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Influence of rearing conditions of pullets on space use and performance of hens placed in aviaries at the beginning of the laying period

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Abstract

Many studies have shown how laying aviaries can improve hens' welfare, but little work has been done on the adaptation of hens to this system according to their previous rearing conditions, despite the specific adaptation skills it requires of them. The adaptation to laying aviaries of hens previously reared in different conditions was assessed here through their use of vertical levels, numbers and distances of flights and jumps (in week 20 after transfer and, only in rearing aviaries, in week 15 before transfer), eggs location and laying rate (from weeks 18 to 27 after transfer) and mortality (from weeks 1 to 27). Twelve batches of 282–308 ISA Brown hens were reared from 1 day to 17 weeks of age in floor pens furnished with platforms and perches with manual feed hoppers on litter (FH hens), in rearing aviaries with platforms and manual feed hoppers on litter (AH hens), or in rearing aviaries with automatic chain troughs on platforms (AC hens). Hens in each of these treatments were then transferred to similar laying aviaries with automatic chain troughs on platforms. The FH hens used upper levels less, showed lower accuracy in long flights and jumps and displayed a preference for staying on litter and lower levels, compared with AH and AC hens. They laid fewer eggs inside nest boxes during the first 2 weeks of lay, laid more eggs on litter throughout the observed period, and had a lower onset of laying than AH and AC hens. The FH mortality rate was higher than that of AC hens after transfer, and higher than that of AH and AC pullets before transfer. AH pullets used the lower levels more and made more and longer flights than AC pullets before transfer, but these differences did not persist after transfer. Mortality rates did not differ between AH and AC pullets before transfer, whereas it was higher in AH hens after transfer. AH hens laid slightly more eggs inside nest boxes and had a similar laying

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rate to AC hens. The present study shows that the design of rearing pens largely influences adaptation: rearing aviaries ensured a better adaptation than furnished floor pens. On the other hand, the feeding system used during the rearing period, particularly troughs location, largely influenced the use of space before transfer, but only slightly influenced the adaptation after transfer in laying aviaries: higher vertical distance between feed and water ensured a better adaptation.

Keywords: Adaptation; Early experience; Housing system; Laying hen; Nests use; Spatial distribution

1. Introduction

Laying aviaries are one of the housing systems for laying hens authorised by the Council of Europe Directive 1999/74/EC from 2012. Several studies have shown how aviaries can improve hens' welfare compared with conventional cages (for review see Barnett and Newman, 1997). Aviaries diversify the behavioural repertoire of hens (dustbathing, nesting, perching . . .) (Blokhuis and Metz, 1992), lower their level of fear and increase their bone strength (Newman and Leeson, 1998) and overall body condition (Michel and Huonnic, 2003). Depending on the type of aviary, hens' disturbance (changes of activity) and abnormal behaviours (feather pecking, stereotypies . . .) are lower than or the same as (Hansen, 1994) in conventional cages. The review of Tauson (2005) underlined negative consequences of aviaries compared with conventional cages: higher levels of dust and ammonia, higher risks of health problems, spread of cannibalism, bone deformation or breaking and high rates of floor eggs. This author also reported higher mortality rates and lower production levels in aviaries than in small group of less than 10 hens reared in conventional cages. However, other studies (Taylor and Hurnik, 1996; Häne et al., 2000 and Aerni et al., 2005 for review) reported no significant difference in mortality between these two systems. These discrepancies are probably explained by the fact that welfare improvement depends on design and management of aviaries and on beaktrimming of birds, as underlined by Van Horne (1996) and Barnett and Newman (1997).

Compared with cages and one-level non-cage systems, aviaries are characterized by several vertical levels and thereby require specific adaptation skills of hens. Underuse of facilities (nests, drinker nipples, perches . . .), due to poor adaptation may lead to problems of welfare, production or health. For example, if hens do not use platforms where drinkers are, they could not drink and are exposed to dehydration. Early experience influences the development of individuals and how they interact with their environment thereafter (Denenberg, 1969). For example, the enrichment of the environment with manipulable or moving objects, or changes of feed at an early age lowers the emotional reactivity and fearfulness of chicks (Candland et al., 1963; Broom, 1969; Jones, 1986; Gvaryahu et al., 1989), adult hens (Reed et al., 1993) or quails (Jones et al., 1991). Previous experience also influences the preferences for additional space in the litter area (e.g. Faure, 1991) and the use of perches or nest boxes by adult hens (e.g. Huber-Eicher, 2004; for review see Mench et al., 1998). Thus, adaptation of adult hens to laying aviaries is certainly influenced by their previous experience. To maximise their adaptation to laying conditions, pullets should be reared in a housing system similar to the laying system (Fröhlich, 1989; Abrahamsson and Tauson, 1995, 1998; Häne et al., 2000). However, floor pens furnished with perching structures offer a desirable alternative to aviaries for the rearing of pullets, being less expensive and easier to manage. Few studies have focused on the influence of different designs of rearing pens on the subsequent adaptation of hens to laying systems, and furthermore they mainly focused on long-term adaptation. These studies demonstrated that access to perches during the rearing period decreased the incidence of floor eggs in a laying aviary (Gunnarsson et al., 1999) and in a deep litter laying house (Petersen, 1991), compared with rearing without perches, probably owing to a better use of vertical space resulting in better finding of nest boxes. Other authors have shown that in laying aviaries, hens coming from floor pens with perching enrichments use the vertical levels less readily, move less between these levels, and show lower production performance with higher rates of non-marketable or misplaced eggs than hens coming from aviaries (Michel and Huonnic, 2003; Colson et al., 2005). However, in these last two experiments the differences recorded may derive not only from pen design, but also from management differences. Indeed, it was shown that a change of feeder shape between rearing and laying systems influenced the subsequent adaptation of hens (Petersen, 1991); and in the study of Colson et al. (2005) the two housing systems for pullets differed in the shape of the feeders they contained.

