Acta Agric. Scand. Sect. A, Animal Sci. 1995: 45, 191–203

ACTA AGRICULTURÆ
SCANDINAVICA
ISSN 0906–4702

Aviary Systems and Conventional Cages for Laying Hens

Effects on Production, Egg Quality, Health and Bird Location in Three Hybrids

Abrahamsson, P. & Tauson, R. (Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences, Funbo-Lövsta Research Centre, S-755 97 Uppsala, Sweden). Aviary systems and conventional cages for laying hens. Effects on production, egg quality, health and bird location in three hybrids. Accepted October 10, 1994. Acta Agric. Scand., Sect. A, Animal Sci. 45: 191–203, 1995. © 1995 Scandinavian University Press.

In two experiments, a total of 4346 laying hens housed in battery cages, with three hens per cage (C), and in two aviary systems, both with tiered wire floors and litter (Lövsta with two tiers (L) and Marielund with three tiers (M)), were used for studies on production, egg quality, health, plumage and foot condition, bone strength and bird location. Three hybrids were used: Lohmann Selected Leghorn (LSL) were kept in all three systems, Dekalb XL (DK) were kept in both aviaries and Lohmann Brown (LB) in M only. Production and feed conversion in M were inferior but not significantly different from C but significantly better than in L. Proportions of dirty eggs were significantly higher in the avaries. No significant differences were found in interior egg quality traits between keeping systems. LSL showed higher production and better feed conversion than the other hybrids and a tendency for a lower proportion of mislaid eggs. Mortality varied considerably between the aviary pens, reaching 35% in LB mainly owing to cannibalism and salpingitis. Keel bone lesions and bumble foot appeared in the aviaries, while toe pad hyperkeratosis was observed in C. Hens in aviaries had significantly stronger bones (tibia and humerus) and showed more wounds from pecks, inferior plumage condition and dirtier feet than in C. LSL had more bumble foot injuries than LB but better plumage condition than DK. The birds used the different parts in the aviaries well, especially the perches on the resting top tier during the night.

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Key words: behaviour, foot condition, housing systems, plumage.

Introduction

Conventional battery cages for laying hens restrict the movements and behavioural repertoire of the birds. Hence, changes to other systems are being discussed in several European countries. Mainly because of risks of parasitic disease in the old traditional deep litter systems, in combination with the often poor working environment due to high ammonia levels and economic pressure on egg production today, there is a need for more efficient and competitive alternatives. In order to minimize the risk of disease and to improve the working environment, the

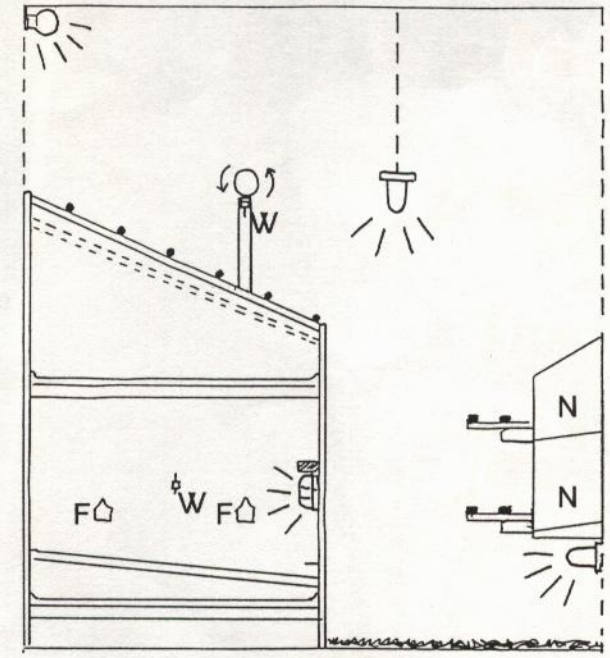

Fig. 1. The Lövsta aviary system in Expt. 1. In Expt. 2 there were only five perches and the feed trough on the left was moved to the wall. Broken lines represent welded wire partitions. F = feed troughs, N = nests, W = water nipples.

