Health and Production in Improved Cage Designs

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ABSTRACT This paper describes the effects of various cage designs on health characteristics such as skeleton strength, plumage and foot condition, mortality, and some production traits such as egg quality and feed consumption. Three major steps in improving cage design and in developing new cage designs are described. Firstly, cage design in general has been improved by comparing different conventional commercial cage designs under the same experimental conditions. Secondly, unconventional design features, such as an abrasive strip to reduce excessive growth of claws or a perch to improve the behavioral repertoire for the hens as well as to strengthen skeletal structure, are described. Thirdly, the effects of fully furnished cages that also include a nest and dustbath for smaller or larger groups of birds are discussed. These designs create an environment in which the problems of conventional cages, such as behavioral restriction, are reduced and the shortcomings of large litter avaries, such as cannibalism, parasites, and a poor working environment, are improved. Cages with one perch level containing groups of 4 to 10 hens seem more likely alternatives to conventional cages on larger scale farms than litter systems or colony cages for more than 10 birds. This is due mainly to the higher predictability of production, the decreased risk of cannibalism, and improved hygienic conditions.

(Key words: health, housing system, layer, modified cages, welfare)

INTRODUCTION

The keeping of laying hens developed rapidly around the world during the 1960s and 1970s. In most developed countries today, about 90% of hens are kept in cages. Worldwide, it is estimated that 70 to 80% of flocks are caged. Although more floor housing systems are now being built in some European countries, the use of cages is increasing in developing countries (Bell, 1995). There are several reasons for changing to cages instead of keeping birds in flocks on the floor, which include economic reasons as well as considerations of animal health and working environment. Cages allowed large units to be built, and mechanization of production permitted considerably higher stocking densities and less investment and labor costs per bird and per weight of egg produced. When average flock size became considerably larger, outbreaks of cannibalism also turned out to be a problem that was reduced in cages (Hilbrich, 1985; Hansen, 1993; Abrahamsson and Tauson, 1995). However, outbreaks of cannibalism also appeared in cages as groups became too large. Hence, group sizes were successively reduced to three to six birds. One very important reason for changing to cages was the severe and unpredictable problem of coccidiosis in flocks on litter (Engström and Schaller, 1993; Morgenstern and Lobsiger, 1993). Dust and ammonia levels were also reduced, providing a better working environment (Hauser, 1988; Kangro, 1993).

Although both economics and animal health have been improved by the introduction of cages, the caging of laying hens resulted in a drastic change for the bird, with very restrictive behavioral consequences. This fact has also made the caging of hens more and more controversial, and bans on certain cages, or possibly on cages altogether, have been discussed in several countries (Appleby, 1993; Craig and Swanson, 1994).

The very limited area that a hen has in a cage suggests that the quality of the design of the cage may have a great effect on both health and production (Tauson, 1986a). However, the stocking densities used for layers in cages vary considerably, from on average about 350 cm² cage floor area per bird in the U.S. to 700 and 800 cm² in Norway and Switzerland, respectively.
The present paper describes studies of a wide range of cage designs, and also discusses some trends shown by the egg industry and by the manufacturers that design equipment. The objectives of these studies can be classified according to three main approaches or steps of development: 1) Comparison and development of conventional cage designs; 2) Unconventional design features in conventional cages; 3) Major modifications to cages to improve the birds' behavioral repertoire (so-called "fully furnished" cages).

In this paper, I will illustrate and discuss the health and production effects of such design developments, and comment on the behavioral effects for the hen. These latter effects, which are considerable and the main purpose of the third approach, are discussed in detail elsewhere in these proceedings. The first step above and parts of the second originate largely from studies of commercial and improved cage equipment (Tauson, 1986a), whereas the third deals with some of the recent research carried out on fully furnished cages (Sherwin, 1994; Kronägg, 1995).

**COMPARISON AND DEVELOPMENT OF CONVENTIONAL CAGE DESIGNS**

Many of the findings from the study of commercial national and international cage equipment for layers carried out within the same building at Funbo-Lövsta Research Centre (Tauson, 1986a), came as a surprise to the manufacturers. However, through active contacts and regular presentation of results, these studies increased awareness, involvement, and responsibility of the industry. Cage manufacturers discovered facts about their own equipment in relation to that of others and also obtained completely new ideas for design from results of the scientific studies. Some of these findings also eventually influenced animal welfare directives, e.g., in Sweden.