The aim of this experiment was to investigate the short-term adaptation of hens to laying aviaries according to their rearing conditions before their transfer. Three treatments were compared, differing in the rearing conditions of pullets, but with similar laying conditions. Pullets were reared in floor pens with manual feed hoppers on litter and furnished with perching enrichments (FH), in rearing aviaries with manual feed hoppers on litter (AH), and in rearing aviaries with automatic chain troughs on platforms (AC). The adaptation of hens to laying aviaries was evaluated just after transfer from rearing housing, before any possible decrease in the effects of rearing conditions on it. Adaptation was evaluated by several parameters used in non-cage systems: use of vertical levels (Hansen, 1994; Channing et al., 2001; Odén et al., 2002), numbers and distances of flights and jumps (Carmichael et al., 1999), eggs location, laying rate and mortality (Koelkebeck and Cain, 1984; Petersen, 1991; Taylor and Hurnik, 1996; Van Horne, 1996). Our hypothesis was that the adaptation to laying aviaries with automatic chain troughs would be influenced by the rearing conditions of pullets. Based on preliminary studies (Colson et al., 2005, 2006), we hypothesised that FH hens would do one or more of the following: use the upper levels less, make fewer and shorter flights and jumps, lay fewer eggs inside nest boxes, and show a lower laying rate and higher mortality level than AC hens. Results for AH hens would enable us to determine which effect, if any, influenced the difference between FH and AC hens: rearing pen design (rearing aviary versus furnished floor pen) or rearing feeding system (automatic chain troughs on platforms versus manual feed hoppers on litter).

2. Materials and methods

2.1. Animals and housing

The same experiment was replicated twice over two consecutive years. There were two batches per treatment in every replication of the experiment, which gave a total of four batches per treatment. For each replication of the experiment, ISA Brown pullets arrived on day 1 from a commercial hatchery, were beak-trimmed at 8 days and transferred from rearing to laying systems at 17 weeks. Experiments were stopped at 27 weeks of age. Three treatments, differing only in their rearing conditions, were compared. Floor-hopper pullets (FH) were reared in two floor pens (308 pullets each: 1073 cm^2 of usable area per pullet), with manual feeding in feed hoppers suspended above the litter. Floor pens were furnished with three perches (41, 76 and 111 cm high) and two platforms with heights similar to those of lower and middle platforms of rearing aviaries (42 and 112 cm high—Fig. 1). Aviary-hopper pullets (AH) were reared in two rearing aviaries (Natura Rearing type, Big Dutchman, Germany—282 pullets each: 1004 cm^2 of usable area per

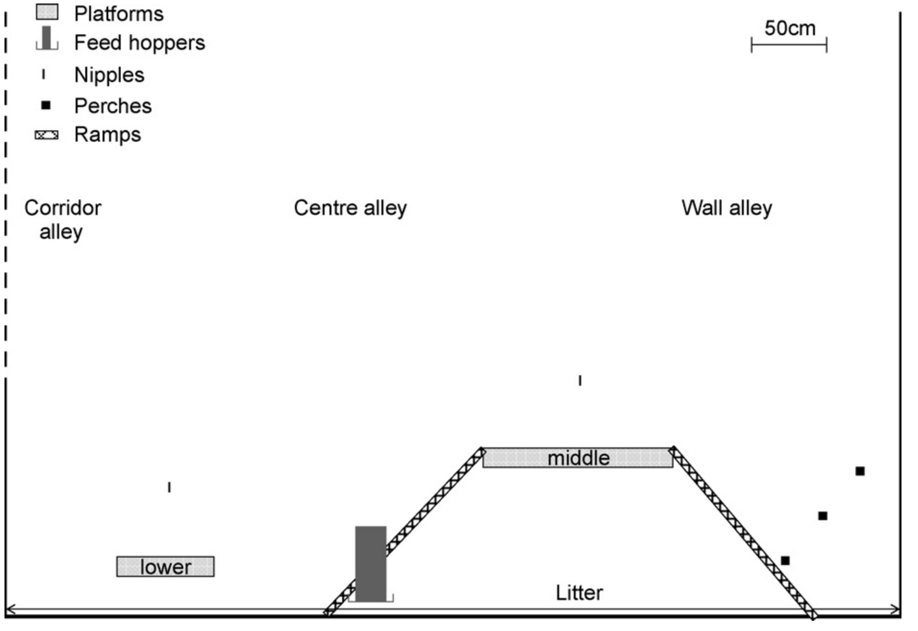

Fig. 1. Cross section of a rearing pen for FH pullets, which were reared in furnished floor pens with manual feeding in feed hoppers on litter. Slatted platforms and ramps were installed when pullets were 29 days old.