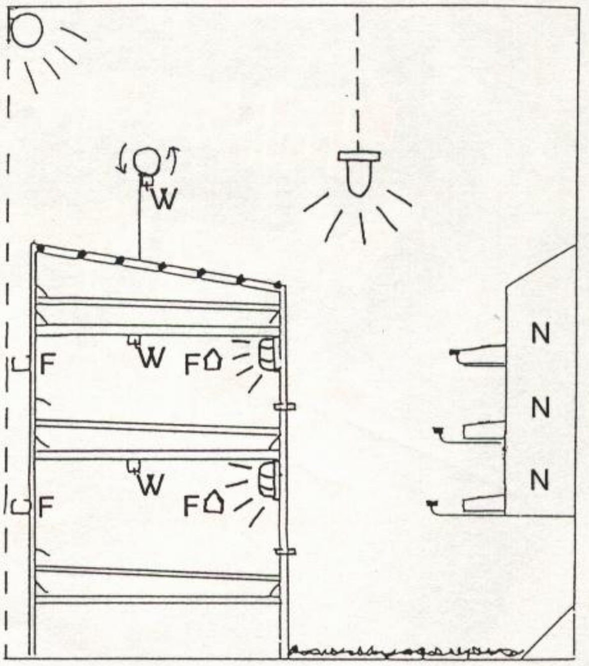

Fig. 2. The Marielund aviary system. Broken lines represent welded wire partitions. F = feed troughs, N = nests, W = water nipples.

manure needs to be removed regularly. By increasing the stocking density the buildings will be more effectively used, which also reduces the need for extra heating in colder climates during the winter. In order to try to overcome these problems, different types of wire floor or tiered wire floor aviary systems are being developed, as reported by Nørgaard-Nielsen (1986), Wegner (1989), Amgarten & Meierhans (1991), Tanaka & Hurnik (1992), Reuvekamp (1992), Hansen (1993) and Nørgaard-Nielsen et al. (1993a). However, several studies have involved results collected from farms or, if aviaries have been compared with cages, most often replicates of the aviaries have not been used, which has made statistical analyses difficult. The aim of the present experiments was to study low-density and high-density aviaries, still under development at the Funbo-Lövsta Research Centre, and conventional battery cages using replicates in the same building. The study focused on health and production in different commercial laying hybrids.

Materials and methods

Two experiments were carried out between April 1990 and December 1992, with a total of 4346 hens. In both experiments, three different housing systems, all in the same building, were used: battery cages (C) and two aviary systems with tiered wire floors and litter (wood shavings) – Lövsta (L) and Marielund (M). All systems had belts for manure removal under each wire tier floor, and automatic flat-chain feeders. Egg collection belts were used in L and M, while eggs were collected by hand in C. All egg collection was carried out daily. Manure removal from belts was carried out twice a week. The litter was kept in acceptable condition by adding some fresh wood shavings every second month. Regular removal of litter was not necessary and, hence, scarcely carried out.

Systems, stocking densities and birds

The L system (Fig. 1) had two tiers, the lower tier with feed troughs and the upper resting tier with perches (Tauson & Jansson, 1990). Each pen measured 6.0 × 2.7 m. Water nipples were present on both tiers. The litter area comprised 33% of the total available area. The single nests were made of metal with nest linings of brown artificial grass (Astro-turf) with small holes in Expt. 1 (4.8 hens/nest) and of white plastic with green "rubber finger" mat linings in Expt. 2 (3.6 hens/nest).

The M system (Fig. 2), a modified Swiss system, consisted of three tiers. Each pen measured 5.8 × 2.8 m. The two lower tiers had feed troughs and the top resting tier had perches. All three tiers were equipped with water nipples. The litter area comprised 20% of the total available area. Single nests were used of plastic bowl design (4.2 hens/nest) with perforated bottom (Facco). In order to reduce soiling of the nests these were equipped with a time-monitored one-way closing/folding and sloping metal

Table 1. Description of the experimental layout of keeping systems, hybrids and groups used in Expts. 1 and 2

System	Hybrid[1]	No. of groups	Hens per group	Hens per m^2 floor area	Hens per m^2 available area	Perch length per hen (cm)
Expt. 1						
Lövsta(L)	LSL	2	231	14.1	9.5	15.6
Marielund (M)	LSL	2	290	17.7	9.2	14
Marielund (M)	LB	2	290	17.7	9.2	14
Cage C (C)	LSL	2	216	–	15.6	–
Expt. 2						
Lövsta (L)	LSL	2	175	10.7	7.2	17.1
Lövsta (L)	DK	2	175	10.7	7.2	17.1
Marielund (M)	LSL	2	290	17.7	9.2	14
Marielund (M)	DK	2	290	17.7	9.2	14
Cage (C)	LSL	2	216	–	15.6	–

[1] LSL = Lohmann Selected Leghorn; LB = Lohmann Brown; DK = Dekalb XL.

plate, which prevented birds from entering the nests 30 minutes before dark until 30 minutes before light. When folded forwards, this plate also had old litter, accumulated during the day under the perforated nest bottom, sliding and falling out into the litter bed.

