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Original article

Laying performance and egg quality in hens kept in standard or furnished cages

Vanessa GUESDON*, Jean Michel FAURE

Station de Recherches Avicoles, INRA Centre de Tours, 37380 Nouzilly, France

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Abstract – A total of 1992 ISA Brown hens were housed from 18 to 70 weeks of age, in four different types of cages: 2 models of standard cages (S5 and S6) and 2 models of furnished cages (F7 and F15). These cages housed 5, 6, 7 and 15 hens respectively with areas per hen of 660, 635, 826 and 1134 cm^2. Furnished cages were fitted with a nest, a dust-bath and perches. The mortality rate was higher in the standard cages than in the furnished cages (cumulative mortality: S6 = 21%, S5 = 17%, F15 = 11%, F7 = 10%; $P < 0.001$). Mortality was mostly due to thermal stress and the difference between the 2 types of cages was probably attributable to the larger available floor space in the furnished cages, facilitating heat dissipation. The type of cage did not affect the laying rate. In the furnished cages, the percentage of eggs laid in the nest was low, especially in F15 (43.5% versus 68.1% in F7). The percentage of broken eggs was significantly higher in the furnished than in the standard cages (S5 = 5.4%, S6 = 3.3%, F7 = 7.7%, F15 = 8.4%). The difference between these two rearing systems was, however, considerably reduced when only the eggs laid in the nest were considered in the furnished cages (F7 = 4.9% and F15 = 5.1%). The percentage of dirty eggs was significantly different between the types of cages (S5 = 7.7%, S6 = 9.2%, F7 = 10.3% and F15 = 8.2%; $P = 0.002$). However, in the furnished cages, the number of dirty eggs was reduced when only the eggs laid in the nest were taken into account (F7 = 8.2% and F15 = 6.7%). We conclude that egg production could be similar in furnished and standard cages if most of the eggs were laid in the nest in furnished cages. This suggests that the improvement of furnished cages should first focus on the provision of more attractive nests.

cage design / laying hen / nest / egg / quality

Résumé – **Performances de ponte et qualité de l'œuf de poules élevées en cages standard ou en cages aménagées.** Un total de 1992 poules ISA brown étaient logées de 18 à 70 semaines d'âge dans 4 modèles de cages différents : deux modèles de cages standard (S5 et S6) et deux modèles de cages aménagées (F7 et F15). Ces cages logeaient respectivement 5, 6, 7 et 15 poules avec respectivement des surfaces par poule de 660, 635, 826 et 1134 cm^2. Les cages aménagées étaient munies d'un nid, d'un bac à poussière et de perchoirs. Le taux de mortalité était plus élevé dans les cages standard que dans les cages aménagées (mortalité cumulée : S6 = 21 %, S5 = 17 %, F15 = 11 % et F7 = 10 % ; $P < 0{,}001$). Cette mortalité était majoritairement due à un stress thermique et la différence entre les deux types de cages peut sans doute être attribuée à l'espace disponible plus grand dans les cages

* Corresponding author: guesdon@tours.inra.fr

aménagées qui facilite la dissipation de la chaleur. Le taux de ponte était semblable dans les 4 modèles de cages. Les pourcentages d'œufs pondus au nid étaient bas dans les cages aménagées ; spécialement pour F15 (43,5 % versus 68,1 % en F7). Les pourcentages d'œufs cassés étaient significativement plus élevés en cages aménagées qu'en cages standard (S5 = 5,4 %, S6 = 3,3 %, F7 = 7,7 % et F15 = 8,4 %). Cependant, les différences entre les deux systèmes d'élevage étaient nettement réduites lorsque seulement les œufs pondus dans le nid étaient pris en compte pour les cages aménagées (F7 = 4,9 % et F15 = 5,1 %). Le pourcentage d'œufs sales était significativement différent entre les types de cages (S5 = 7,7 %, S6 = 9,2 %, F7 = 10,3 % et F15 = 8,2 % ; *P* = 0,002). Cependant, le pourcentage d'œufs sales était réduit en cages aménagées lorsque seulement les œufs pondus dans le nid étaient pris en compte (F7 = 8,2 % et F15 = 6,7 %). Nous concluons que la production d'oeufs pourrait être similaire en cages standard et aménagées si la majorité des œufs étaient pondus au nid dans les cages aménagées. Ceci suggère que l'amélioration des cages aménagées passe d'abord par la conception de nids plus attractifs.

cage / poules pondeuses / nid / œuf / qualité

1. INTRODUCTION

The vast majority of the world's population of laying hens is kept in battery cages [2]. Battery cages provide good economic results and limit sanitary problems but also have the disadvantage of being a small and bare environment [10]. Such space restriction limits the possibility of bird movement and appears to be at the origin of weak skeletons [27, 33]. This bare environment limits and disturbs the behavioural repertoire [11, 35]. Indeed laying, dust-bathing and perching behaviours cannot be fully performed or not performed at all in the absence of a nest, litter and perches and because of the space limitation. Nevertheless these resources are widely used when available [6, 9, 18, 22–24, 34, 36, 38] and such battery cages are reported to be unsuitable for the needs of the hen [16].

