wire mesh). The litter mat, measuring 1,125 cm^2 in T20, was located on the opposite end of the cage in relation to the nest, whereas in T40 2 identical litter mats were located on opposite sides of the rear partition. In one-half of the T20 cages in trial 2, the litter mat was lit up by a lamp shining on the turf from above. In T10, T20, and T40 a daily portion of saw dust was delivered through an auger tube system, whereas the replenishment of litter in T8 was conducted by hand twice weekly. Calculated per day, each hen in T8, T10, T20, and T40 received an average daily portion of 5, 3, 4, and 4 g of saw dust, distributed either in the litter box or on top of the litter mat. In T8 and T10, access to the litter area was restricted by a time-controlled closing mechanism. A gate of welded wire prevented birds from entering. This gate was either turned up against the roof of the cage (T10) or turned down into the litter (T8) when hens were given access to the litter. At closing, birds inside the litter area either were gently pushed out of the litter when the gate was raised (T8) or could leave by pushing the gate open (T10). At 16 wk of age, hens in T8 and T10 had access to litter for 3.5 h in trial 1 and for 3 h in trial 2. Thereafter, access to litter was gradually increased to final opening hours at 31 wk of age in trial 1 and 23 wk of age in trial 2. In trials 1 and 2, litter baths then opened 7.5 and 8 h after lights-on, respectively, and remained open for 7.5 and 5.5 h, respectively. In both trials, litter bath closing time was set to 30 min before lights were turned out.

Figure 1. The furnished cage for groups of 8 layers with the nest box located to the right. The litter facility is positioned on top of the nest. During the daily period of access to the litter facility the wire gate was turned down into the litter. No egg belts were present when conducting the trials. Color version available in the online PDF.

In all cages, nest bottoms were lined with artificial turf and all cages fulfilled the requirement of 15 cm of perch length per housed hen. All cages had hard wooden perches. In T8 the nest was enclosed in the front by plastic black curtains, hanging behind the bars of the front gates of the cage. This curtain, ending 1 cm above the cage floor, acted as an egg saving device by reducing the speed of eggs rolling out of the nest into the cradle (Wall and Tauson, 2002). The T10, T20, and T40 cages had egg saver wires (i.e., a wire extending parallel to and underneath the feed trough that stopped eggs on the way out of the cage). The wire lifted every 10 min during the first 6 h after lights were turned on and thereafter twice per hour, allowing eggs to slowly roll the last short distance to the egg cradle.

Figure 2. The furnished cage for groups of 10 layers with the nest box located in the rear of the cage. The litter facility is positioned on top of the nest. During the daily period of access to the litter facility the wire gate was turned up against the roof of the cage. No egg belts were present when conducting the trials. Color version available in the online PDF.

Figure 3. The cage for 20 layers (T20), with the nest to the left behind the plastic curtains and the litter scratch pad (piece of artificial turf) located to the right. A cage for 40 layers (T40) was constructed by making 2 T20 cages into a single T40 either by removing the metal rear partition in the perch area or by providing the rear partition with pop holes. Color version available in the online PDF.

Birds, Lighting, and Feeding

In the trials all pullets were reared in conventional rearing cages in the same building. In accordance with prohibition in Sweden, beaks were not trimmed.

Trial 1 included 1,048 layers, of which 588 were Hy-Line White W-98 (**HyW**) and 460 were Hy-Line Brown (**HyB**). When transferred to the experimental building at 16 wk of age, birds received 10 h of light/d. The light was successively increased to 16 h at 31 wk of age.

Trial 2 included 1,160 hens, of which 572 were Lohmann Selected Leghorn (**LSL**) and 588 were Lohmann Brown (**LB**). On arrival to the experimental building at 16 wk of age, light was on for 9 h/d and was successively increased to 14 h at 23 wk of age. In both trials, light was increased for 7 min when lights were turned on in the morning to imitate dawn and dimmed for 7 min in the evening to immitate dusk.

Feed was distributed by an automatic flat chain feeder 4 times/d and water was provided from nipple drinkers. The hens received a conventional crumbled layer diet. Manure was removed twice per week with an automatic belt system.