**Foot Condition and Floor Design**

Severe damage to the exterior part of the foot digits (hyperkeratosis and inflammations) was found in more than 60% of birds that were housed in cages having floors with an unnecessarily steep slope (>20%) and poor galvanizing quality, compared with only 1 to 3% damage on floors with gentler slopes (<14%) or with plastic-coated wire. Today, clear differences in foot condition between hens kept on a well-galvanized floor or a plastic floor in cages are usually not seen. Hence, plastic floors are not very common. One could argue, however, that plastic floors made of more solid material might be perceived as more comfortable by the birds because there is better insulation for the feet and breast than there is on a colder metal wire floor.

Great variation among birds within the same cage suggested that there were individual differences in sensitivity or behavior in terms of standing posture on the cage floor (Hughes and Black, 1974). The floor slope used today in Sweden may not exceed 12% by law, and in the EU it must not exceed 14%. In a special study it was found that, at a stocking density of 480 cm² per hen, the optimal cage floor slope was about 10% both for egg quality traits (cracks and dirties) and for foot condition. A significant further improvement in foot condition could not be detected until the slope was further decreased to 3%. However, as expected, at that slope, eggs did not roll out efficiently and egg quality could not be maintained. It should be emphasized that the cage floor slope alone cannot be considered—neither for foot condition trait nor for egg quality—without taking into account other variables such as the number and density of birds, wire floor mesh size, thickness of floor wire, and cage depth.

**Feed Troughs, Feed Wastage, and Neck Skin Condition**

Due to deep (14 cm) feed troughs with sharp lips that were installed too high, a majority of birds in a very well-known cage design developed severe neck skin atheroma. The manufacturer justified this trough design as a way of keeping feed wastage low when using a travelling feed hopper system. However, by using a flat chain feeder and a shallower and more convenient trough only 10 cm deep, a lower level of feed was obtained. These changes prevented flicking, and feed wastage was reduced by 50% while neck skin atheroma disappeared (Tauson, 1978). Hence, this defect was easily corrected and should no longer be a problem in modern cages.

Using a special technique to measure and calculate feed wastage, it was also shown that, depending on feed trough design, the ratio between feed flicked outwards and inwards from the feed trough ranged from about 0.1 to 0.5. Feed wastage varied between 0.6 to 2.7 g per hen per d among six different systems (e.g., flat chains, augers, belts, and hoppers). Because feed wastage is often estimated by looking at the feed found in the aisles between the blocks of battery cages, this finding also led to more awareness of the importance of the feed wastage generally, feed trough design, and especially the proper operation of devices for setting the level of the feed. A difference in feed wastage of 2 g per bird per d in a 10,000 layer unit corresponds to a loss of about 8 metric tons of feed per batch.

**Complexity in Cage Design and Mortality**

Due to complex and faulty cage design, especially involving the cage fronts, the frequency of accidentally trapped hens (often killed) in some cage designs reached more than 3.5% of hens housed (Tauson, 1985). Apart from being an obvious welfare problem, such figures imply considerable loss in production capacity of the flock, especially as most cases of trapping occur at a young age. Today, trapping accidents normally do not exceed 0.5% in
the systems studied, primarily due to simplification of the cage design. This simplification of design also results in a saving of material and facilitates removal of hens from the cages. The latter consideration is important because it reduces the risk of broken bones in spent laying hens when they are removed from the cages (Elson, 1992).

Plumage Condition, Cage Design, and Stocking Density

The use of solid side partitions (sheet metal or plastic) instead of wire partitions reduced feather damage due to wear and pecking between cages by 15 to 20%. This damage involved mostly wing, tail, and back feathers (Tauson, 1984a). The effect of solid side partitions was similar to that of reducing stocking density by 25%. A further reduction in deterioration of plumage was found in cages with an almost solid rear partition in which air ventilation was provided through slats. Cages with wire side partitions were banned in Sweden in 1994, but in fact no such cages have been sold in Sweden since 1979.