Battery cages will be banned in Europe by 2012 and since the beginning of 2003 they can no longer be installed [21]. Alternative systems will therefore have to be used. Several alternative systems are possible: floor rearing systems and two new systems, which have been developed relatively recently, namely furnished cages and aviaries [31]. These three alternative systems allow the birds access to resources unavailable in standard cages and increase the behavioural repertoire [6]. Hens use the perches to roost especially at night [3, 12, 23], the litter is used for exploratory (pecking and scratching) and dust-bathing behaviours [8, 17, 19], the increased space enables physical exercise, comfort (wing-flapping and wing- and leg-stretching) [15, 19, 40], and pre-laying behaviours and a suitable nest can be used for laying [7, 12]. Furnished cages when compared to aviaries, floor rearing systems and standard cages, retain the advantages and limit the disadvantages of the three other rearing systems [41].

Indeed furnished cages retain the advantage of standard cages in separating birds from manure and permitting the rapid removal of manure from the building and consequently reducing the levels of ammonia and dust in the poultry house [42]. This system also provides more space than standard cages but, as in aviaries, more animals can be reared in a given building than with floor pens, and the hens can be kept in small groups like in standard cages in order to decrease the risk of cannibalism. Mortality due to cannibalism is relative to group size, and large groups or flocks housed in aviaries or floor rearing systems often have unacceptably high mortality rates due to cannibalism [1, 25, 43, 44]. Bird flocks kept on litter also have more problems with parasites and diseases than birds housed in standard or furnished cages [25, 28, 32, 44].

The above findings indicate that furnished cages might be better than standard cages and may also be the best of the three alternative systems. However, this system may have some disadvantages. There is a tendency to build large furnished cages (12 to 70 hens) whereas standard cages are rarely large enough to accommodate more than 6 birds. High mortality rates due to cannibalism may occur in large groups of non-beak trimmed hens, and the percentages of broken, dirty eggs or eggshell contamination can be higher in furnished cages and in the two other alternative systems than in standard cages. Indeed the results obtained to date with furnished cages are highly dependent on cage design, especially in the width of the cage in relation to depth, group size and the installation of perches [5, 20, 23, 32]. The latter might influence the percentage of cracked or broken eggs [24].

The present experiment was conducted to test the effects of two types of commercial furnished cages on various production and welfare measures. We purposely chose one small (7 hens) and one relatively large (15 hens) cage to test the consequences of group size. The two types of furnished cages were compared to two standard cages made by the same manufacturers. Only the data on production are presented in the present paper. The welfare measures will be presented in the following papers.

2. MATERIALS AND METHODS

2.1. Animals and husbandry

Beak trimmed ISA Brown hens were housed for 52 weeks in standard or furnished cages, starting at 18 weeks of age. Food (2800 kcal, 16.3% CP, 3.6% Ca, 0.3% available P) and water were available ad libitum. Light was provided from 2 a.m. to 5 p.m. and light intensity, as measured in front of the cage doors, varied from 8 to 80 lux according to the cage level and orientation. Sawdust was distributed in the furnished cages once a week.

2.2. Housing

Standard and furnished cages were used in agreement with directive 1999/74/CE [21] that is, a minimum area of 550 cm^2 per hen was available in the standard cages with free access to feed and water. In the furnished cages, the hens had at least 750 cm^2 floor space per hen including 150 cm^2 for the nest and the dust-bath, with 12 cm trough space per hen, perches and a claw-shortener.

Two models of standard cages and furnished cages were used (Fig. 1). Standard cages were built to fit 6 (S6, 108 cages) or 5 (S5, 96 cages) hens. The dimensions of the S6 model of the standard cages were the following: length (L) 60 cm, depth (D) 63.5 cm, front height (H) 51 cm and rear height (h) 45 cm. The average area per hen was 635 cm^2, with 11.9 cm of access to the food trough and 0.3 nipples per hen. The dimensions of the S5 model of the standard cage were the following: L = 59.5 cm, D = 55.5 cm, H = 41.5 cm and h = 38 cm. The average area per hen was 660 cm^2, with 10.0 cm of access to the food trough and 0.4 nipples per hen. There was no fixture in S5 and S6. The furnished cages were built to fit 7 (F7, 72 cages) or 15 hens (F15, 24 cages). The dimensions of the F7 model of the furnished cages were the following: L = 91 cm, D = 63.5 cm, H = 51 cm and h = 46 cm. The average area per hen was 826 cm^2, with 13.0 cm of access to the food trough and 0.4 nipples per hen. The nest area was 860 cm^2 and its height was 23 cm. The nest was lined with Astroturf (Monsanto®). The dust-bath area was 860 cm^2. The dust-bath was placed above the nest and it consisted of a metal box with a wire mesh door. This door was opened only from 11 a.m. to 4:30 p.m. in order to prevent the hens from laying in the dust-bath. Two plastic perches (length = 71 cm each) were placed parallel to the food trough. The dimensions of the F15 model of the furnished cages were the following: L = 233 cm, D = 73 cm, H = 54 cm and h = 47 cm. The average area per hen was