Recording

All eggs were collected manually each day. Production and mortality were recorded daily per replicate (Table 1) from 20 until 72 wk of age. On occasion, when several hens died during a short period, dead birds were subjected to necropsy. For each dead hen the animal caretaker recorded whether cannibalism appeared to be the main cause of deaths. Dead birds were not replaced. The weight of eggs was recorded once every week. The position in the cages of all eggs was recorded on 6 occasions: at 22, 33, 40, 48, 57, and 65 wk of age in trial

1 and at 24, 32, 41, 49, 56, and 68 wk of age in trial 2. A small version of a commercial egg-candling machine was used to detect cracked and dirty eggs. All eggs collected during 5 consecutive days were candled on 5 occasions in trial 1 (at 28, 37, 51, 62, and 69 wk of age) and on 4 occasions in trial 2 (at 26, 36, 45, and 69 wk of age).

Statistical Analysis

Before statistical analyses, traits given in proportions (mortality, cracked and dirty eggs, and egg position) were subjected to arcsine transformation to achieve normal distribution (Snedecor and Cochran, 1989). Data were analyzed using the MIXED procedure of SAS (release 9.1, SAS Institute Inc., Cary, NC).

Nonrepeated measures (i.e., production traits and mortality) were analyzed as follows: PROC MIXED; CLASS CGR; MODEL Y = CGC × G, where C = cage model, G = genotype, and R = replicate. Traits measured repeatedly (i.e., egg position and exterior egg quality) were analyzed as follows: PROC MIXED; CLASS CGAR; MODEL Y = CGAC × GC × AG × A; RANDOM R × G × C, where C = cage model, G = genotype, R = replicate, and A = bird age. To analyze individual differences, Fisher's protected least significance difference test and Bonferroni corrections for multiple comparisons were used.

RESULTS

General

No significant differences related to the provision of pop hole passages in T40 (trials 1 and 2) or of illuminated litter mat (trial 2) were found for any of the parameters measured; therefore, results from those treatments are not presented in tables. In the comparison between cage designs, all T40 cages were treated as replicates regardless of having pop holes or not; similarly, all T20 cages were considered as replicates regardless of litter mats being illuminated or not. In both trials hens were infected by the poultry red mite (*Dermanyssus gallinae*), which was undesirably present in the building. It cannot be excluded that the mite infestation affected the well-being of the layers and to some extent the mortality.

Trial 1

In trial 1, with only HyW hens present in the T8 cage, results of production performance, mortality and exterior egg quality are presented in Table 2 (only HyW hens) and Table 3 (HyW and HyB hens). In trial 1, cage model had no effect on laying percentage, kilograms of eggs per hen housed, or egg weight. According to postmortem observations of dead birds conducted by the animal caretaker, cannibalism was recorded as likely cause of death in 3 of 68 dead birds throughout the study. In a comparison within HyW hens (Table 2), exterior egg quality was superior in T8 compared with T20 and T40 (cracks $P < 0.001$; dirties $P < 0.01$). The T10 cage with intermediate levels of cracked and dirty eggs did not differ significantly from any of the other cage designs in exterior egg quality. Within HyW hens, mortality rates were not significantly affected by cage design ($P < 0.33$).

Analyzing results over both genotypes (Table 3), a tendency ($P = 0.07$) indicated an effect of cage design on mortality. Except for a higher weight of eggs laid by HyW hens compared with those laid by HyB ($P < 0.05$), genotypes did not differ in production traits. The proportion of cracked eggs was lower in T10 than in T20 and T40 ($P < 0.01$), but no difference was found between cage designs in proportion of dirty eggs ($P < 0.22$). Proportions of cracked and dirty eggs were both higher in eggs laid by HyW hens than in eggs laid by HyB hens ($P < 0.001$).

