Laying Hens in Furnished Cages

- Use of Facilities, Exterior Egg Quality and Bird Health

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Abstract

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Concern for the welfare of laying hens housed in conventional cages has led to a change of the Animal Welfare Legislation in Sweden, implying that cages must provide possibilities for hens to lay eggs in a nest, to rest on a perch and to use litter. Such requirements are also being considered within the whole European Union. The purpose of this thesis is to contribute to the general knowledge of, and further development of, furnished cages, both as regards birds' use of facilities and their welfare, as well as with regard to production. The furnished cages housed 6 to 16 birds and the genotypes included were the commercial hybrids Lohmann Selected Leghorn (LSL), Hy-Line White and Hy-Line Brown. Passive Integrated Transponders were used in order to record individual bird's use of litter baths, nests and passages through pop holes in larger cages divided into two halves.

With some exceptions, nest and perches were generally used by 80-90% of the birds, and nest use was affected by nest design. There was a very large variation in the number of days individual birds visited the litter bath, and almost 30% of the birds never entered the baths. Frequent use of litter affected neither a hen's exterior appearance (feather cover, pecking wounds) nor her estimated level of stress. Providing cages for larger groups of hens with a partition with pop holes, in order to improve their escape possibilities, did not affect any of the measured welfare traits. However, the pop holes were frequently used and the cage proved to work in all practical aspects. Two different measures to reduce egg shell cracks, both reducing the speed of the eggs on their way out of the nest, proved to be very efficient. Egg production and mortality rates were normal and similar to levels recorded in conventional cages. Differences in behaviour, indicators of stress and fear, exterior egg quality and exterior appearance were identified between genotypes. In conclusion, most birds found nests and perches attractive, whereas litter was used to varying extents. With inexpensive measures to reduce egg cracks, the proportion of cracks can be reduced to the level found in conventional cages.

Keywords: behaviour, passive integrated transponder, modified cage, enriched cage, nest, litter bath, dust bath, perch, pop hole, layer.

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To my parents:
Siri and Ulf Wall

Contents

Appendix

Papers I-IV

This thesis is based on the following papers, which will be referred to by their Roman numerals:

I. Wall, H., Tauson, R. & Elwinger, K. 2003. Layers' individual long-term use of litter in furnished cages – effects of substrate and genotype. (Submitted)

II. Wall, H., Tauson, R. & Elwinger, K. 2003. Pop hole passages and welfare in furnished cages for laying hens. (Accepted for publication in *British Poultry Science*)

III. Wall, H., Tauson, R. & Elwinger, K. 2002. Effect of nest design, passages, and hybrid on use of nest and production performance of layers in furnished cages. *Poultry Science* 81, 333-339.

IV. Wall, H. & Tauson, R. 2002. Egg quality in furnished cages for laying hens – effects of crack reduction measures and hybrid. *Poultry Science* 81, 340-348.

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Introduction

Background

During recent decades the housing of layers in commercial egg production has become widely discussed, especially in North Western Europe. The debate has focused on the barren environment and restricted available area in conventional cages and the welfare of hens housed in such cages has been questioned (*e.g.*, Baxter, 1994; Craig & Swanson, 1994). In Sweden this resulted in a new Animal Welfare Ordinance in 1988, implying that cages should be banned in 1999 (SFS, 1988). However, the Standing Committee for Agriculture and Environment stated that the change to alternative housing systems must not lead to impaired animal health, increased medication, impaired working conditions, introduction of beak-trimming (prohibited in Sweden, Finland and Norway) or Swedish egg production being out-competed by foreign cage egg production. The last criterion was added in 1995 when Sweden joined the EU.

In Sweden, all animal housing systems considered to be new must be tested in a so-called “New Technique Evaluation Programme” in order to ensure that health and other animal welfare traits as well as production and mortality rates are acceptable. Hence, in the early period following the ban on cages several different aviary systems, *i.e.*, floor systems in multi-tier designs, were tested in this programme as well as in research. Mainly due to problems with feather pecking, cannibalism, air condition and some health problems, such as parasitic disorders and bumble foot, showing up in the testing programme (Algers *et al.*, 1995; Ekstrand *et al.*, 1997; Tauson & Holm, 1998), the aviary systems did not live up to the criteria established by the Committee in 1988. Thus, in 1997 the Welfare Ordinance of 1988 was altered, implying that cages were permitted only if furnished with a nest, litter bath and a perch (SFS, 1997).

The need for development of furnished cages has become evident also in other European countries because of the change to alternative housing systems being prepared in the European Union. Thus, in 1999 the European Commission decided that by 2012 all laying cages must be ‘enriched’ with a nest, a litter area for scratching and pecking and a perch (European Commission, 1999). At the moment in Sweden, conventional cages are being replaced either by floor-housing systems or by furnished cages. Today, 25-30% of the national flocks are housed in furnished cages (Tauson, 2003).

Early and recent designs of furnished cages

Research designed to make the environment of cages for layers less restricted and less barren has been on-going for quite some time. Thus, the Get-Away-Cage, developed in the 70’s by Bareham (1976) and Elson (1976), had perches on different levels in order to allow birds to escape. However, disadvantages such as high mortality rates, less good inspection possibilities, inferior egg quality as regards cracked and dirty eggs (Abrahamsson *et al.*, 1995) and inferior plumage hygiene (Abrahamsson *et al.*, 1996a) made this cage less suitable for commercial egg production both from practical and animal welfare points of view. Hence, research tended to turn to cages with perches on one level (*e.g.*, Tauson, 1984; Abrahamsson & Tauson, 1993). In the early 90's different designs of nests and litter baths and the optimal position of these facilities within a cage, were systematically evaluated with focus on birds' use of facilities as well as on practical considerations (Appleby *et al.*, 1993). This research resulted in the Edinburgh Modified Cage or the "EMC" concept (Appleby & Hughes, 1995) in which a nest was placed at one end of the cage, a litter bath was positioned on top of the nest and a perch was placed across the cage width, *i.e.*, parallel to the feed trough. Originally the cage was designed for groups of 4 birds (Appleby & Hughes, 1995) but in further development of the system into a commercial design, it was shown that housing 8 hens together in a larger cage worked well too (Abrahamsson & Tauson, 1997). The larger group size also implied a lower investment cost as well as a larger available area for birds to move around in.

In the early designs nest boxes were closed during the night in order to prevent defecation of the nest bottom by birds spending the night inside the nest (Appleby & Hughes, 1995). However, when the nest design was developed further the closing of nests during the night proved to be unnecessary (*e.g.*, Appleby *et al.*, 2002) and hence, in more recent designs the nest is available all the time. The closing of litter baths during the period of the day when most hens lay their eggs, is still practised in this concept of a furnished cage. Further development of the EMC cage has led to commercial designs of furnished cages, of which several have been tested and approved in the compulsory New Technique Evaluation Programme in Sweden (*e.g.*, Tauson & Holm, 2002). These are, for example, the "Comfort Cage" manufactured by Bröderna Victorsson AB (Figure 1) and the "Environment system" manufactured by Hellmann Poultry GmbH, both aimed for groups of eight hens.

Figure 1. An example of the Edinburgh Modified Cage, or the "EMC" concept, in which a nest is placed at one end of the cage (lower right), a litter bath positioned on top of the nest (upper right). A perch is also provided. This particular cage is for 8 birds. Photo: Istvan Pamlényi.