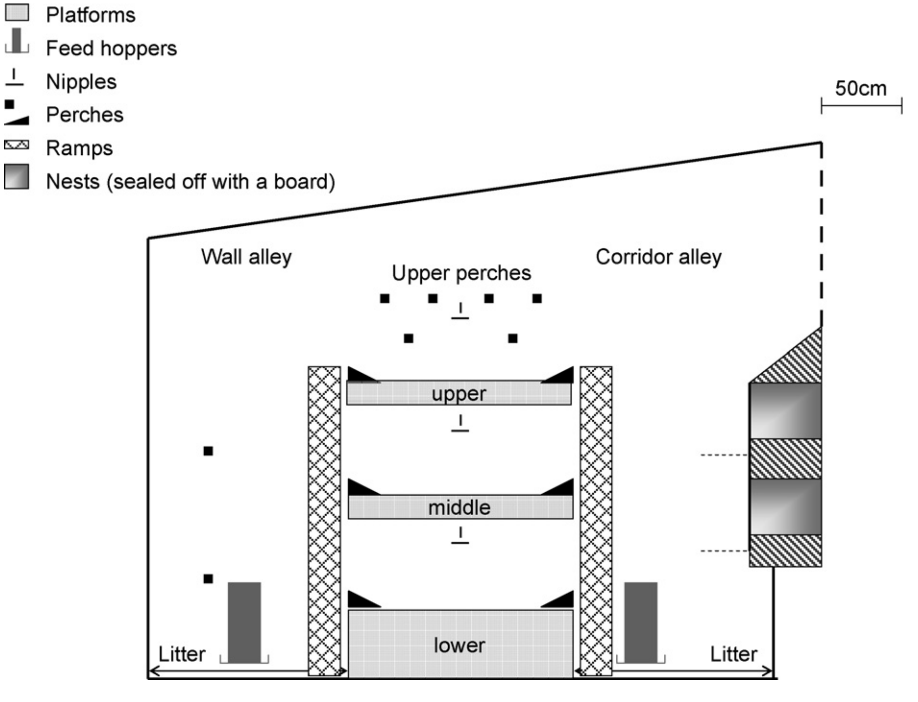

Fig. 2. Cross section of a rearing pen for AH pullets, which were reared in rearing aviaries with manual feeding in feed hoppers on litter. Pullets were freed from the middle platform and ramps were installed when pullets were 29 days old. Pullets had no access to nest boxes.

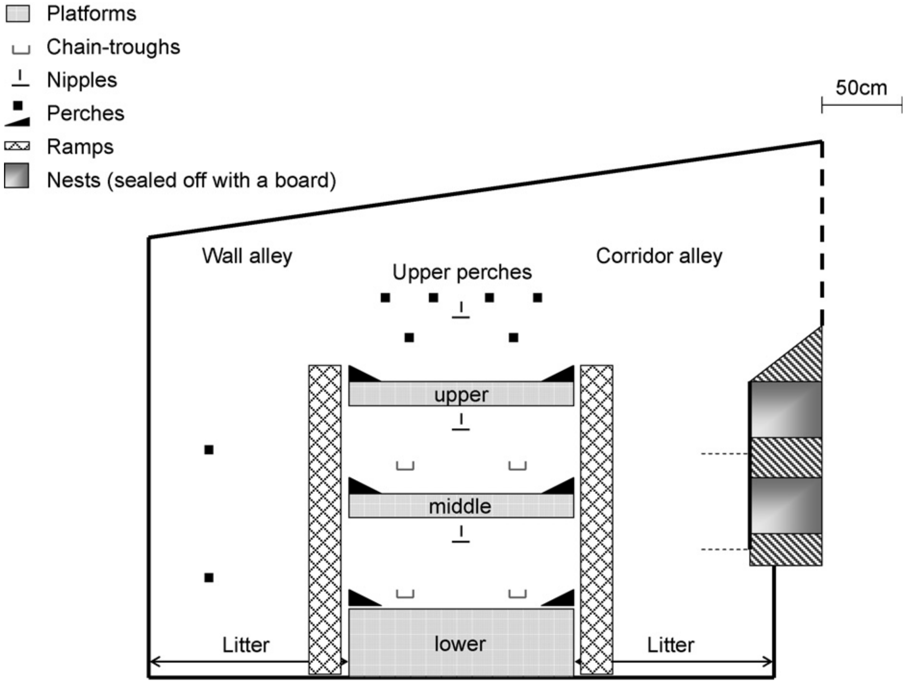

Fig. 3. Cross section of a rearing pen for AC pullets and of a laying pen for all treatments. AC pullets were reared in rearing aviaries with automatic feeding in chain troughs on platforms. Pullets were freed from the middle platform and ramps were installed when pullets were 29 days old. Pullets had no access to nest boxes. Similar aviaries were used to house hens during the laying period. There were no ramps and hens had a free access to nest boxes.

pullet) with a manual feeding in feed hoppers suspended above the litter as in FH treatment (Fig. 2). Rearing aviaries contained three platforms (43, 113 and 184 cm high) and eight perches (two at 60 and 140 cm above the floor and the others at 35 and 62 cm above platforms). Aviary-chain pullets (AC) were reared in two rearing aviaries similar to the AH treatment (282 pullets each: 1004 cm^2 of usable area per pullet), but were fed with automatic chain troughs on lower and middle platforms (Fig. 3). For the three treatments, the 'usable area' includes the litter and the platforms. At 17 weeks of age, pullets were transferred to six laying aviaries with automatic chain troughs. These laying aviaries were the same as rearing aviaries except that free access to nest boxes was allowed (Pondoir Colony, Big Dutchman, Germany—Fig. 3). For every batch, 210 pullets from each rearing pen were transferred to one laying aviary (1349 cm^2 of usable area per hen), without mixing with pullets from another batch. None of the transferred pullets had been previously tested during the rearing period. The transport of pullets during the transfer was standardised and batches of AH and AC pullets did not return to the same pen after transfer.

At the beginning of the rearing period, there were no platforms in the FH pullets pens, and AH and AC pullets were restricted to the middle platform of rearing aviaries. At 29 days old, platforms were installed in FH pullets' pens, and AH and AC pullets were freed from the middle platform of the rearing aviaries. At this age, pullets had grown enough to move between vertical levels. To facilitate their access to the middle platform (and higher levels in rearing aviaries) two ramps were installed at the same time in all pens. One ramp was removed when the pullets were 12 weeks old.

For all batches, the time of presence of humans was homogenised and all conditions were standardised and similarly controlled. Every batch was visually isolated from the rest of the barn. Litter was composed of wood shavings in all rearing and laying pens.