The position of laid eggs in the different cage designs in trial 1 is illustrated in Figures 4a and 4b. The proportion of eggs laid in nest varied with cage design ($P < 0.001$) and use of nests was lower in T20 and T40 than in T8 and T10. This difference in nest use was prominent especially in HyB hens, implying an inter-

Table 2. Production performance, mortality, and exterior egg quality in Hy-Line White layers housed in 4 furnished cage models from 20 to 72 wk of age in trial 1

	Cage[1]					
Trait	T8 (n = 8)	T10 (n = 5)	T20 (n = 6)	T40 (n = 6)	P-value	SEM
Laying, %/hen day	86.3	84.0	85.0	84.9	0.43	0.494
Egg mass, kg/hen housed	19.5	19.4	19.4	19.8	0.68	0.120
Egg weight, g	65.8	65.7	64.9	65.2	0.12	0.155
Mortality,[2] % of hens housed	10.9	6.0	5.0	5.0	0.33	1.096
Cracked eggs,[2,3] %	1.9^{a}	3.1^{ab}	4.7^{b}	4.9^{b}	0.001	0.261
Dirty eggs,[2] %	7.5^{a}	11.3^{ab}	13.6^{b}	13.7^{b}	0.01	0.759

[a,b]Means within a row lacking a common superscript differ ($P < 0.05$).

[1]Furnished cages housed 8 (T8), 10 (T10), 20 (T20), or 40 (T40) layers.

[2]P-values based on statistical analysis of arcsine-transformed values.

[3]Gross cracks included.

Table 3. Production performance, mortality, and exterior egg quality in 3 furnished cage models from 20 to 72 wk of age in trial 1

	Cage[1]			Genotype[2]		*P*-value			
Trait	T10 (n = 10)	T20 (n = 12)	T40 (n = 12)	HyB (n = 17)	HyW (n = 17)	Cage	Genotype	Cage × genotype	SEM
Laying, %/hen day	84.2	84.8	85.8	85.2	84.6	0.41	0.55	0.65	0.499
Egg mass, kg/hen housed	19.4	19.5	19.6	19.5	19.5	0.90	0.87	0.67	0.139
Egg weight, g	64.9	64.8	64.8	64.4	65.3	0.96	0.05	0.23	0.165
Mortality,[3] % of hens housed	4.0	3.8	7.7	5.0	5.3	0.07	0.69	0.14	0.809
Cracked eggs,[3,4] %	2.3[a]	3.9[b]	3.6[b]	2.2	4.2	0.01	0.001	0.78	0.196
Dirty eggs,[3] %	8.1	10.4	10.2	6.3	12.9	0.22	0.001	0.93	0.601

[a,b] Means within a row lacking a common superscript differ ($P < 0.05$).

[1] Furnished cages housed 10 (T10), 20 (T20), or 40 (T40) layers.

[2] HyB = Hy-Line Brown; HyW = Hy-Line White W-98.

[3] *P*-values based on statistical analysis of arcsine-transformed values.

[4] Gross cracks included.

action between genotype and cage design ($P < 0.01$) and a difference between genotypes ($P < 0.001$). There was an effect of bird age on percentage of nest eggs ($P < 0.001$), and from first recording at 22 wk until last recording at 65 wk the percentage of nest eggs in HyW changed from 99.1 to 94.3% in T8, 94.3 to 98.3% in T10, 69.1 to 86.9% in T20, and 77.3 to 89.6% in T40. In HyB hens the percentage of nest eggs increased from 96.2 to 98.9% in T10, 37.5 to 56.7% in T20, and 42.7 to 60.8% in T40, from first to last recording.

Trial 2

In trial 2, with LB and LSL hens represented in all 4 cage designs, no differences between cage designs were found in laying percentage ($P < 0.43$), egg mass per hen housed ($P < 0.80$), egg weight ($P < 0.32$), or mortality ($P < 0.33$; Table 4). The LSL hens had a higher laying percentage ($P < 0.001$), lower egg weight ($P < 0.001$), and lower egg mass per hen housed than LB ($P < 0.01$). The genotypes did not differ in mortality rate ($P < 0.91$). Postmortem observations stated cannibalism as probable cause of death in 3 of 65 birds that died during the study.