1134 cm^2 with 12.0 cm of access to the food trough and 0.4 nipples per hen. The nest area was 4380 cm^2 and its height was 47 cm. The nest was lined with a thin plastic mesh. The dust-bath area was 1386 cm^2. The dust-bath consisted of a piece of Astroturf and was placed at the rear of the cage, adjacent to the nest. Two plastic perches (length = 151 cm each) were placed parallel to the food trough.

Standard and furnished cages were placed in different rooms of a building and husbandry conditions were kept as similar as possible in the two rooms. Each room contained 2 batteries of 2 sides with 3 cage levels and each battery contained one cage type.

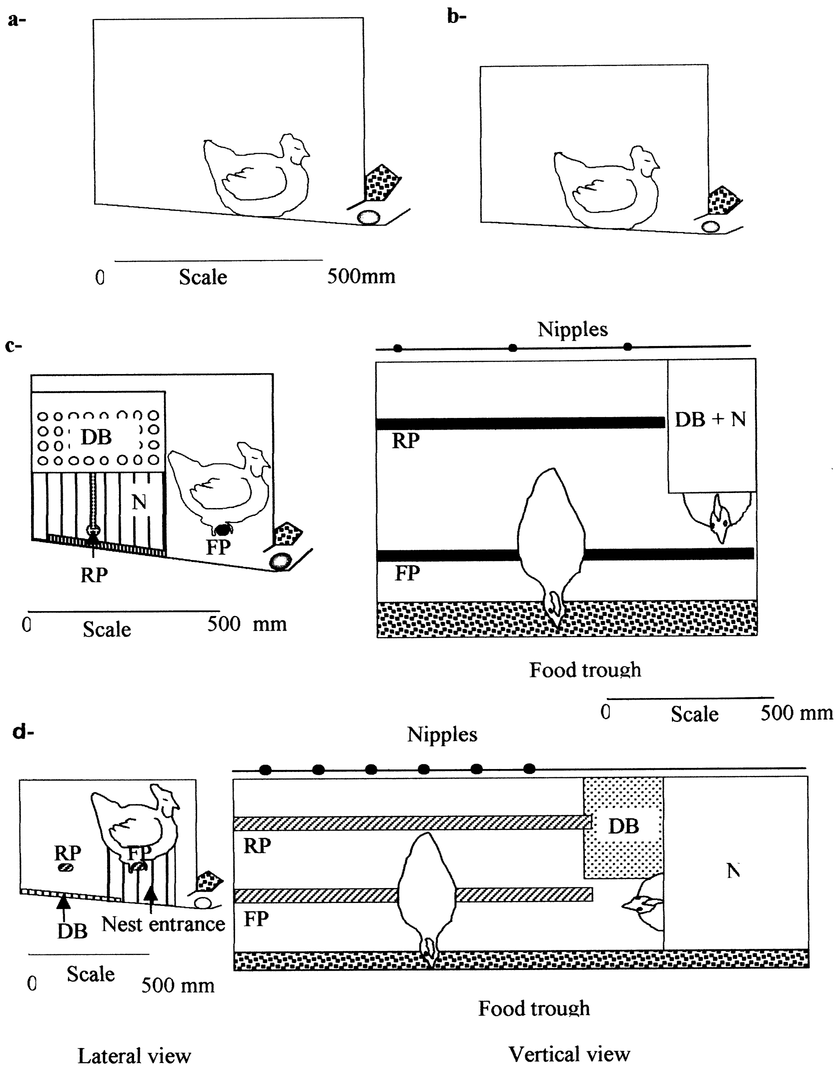

Figure 1. (a-b) Lateral view of the two standard cage types: S6 cage and S5 cage; (c-d) lateral and vertical views of the two furnished cage types: F7 cage and F15 cage. RP and FP = rear and front perches, DB = dust-bath, N = nest.

2.3. Measurements

2.3.1. Mortality

Dead and culled birds were recorded daily per cage, and mortality due to cannibalism was distinguished from other causes.

2.3.2. Egg production

The eggs laid per cage from Tuesday to Friday were recorded each week and the laying performances were extrapolated to the entire week. The eggs from each cage were visually examined to record the number of broken and soft shelled eggs. All these data were analysed after pooling daily data into 13 periods of four weeks. When the hens were 34 and 63 weeks of age, all the eggs collected over one day were candled in order to estimate the percentage of cracked eggs that were not detected by visual observation. In furnished cages, this information was classified according to where the eggs were laid (nest, dust-bath or the rest of the cage). The proportion of dirty eggs was estimated during egg collection when the hens were 38, 47, 55, 63 and 70 weeks of age. This information was also related to where the eggs were laid in furnished cages. Hen housed production and hen day egg production were calculated.