2.2. Observations

2.2.1. Use of vertical levels

The numbers of animals on lower, middle and upper platforms and on the upper perches (only in the second experiment) were recorded by scan sampling. Animals were observed from the outside of the pens. Twelve observations were performed, on six consecutive days (two schedules per day: morning and early afternoon, when the majority of hens were not interested in the feed, i.e. about 20 min after the turning on of the chain trough). Three scans with a delay of 3 min were made per observation. For each observation, the mean of the three scans was calculated and expressed as a percentage of the animals present in the pen. For statistical analysis, means were calculated on the 12 observations. For lower and middle platforms, only half of the platform in the corridor alley was observed (the second half was not visible). We had checked previously for absence of difference between the two halves of the platforms, and so numbers of animals observed were multiplied by two to estimate the use of the whole platform.

2.2.2. Numbers of flights and jumps

Six observations were performed on six consecutive days, alternating two schedules (end of morning and end of afternoon). The two alleys (corridor and wall) were observed simultaneously by two experimenters. After 1 min of habituation of the animals to the presence of the experimenters, numbers of flights (animal no longer in contact with any part of the pen and with wings spread, flapping or not) and jumps (animal no longer in contact with any part of the pen and with wings not spread) were recorded for 10 min, by all occurrences sampling, over the length of the pens. For each observation, data recorded by the two experimenters were pooled and expressed as a percentage of animals present in the pen. For statistical analysis, means were calculated for the six observations.

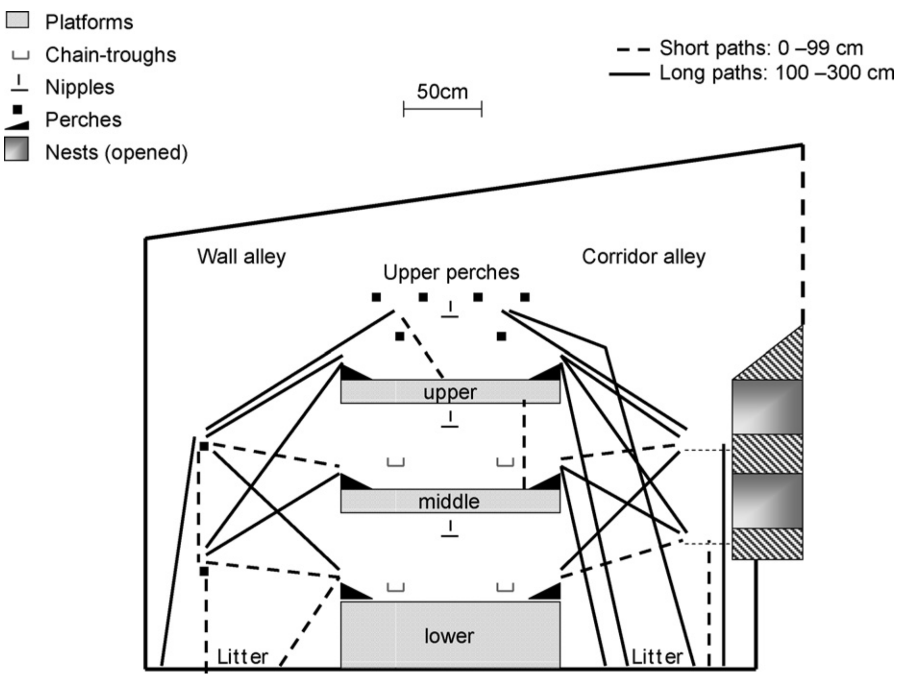

Fig. 4. Cross section of a laying aviary showing all the short paths (shorter than 1 m) and the long paths (equal to or longer than 1 m) used by hens.

2.2.3. Distances of flights and jumps

The distances of flights and jumps were recorded alternating with the recording of the numbers of flights and jumps, with the same method except that we recorded the levels of take-off and landing of every flight and jump seen, and not their numbers. Data were recorded on audio tape. One distance was attributed for each type of path; for example, for the path litter—lower platform the distance was 74 cm. Then, on the all six observations, all flights and jumps recorded were grouped in two classes: short paths (shorter than 1 m) reported as performed easily or with little difficulty, and long paths (equal to or longer than 1 m) reported to cause markedly increased difficulties for the animals (Scott and Parker, 1994; Scott et al., 1999; Taylor et al., 2003; Moinard et al., 2004). All paths observed are drawn on Fig. 4, indicating to which class they belong.

2.2.4. Eggs location

Numbers of eggs laid inside nest boxes, on platforms and on the litter were recorded every day. Results were expressed, per week, as a percentage of the total number of eggs laid per day.

2.2.5. Laying rate

The percentage of eggs produced per hen present in aviaries and per day (hen-day production), including eggs laid outside nest boxes, was calculated every week. The mean was then calculated for the 10 weeks of lay studied.

2.2.6. Mortality

Each day, mortality and its causes were recorded. At the end of the rearing and laying periods, the mortality was calculated for each batch as a percentage of the number of animals introduced into the pen in the beginning of each period.

2.2.7. Schedule

Measures were made in week 20 for use of vertical levels, numbers and distances of flights and jumps, and from weeks 18 to 27 for eggs location and laying rate. The use of vertical levels, numbers and distances of flights and jumps were also observed in week 15 (i.e. before transfer), for AH and AC pullets to provide further data to explain results obtained after transfer. This was possible because observational methods were comparable in these two rearing conditions, but not to the FH pullets rearing condition.

2.3. Statistical analysis

The statistical unit was the batch: $n = 4$ for each treatment. Except for the ‘‘distances of flights and jumps’’, which were grouped in classes and analysed by a χ^2 test, data were analysed using an analysis of variance (proc glm, SAS 9.1 software; SAS Institute Inc., Cary, NC, USA). Data before and after transfer were analysed separately. Before transfer, the analyses concerned only AH and AC pullets. After transfer, the analyses concerned the three treatments. The model was: Var(Y) = Var(Treatment) + Var(Year) + Var(Treatment × Year) + Var(Error), with ‘‘Year’’ and ‘‘Treatment × Year’’ as random effects. For ‘‘eggs location’’, the model was repeated per day of production. If the ‘‘Treatment’’ had an effect, the three treatments were compared using the Student–Newman–Keuls test. The significance threshold was set at 0.05, and tendencies were considered up to 0.10.