A totally different concept, also approved in the Swedish New Technique Evaluation Programme (Tauson & Holm, 2003), is the Aviplus cage for groups of 10 birds, manufactured by Big Dutchman GmbH. This cage is sometimes described as a reversed cage, because it has the nest, litter facilities and egg collection belt at the rear of the cage, *i.e.*, in the centre of the cage battery, see Figure 2.

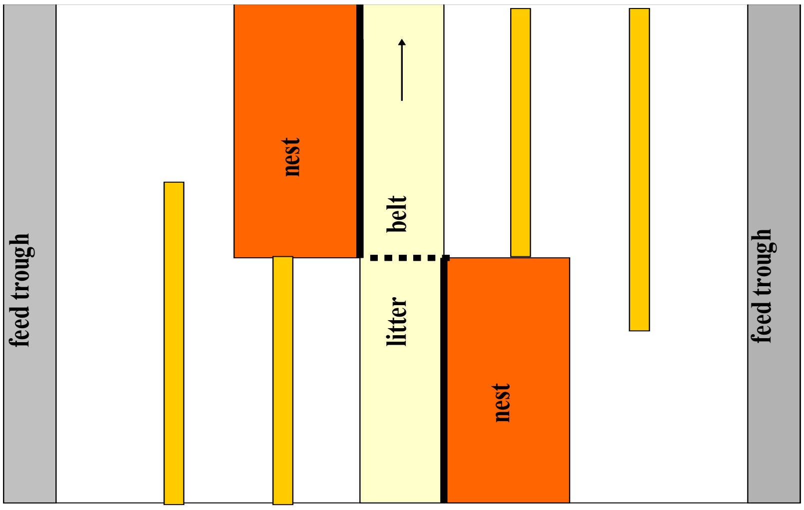

Figure 2. The Aviplus cage for 10 birds viewed from above. Litter is distributed automatically by running the litter belt.

In contrast to nest and perches, the introduction of litter involves a new technical procedure as litter baths have to be replenished. In large-scale egg production, filling baths manually is not a realistic solution and the Aviplus cage is one example of a cage with automatic distribution of litter. The litter facility consists of a trough, with a belt on its bottom whereby litter is distributed to all cages in the battery tier.

The furnished cages mentioned above are all for relatively small groups but research is on-going also on furnished cages for larger groups of birds, housing up to 54 hens (Fiks-van Niekerk *et al.*, 2001; Rauch *et al.*, 2002). A larger total cage area, as a consequence of a larger group size, improves the opportunities for birds to move within the cage, which in turn may lead to better bone strength. In a larger cage it is also possible to incorporate more than one nest and a larger litter bath. Thus, hens can choose between nests and more hens can dustbathe together. However, the risk of problems with feather pecking (Bilčík & Keeling, 2000), cannibalism (Fiks-van Niekerk *et al.*, 2001) and aggressive interactions (Al-Rawi & Craig, 1975; Hughes & Wood-Gush, 1977) are associated with group size. It has been suggested that severe feather pecking and cannibalism are expressed mainly by some of the birds in a group (Keeling, 1994; Yngvesson & Keeling, 2001) and in a small group only a limited number of animals are affected by the behaviour of these individuals. However, as regards aggressive encounters, some studies have reported on the frequency being lower in large group sizes than in small (Nicol *et al.*, 1999) and at higher stocking densities (Al-Rawi & Craig, 1975; Nicol *et al.*, 1999). This may occur because birds in smaller group sizes attempt to form social hierarchies (Nicol *et al.*, 1999), and at lower densities an individual entering another individual's "personal space" may trigger an agonistic encounter (Hughes & Wood-Gush, 1977). These behaviours are important to consider, especially in countries where beak-trimming is not allowed, like in Sweden, Norway and Finland. It is also possible that beak trimming will shortly be banned in more European countries.

Use of nests, litter and perches

Under non confined conditions, nesting behaviour starts with the hen moving away from the flock, seeking out a protected place where she can build a nest (Duncan *et al.*, 1978). In captivity, *e.g.*, in a pen, with artificial nests, nesting behaviour begins with the hen showing some restlessness and giving a characteristic call (Wood-Gush, 1982). Eventually, after some pacing along the sides of the pen, explained as trying to find a way out, the hen examines the nests. After having examined several nests she may alternate between periods of feeding and drinking, and periods of nest examinations, for up to 3 h (Wood-Gush, 1982), before she finally settles down in one of the nests. Nesting behaviour is controlled by several endocrine events following oviposition (see Petherick & Rushen, 1997) and hence, the behaviour does not disappear in the absence of a nest site but will merely be modified (Wood-Gush, 1982).

The aim of providing litter in furnished cages is to facilitate foraging, *i.e.*, pecking and scratching, and dustbathing. The latter consists of a sequence of behavioural elements which function to work the substrate all the way into the proximal integument of the hen, ending in dust being shaken out of the plumage (van Liere, 1992). This behaviour regulates the amount of feather lipids and keeps the downy part of the plumage fluffy (van Liere & Bokma, 1987; van Liere, 1992; Sandilands *et al.*, 2001). Peat and sand have proved to be effective in removing excessive lipids, whereas with wood-shavings the contact between the litter and the bird's proximal integument is not sufficient, resulting not only in higher lipid levels but also in interrupted and short baths (van Liere, 1992). According to observations of birds housed in pens, it appears that the average hen dustbathes on every second day (Vestergaard, 1982; van Liere & Bokma, 1987), but there may be a large variation in this frequency between individual birds (Vestergaard, 1982). When hens are housed in environments without litter they may perform sham dustbathing, *i.e.*, they perform some of the elements of the dustbathing behaviour on the wire floor. However, this behaviour has been reported to be common also in furnished cages, where in fact, litter is provided (Olsson & Keeling, 2002a).

Perches are used both during the day and night. Under feral conditions resting in a tree provides protection from predators. Abrahamsson *et al.* (1996b) found that in day-time one-third of the hens rested on the perch in furnished cages housing 4 or 5 birds. In furnished 8-hen cages used in practice, about 80 to 85% of the birds used the perch during the night (Tauson & Holm, 2002). However, in most farms in that survey the light was abruptly turned off instead of successively decreased.

Hence, in studies on research stations, where the light has been dimmed before lights-off, the recorded use of perches has been higher, about 90% (*e.g.*, Abrahamsson *et al.*, 1996a; Abrahamsson & Tauson, 1997).

Is birds' use of facilities of significance?

A question of significance when discussing birds' use of facilities in furnished cages is to what extent use of nests, litter and perches is of importance and, if so, to whom - the hens, the egg producer or both?

Several studies have shown that hens are willing to work to gain access to nests (Smith *et al.*, 1990; Cooper & Appleby, 1994) and when housed in barren environments such as conventional cages, they may show frustration prior to oviposition (Mills & Wood-Gush, 1985). Furthermore, in cages, birds with nests show a more settled and less frustrated pre-laying behaviour than birds without nests (Appleby, 1998; Yue & Duncan, 2003). Similarly, hens accustomed to perches showed signs of unrest when access to perches was thwarted, possibly indicating frustration (Olsson & Keeling, 2000). Furthermore, hens with prior experience of perches were found willing to work in order to gain access to perches for night-time roosting (Olsson & Keeling, 2002b). Also, perches improve the bone strength of hens in cages (Abrahamsson & Tauson, 1993) and, hence, reduce the risk of bone breakages when birds are taken out of cages and transferred to the slaughter plant at the end of lay. Evidently, nests and perches appear to be important resources to laying hens.