In large-scale comparisons, reduced stocking density has been shown to decrease mortality and to increase production and feed consumption, implying an overall economic improvement (Bell, 1995). Reduction of stocking density has also been shown to reduce toe hyperkeratosis in caged hens (Tauson and Abrahamsson, 1994a). Because reduced stocking density improves locomotor activity it may also contribute to a stronger skeleton.

Cage Shape

The introduction of shallow cages that provide a wider feeder space than deep cages was shown to improve production (Bell, 1972). Hughes and Black (1976) suggested that some of the advantages shown—higher production, less feather pecking, and a lower proportion of cracked eggs—were related to the better feeding pattern and greater accessibility to the wider feed trough space in the shallow cages. Hence, effects seen in shallow cages vs deeper cages are also likely to depend on a comparison of feed trough space.

UNCONVENTIONAL DESIGN FEATURES IN CONVENTIONAL CAGES

Claw Abrasives

It was found that up to 30% of caged Single Comb White Leghorn (SCWL) layers had broken claws after one production cycle. The excessive growth of claws due to lack of natural wear can cause trapping, bleeding from the broken stump, and scratches on cage mates. By introducing a claw abrasive strip on the egg guard deflector on the inside of the feed trough, the scores for claw condition improved dramatically and claws became short and blunt (Tauson, 1986b). Under Swedish animal welfare legislation, claw abrasives were made compulsory as of 1994. The abrasive strip is easy to install and is one of the few examples of a method for improving the health status of layers in existing cages. The material used by Tauson (1986b), 3M Safety Walk General Purpose®, still showed abrasive effects after three batches of hens. Recently, other materials and methods have been developed by the industry in order to provide a similar effect while eliminating the problem of wear of the tape. These materials include the use of a mixture of paint or glue and sand or indentations pressed into the sheet metal of the egg guard.

Perches

The introduction of a perch into conventional cages provides hens with an opportunity for an enriched behavioral repertoire (Luescher et al., 1982; Tauson 1984b; Hughes and Appleby 1989; Braastad 1990; Duncan et al., 1992; Abrahamsson and Tauson, 1993). These studies show that the perch is used very intensively, particularly at night. Feed consumption is reduced in cages with a perch (Tauson and Jansson, 1988; Braastad, 1990), probably due to better insulation of the hens’ bodies at night when roosting (Lill, 1968) on the perch, as well as by increasing the amount of resting behavior occurring in the cage. Also, the breaking strength of parts of the skeleton was found to increase by about 15% in cages with perches (Duncan et al., 1992; Tauson and Abrahamsson, 1994a), which reduces the risk of bone breakage during handling and processing of the birds (Gregory and Wilkins, 1989). Depending on cage floor designs, a slight increase in the proportion of cracked eggs is sometimes seen. Hygiene may be somewhat impaired in parts of the cage because manure is less effectively trampled through the cage floor at the rear and under the perch. Because of this manure accumulation, there may be more dirty eggs and a perch cannot yet be recommended generally for all cage floor designs. However, in Sweden a perch has been compulsory for new cages since 1993.

Depending on the shape and hygiene of the cage, a perch may negatively affect the condition of the feet and keel bone. However, in some studies, the perch is reported to improve foot condition (Appleby et al., 1992). The differences in findings from various studies of perches (e.g., Appleby et al., 1992; Tauson and Abrahamsson, 1994a) may be because the perches have differed in design and configuration and the recording of foot and keel bone defects have also differed.

Production and Health

In the comparison of cage equipment at Funbo-Lövsta, it was found that it was easier to persuade manufacturers to change cage design when both bird welfare and the economics of egg production were improved than when the latter of these effects was not so obvious. This point raises the well-known question as to whether egg production is a relevant index of the total welfare of the
hen. Egg production may well indicate very important aspects of welfare status, i.e., when it reflects the provision of high quality food and water to all birds in a flock, which is a primary component of welfare. Furthermore, birds suffering from serious disease are unable to produce at their normal capacity. On the other hand, to some extent, feather condition and renewal of plumage are inversely related to production due to hormonal (estrogen) blocking effects. Generally speaking, an almost featherless hen consumes in the range of 30% more feed due to heat losses than a well-feathered bird at similar production levels, and hence, in this sense, welfare and economy are positively correlated (Tauson and Svensson, 1980). Birds with claw fold lesions and excessively long claws have been shown to be able to produce well (Tauson, 1986b). Whereas these examples show that production is not always a relevant index of welfare, most egg producers still believe that production is the best indicator of welfare.