Cage design affected exterior egg quality (cracks, $P < 0.001$; dirties, $P < 0.01$). The percentages of cracked and dirty eggs were both lower in T8 compared with T20 and T40. The T10 cage, having intermediate levels of cracked and dirty eggs, did not differ significantly from any of the other cage designs in exterior egg quality. In LSL the proportion of cracks increased with increasing group size, causing an interaction between genotype and cage design ($P < 0.05$). Genotypes did not differ in proportion of cracked eggs ($P < 0.89$), but the proportion of dirty eggs was higher in eggs from LSL hens than in eggs from LB hens ($P < 0.001$).

The proportion of eggs laid in nest (Figures 4c and 4d) differed between cage designs ($P < 0.001$) and use of nest was higher in T8 and T10 than in T20 and T40. No significant difference was found between genotypes in use of nests. Illumination of litter mats in T20 did not reduce the proportion of eggs laid there. Bird age affected the proportion of eggs laid in nests ($P < 0.001$) and from first recording at 24 wk until last at 68 wk a change occurred in LSL hens from 94.1 to 96.8% in T8, 93.9 to 97.5% in T10, 88.6 to 83.5% in T20, and 81.9 to 89.2% in T40. In LB hens the percentage of nest eggs increased from 90.6 to 98.3 in T8, 89.8 to 100% in T10, 78.6 to 84.8% in T20, and 59.9 to 73.7% in T40, from first to last recording.

DISCUSSION

Production and Mortality

In the present study comprising 2 full laying hen cycles, production performance (in terms of laying percentage, kilograms of eggs produced per hen housed, or egg weight) was not affected by cage design. Despite a