2.3.3. Egg quality

When the hens were 33, 44, 52 and 62 weeks of age, 50 eggs were sampled at random from each cage type. The eggs were weighed and the eggshell breaking strength was measured with an Instron testing machine (Number1102, High Newcombe, UK). The force needed for shell breakage was noted as Fmax (N) and the stiffness was calculated as the slope of the loading curve before the bioyield point, i.e. the point of inflexion of the loading curve.

2.4. Statistical analysis

Mortality rates were analysed by a χ^2 test, followed by a χ^2 pair comparison when the overall comparison was significant.

The frequencies of dirty eggs according to where they were laid in each cage, were too low to be analysed as such (too many 0 values). The data were grouped by battery levels (n = 3) and sides (n = 2) and the number of repetitions per treatment was consequently reduced to 6 for this measurement.

All the egg production measurements expressed as percentages were transformed to arcsin square root [39] for statistical analysis but the raw data means are used in the text, tables and the graphs. The egg production measurements (hen housed production and hen day egg production, proportion of eggs: broken, cracked and dirty; the proportion of eggs laid in the nest, the dust-bath and the cage; the proportion laid in the nest, the dust-bath, and the cage: broken, cracked and dirty) were analysed by ANOVA for repeated measures (time: thirteen 4-week periods for all production measurements except for the dirty and cracked egg measurements: only two and five ages, respectively) followed by post hoc PLSD Fisher tests for multiple comparisons when significant differences were detected.

Egg quality data (egg weight, Fmax, stiffness) were not treated as repeated measures because the eggs were sampled at random from each cage type treatment with no reference to the identity of the cage where they were laid. Egg quality measurements were analysed by two way ANOVA (cage type and time) followed by post hoc PLSD Fisher tests when significant differences were detected. The significance level used was 0.05. *P* values between 0.05 and 0.08 are documented for information.

3. RESULTS

3.1. Mortality

Mortality was analysed globally for the 52 weeks and cumulative mortality for each 4-week period is represented in Figure 2. There was a significant effect of

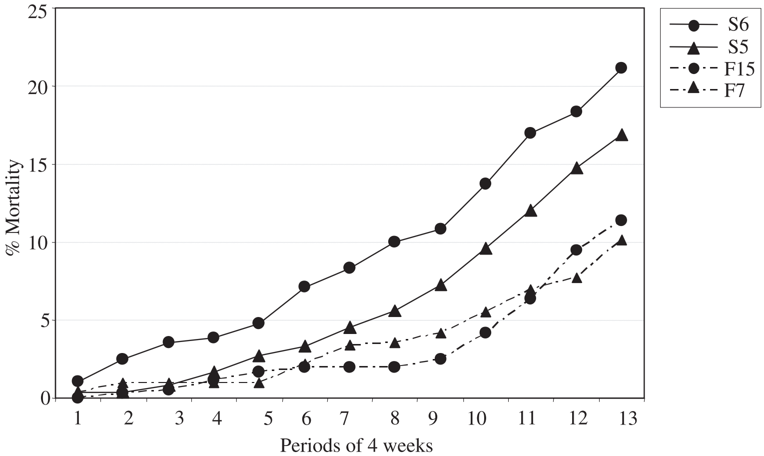

Figure 2. Percentage of cumulative mortality for the 4 cage types during the laying period (18–70 weeks of age).

cage type ($P < 0.001$), with a higher mortality rate in standard cages (S6 = 21% and S5 = 17%) than in furnished cages (F15 = 11% and F7 = 10%). S6 tended to have a higher mortality than S5 ($P = 0.07$) whereas there was no significant difference between F7 and F15. Three birds only died by cannibalism during the 52 weeks of the experiment.

3.2. Egg production

The egg production data were analysed twice (except cracked egg data). The first statistical analysis included all cages of each cage type whatever the mortality recorded. The second analysis included only cages with no mortality or one hen lost for S6, S5 and F7 and cages with less than two hens lost for F15. Similar results were obtained with both analyses. Only the results including all cages are shown in the present paper.