As the Swedish Animal Welfare Ordinance (1989) was formulated, cages would be prohibited as of 1999. However, strict requirements are set for any alternative system. The new systems must not impair bird health, increase medication, require the introduction of beak trimming (prohibited in Finland, Norway, and Sweden), or impair the working environment. These limitations mean that alternatives need to be compared with current cage designs under identical conditions. Recent experiments of this type include work by Tauson et al. (1992), Tanaka and Hurnik (1992), Hansen (1993), and Abrahamsson and Tauson (1995). According to the Swedish Animal Welfare Act, the systems also have to be approved in experimental and field tests. Since 1993, yearly reports on the stage of development of alternatives have been required by the Swedish Parliament. Until now, no aviary system has been approved by the authorities, and there is only 1 yr for the last flocks of hens to go through a full production cycle. Hence, about 85% of birds are still kept in cages in Sweden. Changing from cages to floor systems is occurring slowly, and most floor systems used are traditional systems with low stocking densities, although some multi-tiered aviaries with higher stocking densities are undergoing practical tests for possible approval.

**MAJOR MODIFICATIONS TO CAGES TO IMPROVE THE BIRDS’ BEHAVIORAL REPETOIRE**

**The Large Get-Away Cage**

Mainly because of unpredictable problems of cannibalism and hygiene in larger flocks of litter-kept birds, attention has been drawn to fully furnished cages that include features intended to increase behavior expected to be of major importance to the birds’ welfare. These include a nest, a perch, and litter material for scratching and dustbathing. One of the first cage designs of this type was the so-called Get-Away cage (GA). This model was first described and studied by Bareham (1976) and Elson (1976), and these cages have been studied further and the results reviewed (Wegner, 1990). A great variety of models of this design, including models with different stocking densities, have been presented through the years (Brantas et al., 1978; von Kleist, 1985; Rauch, 1994). Today, such cages are approximately 1 m³ in size and house 15 to 40 hens (Wegner, 1989; Abrahamsson et al., 1995). Time monitored opening and closing of the nest and dustbath is used to avoid defecation and eggs laid in the dustbath (Figure 1). Unlike a conventional cage fitted with one perch, this design has perches on two levels, which increases bird movement and wing flapping. These movements have been shown to increase skeletal strength more than in a conventional cage with a perch (Tauson and Abrahamsson, 1994a). Also, tibia strength increases by about 15% compared to conventional cages. The use of perches during the daytime in the GA cage has also been shown to be considerably greater than daytime perch use in a conventional cage with a perch. The drawbacks of the GA cage include the possibility that the birds will defecate on one another (because of perches at two levels), inferior

**FIGURE 1.** Modern Get-away cage with perches, nests and a dustbath for 15 hens at 600 cm² cage floor space per hen. Funbo-Lovsta Research Centre.
Small, Fully Furnished Cages

Small group cages (5 to 10 birds) that include nests, perches, and a dustbath (Figure 2) have been studied with increased attention during recent years, originally in smaller scale studies in the U.K. (Sherwin and Nicol, 1992, 1993; Appleby et al., 1993; Appleby and Hughes, 1995) and later in more applied studies in Sweden (Tauson and Abrahamsson, 1994b; Abrahamsson et al., 1995, 1996) and the Netherlands (van Niekerk and Reuvekamp, 1995). At the moment, studies are also being carried out in Germany and Australia, and further larger-scale studies are presently being carried out in the U.K. Recent comprehensive reports from seminars about these systems were edited by Sherwin (1994) and Kronägg (1995). In a preliminary study of some prototypes, Sherwin and Nicol (1992) reported that these radical modifications to cages might provide a suitable alternative housing system that satisfies both welfare and production considerations.

Appleby and Hughes (1995) reported that production from 20 to 44 wk of age in one specified model of a small furnished cage, The Edinburgh Modified Cage, was similar to conventional cages. Almost all eggs (95 to 100%) were laid in the nestboxes. Prelaying behavior is much more settled in these cages than in conventional cages (Appleby et al., 1993).