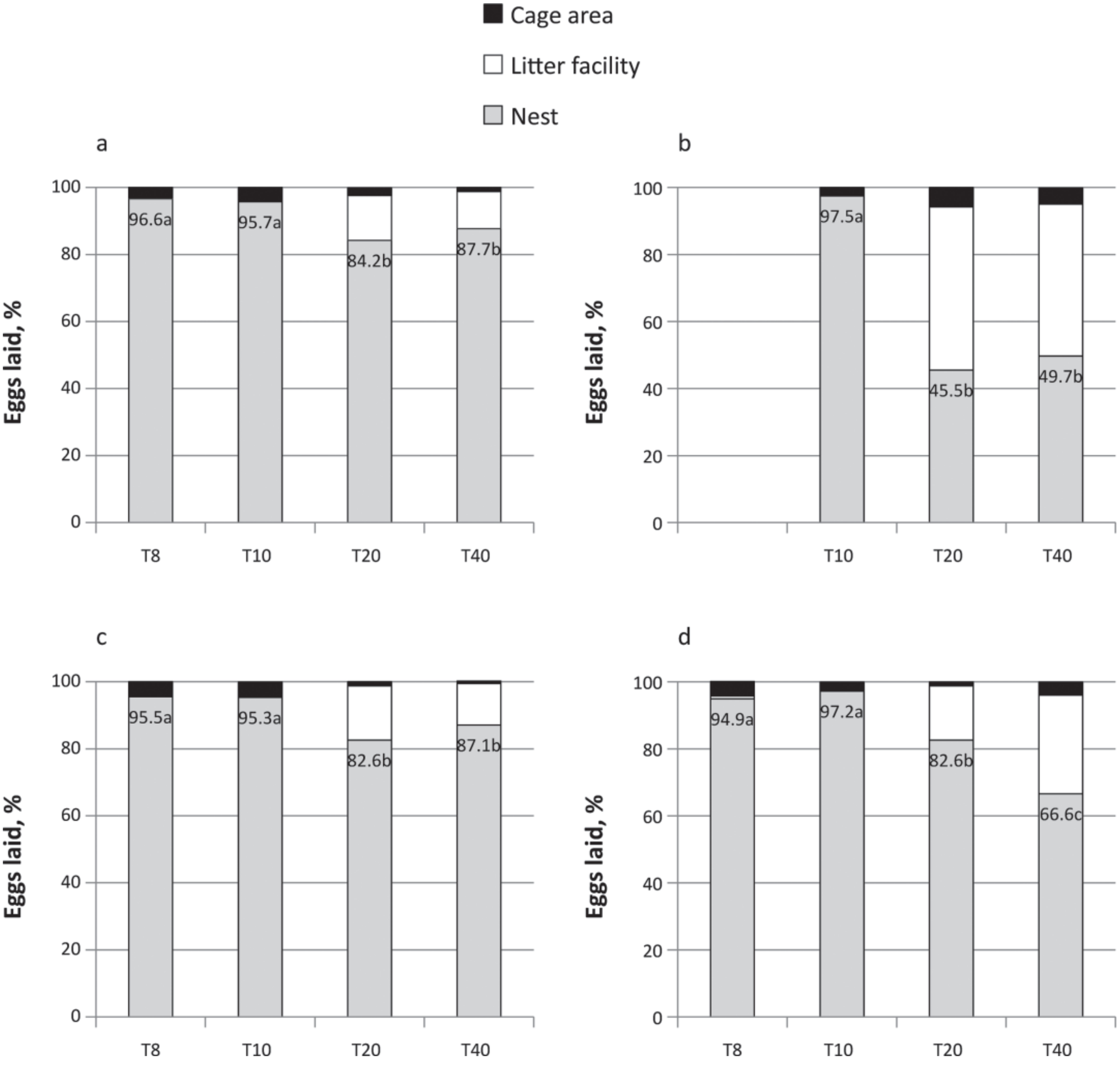

Figure 4. a) Percentage of eggs laid in nest, litter facility, or cage area in 4 furnished cage designs housing 8 (T8), 10 (T10), 20 (T20), and 40 (T40) Hy-Line White W98 layers in trial 1. b) Percentage of eggs laid in nest, litter facility, or cage area in 3 furnished cage designs housing 10, 20, and 40 Hy-Line Brown layers in trial 1. c) Percentage of eggs laid in nest, litter facility, or cage area in 4 furnished cage designs housing 8, 10, 20, and 40 Lohmann Selected Leghorn layers in trial 2. d) Percentage of eggs laid in nest, litter facility, or cage area in 4 furnished cage designs housing 8, 10, 20, and 40 Lohmann Brown layers in trial 2. Figures of nest use followed by different letters are significantly different.

high variation in percentage of cumulative mortality, the numerical differences did not generate significant differences in mortality. The mortality rate of 10.9% in HyW hens in T8 (trial 1) is higher than reported in earlier studies using the same cage design (Wall and Tauson, 2002, 2007; Wall et al., 2002). When trial 1 ended and cages were prepared for cleaning it became evident that red mites had accumulated in the saw dust in the litter facility of T8 cages, likely affecting the mortality because of anemia. Although the T10 cage had a litter facility of similar design as T8 (i.e., a tray on top of the nest), the litter provided in T10 was depleted daily because of lower edges of the tray; therefore, the litter therefore probably did not accumulate red mites to the same degree.

As long as mortality is at moderate levels and the housing environment does not allow loss of egg mass due to, for example, egg eating, similar production levels can be expected in different cage designs (Tactacan et al., 2009). However, if cannibalism occurs in flocks with intact beaks, the outcome may become worse when housing larger groups of laying hens together

Table 4. Production performance, mortality, and exterior egg quality in 4 furnished cage models from 20 to 72 wk of age in trial 2

Trait	Cage[1]				Genotype[2]		P-value			SEM
	T8 (n = 15)	T10 (n = 10)	T20 (n = 12)	T40 (n = 12)	LB (n = 25)	LSL (n = 24)	Cage	Genotype	Cage × genotype	
Laying, %/hen day	89.3	90.2	89.7	90.6	88.9	91.0	0.43	0.001	0.28	0.298
Egg mass, kg/hen housed	20.0	20.0	20.2	20.2	20.4	19.9	0.80	0.01	0.21	0.0903
Egg weight, g	63.3	62.8	63.1	62.8	64.6	61.4	0.32	0.001	0.25	0.113
Mortality,[3] % of hens housed	5.9	7.5	5.4	4.8	6.4	5.4	0.33	0.91	0.84	0.778
Cracked eggs,[3,4] %	2.1^{a}	2.9^{ab}	3.3^{b}	3.8^{b}	2.9	3.1	0.001	0.89	0.05	0.188
Dirty eggs,[3] %	5.9^{a}	6.6^{ab}	8.1^{b}	8.4^{b}	5.2	9.3	0.01	0.001	0.72	0.299

[a,b] Means within a row lacking a common superscript differ ($P < 0.05$).