Hen housed production and hen day egg production (mean at peak of laying: 91.2%; 91.9%/end of laying: 58.2%; 67.3%, respectively; $P < 0.001$) did not differ significantly between cage types and they decreased significantly over time. Despite the differences in mortality between the cage types, the interaction between cage types and time was not significant for hen housed egg production. Within furnished cages, the percentage of eggs laid in the nest differed significantly between cage types ($P < 0.001$), with a higher proportion in F7 (68%) than in F15 (43%). The time effect ($P < 0.001$) and time × cage type interaction were also significant ($P < 0.001$) and reflected the increase over time in F7 and the nearly stable proportion in F15 (Fig. 3). Eggs were more frequently laid in the dust-bath in F15 (43%) than in F7 (7%) ($P < 0.001$) and this proportion evolved significantly over time ($P = 0.03$) without a clear trend and the time × cage type interaction was not significant ($P = 0.06$). The percentage of eggs laid in the cage was higher in F7 (25%) than in F15 (14%) ($P < 0.001$). It evolved significantly over time ($P < 0.001$). Time × cage type interaction was significant ($P < 0.001$) and reflected the decrease over time in the proportion of eggs laid in the cage in F7 and the relative stability of this variable in F15.

The highest percentage of broken eggs was observed in furnished cages ($P < 0.001$). This percentage tended to be higher in F15 (8.4%) than in F7 (7.7%) ($P = 0.06$) and was higher in S5 (5.4%) than in S6

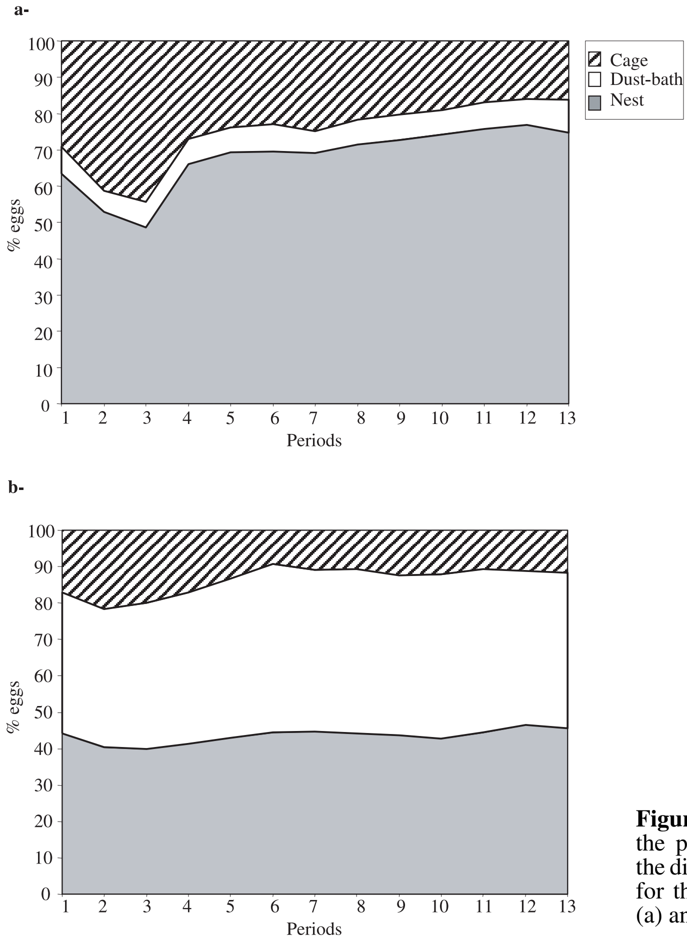

Figure 3. Evolution over time of the percentages of eggs laid in the different locations of the cage for the furnished cage types F7 (a) and F15 (b).

(3.3%) ($P < 0.001$). The time effect ($P < 0.001$) illustrated a classical increase in the proportion of broken eggs with age. The significant interaction between cage type and time ($P < 0.001$) resulted mostly from the steeper increase in the proportion of broken eggs in F7 according to age, compared to the other treatments. Within furnished cages, the percentages of broken eggs among eggs laid in the nest and in the dust-bath did not differ significantly between F15 and F7 (Fig. 4). Both proportions increased over time ($P < 0.001$). However, the percentages of broken eggs among eggs laid in the rest of the cage was higher in F15 (32.1%) than in F7 (13.5%) ($P < 0.001$). This evolved significantly over time ($P < 0.001$). The time × cage type interactions for eggs laid in the nest, in the dust-bath and in the rest of the cage were significant ($P = 0.007$, $P < 0.001$ and $P = 0.02$, respectively). These interactions reflected the increase with time in the percentage of broken eggs in the dust-bath in F7 and its relative stability in F15.