The intention of a small group modified and enriched cage like this is to overcome the problems of cannibalism, working conditions, and labor requirements that are found in aviary systems for large groups of birds on litter. Studies of models of more or less commercial design with several tiers have been evaluated over several production cycles (Abrahamsson et al., 1995, 1996). Hence, in order to get an indication of how far one such model (Figure 2) fares in relation to other systems such as GA cages, conventional cages and, to a certain extent, aviary systems, let us look at some results of recent studies in which these models were compared using both SCWL and a medium-heavy brown hybrid (Abrahamsson et al., 1995, 1996; Tauson and Abrahamsson, 1995).

Two kinds of furnished cages including nests, perches and dustbaths were used: 1) Modified and enriched small cages (MEC) with 5 light-white hybrids (LSL) or 4 medium-heavy hybrids (ISA-Brown); or 2) GA with 15 birds of the same hybrids. The controls were two commercial cage models: 3) Conventional cages with 4 birds (C); and 4) Conventional plastic cages with solid side- and slatted rear partitions with 3 birds (PLC). A total of 1,455, cage-reared birds without beak trimming were housed in these cages at 16 wk of age. Records were kept from 20 to 80 wk of age. There was also a parallel study of aviaries at Funbo-Lövsta using the same hybrids with floor-reared hens from the same farm. Cage floor space per bird (nests and dustbaths excluded) was 600 cm² in MEC and GA for LSL birds (850 cm² with nests included). The latter figure was about 40% larger than C. Stocking density in PLC was 720 cm² due to the Swedish Directive effective in 1989 requiring that one hen be removed from existing cages at 480 cm² to achieve the stipulated 600 cm² per bird.

Production was higher and mortality lower in LSL hens (22.3 kg egg mass per hen and 3.2%) than in ISA birds (20.8 kg and 7.7%). The average for the two hybrids in MEC (22.3 kg and 2.6%) was similar to the conventional cages (21.8 to 21.9 kg and 4.9 to 5.8%), and better than the GA (20.2 kg and 8.6%). In the aviaries, production varied between 20.8 kg and 22.5 kg (LSL) and 14.8 kg and 17.0 kg (ISA) and mortality between 3.1% and 4.9% (LSL) and 30.0% and 45.3% (ISA). The proportions of cracked (after candling) and dirty eggs were higher and lower, respectively, in MEC (9.2% and 2.0%) than in C (5.0% and 6.0%) and PLC (8.6% and 6.3%), both traits being lower in MEC than in the GA (18.6% and 4.9%). The increased proportion of cracked eggs in fully furnished cages agrees with early results by van Niekerk and Reuvekamp (1995) and may be due to accumulation of eggs outside the nest in the cradle of the cage floor.

Plumage condition was similar in all models except PLC, where it was better, probably due to the rear
partition with slats and the lower stocking density. Hygiene of the plumage was worse in GA than in all other models and in the aviaries. Birds in GA and in the aviaries had inferior foot condition due to bumble foot, which is believed to be a defect related to perch design or hygiene. In an introductory trial of the MEC (Tauson and Abrahamsson, 1994b), breaking strength of the humerus was clearly affected by the furnished cage designs, and was found to be considerably higher in the modified cages than in the conventional cages. Due to the use of perches, hens in GA and MEC developed keel bone lesions, but of a less severe nature than in the aviaries. The incidence of wounds due to pecking on the comb and the rear part of the body were more common in the aviaries than in the cages. Use of the Astro-turf (artificial grass) lined nests in MEC was 92 and 65%, and in GA 95 and 75%, in LSL and ISA, respectively. Astro-turf nest linings were thus used more than welded wire linings, indicating a preference for the former material. This agrees with Hughes (1993) and Sherwin and Nicol (1993). The latter authors also reported that cage-reared hens housed at an early age (16 wk) lay fewer floor eggs than litter-reared birds that are housed later. In aviaries, eggs laid outside of the nestboxes cause problems with inferior egg quality, extra work, and inferior working conditions. However, this does not represent a problem in modified cages, at least in a system like the MEC, in which cage floor hygiene is similar to that of a conventional cage.