3. Results

3.1. Use of vertical levels

Before transfer (Fig. 5A), the effect of treatment had a tendency to be significant for the number of pullets on the lower platform ($F = 4.01$, d.f. = 1, $P = 0.092$) and was significant for the number of pullets on upper perches ($F = 156.74$, d.f. = 1, $P = 0.007$), but not for the number of

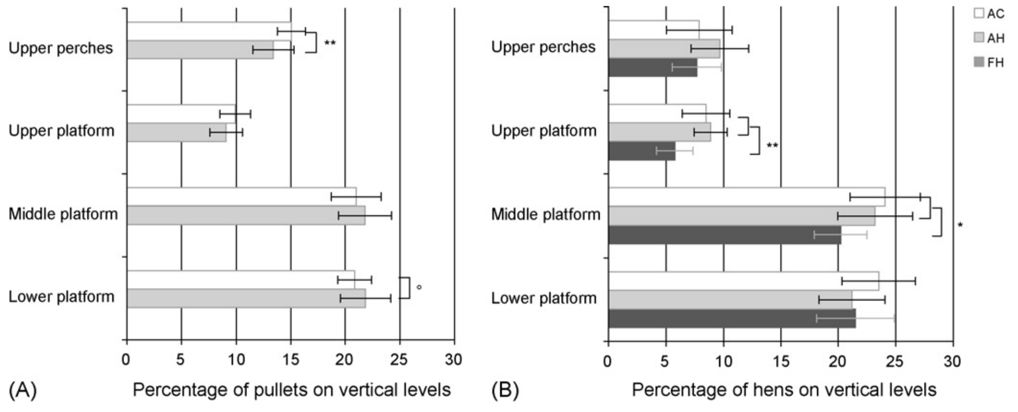

Fig. 5. Means ± standard deviation of numbers of hens on platforms and upper perches, before (A) and after transfer (B), expressed as a percentage of hens present in each pen, for each treatment: hens reared in furnished floor pens with manual feed hoppers on litter (FH hens), hens reared in rearing aviaries with manual feed hoppers on litter (AH hens) and hens reared in rearing aviaries with automatic chain troughs on platforms (AC hens), before being transferred to laying aviaries with automatic chain troughs ($^{\circ}P < 0.10$; $^{*}P < 0.05$; $^{**}P < 0.01$).

pullets on middle ($F = 1.56$, d.f. = 1, $P = 0.258$) and upper platforms ($F = 2.43$, d.f. = 1, $P = 0.170$). AC pullets used the lower platform less and the upper perches more than AH pullets. After transfer (Fig. 5B), the effect of treatment was significant for the number of hens on the middle ($F = 5.17$, d.f. = 2, $P = 0.032$) and upper platforms ($F = 13.80$, d.f. = 2, $P = 0.002$), but not for the number of hens on the lower platform ($F = 1.67$, d.f. = 2, $P = 0.242$) and upper perches ($F = 1.23$, d.f. = 2, $P = 0.406$). FH hens used middle and upper platforms less than AH and AC hens.

3.2. Numbers of flights and jumps

Before transfer (Fig. 6A), the effect of treatment was significant for the number of flights ($F = 26.41$, d.f. = 1, $P = 0.007$) but not for the number of jumps (for the global model: $F = 3.74$, d.f. = 3, $P = 0.118$). AH pullets flew more than AC pullets. After transfer (Fig. 6B), the numbers of flights and jumps in the three treatments were not statistically different (flights $F = 0.72$, d.f. = 2, $P = 0.514$; jumps $F = 1.56$, d.f. = 2, $P = 0.268$).

3.3. Distances of flights and jumps

Before and after transfer (Table 1), the effect of treatment was significant only for the distances of flights. Before transfer AH pullets made more numerous long flights than AC pullets, and after transfer hens from these two treatments made more numerous long flights than FH hens. Also, before and after transfer, animals in the three treatments made more numerous short flights (59–65% of flights) and very few long jumps (less than 0.3% of jumps).

3.4. Eggs location

For the rate of eggs laid inside nest boxes (Fig. 7), the effects of treatment ($F = 5.69$, d.f. = 2, $P = 0.029$) and of day of production ($F = 4.58$, d.f. = 60, $P = 0.005$) were significant, but not the

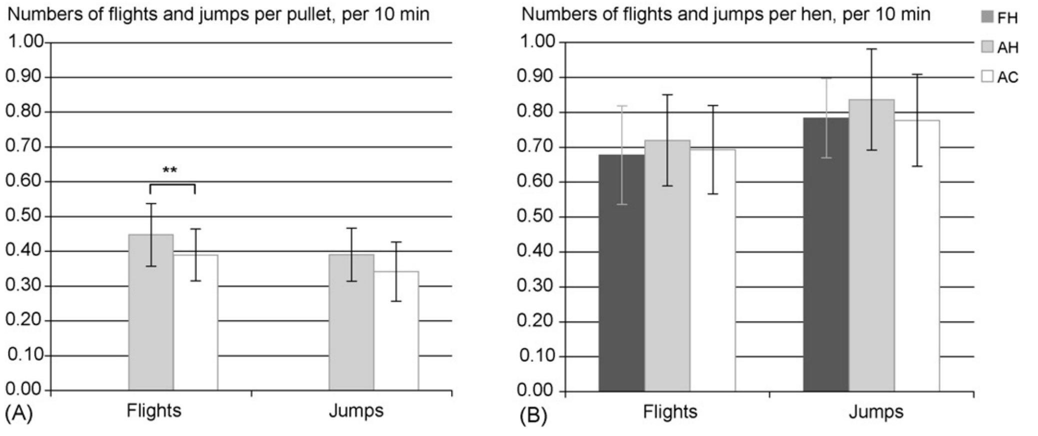

Fig. 6. Numbers of flights and jumps per hen per 10 min (means ± standard deviation), before (A) and after transfer (B), for each treatment: hens reared in furnished floor pens with manual feed hoppers on litter (FH hens), hens reared in rearing aviaries with manual feed hoppers on litter (AH hens) and hens reared in rearing aviaries with automatic chain troughs on platforms (AC hens), before being transferred to laying aviaries with automatic chain troughs ($^{**}P < 0.01$).