The percentage of cracked eggs was not significantly different over time but differed significantly between cage types ($P = 0.03$) (Tab. I). Standard cages with 5 birds (S5) produced the best performance (4.8%

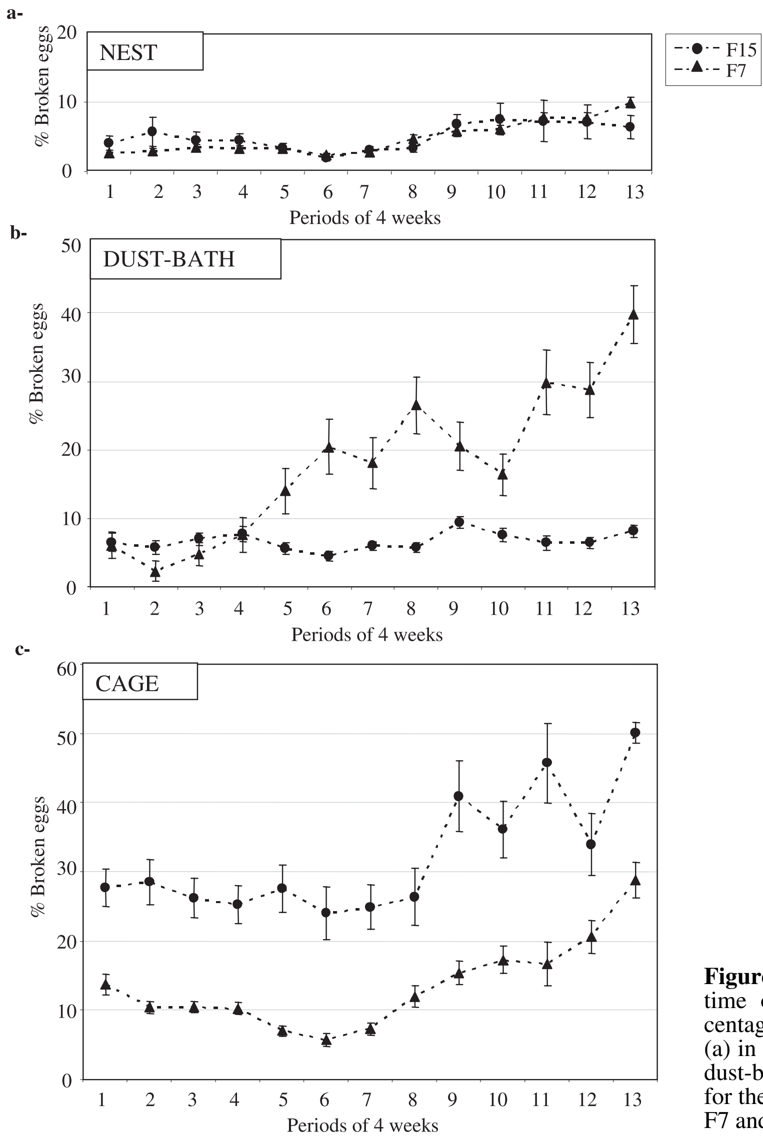

Figure 4. Evolution over time of the mean percentage of broken eggs: (a) in the nest, (b) in the dust-bath, (c) in the cage for the 2 furnished cages F7 and F15.

of cracked eggs) which was significantly different from that of F7 (9.6%) and F15 (9.5%) (P = 0.009 and P = 0.01 respectively) and tended to be different from that of S6 (7.3%) (P = 0.07). Within the furnished cages, the percentages of cracked eggs among eggs laid in the nest, in the dust-bath and in the rest of the cage did not differ significantly between cage types nor over time (Tab. I). The time × cage type interaction for cracked eggs in the dust-bath was significant (P = 0.009) and reflected the decrease in the percentage of cracked eggs in the dust-bath in F7 compared to an increase in F15 with time.

The percentage of dirty eggs differed significantly between cage types (P = 0.002) (Tab. II). The percentage of dirty

Table I. Overall percentages of cracked eggs at 34 and 63 weeks of age for the 4 cage types. Egg location is detailed for the 2 furnished cage types (m ± se).

	Cages[2]	Age (weeks) 34	63	ANOVA *P*-value[1] Cage	Time	Cage × Time
	S5	5.7 ± 1.5	3.8 ± 1.9	0.03	0.73	0.56
	S6	6.5 ± 0.9	8.1 ± 1.6			
	F7	10.0 ± 1.0	9.1 ± 1.9			
	F15	6.9 ± 1.0	12.0 ± 2.1			
Nest	F7	8.5 ± 1.4	10.1 ± 2.3	0.88	0.68	0.96
	F15	9.3 ± 2.1	12 ± 3.5			
Dust-bath	F7	36.7 ± 15.8	0.0 ± 0.0	0.69	0.07	0.009
	F15	4.7 ± 1.1	13.2 ± 3.3			
Rest of cage	F7	5.9 ± 2.2	10.1 ± 5.2	1	0.85	0.72
	F15	16.7 ± 16.7	7.5 ± 4.8			

[1] Results of ANOVA for repeated measures with transformed data; [2] number of repetitions were for S5 n = 6, S6 n = 6, F7 n = 6 and F15 n = 6.

Table II. Overall percentages of dirty eggs at 38, 47, 55, 63 and 70 weeks of age for the 4 cage types. Egg location is detailed in the 2 furnished cage types (m ± se).