Studies of birds' motivation for litter have resulted in contradictory conclusions. Lagadic & Faure (1987) and Faure (1991) for example, using operant conditioning, did not find evidence of a need for litter in caged laying hens, whereas others have shown that hens are willing to work in order to gain access to litter (Bubier, 1996; Gunnarsson *et al.*, 2000a; Widowski & Duncan, 2000). However, there is evidence that providing litter may be of importance in order to avoid feather pecking, which is a severe welfare, as well as an economic problem (Tauson & Svensson, 1980; Peguri & Coon, 1993). Blokhuis (1986) explained feather pecking as redirected ground pecking, related to foraging, whereas Vestergaard (1994) suggested that feather pecks are redirected dustbathing pecks, originating because birds do not have access to an adequate dustbathing substrate early in life. Both theories have subsequently been confirmed; the foraging theory, *e.g.*, by Huber-Eicher & Wechsler (1997) and the theory related to dustbathing, *e.g.*, by Johnsen *et al.* (1998).

Eggs laid in the cage area instead of in the nests of furnished cages do not require to be collected separately as they roll out into the same cradle as the nest eggs and, hence, are not a load in terms of causing extra work. However, these eggs run a higher risk of getting cracked as they may attract the attention of other birds, or being stepped on as they roll towards the egg cradle (Bell, 1999). Furthermore, if an egg is laid at the rear of the cage, it has to roll underneath the perch where floor hygiene may be inferior because droppings can not be effectively trampled down (Abrahamsson & Tauson, 1993; Glatz & Barnett, 1996). Thus, eggs laid in the cage area may run a higher risk of becoming dirty compared with eggs being laid in the nest, providing of course, that the nest is not defecated by birds spending the night there (Sherwin & Nicol, 1992). Thus, it is important that birds find it more attractive to rest on the perch than in the nest.

In cages furnished with perches but without nests, birds may lay eggs when sitting on the perches (Glatz & Barnett, 1996; Appleby *et al.*, 1998) resulting in high proportions of cracked eggs (Glatz & Barnett, 1996). Thus, in cages and other housing environments furnished with nests, perches and litter, a proper and good use of the facilities may not only be important from bird welfare points of view, but may also be of considerable economic interest.

Exterior egg quality

The income from eggs delivered to a packing plant depends not only on the produced quantities, but also on characteristics of the eggs, *e.g.*, their exterior quality. Thus, cracked and dirty eggs decrease the egg producer's income. In countries within the European Union washed eggs are not allowed to be sold as first-class eggs (Hutchison *et al.*, 2003), and hence, the revenue for these eggs may be reduced. The housing environment and the way eggs are handled when transferred from the laying house to the packing unit have a large impact on the risk of an egg getting cracked (Bell, 1999). In conventional cages, eggs rolling out from the cage are spread over the whole cage width, whereas in furnished cages, with most eggs laid in the nest, there is an accumulation of eggs in the cradle in front of the nest. Thus, the risk of an egg being cracked on account of rolling into another egg in the cradle is high, especially in the EMC concept (Figure 1) with a deep and narrow nest. Also in conventional cages, depth and width may be of importance with regard to the risk of eggs getting cracked (Hughes & Black, 1976). In the Aviplus cage (Figure 2), the nest is wider and less deep, and hence, the risk of cracks due to eggs colliding in the cradle is considerably lower.

Some hybrids have the ability to produce eggs with better shells than others. Egg shell thickness may explain about 50% of the variation of the egg shell's crushing strength (Richards & Swanson, 1965). However, the egg shell must be fragile enough to enable the chick to break free at hatching (Hunton, 1995). Also the shape of the egg, *i.e.*, the egg shape index affects the risk of egg cracks (Richards & Swanson, 1965). The common way to sort out eggs with defects like cracked or dirty egg shells, is by visual inspection at candling. However, research has shown that egg shell cracks can also be effectively detected by acoustic resonance frequency analysis (De Ketelaere *et al.*, 2000), or by laser detection (Chalukova-Dimitrova *et al.*, 1998). The latter method can also detect eggs with dirty shells or shells with local thinnings.

Methods to study layers' use of facilities

Usually, birds' use of facilities is studied by direct observations (*e.g.*, Smith *et al.*, 1990) or video recording (*e.g.*, Cooper & Appleby, 1995) but also photocell technique has been used (Reed & Nicol, 1992; Ceular *et al.*, 2003). However, direct observations are time consuming if used in long-term studies or in continuous observations, and video recording may be associated with difficulties to identify individuals in a group of birds. In addition, when used on its own, photocell technique does not enable identification of animals.

Hence, in long-term studies it may be more feasible to use some kind of automatic recording system with possibilities to identify individuals, like *e.g.*, Passive Integrated Transponder (PIT) tags. The PIT tag technique is an identification system previously used to mark animals of various species, *e.g.*, fish (Brännäs & Alanärä, 1993), laying hens (Brännäs *et al.*, 2001) as well as pet animals. A PIT tag consists of an electromagnetic coil and a microchip, sealed in a glass capsule, 12 mm long and 2 mm in diameter (Figure 3). The technique has been described in detail by Prentice *et al.* (1990). Every time the tag is close enough to a reader (antenna) it becomes activated and sends out a unique combination of numbers and letters which can be transferred to a reader board and stored in a computer. In birds and mammals tags are generally implanted subcutaneously, through a cannula (*e.g.*, Jamison *et al.*, 2000; Schooley *et al.*, 1993).

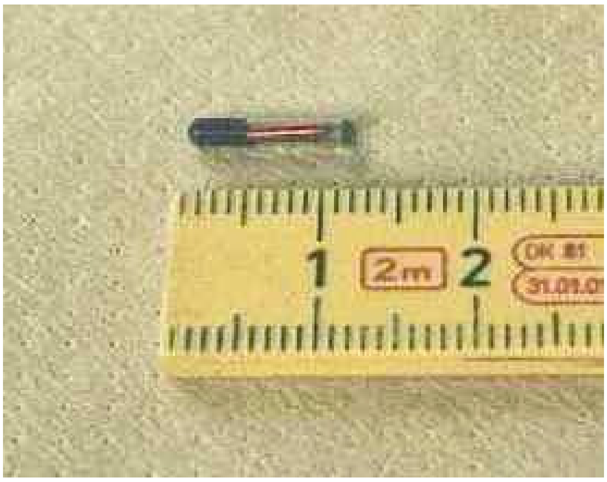

Figure 3. A Passive Integrated Transponder (PIT) tag. Photo: Istvan Pamlényi.

Measurements of stress and fear

Two widely used measures of welfare are tonic immobility (TI) and heterophil/lymphocyte (H/L) ratios. The former is an unlearned fear response which is elicited by a brief period of physical restraint. Birds with high fearfulness are assumed to have a long TI response, *i.e.*, remain immobile for a longer period than birds with a low level of fearfulness (reviewed by Jones, 1986). The ratio of heterophils and lymphocytes in blood is considered to be a reliable measure of stress in avians. During mild to moderate stress, an increase in birds' H/L ratios is expected (reviewed by Maxwell, 1993).