effect of their interaction ($F = 1.53$, d.f. = 120, $P = 0.189$). AC hens laid a high percentage of their eggs inside nest boxes from week 18 (more than 90%), whereas AH hens needed one more week, and FH hens two more weeks, to lay more than 90% of eggs inside nest boxes. After week 19, AH hens laid slightly more numerous eggs inside nest boxes than FH and AC hens. Over the whole observed period, FH hens laid fewer eggs inside nest boxes than AH and AC hens (FH hens 90.84%, AH hens 94.18%, AC hens 93.03%). We observed that FH hens used the upper level of nest boxes in more than 50% cases only from week 20, whereas AH hens did so from week 19 and AC hens did so from the beginning of the laying period.

For the rate of eggs laid on platforms, the effect of treatment was not significant ($F = 2.41$, d.f. = 2, $P = 0.146$), the effect of day of production was significant ($F = 2.54$, d.f. = 60, $P = 0.025$), and the effect of their interaction was not significant ($F = 0.86$, d.f. = 120,

Table 1
Number (%) of flights and jumps in the two classes of distances, before and after transfer, for each treatment: hens reared in furnished floor pens with manual feed hoppers on litter (FH hens), hens reared in rearing aviaries with manual feed hoppers on litter (AH hens) and hens reared in rearing aviaries with automatic chain troughs on platforms (AC hens), before being transferred in laying aviaries with automatic chain troughs

Distances	Before transfer		After transfer		
	AH	AC	FH	AH	AC
Flights					
Short (0–99 cm)	1417 (58.85)	1356 (64.11)	2032 (64.90)	1977 (58.75)	1830 (59.86)
Long (100–300 cm)	991 (41.15)	759 (35.89)	1099 (35.10)	1388 (41.25)	1227 (40.14)
P (χ^2)	<0.001		<0.001		
Jumps					
Short (0–99 cm)	1847 (99.73)	1705 (99.71)	3354 (99.94)	3612 (99.89)	3434 (99.83)
Long (100–300 cm)	5 (0.27)	5 (0.29)	2 (0.06)	4 (0.11)	6 (0.17)
P (χ^2)	0.899		0.376		

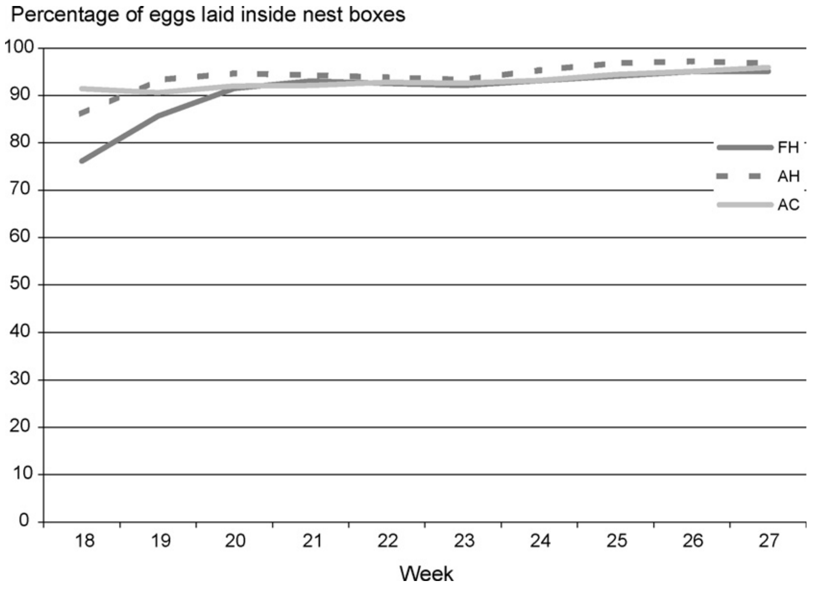

Fig. 7. Evolution of the rate of eggs laid inside nest boxes, expressed per week as a percentage of eggs produced, for each treatment: hens reared in furnished floor pens with manual feed hoppers on litter (FH hens), hens reared in rearing aviaries with manual feed hoppers on litter (AH hens) and hens reared in rearing aviaries with automatic chain troughs on platforms (AC hens), before being transferred to laying aviaries with automatic chain troughs.

$P = 0.600$). Hens from the three treatments laid eggs at similar rates on platforms over the whole observed period (means: FH hens 2.58%, AH hens 2.37%, AC hens 3.39%). These rates decreased from weeks 18 to 27, in the same way for the three treatments (the decrease was of 2 or 3% according to treatments).

For the rate of eggs laid on the litter, the effect of treatment ($F = 8.35$, d.f. = 2, $P = 0.011$) and of day of production ($F = 4.26$, d.f. = 60, $P = 0.003$) were significant, and the effect of their interaction had a tendency to be significant ($F = 1.84$, d.f. = 120, $P = 0.086$). Over the whole observed period, FH hens laid more numerous eggs on the litter than AH and AC hens (FH hens 6.58%, AH hens 3.45%, AC hens 3.58%). The rate of eggs laid on the litter decreased over the entire observed period for the three treatments, but the decrease was slower for FH hens (the rate fell below 5% in week 19 for AH and AC hens and only in week 21 for FH hens).