Even in a cage, however, eggs laid in the dustbath can cause problems. The average proportion of eggs laid in the dustbath in the present study was lower in MEC (0.1%) than in GA (1.7%). Age at first opening of the dustbath in MEC (16 or 26 wk) did not affect egg location. Opening at 16 wk compared with 26 wk increased the frequency of birds visiting the bath from 5 to 11% of observations per day between 30 and 70 wk. The use of perches in MEC averaged 96% during the night.

A study of three different SCWL hybrids (Tauson and Abrahamsson, 1994b) revealed that the genetic by environment interaction is considerable even for such birds. This is true for traits like production as well as health parameters like foot and plumage condition.

Fully furnished cages for small groups of birds (<10 per cage) may compete well with conventional cages as far as production and mortality are concerned. The smaller group size and, hence, probably, more stable rank order, the improved hygiene due to the presence of perches on only one level, and the greater ease of inspection, are benefits of MEC compared with GA cages. Results from MEC models so far have also shown a higher predictability and achievement of normal production and mortality rates than are normally found in aviaries when using brown medium hybrids not subjected to beak trimming. The MEC system needs some further development regarding the design of the perch and possibly the egg cradle, the egg collection procedure, and the management of the dustbath. Also, a slightly larger group size would reduce the investment cost per hen regarding nest and dustbath as well as increasing the total available area per bird, although it is already 40% greater per hen in the present model than in a conventional cage with 600 cm². Group size is a very important issue because the restricted area in a cage will remain a critical point. Such studies are under way.

**FUTURE OF ALTERNATIVES TO CONVENTIONAL CAGE KEEPING**

Apart from the degree of success in development, the possible use and acceptance of alternative housing systems for layers similar to those described above will probably be highly influenced by several factors. These include size and structure of farms, policy and veterinary legislation with regard to egg trade between countries, interpretation of scientific results by politicians, legislation, and acceptance of higher food costs in various countries. The experience so far in a country like Sweden, where the great majority of egg production is carried out in larger units, as in most other countries, is that it is difficult to tell if and when modern litter floor alternatives will be similar to conventional cages, with regard to bird health, working environment, and general predictability. Certainly, the cost of eggs from such systems will be considerably higher, especially when the factors of labor costs and general unpredictability of these systems are included. The fact that production in aviaries, even when the problems mentioned above do not appear, may be 3 to 5% lower than in cages (Tanaka and Hurnik, 1992; Hansen, 1993; Abrahamsson and Tauson, 1995) must also be taken into consideration.

In countries in which conventional cages may have to be altered or alternatively be prohibited, a future possibility might be a system similar to the MEC, in which the obvious advantages of hygiene and small group sizes in cages can be combined with an increased behavioral repertoire, as well as the increased skeletal strength characteristic of hens kept in loose housing systems. Such improvements will also have associated costs, but may be less expensive than more radical alternatives, while having more predictable benefits for welfare (Duncan et al., 1992). Consequently, the Swedish Animal Welfare Ordinance from 1989 was modified in 1997. Thus, instead of banning cages generally, requirements were set implying that cages should be equipped with a nest, a perch, and a dustbath.

**CONCLUSIONS**

Introductory studies in which cage equipment for laying hens was evaluated demonstrated considerable and sometimes unexpected differences between commercial cage equipment. This led to greater awareness of bird welfare in the industry and to general improvements in cage design. Hence, considering details of design may give considerable benefits mainly on health characteristics like foot, plumage, and skin condition,
and mortality, but also on production traits like feed wastage and egg quality traits. Keeping the plumage of hens as intact as possible decreases the feed requirement due to reduced heat losses. Unconventional features of design led to proposals for cage modifications and to the introduction of extra features in cages, such as claw abrasive tapes that eliminate excessive growth of claws, and perches that considerably increase bone strength. For countries in which conventional cages are very much discussed and especially where beak trimming is not allowed, it is difficult to predict if and when an accepted aviary-type alternative will be ready for practical use on a scale comparable to conventional cages. Currently, furnished and modified cages for small groups of hens seem more realistic as alternative systems in large-scale production than litter systems in which birds are kept in larger groups.

REFERENCES