Aims of the thesis

The furnished cages for small group sizes represent new housing systems that recently (1998) have been introduced in practice in Sweden (Tauson, 2003). The aim of this thesis was to contribute to general knowledge and further development of furnished cages, both as regards birds' use of facilities as well as production traits. Studying effects of genotypes was also considered to be important. More specific aims were:

- To study the long-term use of litter baths on groups as well on an individual basis, with sand or sawdust as litter bath substrate, and to find possible associations between use of litter and selected welfare traits.
- To study whether dividing cages for larger group sizes into apartments is of benefit to the birds, by *e.g.*, improving their possibilities to move away from other birds. Furthermore, the bird's use of pop holes in the partition dividing the cage, was also important to study.
- To study nests of varying designs as regards their use by the birds and to study possible associations between nest designs and exterior egg quality.
- To study different measures to reduce egg shell cracks.
- To adapt and use the PIT tag technique in studies of bird's visits to nests and litter baths in furnished cages.

Materials and methods

General designs of furnished cages

The furnished cages used were based on the Edinburgh Modified Cage (EMC) concept (Appleby & Hughes, 1995; Abrahamsson *et al.*, 1996a), with the litter bath placed on top of the nest (Figure 1). Furnished 6-hen (FC-6) and furnished 8-hen cages had one nest box, one litter bath and one perch (Figure 1). Furnished 14-hen and 16-hen cages, from now on referred to as FC-14 and FC-16, had two nest boxes, a litter bath twice as large as the regular sized baths in the other group sizes, and two perches. These cages were constructed either by taking away the rear partition of 7- and 8-hen cages, resulting in fully open cages (O-cages), or by providing the partition with pop holes through which the birds could pass and hence use both "apartments" (H-cages). In the present studies, the furnished cages for 8 hens were either the "Comfort cage" or the "Environment cage", manufactured by Bröderna Victorsson AB and Hellmann Poultry GmbH, respectively. From now on these cages are referred to as the Victorsson and Hellmann furnished cages. In the Victorsson cages, curtains of plastic, hanging behind the gates, screened-off the nests from the aisle. These curtains either did not reach below the manure deflector (short nest curtain) or ended 1 cm above the cage floor (long nest curtain). Long curtains, reduced the speed of eggs rolling out from the nest. In the Hellmann cage, in every second, a wire extended parallel to and underneath the feed trough (see Paper IV). Hence on the way out of the cage, rolling eggs were stopped by this so-called egg saver wire. The wire was lifted regularly, allowing eggs to slowly roll the last short distance into the egg cradle.

The perch length per hen was 12 cm in all furnished cages except for the Hellmann cage in which the length was 17 cm per hen. Due to successive development none of the cages used was identical to the ones later introduced in commercial production.

In the studies regarding egg quality (Papers III & IV), conventional 4-hen cages (Trional) were included as comparison. The conventional as well as the furnished cages fulfilled the Swedish Animal Welfare Directives of a minimum of 600 cm^2 cage floor area and 12 cm feed trough length per bird.

The following section gives a short overview of cage designs and measurements included in the studies.

In Paper I, the effect of sand or sawdust on birds' use of litter baths, exterior appearance and H/L ratios was studied in FC-14 cages without a rear partition, *i.e.*, O-cages. Use of litter was recorded in individual birds by means of the PIT tag technique and on group basis by direct observations.

In Paper II the studies used FC-16 cages of H- and O-design. The welfare of birds housed in H- or O-cages was estimated by measures of exterior appearance, H/L ratios and tonic immobility. Passages through partition pop holes (H-cages) and visits to nests (H- and O-cages) were followed in individual birds using PIT tag transponder technique. Birds entered and left the nests through separate openings, which both were equipped with tubes allowing passages in only one direction. The pop holes were designed as the nest openings.

Paper III focused on use of nests and production traits, including exterior egg quality. The effect of covering 30, 50 or 100% of the nest bottom with artificial turf was studied in FC-6 cages. Furthermore, H- and O-cages was compared using FC-14- and FC-16 cages. Conventional 4-hen cages were included as comparison. Nest openings and pop holes were designed as in Paper II (one-way passages).

In Paper IV, two crack reduction measures - long nest curtain and egg saver wire – were compared in Victorsson and Hellmann furnished cages, respectively. Covering 30 or 100% of the nest bottom with artificial turf and having the nest opening positioned in the front or in the rear was compared in FC-6 cages. Conventional 4-hen cages were included as comparison.

Animals and management

The hybrids used were Hy-Line White hens (HYW; in all papers), Hy-Line Brown (HYB; in Papers I & IV) Lohmann Selected Leghorn hens (LSL; in Papers II, III & IV). The birds were reared in conventional rearing cages by commercial breeders and were not beak-trimmed (prohibited in Sweden). At 16 weeks of age (w) the pullets were transferred to the experimental building and were given 10 h of light per day. Light was successively increased to 15 h at 24 w and was increased during 6 min at lights-on in the morning (at 03.00 h) to imitate dawn, and dimmed 6 min before lights-out in the evening to imitate dusk (at 18.00 h). All furnished cages except Hellmann had a time-controlled closing mechanism of the litter bath. The baths were open for 4 h and 30 min at 16 w and the opening period was successively increased to 6 h and 30 min at 24 w. The baths were then open between 11.00-17.30 h. However, in the Hellmann cage (Paper IV), baths were not available to the birds until 24 w, but from then on they were available around the clock. Litter baths were replenished twice a week with sand (Papers II & III), sawdust (IV) or sand or sawdust (Paper I).

During rearing the pullets were fed a conventional grower crumbled diet and from 17 w until slaughter the birds received a normal layer crumbled diet (Papers I-IV). Birds in conventional cages (Papers III & IV) were manually fed once a day, whereas the feed was distributed by an automatic flat chain feeder four times a day in the furnished cages. Eggs were collected daily (Papers I-IV) and during periods when exterior egg quality was measured, eggs were collected by hand.

Collection of data

Exterior egg quality, production and mortality

Eggs were collected and analyzed for proportions of cracked and dirty eggs in a small version of a commercial egg candling machine on six (Paper III) and seven (Paper IV) occasions during the production cycle. Shape index, shell breaking strength and shell thickness were analyzed in a sample of eggs from the FC-16 cages at 60 w in Paper III. In Paper IV, samples of eggs from the 6-hen and 8-hen furnished cages were analyzed for shape index, shell breaking strength and shell deformation, at 62 w of age. Production was recorded daily per replicate from 20 to 80 w (Papers III & IV). Dead birds were recorded daily and were subjected to autopsy (Papers I-IV).

Exterior appearance

Birds were scored for plumage condition (neck, breast, back, wings, tail and cloaca) and wounds on the comb and around the cloaca at 52 or 54 w (Papers I & II). The scoring system assigned values of 1 to 4 points for each trait (Tauson *et al.*, 1984), where score 4 was the best and score 1 the worst condition. The six parameters for plumage condition were added into a total score ranging from 6 to 24 points. Cleanliness of feet and plumage (Papers I, III & IV) and length of claws (Paper I) was scored at 52 or 54 w with the same scoring system as was used for plumage condition. Bird live weight was recorded in all studies at the time of scoring.