3.5. Laying rate

The effect of treatment was significant for the mean laying rate from weeks 18 to 27 ($F = 6.36$, d.f. = 2, $P = 0.022$): FH hens produced fewer eggs than AH and AC hens (FH 69.2%, AH 70.9%, AC 70.6%). By looking at curves more in details, we see that the difference of production on all laying period was linked with the first 3 weeks of lay. Indeed, although hens of the three treatments began to lay before 18 weeks of age (Fig. 8), the laying rate was lower in FH hens and ISA reference than in AH and AC hens until week 20. Thereafter, this difference disappeared. The peak of lay was reached at the same time (in week 22) in the three treatments (FH 89%, AH 88%, AC 87%). From week 21, the production of the three treatments was under the ISA reference, and it even stopped increasing in week 24 in FH hens and in week 23 in AH and AC hens, i.e. before the ISA reference (week 26).

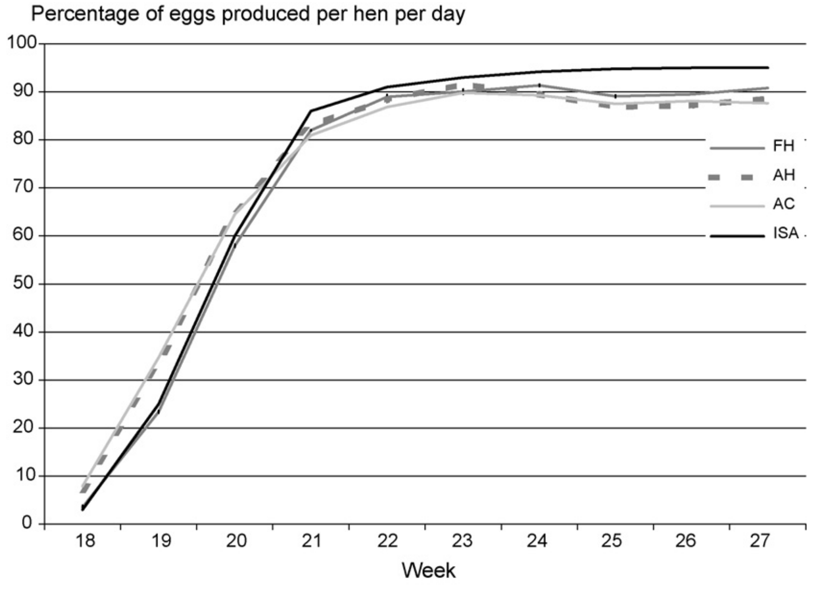

Fig. 8. Evolution of the laying rate, expressed per week as a percentage of eggs produced per hen per day, for each treatment: hens reared in furnished floor pens with manual feed hoppers on litter (FH hens), hens reared in rearing aviaries with manual feed hoppers on litter (AH hens) and hens reared in rearing aviaries with automatic chain troughs on platforms (AC hens), before being transferred to laying aviaries with automatic chain troughs.

3.6. Mortality

The effect of treatment on mortality was significant before transfer ($F = 6.10$, d.f. = 2, $P = 0.036$): the mortality rate was higher in FH pullets than in AH and AC pullets (FH 4.09%, AH 1.35%, AC 0.79%). The effect of treatment was also significant after transfer (F = 9.54, d.f. = 2, $P = 0.006$): the mortality rate was higher in FH and AH hens than in AC hens (FH 0.59%, AH 0.36%, AC 0.00%).

4. Discussion

Our results indicate that hens coming from furnished floor pens (FH hens) used the upper levels less, and the litter probably more, than hens coming from rearing aviaries (AH and AC hens). FH hens made as many flights and jumps but took fewer long paths than AH and AC hens. Since long paths were needed to reach upper levels, the lower use of upper levels by FH hens could be explained by their weaker ability to make long flights. FH pullets could also have developed a preference to stay on litter rather than to move upward because of their rearing environment. Birds develop preferences in their early age, when they are flexible (Denenberg, 1969; Gvaryahu et al., 1989; Reed et al., 1993), and during the rearing period there was neither an upper platform nor upper perches in furnished floor pens, and the litter area was larger than in rearing aviaries. The results of the present experiment confirm those of previous non-replicated studies performed on hens housed in laying aviaries in large groups of more than 2500 hens (Michel and Huonnic, 2003; Colson et al., 2004, 2005). Our results also confirm those of a study performed on hens housed in two types of laying aviaries, different from the one we tested, and previously reared in furnished floor pens or rearing aviaries (Abrahamsson and Tauson, 1995). However, even though FH hens used the upper levels less than AH and AC hens, they seemed to adapt quickly to the vertical space, using vertical levels to a similar extent as in previous studies performed over a laying period of about 1 year (Hansen, 1994; Abrahamsson and Tauson, 1995; Carmichael et al., 1999; Channing et al., 2001; Odén et al., 2002; Michel and Huonnic, 2003; Colson et al., 2005).

The effect of the feeding system (trough type and location) used during the rearing period on the use of platforms and perches was slight and only apparent during this rearing period and did not influence the use of platforms during the laying period. This effect seemed to be due to the troughs location. During the rearing period, the location of feed on a different level (litter) from the ones where water was available (platforms) induced a higher use of lower levels and more numerous and longer flights (probably to reach feed and water) in AH than in AC pullets, which had water available on the same levels as feed. It was previously found that pullets would learn to use the vertical space if they were forced to move vertically by having one or more important resources, such as feed or water, on the raised levels (Abrahamsson and Tauson, 1998; Gunnarsson et al., 1999). The present results indicate that to ensure a good vertical space use, at least during the rearing period, it is important to have a large vertical distance between important resources, as was the case in AH pullets.