[1] Furnished cages housed 8 (T8), 10 (T10), 20 (T20), or 40 (T40) layers.

[2] LB = Lohmann Brown; LSL = Lohmann Selected Leghorn.

[3] P-values based on statistical analysis of arcsine-transformed values.

[4] Gross cracks included.

compared with small groups. A higher incidence of cannibalism in noncage housing systems (single-tiered or aviary systems) compared with conventional cages (Abrahamsson and Tauson, 1995; Fossum et al., 2009) is generally explained as a consequence of the number of potential victims being greater in a larger group of hens compared with in a smaller group. Several studies indicate that cannibalism is also a problem in caged layers housed in furnished as well as in conventional cages (Fiks-van Niekerk et al., 2001; Weitzenbürger et al., 2005; Guesdon et al., 2006), although the mortality may be kept moderate because of beak trimming (Guesdon et al., 2006). However, in several countries such as Sweden, beak trimming is not allowed and other solutions to the problem must be sought. In the present study, using hens with intact beaks, the precise causes of deaths of all hens that died during the trials are not known. However, result from the necropsy of a sample of hens as well as the recording of likely cause of death conducted by the animal caretaker indicated that cannibalism was rare.

The lack of effect on production performance and mortality of dividing the T40 cages in 2 equal subdivisions by a rear partitioning with pop holes is in agreement with earlier studies with a similar approach (Wall et al., 2002, 2004). However, the previous studies were conducted in furnished 14- and 16-hen cages housing only white hybrids, whereas the challenge in the present study was likely higher because of the considerably larger group size and the inclusion of brown hybrids. As in the study on 16-hen cages (Wall et al., 2004), deaths resulting from cannibalism were at low levels in the present study.

Differences between genotypes in production performance were found mainly in trial 2. Genotype differences in egg weight and hen day production are commonly reported (e.g., Wall and Tauson, 2007), reflecting differences in hens genetic capacity.

Use of Nests and Egg Quality

According to several studies, hens in small-group FC with well-designed nests generally have a high nest usage (Wall and Tauson, 2002, 2007), which is also confirmed in the present study with a minimum of 95% of nest eggs in T8 and T10. In the small-group FC, the closing of the litter facility during the period when most eggs were laid efficiently prevented hens from laying in the litter box and the rather low proportion of misplaced eggs was instead laid in the cage area.

Although all nests in the present study provided enclosure and artificial turf lining, known to be important nest attractants (Appleby and McRae, 1986; Wall and Tauson, 2002), nests in the larger cages for 20 and 40 hens were rejected by a considerable proportion of hens, the majority of which instead laid their eggs on the litter mat. In agreement, other studies on FC for medium or large groups report problems with eggs laid on litter mats (Guesdon et al., 2006; Tactacan et al., 2009).

Evidently, in the present study the misplaced eggs were not laid at random in different parts of the cage, which suggests some hens made an active choice laying their eggs on the litter mat located in the opposite end of the cage in relation to the nest. When groups of hens are housed together in floor systems a general opinion is that dark spaces may encourage the laying of floor eggs. However, in the present study illumination of the litter mat did not reduce the proportion of eggs laid there, a result in agreement with Appleby et al. (1984), suggesting that factors other than light intensity are of considerable importance for selection of nest site in layers. It has been suggested that when hens are group housed, social factors contribute to hens laying outside the nest box (Cronin et al., 2009). Also, earlier studies indicate that loose substrate such as straw or wood shavings enhances the attractiveness of nests (Huber et al., 1985; Appleby and Smith, 1991). Although most of the daily portion of saw dust delivered on the litter mat was finished in a rather short time, saw dust particles were more or less incorporated in the turf and for some individuals this may be a stronger nest attribute than nest itself. Using dry mash feed as litter substrate is the norm in most countries in Europe, but feed is not considered to be an appropriate litter substrate in Sweden. The considerably lower use of nests in the brown genotypes housed in T20 and T40 compared with the white genotypes was prominent especially in trial 1. Studies indicate that compared with white genotypes, brown genotypes lay a higher proportion of misplaced eggs when housed in floor housing systems (R. Kalmendal and H. Wall, Swedish University of Agricultural Sciences, Uppsala, Sweden; personal communication), which is sometimes interpreted as a lower motivation for nest box use (Singh et al., 2009). However, in the small FC models in the present study, the use of nests by brown genotypes was at similar level as that of white genotypes, indicating a high motivation for use of a nest in all genotypes. Contradictory to the results in present study, Sandilands et al. (2009) reported a better use of nests in brown Hy-Line layers than in white in FC housing 20, 40, and 80 hens/cage.