Estimates of stress and fear

Birds were tested for duration of tonic immobility (TI) at 90 w (Paper II). TI was induced by restraining the bird as described by Jones & Faure (1981). Birds were sampled for blood once (37 w, Paper I) or twice (37 and 72 w, Paper II) and the H/L ratios were calculated.

Use of facilities

The proportion of birds on the perches, on the cage floor, in the nests or in the litter baths was recorded one hour after lights-out every eighth week (Paper III) or on three occasions (at 31, 53 and 77 w, Paper IV). The position of all laid eggs was recorded every fourth week in Papers III & IV. Visits to nests and passages through partition pop holes in FC-16 cages were studied in samples of 35 and 21 birds, respectively, using PIT tag technique (Paper II). Use of litter baths was followed daily in a sample of 118 birds in FC-14 cages using PIT tag technique and recorded by direct observations at two ages (Paper I). Birds visiting the litter bath in more or less than 200 days, out of the total 420 days recorded, were classed as high frequency (HF) and low frequency (LF) birds, respectively.

Statistical methods

Statistical analysis was performed using the GLM, MIXED and FREQ procedures of the statistical system SAS. To satisfy assumptions of normality in the analysis of variance, data were arcsine or log transformed where necessary.

Summary of results

Use of litter and welfare traits

There was a large variation in the number of days that individual birds visited the litter baths (Paper I). Thirty percent of the birds never visited the litter bath and forty percent visited it in more than 300 days of the 420-day long recording period. Hence, the majority of birds showed either a very high or a low interest in the litter bath, at least as regards the number of days they used it. A higher proportion of the Hy-Line White birds visited the litter bath often, *i.e.*, they were classed as HF, when the litter bath contained sand as compared with sawdust, whereas Hy-Line Brown birds used the litter bath to an equal extent regardless of litter substrate. No differences in measured traits, *i.e.*, mortality, plumage condition, wounds on comb, H/L ratio, claw length or feet hygiene, were found between HF and LF birds or between the two litter bath substrates (sand or sawdust). However, the feather cover of birds using the baths on many days (HF birds) was significantly better with sand as litter bath substrate than with sawdust, and in groups with sand, the HF birds had a better plumage condition than the LF birds (low frequency users). Hy-Line White had a better feather cover than Hy-Line Brown, but there was no other difference between the hybrids. In the direct observations of litter baths more dustbathing was seen in the late morning (approx. 30 min after the opening of the litter bath) than in the afternoon (approx. 60 min before closing of bath). Neither the proportion of birds being in the litter bath nor the proportion bathing, were affected by genotype or litter substrate in these direct observations.

When the observations of birds' visits to the litter baths were ended at 80 w (Paper I), PIT tags were missing in 24 of the 150 birds still alive, implying a tag loss of

16%. In addition, tags were out of position in six birds (had moved under the skin) and not working in two birds.

Use of nests

Nests were perceived less attractive when the front part of the nest bottom was left as wire mesh instead of covered with artificial turf (Papers III & IV). Nest opening in the front, close to the feed trough, or in the rear of the nest did not significantly affect the number of eggs laid in the nest (Paper IV). In Paper IV, between 88 and 95% of the eggs were laid in the nests and no differences between hybrids were found. With the specially designed nest openings used in Paper III (tube with one-way passage), Hy-Line White laid a significantly higher percentage of eggs in the nest (90%) than LSL (70%). Furthermore, LSL birds laid a much higher percentage of their eggs in the nests in cages with a rear partition (H-cages) compared with fully open cages (O-cages), whereas no such difference was found for the Hy-Line birds. The daily average time individual hens spent in nests varied between 11 and 86 min (mean 41 min) and the number of visits to nests per day varied between 1 and 2.4 (mean 1.4). Although the two nests were identical, most hens visited one of them far more often - the average hen made 90% of her visits to the nest she visited most frequently.

Use of perches

The use of perches after dark varied throughout the studies. Generally, perch use was significantly higher in the Hy-Line White birds compared with the other hybrids observed. For example, in the Victorsson furnished cage for 8 hens (Paper IV), the perches were used by 88% of Hy-Line White birds, 79% of the Hy-Line Brown birds and 78% of the LSL birds, and the use was significantly higher in Hy-Line White. In the Hellmann furnished cage for 8 hens, 81% of the birds used the perch at night, with no significant difference between the hybrids, *i.e.*, between Hy-Line Brown and LSL (Paper IV).

Use and effects on welfare traits of a partition with pop holes

Birds housed in cages divided into two identical halves by a partition with pop holes (H-cage) frequently used the possibility to pass through the pop holes (Paper II). The 21 hens recorded by the PIT tag technique passed through the pop holes on average between 1 to 8 times per day. However, no significant differences in any of the measured traits, *i.e.*, mortality, H/L ratios, duration of tonic immobility or exterior appearance were found between H-cages and fully open cages (O-cages). Hy-Line White birds showed significantly better plumage condition, higher H/L ratio and longer duration of TI than LSL.

Use of facilities in an unintended way

In the cages where the litter baths were closed prior to lights-off no birds were found inside the bath after dark in the 6-hen cage in Paper III or in the Victorsson cage in Paper IV. In the larger cages for 14 or 16 hens (Paper III), 0.14% of the birds were found in the litter bath after dark. In the Hellmann cage where litter baths were available around the clock, 1.6% of the birds spent the night inside or on the edge of the litter baths (Paper IV). Overall, the percentage of birds spending the night inside the nests was less than 1% in the studies in Paper III and varied between 0.7 and 4% in the 8-hen furnished cages in Paper IV. In the Hellmann cage, the proportion of hens in the nest after dark was significantly higher in LSL birds than in Hy-Line Brown. In the Hellmann cages, with litter baths available around the clock, 1.0% of eggs were laid in the litter baths (Paper IV). In the cages where the litter baths were closed during the morning, between 0.1 and 0.3% of the eggs were laid inside the baths (Paper IV).

Exterior egg quality, production and mortality

In Paper III, eggs laid by Hy-Line White birds had a significantly thinner egg shell and a higher shape index, *i.e.*, a more globular shape, than eggs from LSL birds. Interestingly, when housed in FC-14 or FC-16 cages, the proportion of cracked eggs was considerably higher in eggs laid by Hy-Line (14%) than by LSL (6%), whereas there was no difference between the hybrids in conventional cages (3.4 vs. 3.3%). The egg saver wire and prolonged nest curtain both proved to be very efficient in reducing the percentage of cracked eggs (Paper IV). Having only a part (30 or 50%) of the nest floor covered with artificial turf did not result in cleaner eggs or reduced percentages of cracked eggs in Paper III. Actually, the percentage of dirty eggs was higher in cages with 30% artificial turf than with 100% (Paper IV). Generally, proportions of dirty eggs appeared to be on the same level or better in furnished cages compared with conventional (not statistically evaluated).

The average mortality in the furnished cages appeared to be on a level with the conventional ones, and was between 3 and 11%. The levels were higher in Papers I & IV than in Papers II & III, most likely on account of the invasion of red mites in the two former studies. Generally, the production parameters (laying %, egg weight, egg mass) were affected by genotype but not by differences in cage design, *e.g.*, by egg crack reduction measures. The production rates were normal in furnished as well as in conventional cages, with 21 to 22 kg eggs produced per hen housed.