The period until more than 90% of eggs was laid inside nest boxes was longer for hens coming from furnished floor pens (FH hens) than for hens coming from rearing aviaries (AH and AC hens). This delay, related to the design of the rearing pens, could be caused by the lower ability of FH hens to jump over long distances, what led to difficulties reaching nest levels, particularly the upper one and during the first 2 weeks of lay. This delay could also be caused by the preference of FH hens for staying on litter, since the difference in eggs laid inside nest boxes between treatments was linked to a difference in eggs laid on litter. Even though the rate of eggs laid inside nest boxes increased more slowly in FH hens than in AH and AC hens, the increase in FH hens was similar or even faster than in previous studies (Taylor and Hurnik, 1996; Abrahamsson and Tauson, 1998; Michel et al., 2004). The present results are consistent with previous studies that showed that rearing conditions of pullets (access to perches or not, or use of rearing aviaries) influenced the rate of floor eggs once housed in a deep litter laying house (Petersen, 1991) or in a laying aviary (Michel et al., 2004). However, Gunnarsson et al. (1999) found no influence of rearing pen design on rates of eggs laid inside nest boxes, in a cohort study. In the latter study several types of design were studied for each furnished floor pen, rearing and laying aviaries, and management practices (gathering of eggs ...) were not controlled. These factors probably also influenced the misplaced eggs level. The discrepancies between these results seem to come mainly from the type of study (cohort versus experimental) and the management of the birds.

The feeding system (trough type and location) used during the rearing period involved a rate of eggs laid inside nest boxes that was slightly higher in hens previously fed with hoppers on litter (AH hens) than in hens previously fed with chains on platforms (AC hens). This difference was linked neither to the use of space after transfer, nor to the rate of eggs laid on platforms or on litter, since these variables were not different between AH and AC hens. Thus, AH hens probably found nest boxes a little bit more efficiently once in laying aviaries. They probably learnt to explore their environment to a fuller extent than AC pullets during the rearing period, owing to the higher vertical distance between feed and water.

The lower laying rate over the whole production period of hens coming from furnished floor pens (FH hens) could be explained by two causes: the lower onset of laying of FH hens and the more numerous eggs that FH hens laid on litter, in comparison with hens coming from rearing aviaries (AH and AC hens). First, during the rearing period, pullets of the three treatments received the same manipulations, photoperiod and feed. Hence, their physiological maturation was certainly similar at transfer (also, birds' weights measured at transfer were similar between the three treatments). However, a lower feed intake of FH hen compared to AH and AC hens at this time could have slower their maturation just after transfer, leading to a lower laying rate. Indeed, FH hens used the middle platform, where feed was available, less than AH and AC hens. Furthermore, we observed that the noise of the feeding chain frightened them during the first week after transfer. Second, as FH hens laid more eggs on litter than AH and AC hens, a larger proportion of their eggs were subjected to pecking and eating. The number of gathered eggs, thus, probably diminished, as previously reported by other authors (Abrahamsson and Tauson, 1998; Tauson et al., 1999; Michel and Huonnic, 2003). However, although the onset of laying was lower for FH hens than for AH and AC hens, it was similar to the ISA Brown reference and higher than in other studies on hens kept in laying aviaries (Taylor and Hurnik, 1996; Michel et al., 2004).

The feeding system used during the rearing period had no effect on the laying rate, in spite of the slight influence it had on the eggs location, as the increases in the laying rate of AH and AC hens were similar.

Comparison with the ISA Brown reference indicates an early stop in the increase of laying rates in the three treatments. This was probably due to the disturbance caused by the catching of hens for blood sampling performed weekly from weeks 22 to 27, for a parallel study on stress response.

The influence of rearing pen design on mortality rates was clear before transfer: less pullets died in rearing aviaries (AH and AC) than in furnished floor pens (FH). The main causes of mortality differed between rearing systems: culling after trapping of some parts of the body in rearing aviaries, and suffocations in furnished floor pens. The mortality rates of AH and AC pullets were very low, under 1.4%, which is lower than usually constated on the field. The mortality rate of FH pullets was artificially increased because pullets of one batch crowded at night in a recess of the wall that was filled after its discovery, which led to 8.88% mortality in this batch. However, in spite of this artificially increased mortality of one batch, the mean mortality rate of FH pullets stayed similar to the 4% expected by the chicks' producer. After transfer, mortality rates obtained, under 0.60%, were low compared with the ISA Brown reference (0.72%) and the rates reported in other studies, over 10 weeks (Taylor and Hurnik, 1996—1.26%; Van Horne, 1996—1.13%; Tauson et al., 1999—0.92 and 4.16%). The influence of the rearing pen design on mortality seemed to persist and the feeding system used during the rearing period seemed to have a slight influence on mortality: mortality was higher in FH and AH hens than in AC hens. This higher mortality was perhaps due to the death of some hens, which did not find feed or were frightened to approach chain troughs. However, these differences were limited and did not reveal great differences in adaptation.

5. Conclusion

The adaptation to laying aviaries was mainly influenced by the design of the rearing pens. Hens coming from furnished floor pens jumped and flew less accurately and had a preference for staying on litter and lower levels, compared with hens coming from rearing aviaries. This led to difficulties reaching upper levels (including higher nest level) and finding the feed, and had a negative impact on laying and mortality rates. Thus, the floor pen design proposed in our experiment did not ensure a similar adaptation to that provided by rearing aviaries.

The feeding system (trough type and location) used during the rearing period had a slight influence on the adaptation to laying aviaries, since there were fewer differences between hens previously reared with different feeding systems than in different pen designs. The effect of feeding system, visible on the use of space before transfer, was only visible on the eggs location after transfer. It seemed to be due to the troughs location. The adaptation was slightly better when the vertical distance between feed and water was high during the rearing period.

Based on these results, we recommend rearing pullets assigned to laying aviaries in rearing aviaries. However, if pullets are to be reared in furnished floor pens, we advise adding perching enrichments very early to limit preference for litter, with one important resource on the highest levels and another one on the lowest levels to force pullets to move up and down.

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