Taking the egg quality results of trials 1 and 2 of the present study, it can be concluded that exterior egg quality was superior in T8 compared with T20 and T40. On the whole, T10 had intermediate levels of cracked and dirty eggs. These differences in egg quality probably reflect differences mainly in cage design rather than group size. In early designs of FC, high proportions of cracked eggs was a problem (Wall et al., 2002), especially in FC with a deep and narrow nest like in T8 in the present study. It became evident by the accumulation of eggs in the egg cradle outside the nest that some kind of egg-saving device was needed, either a prolonged nest curtain or an eggsaver wire (Wall and Tauson, 2002). In the present study, the high number of eggs laid outside the nest in T20 and T40 likely affected proportions of cracked eggs. Although the egg-saver wire extended along the whole width of these cages, an egg laid outside the nest likely was at a higher risk of being damaged because of the presence and activities of hens in the cage area or on the litter mat. In addition to egg-saving devices, when housing large groups of hens together in FC, running the egg belt a short distance in intervals may be necessary to prevent crowding of eggs in the cradle outside the nest and to limit the risk for egg eating.

It has been shown that in well-developed FC of similar design as the T8 in the present study, the same low numbers of dirty eggs as generally achieved in battery cages can be expected (Wall et al., 2002, 2008; Wall and Tauson, 2007). In T8, the position and design of the nest allowed for eggs laid in the nest to reach the egg cradle without contacting the bare cage floor area. In T10, in which the nest was at the rear of the cage, all eggs rolling out of the nest on the way to the egg cradle passed over the bare cage area in which hens moved around, fed from the trough, and defecated. Similarly, in T20 and T40 the cage area and feed trough extended in front of the nest, implying that nest eggs in those designs contacted the cage area on the way to the egg cradle. The overall hygiene of the cage floors of FC is generally inferior compared with that of battery cages (Wall and Tauson, 2007) because manure is not as efficiently trampled down when perches are present. Therefore, in FC the risk of an egg becoming dirty probably increases when contacting the bare cage floor when newly laid. In a study on furnished 15-hen cages, Mallet et al. (2006) showed that the proportion of dirty eggs was lower among eggs laid in a nest than among eggs laid on the litter mat or in the cage area, but only in cage designs in which the nest location allowed for eggs to roll straight into the egg cradle without contacting the bare cage floor. In the present study, the hens in T20 and T40 did not fully differentiate between litter mat and nest area, which likely had a major effect on the exterior egg quality. In agreement, Tactacan et al. (2009) reported similar problems with high proportions of dirty eggs because eggs were laid on the litter mat in FC housing 25 hens.

The lower percentage of dirty eggs in the brown genotype compared with the white in the trials is a common finding (Wall and Tauson, 2002, 2007), partly because it is easier to detect dirt on a white egg shell than on a brown egg shell.

Conclusions

It is possible to maintain up to at least 40 non-beak-treated hens together in FC without adversely affecting egg production and mortality compared with that achieved in small group FC, provided that feather pecking and cannibalism are at low levels. The likelihood of cannibalism in relation to group sizes and measures to minimize that likelihood need further investigation. In cage designs with sawdust litter distributed onto litter mats and thus available continuously, a considerable proportion of the eggs can be expected to be laid on the mats instead of in the nest boxes, resulting in inferior egg quality, especially because of dirty shells. Further development is needed to improve designs and improve management in furnished cages with litter distributed on mats to reduce the problem of misplaced eggs.

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