Further results

In order to follow up the results regarding use of litter and feather pecking in furnished cages a new experiment has been started (Wall *et al.*, 2003). This study focuses on effects of rearing on floors or in cages on feather pecking and use of litter later in life. Bunches of string have been found to be attractive pecking stimuli for hens and may also reduce the amount of feather pecking in conventional cages (Jones *et al.*, 2002). Hence, effects of enriching furnished as well as conventional cages with such pecking devices are also being studied.

This study includes 384 Hy-Line White and 384 Hy-Line Brown birds, of which half have been reared in conventional rearing cages, *i.e.*, without litter, and half in a two-tier aviary system with free access to litter from 6 w. At 16 w the birds were transferred to the experimental building and housed in either Victorsson's furnished 8-hen cage, which has been described earlier, or in a conventional 4-hen cage. Half of the conventional cages and furnished cages are enriched with pecking devices, positioned above the feed trough (Figure 4). There is one pecking device per cage in the conventional cage and two per cage in the furnished cages.

Figure 4. A pecking device positioned above the feed trough of a conventional cage. Originally, the device consisted of 8 separate strings but frequent pecking has turned it into a soft "ball". Photo: Karl-Erik Holm.

Use of litter baths in the furnished cages was recorded by direct observations every second week, between 18 and 42 w, 30, 60 and 90 min after the opening. Scoring of birds' plumage (Tauson *et al.*, 1984) was performed at 39 w.

Mean proportions of birds in the litter baths (Table 1) were found higher in Hy-Line Brown birds than in Hy-Line White and in birds reared on floors as compared with in cages. The percentage of floor-reared Hy-Line Brown birds in the litter bath was significantly higher than the other combinations of hybrid and rearing (not in tables), resulting in a significant interaction ($P<0.001$). There was no significant effect of pecking devices on the use of litter baths (not in Table). Although, the plastic strings were pecked at, see Figure 4, they had no effect on birds' plumage condition, either in furnished or conventional cages up to the present stage of the study (42 w). In conventional cages birds reared on the floor showed significantly better plumage condition than birds reared in cages, whereas no such difference was found in the furnished cages (Table 1). In the furnished cages, a rearing×hybrid interaction ($P<0.05$) occurred because Hy-Line White hens had a higher plumage score when reared on the floor compared with those reared in cages, whereas the opposite condition was found in Hy-Line Brown hens.

Table 1. *Effect of hybrid and rearing on occupation of litter baths in furnished cages and plumage scores of birds in furnished and conventional cages, respectively. Because the size of the litter baths did not allow more than two birds to visit the bath at same time, the maximum possible use, 100%, was considered to be when the bath was visited by two birds simultaneously*

	Hybrids		Rearing		P-value	
	Hy-Line Brown	Hy-Line White	Floor	Cage	Hybrids	Rearing
Birds occupation of litter baths, % of max. possible	22	5.3	23	3.9	0.001	0.001
Plumage score furnished cage	20.0	20.9	20.6	20.4	0.06	0.69
Plumage score conventional cage	19.8	21.0	21.0	19.8	0.01	0.01

General discussion

Litter – use and effects on bird welfare

Of the facilities represented in furnished cages, the litter bath is probably the most disputed, partly due to the contradictory findings regarding birds' behavioural need for litter, but also likely due to the use being low in some concepts of furnished cages (*e.g.*, Tauson & Holm, 2002; Olsson & Keeling, 2002a). In the present work (Paper I), some individuals visited the litter bath practically every day whereas others never entered the bath. Whether the large variation was due to differences in the birds' motivation to use litter, or in their perception of the litter bath or the substrate, is not known. Although a flock (hatch) of birds have a very similar genetic origin the observations indicate that layers used in commercial egg production are individuals that may differ in their behaviours as well as their needs. In the concept of cage used, with the litter bath on top of the nest, a considerable proportion of baths may be empty when observed after being opened (Tauson & Holm, 2002; Paper I). In other concepts of furnished cages where the litter baths are less enclosed and situated more on a level with the cage floor, and hence are easier for birds to enter, a considerably higher use has been reported (van Niekerk & Reuvekamp, 2000; Tauson & Holm, 2003). Thus, when observing the litter baths of the Aviplus cage (Figure 2) half an hour after the opening, most baths were occupied by one or two hens (Tauson & Holm, 2003), whereas only 50-60% were occupied in the Victorsson cage (Tauson & Holm, 2002).

In Paper I, there were some indications of benefits with sand as compared with sawdust, as regards the Hy-Line White birds use of litter as well as the plumage condition of birds visiting the litter bath frequently. However, these differences are difficult to explain. A more detailed study of the behaviour of individual birds *e.g.*, as regards the performance of feather pecking, or what they actually were doing during their visits to the litter bath, could perhaps have been helpful in interpreting those differences. However, as sand is associated with practical disadvantages such as wearing of the equipment and difficulties to use in automatic distribution systems, utilizing sawdust is probably the best solution at the moment.

In commercial egg production in Sweden, most birds housed in furnished cages have been reared in cages (Tauson & Holm, 2002), as were all birds in the present work (Papers I-IV). Thus, they had no experience of litter during the rearing period. However, Wall *et al.* (2003) showed that use of litter was higher in birds reared on the floor than in birds reared in conventional rearing cages. The difference in use may have occurred due to the absence of litter in the early life of cage-reared birds. Johnsen *et al.* (1998) showed that chicks reared on a wire floor during the first 4 w of life, performed less dustbathing as adults than those given access from day-old and a rather high use of litter baths was reported in floor-reared hens housed in furnished cages (Appleby & Hughes, 1995). However, in Wall *et al.* (2003) it can not be excluded that the birds reared in a two-tier aviary system became more spatially skilled and, hence, better in using a three-dimensional space (see Gunnarsson *et al.*, 2000b). This may have been important in the EMC concept as the litter bath was positioned on top of the nest and not on a level with the cage floor.

The interaction between rearing and genotype on birds' occupation of litter baths and plumage condition, reported in the on-going study (Wall *et al.*, 2003), is interesting. It indicates the importance of including several genotypes in research and that rearing conditions may be of importance to a bird's expression of certain behaviours later in life.

Nest use

Although it has been shown that hens have a strong motivation to lay their eggs in a secluded environment, like a nest (*e.g.*, Cooper & Appleby, 1994), a certain proportion of the eggs in furnished cages are not laid inside the nest. These so-called misplaced eggs are not unique for furnished cages but occur to a varying degree also in floor housing systems (*e.g.*, Abrahamsson et.al., 1996b; Wahlström *et al.*, 1998). A large proportion of misplaced eggs in the latter system is a severe problem as they require manual collection and may be of inferior shell hygiene if laid in the litter area. An interesting question is whether the misplaced eggs are laid by some hens consistently laying outside the nest or if occasionally all hens lay eggs outside the nest. In a review, Appleby (1984) concluded that most hens are consistent in laying either in nests or on the floor. In experimental cages with nests, 67% of the hens laid all their eggs in the nests, whereas 4% consistently used the cage area when observed during 9 days (Sherwin & Nicol, 1993). The rest of the birds alternated between laying in nests and in the cage area. Since most eggs are laid within 8 hours after lights-on (Figure 5; Lillpers, 1991) in a group of birds, egg-laying will probably coincide for some birds. In the furnished cages used in the present work (Papers I-IV) there was one nest per 6, 7 or 8 hens. It could be argued that hens in furnished cages are forced to lay eggs outside the nests because the nest is occupied. However, when comparing furnished cages where 5, 6, 7 or 8 hens shared one nest there was no difference in the proportion of eggs laid in the nest (Abrahamsson & Tauson, 1997), and also in experimental cages supplying one nest per hen some eggs are laid in the cage area (Sherwin & Nicol, 1993). Furthermore, nests of the design used in the present studies, are often used by several hens simultaneously. When visits to nests were recorded in a group of 5 hens, using PIT tags, up to 4 hens were together inside the nest on one occasion during the 14-day long study (Figure 6; Wall, 1998). In some furnished cage designs, *e.g.*, the Hellmann cage or Aviplus cage, the nest is separated from the rest of the cage by plastic curtains, and not by a fixed wall. Thus, these nests can be entered anywhere along one side, which may be of benefit when several hens use the nest simultaneously.