	Cages[2]	Age (weeks) 38	47	55	63	70	ANOVA *P*-value[1] Cage	Time	Cage × Time
	S5	5.3 ± 0.8	6.2 ± 1.1	8.2 ± 1.4	10.8 ± 1.8	8.0 ± 1.3	0.002	0.002	0.10
	S6	6.2 ± 0.9	8.3 ± 1.1	10.2 ± 1.5	11.5 ± 1.5	9.7 ± 1.5			
	F7	8.7 ± 1.0	12.7 ± 1.5	9.5 ± 0.9	9.7 ± 1.3	10.8 ± 1.3			
	F15	4.8 ± 0.9	5.7 ± 0.8	8.4 ± 1.8	9.6 ± 1.7	12.5 ± 2.2			
Nest	F7	7.2 ± 1.3	9.5 ± 1.0	7.8 ± 0.8	8.8 ± 1.2	7.6 ± 0.8	0.12	0.17	0.12
	F15	3.9 ± 1.4	4.8 ± 1.4	7.3 ± 1.9	7.3 ± 2.0	10.2 ± 1.8			
Dust-bath	F7	12.6 ± 4.5	29.5 ± 10.9	39.8 ± 14.7	27.3 ± 9.7	24.1 ± 5.0	0.03	0.28	0.53
	F15	5.9 ± 0.7	5.3 ± 0.1	9.6 ± 1.7	8.6 ± 1.8	16.7 ± 4.2			
Rest of cage	F7	13.1 ± 3.5	13.6 ± 1.9	10.9 ± 1.1	8.3 ± 1.4	12 ± 1.8	0.003	0.29	0.10
	F15	3.8 ± 2.0	10.6 ± 2.6	6.8 ± 2.3	10.6 ± 1.2	8.9 ± 2.9			

[1] Results of ANOVA for repeated measures with transformed data; [2] number of repetitions were for S5 n = 96, S6 n = 108, F7 n = 72 and F15 n = 24 for overall dirty eggs and were for S5 n = 6, S6 n = 6, F7 n = 6 and F15 n = 6 for the egg location.

Table III. Mean values for egg biomechanical parameters at 33, 44, 52 and 62 weeks of age for the 4 cage types (m ± se).

		Age (weeks)				ANOVA *P*-value[1]		
	Cages[2]	33	44	52	62	Cage	Time	Cage × Time
Fmax (N)	S5	34.8 ± 0.8	33.2 ± 1.0	33.7 ± 0.7	29.5 ± 1.4	0.38	<0.001	0.004
	S6	33.4 ± 1.10	34.2 ± 1.0	30.2 ± 0.9	32.8 ± 1.0			
	F7	34.9 ± 1.3	32.6 ± 1.1	32.2 ± 1.1	27.0 ± 1.3			
	F15	34.3 ± 1.5	31.3 ± 1.3	29.5 ± 1.5	32.2 ± 1.1			
Stifness ($N \cdot mm^{-1}$)	S5	124.1 ± 5.5	146.0 ± 4.5	154.1 ± 4.5	128.7 ± 7.0	<0.001	0.001	<0.001
	S6	91.2 ± 5.6	155.8 ± 4.2	149.8 ± 6.0	137.5 ± 4.9			
	F7	121.5 ± 5.6	137.0 ± 4.6	110.0 ± 6.6	118.6 ± 6.5			
	F15	104.9 ± 6.5	141.8 ± 4.1	131.3 ± 6.3	128.9 ± 6.7			

[1] Results of two way ANOVA with transformed data; [2] number of repetitions were for S5 n = 50 eggs, S6 n = 50 eggs, F7 n = 50 eggs and F15 n = 50 eggs.

eggs did not differ significantly between furnished cage types. It tended to be higher in S6 than in S5 ($P = 0.06$). The percentages of dirty eggs tended to be higher in furnished cages than in standard cages but this was significantly different only when F7 was compared to S5 and S6 ($P = 0.001$ and $P = 0.04$, respectively) and when F15 was compared to S5 ($P = 0.04$). The percentage of dirty eggs increased significantly over time ($P = 0.002$). The time × cage type interaction was not significant. Within furnished cages, the percentage of dirty eggs among eggs laid in the nest did not differ significantly between F7 and F15 cage types nor over time (Tab. II). However, the percentages of the dirty eggs among eggs laid in the dust-bath and in the rest of the cage were significantly higher in F7 than in F15 (dust-bath: 26.7% and 9.2%; cage: 11.6% and 8.1%; $P < 0.03$ and $P = 0.003$, respectively) and did not significantly evolve over time. The time × cage type interactions were not significant.

3.3. Egg quality

Egg weight did not differ significantly between the cage types. Egg weight increased over time (63.8 g ± 0.9 at 33 weeks of age; 67.2 g ± 0.8 at 62 weeks of age, $P < 0.001$). The time × cage type interaction was not significant.