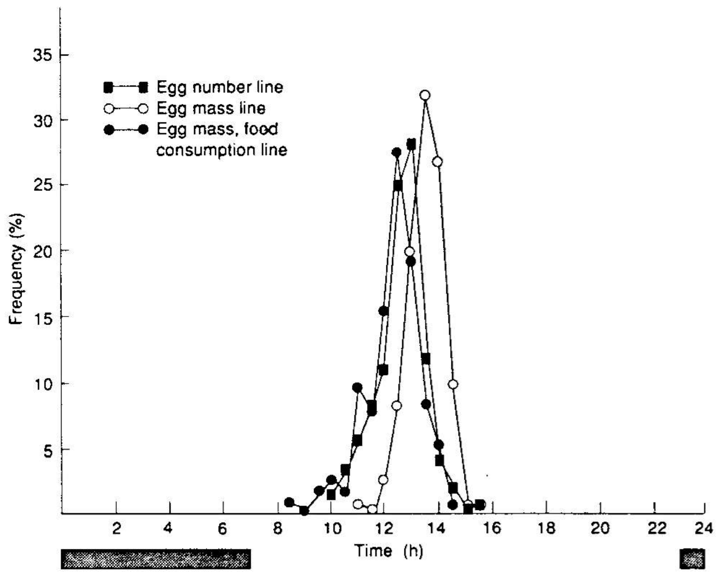

Figure 5. Frequency distribution of mean oviposition times of 486 laying hens of three genotypic lines (Lillpers, 1991). The shaded area represents the dark period.

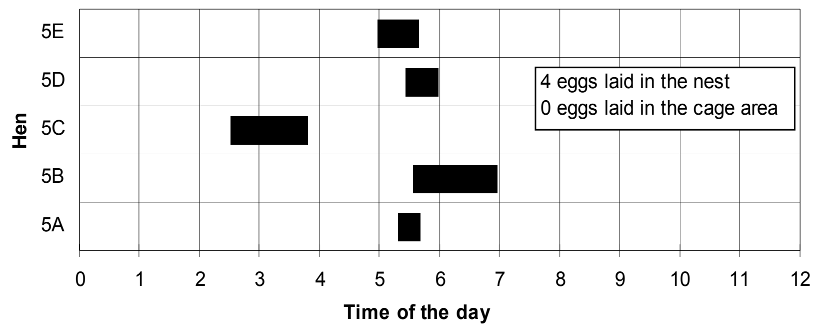

Figure 6. Illustration of nest visits of five birds housed together in a furnished cage with one nest (Wall, 1998). During a short period, 4 of the hens were inside the 50×25 cm large nest simultaneously.

With the specially designed nest openings used in Paper III (tube with one-way passage), LSL birds laid a considerably lower percentage of eggs in the nest when housed in cages without a rear partition (O-cage) than in fully open cages (H-cage). Hence, it appears that the genotypes differed in the ability to learn how to use the experimental doors in the nest openings, and that learning might have been facilitated by the use of the same experimental doors in the partition pop holes. Cooper & Appleby (1997) found that hens occasionally laying eggs outside the nest were as motivated to perform pre-laying behaviour as hens always using the nest. They concluded that the variation in incidence of misplaced eggs was associated with an individual variation in the hens' perception of the nest site. Hence, whereas most birds find enclosed nests lined with artificial turf as an acceptable nesting environment, some birds may not. The finding that nests only partly lined with artificial turf are perceived as less attractive than fully lined nests (Papers III & IV) has been confirmed by Janssen *et al.* (2003). It has been shown that hens, when given a choice, prefer nests with some kind of loose material (Huber *et al.*, 1985) that can be moulded (Duncan & Kite, 1989) but for practical reasons such nests are not used in commercial egg production. If individuals rejecting the artificial nests provided in furnished cages or in other housing systems are as motivated to perform nesting behaviour as the others, it is possible that the housing environment does not meet the behavioural needs of those individuals.

The PIT tag technique in Paper II enabled visits to nests to be followed in a sample of hens. However, egg positions of individual birds were not recorded and, hence, the study does not reveal whether individual birds laid their eggs in the nest that they visited most frequently or, in fact, whether they laid in nests at all. In two studies by Cooper & Appleby (1996; 1997) it was shown that hens laying a considerable proportion of their eggs (at least 15%) outside the nest actually made more visits to the nest than birds laying almost all their eggs in their nest. The fact that the hens that often lay their eggs outside nests may be the ones that pay most attention to them in terms of number of visits, illustrates that although a facility attracts a lot of attention it may not satisfy the behavioural needs of the hen. It has been suggested that a large number of nest visits of short duration in the pre-laying period may indicate that birds do not find nests entirely suitable (Appleby *et al.*, 2002), although they may finally lay their egg there. In Paper II, none of the hens individually followed made, on average, more than 2.4 visits to nests per day and, hence, there was no indication of frustrated pre-laying behaviour in that respect, at least not in this sample of hens.

Perch use

The proportion of birds using perches during the night in the present work (Papers III & IV) varied between 80 and 90 %, and hence, some birds used other locations within the cage. All furnished cages, except for the Hellmann cage (Paper IV), provided 12 cm perch per hen, which was in agreement with the present Swedish Animal Welfare Directives at that time. However, according to the Directive passed by the European Commission (European Commission, 1999), cages should provide a length of 15 cm per hen. Although perch length per hen in the Hellmann cage (Paper IV) was 17 cm, almost 20% of the birds did not use the perch during night. In a study using two different per lengths per hen, 12 vs. 15 cm, the former was provided by one perch placed along the cage width and the latter by placing two perches in the shape of a cross (Tauson, 2003). However, the additional 3 cm perch per hen did not result in a higher use of perches at night, either in brown or white birds. Hence, it can be questioned whether additional perch length provided by two perches placed in a cross, actually results in more usable space, because the point where the two perches meet can be used only by one bird. Such perch arrangements may also restrict birds movements, and hence, imply inferior cage floor hygiene.

Generally, most of the birds that did not use the perches at night, rested on the cage floor and not in the nest and, thus, did not defecate the nest linings. However, in surveys on furnished cages in practice, the proportion of birds inside the nest after dark was <1% on some farms and >10% on others (Tauson & Holm, 2002), which probably had an impact on the proportion of dirty eggs.

Pop holes – use and effects on bird welfare

In the present work, the partition with pop holes was an attempt to find a measure to improve a bird's possibility to avoid a certain hen when needed, *e.g.*, when being subjected to aggression, cannibalism or feather pecking. When comparing cages with a rear partition (H-cage) with those fully open (O-cage) in Paper II, no differences were found in any of the measured welfare traits. However, because of to the total absence of cannibalism and low levels of aggression, there was probably no urgent need for birds to escape. Generally, the problem with cannibalism is larger in brown hybrids than in white, especially when housed in large groups (*e.g.*, Abrahamsson & Tauson, 1995; Abrahamsson *et al.*, 1996b). Hence, using an even larger group size and/or a brown hybrid in the study might have been of benefit when comparing cage designs in this respect.

The hybrid differences in plumage condition, H/L ratios and duration of TI (Paper II) are difficult to explain, because the hybrid showing the best plumage cover appeared to be more stressed than the other one, according to the measurements of H/L and TI. This may indicate a difference in the genotypes' stress thresholds, as suggested by El-lethey *et al.* (2000), or in their so-called copying strategies (Korte *et al.*, 1997).

The PIT tag technique

A problem when PIT tags are used in order to identify individual animals is loss of tags. Most tags are probably lost by exiting through the insertion hole caused by the cannula during implant (Freeland & Fry, 1995; Jamison *et al.*, 2000), and hence, are lost shortly after implantation. Thus, by scanning for tags shortly after implantation, individuals without tags can be identified and implanted with a new transponder. However, in Papers I & II, such a procedure would have required that all birds must be taken out from their cages, and hence exposed to a stressful situation. In Paper II, the PIT tag technique allowed a relatively small sample of birds to be followed, as regards nest visits and passages through pop holes, whereas the technique worked considerably better in Paper I. Metallic surroundings are not optimal for PIT tag reading (Freeland & Fry, 1995) and there was a difference in the environments of nest and litter baths as regards the proximity of metal. Thus, in the nests (Paper II), the antennas were more closely surrounded by metal than in the litter baths, which most likely contributed to a lower proportion of birds being followed in Paper II than in Paper I. Despite the problem with lost tags, the technique is feasible to use, especially in studies conducted over a longer period. However, the technique needs to be further developed in order to avoid interference from metal when used in cage environments.

Production, egg quality and mortality

In the present work, egg production levels were not affected by cage designs, which might have been the case, *e.g.*, if egg eating had been a problem. If so, crack reduction measures such as long nest curtains and egg saver wires, proven to be almost necessary in some designs of furnished cages, may be a disadvantage because they retained eggs within reach of hens for a longer time. The hybrids differed in production capacity, which is a common finding (see *e.g.*, Abrahamsson *et al.*, 1995) and, hence, not surprising. Very similar production and mortality rates have recently been reported in surveys in commercial farms (Tauson & Holm, 2002; Tauson, 2003).

Although egg characteristics, such as shape index (Richards & Swanson, 1965) and shell thickness (Wahlström *et al.*, 1998) affect the risk of cracked eggs, the way the egg is treated after being laid is also very important. This is clearly illustrated in the comparison of LSL and Hy-Line White birds in Paper III. Both hybrids had moderate levels of cracked eggs in the conventional cages, but in the furnished experimental cage the proportion of cracked eggs was considerably higher in Hy-Line White. The thinner egg shell of the eggs laid by Hy-Line had a larger impact in the furnished cage, where eggs were accumulated in the cradle in front of the nest, than in the conventional cage where eggs were spread over the whole cage width. It is possible that the more globular shape of the eggs laid by Hy-Line, enhanced the speed of an egg rolling out of the nest and, thus, increased the risk of an egg getting cracked if colliding with eggs already in the cradle.

Although not statistically analysed, the proportion of cracked eggs was sometimes considerably lower in the conventional 4-hen cage. This is not surprising as the furnished cages used were either experimental cages or early designs of the furnished cages at present used in commercial farms in Sweden (Tauson & Holm, 2002). It is more interesting and important that the studies (Papers III & IV) showed that problems with cracked eggs in furnished cages can be reduced by using rather simple and inexpensive measures, *e.g.*, the prolonged nest curtain. With further developed furnished cages it has been shown that the proportion of cracked eggs is now close to the level of conventional cages. However, there is still a variation in egg quality between furnished cages from different manufacturers. This is probably on account of the cages being subjected to research and development to varying degrees (Tauson, 2003).

The proportion of dirty eggs was always lower in Hy-Line Brown (Paper IV), most likely due to dirt being more difficult to detect in brown-shelled eggs. In ocular inspection of eggs, what is perceived as a dirty egg may vary between different persons and packing stations and hence, comparisons between studies should be made with caution. In the present work (Paper III & IV), the proportions of dirty eggs in the furnished cages appeared to be at the same level or lower than in the conventional cages. This was most likely on account of the hygiene of the nest linings being good. However, another aspect of egg shell hygiene is the microbiological load. When analysing only eggs appearing clean at ocular inspection, Mallet *et al.* (2003) observed a higher bacterial count on eggs from furnished cages than from conventional cages. However, eggs laid outside the nests showed a higher bacterial load than eggs laid in the nest, and it was due to those eggs that the overall bacterial load was found to be higher on eggs from furnished cages. In a similar project, Tauson (2003) found that the bacterial load was higher on eggs from furnished cages than from conventional. However, the levels detected can generally be considered to be low in both categories.

Conclusions

In many respects nest design has a large impact on the extent to which nests are used by laying hens in small group furnished cages. There is also a large variation among individual hens in their pattern of visiting the nest, especially as regards time spent on each visit. With a good design of the nest, most hens prefer to lay their eggs there. After dark, most hens also seem to prefer to use perches.

Long-term use of litter baths in furnished cages varies considerably between individuals, at least when the litter is located on top of the nest. This finding suggests that there is either a difference in individual birds' motivation for litter or in how they perceive the litter bath and its content. The reason for this difference and the effects of early experiences during rearing on use of litter, need to be further investigated.

A question unanswered is whether dividing a furnished cage into "apartments" between which birds can pass through pop holes, would improve a bird's possibility to escape if subjected to aggressive or cannibalistic pecking. However, in these designs hens obviously use the possibility to move between apartments. If, in the future, larger groups of hens are to be housed in furnished cages, it may be worthwhile to look further into this kind of partition due to the risk of cannibalism probably being higher.

Egg production and mortality of hens in small group furnished cages are similar to those in conventional cages. The extensive use of nests results in a considerable accumulation of eggs in a limited area of the egg cradle, which may cause high proportions of cracked eggs. However, the problem can be efficiently reduced by well-designed nests and non-expensive mechanical crack reduction measures. Higher proportions of dirty eggs may occur if it is found that some birds commonly spend the night in the nest. Thus, it is important to have a nest bottom design that remains acceptably hygienic through out the production period, as well as being perceived attractive by the hens. It is also important to optimise perch arrangements and perch lengths per bird in order to minimise interference with bird movements in the furnished cage, retaining good use of the perch and acceptable hygiene of the cage floor area.

The Passive Integrated Transponder tag technique may be feasible to use in long-term studies of individual birds' visits to facilities in their environment. Hence, in combination with, *e.g.*, video recording, it would be possible to observe not only the location of an individual hen but also her behaviour. However, certain identification problems on account of tag loss or tag migration under the skin, as well as possible interference from metallic surroundings, have to be addressed.

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