The breaking strength Fmax did not differ significantly between the cage types but evolved significantly over time ($P < 0.001$) and these two factors interacted significantly ($P = 0.004$) (Tab. III). Fmax diminished with time but the interaction did not follow a steady trend. Stiffness was significantly different between the cage types ($P < 0.001$) and over time ($P < 0.001$) and the interaction was significant ($P < 0.001$) (Tab. III). There was no significant difference between F7 and F15 or between S5 and S6, but F7 differed significantly from S5 and S6 ($P < 0.001$ and $P = 0.003$, respectively) and F15 differed from S5 ($P = 0.003$). The time effect was rather complex, with lower values generally observed at 33 and 62 weeks of age. The time × cage type interaction was significant ($P < 0.001$) but did not follow a steady trend.

4. DISCUSSION

A higher mortality rate in large groups of hens than in small groups of hens has often been reported [26] and this mortality is often due to cannibalism. In our experiment, the mortality rate was high in every cage type but the cannibalism was virtually absent (three deaths by cannibalism). Surprisingly the highest mortality rate was observed in the smallest groups of hens housed in standard cages. Most of the mortality occurred during the summer and was probably due to the excessively high temperature (up to 30 °C was recorded in the building). This may explain the differences observed between the two types of cages since heat dissipation was probably easier in furnished cages where the available space was over 750 cm^2 per hen compared to the 550 cm^2 per hen in standard cages.

Hen day egg production was very similar in the 4 cage models and this shows that even though the thermal stress during the summer led to differential effects on mortality, it had no measurable consequence on the laying rate of surviving hens under our conditions. The similar laying rate in the two types of cages showed that the often reported decreased egg production in furnished cages is a consequence of trouble with egg collection rather than with egg production [14, 23]. Classically egg weight is not affected by rearing conditions and increases with age [40]. Eggshell stiffness was lower in furnished cages whereas breaking strength was not affected by the cage type. These two characteristics are usually linked but Ketelaere et al. [30] suggested that stiffness is a better parameter to estimate eggshell quality because breaking strength is too dependent on the precise place where it is measured. The difference observed in shell stiffness is however unlikely to fully explain the differences in the percentage of broken eggs between the two types of cages. The percentages of broken and dirty eggs may be better explained by cage structure. The depth of furnished cages allowed eggs to roll for a longer distance and thus increased the risk that the egg might get dirty. The distance travelled increases speed and the force of impact, resulting in more broken eggs.

The percentages of broken eggs were similar in standard cages and for eggs laid in the nest in furnished cages. In F15 cages, the dust-bath was lined with Astroturf and had the same slope as the nest and the rest of the cage and consequently the eggs rolled normally to the collection tray. In F7 cages, the dust-bath was a metal tray and thus the eggs remained in the dust-bath until hand collection. This clearly increased the risk of breakage and also the risk for the egg to become dirty. In fact, despite the closure of the dust-bath with a one way swinging door during the laying period, some hens were able to open the swinging door with their head and beak and laid eggs in the dust-bath. This confirms that a swinging door cannot be used to prevent hens from entering the dust-bath [37]. In Smith et al.'s experiment [37] the hens had no nest and the authors concluded that the development of a strategy to obtain access to the dust-bath indicated that the hens were highly motivated to get access to a nest substitute. The fact that some hens did the same in our experiment when they had access to a nest shows that the motivation to lay in the dust-bath was strong in these hens. Indeed the hens had to exert a force to push the dust-bath door of an F7 cage open whereas these hens had a permanently open nest box.

The importance of both the enclosure and nest lining has been shown in the nest-site selection and a large proportion of hens chose the nests with an enclosure and loose mouldable materials when they had the choice between different nests [6, 13, 29]. Astroturf lining is also appreciated by hens [4–6]. In the F7 cages, the nest provided an enclosure and attractive lining whereas in F15, the nest only provided an enclosure and dust-bath attractive lining. Despite this, only 68% of the eggs were laid in the nest in F7. The nest in the F7 cages was apparently convenient for one hen at a time. A competition for the nest site might partially explain the laying of eggs in places other than the nest. Indeed the synchronicity of oviposition of the hens within a cage could favour competition for the nest site. The results in the F15 cages cannot be explained by the nest size because the nest could accommodate several hens at the same time. Forty-three percent of the eggs were laid in the large enclosed nest lined with thin plastic mesh which has been shown to be less attractive than wire floors [6, 13, 29] and the same percentage was laid in the large open dust-bath lined with Astroturf. In this case (F15), the low level of eggs in the nest probably resulted from the competition between two separated attractive features.

Our results show that production traits can be similar in furnished and standard cages. The major problem encountered in furnished cages in the present experiment was a high percentage of broken eggs. However, the eggs laid in the nest were of similar quality to the eggs from standard cages. Economic results can thus be achieved in furnished cages if all or nearly all the eggs are laid in the nest. This implies that furnished cages must have more attractive nests.

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