Perches on the highest tier (the resting area) in both L and M were made of European beech hardwood with a circular profile (diameter 3.6 cm) with a flattened upper and lower surfaces according to Tauson & Abrahamsson (1994).

The C system had solid side partitions and a claw abrasive tape on the manure deflector behind the feed trough, as described by Tauson (1986). There were three hens per cage, implying 640 cm^2 cage floor area per hen, corresponding to commercial egg production in Sweden.

The distribution of birds and groups (replicates) in the different keeping systems in the two experiments are discribed in Table 1. Some minor changes in design of L were made after Expt. 1; the rear feed trough was moved right up to the wall in order to provide more space between the troughs; instead of six perches in the top tier there were only five in Expt. 2 because of the lower number of birds; the nest linings were altered as previously mentioned.

Rearing, lighting and feeding

From day old to 16 weeks of age (w) the chickens in Expt. 1 were reared on litter in a building with perches, water and feed on raised one-tier wire floor platforms covering pits of manure. The pullets in Expt. 2 were reared on a different farm in a two-tier aviary system with litter, and with water and feed on the lower tier and perches on the upper. In both rearings the birds had access to the litter floor from 5 w onwards. No birds were beak trimmed. At 16 w pullets were transferred into the laying house and given $8\frac{1}{2}$ h of light per day. Light was successively increased to 15 h per day at 30 w. In order to prepare birds for certain activities in periods of light and dark (Tanaka & Hurnik, 1991), e.g. to facilitate the finding of food and water and calmly finding their way up to the perches of the resting top tier, the light was turned on/off according to a special procedure. In the morning, the light in the aviaries was first turned on instantly in the feeding tiers and over the litter area and then, 15 minutes later, the light over the top resting tier was successively increased over 15 minutes. In the evening, the procedure was reversed, i.e. the light was turned off first in the feeding tiers and over the litter and then the light over the top tier was dimmed. In the cages, a dawn and dusk period of 7 minutes each was used. Incandescent lamps were used in all systems.

Until 17 weeks of age the pullets were fed a grower's mash containing 15.0% crude protein (CP), 10.9 MJ metabolizable energy (ME) per kg, 1% Ca and 0.7% P. During the following production period until slaughter at 80 w the hens were fed a commercial type of layer's mash meal containing 15.0% CP, 11.5 MJ ME per kg, 3.5% Ca and 0.6% P.

Recording and statistical analysis of data

Production, feed consumption and mortality were recorded from 20 w until 80 w. The weight of eggs was recorded on one day every week. During periods of five days (Wednesday to Friday and Monday to Tuesday) on five occasions in Expt. 1 and on six occasions in Expt. 2, eggs were collected for candling at a commercial egg packing plant in order to record frequencies of cracked and dirty eggs corresponding to normal commercial egg grading procedures. Eggs were also hand-candled individually (in Expt. 1) at the research station at 29, 43, 53, 58, 68 and 77 w, in

Table 2. Expt. 1. Effect of hybrid and housing system on production, mortality and egg quality. Cracked and dirty eggs graded at the egg packing plant

	LSL[1]			LB	Statistical significance[2]	
	L	M	C	M	Hybrid	System
Laying %/hen day	79.8	82.7	84.9	75.8	*	0.08
Egg weight, g	62.4	61.7	61.8	65.7	*	N.S.
Egg mass, kg/hen housed	20.1a[3]	20.8ab	21.6b	18.2	0.07	*
Egg mass, g/hen day	49.8	51.0	52.5	49.8	N.S.	0.06
Feed consumption, g/hen day	130.2a	121.7b	121.7b	126.2	N.S.	***
Feed conversion ratio, kg/kg	2.61a	2.39b	2.32b	2.54	N.S.	**
Mortality, %	8.0	6.2	5.1	35.3	*	N.S.
Mislaid eggs, %	1.4	0.6	–	3.3	N.S.	N.S.
Cracked eggs, %	4.1	4.0	3.9	4.3	N.S.	N.S.
Dirty eggs, %	18.6a	5.0b	2.2c	6.1	N.S.	***

[1] LSL = Lohmann Selected Leghorn; LB = Lohmann Brown; L = Lövsta; M = Marielund; C = conventional battery cage.

[2] *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

[3] If more than two treatments, values within lines are significantly different at least at the 95% level ($P < 0.05$) if followed by a code without any common letter.

order to record frequencies of different kinds of cracks (star, hair and pinhole cracks) as well as frequencies of dirty eggs. At 36 and 72 w in Expt. 1, 20, 30 and 60 eggs were collected from the L, M and C groups, respectively, and, in Expt. 2, 10 eggs from each group to record the interior quality and shell strength. The traits recorded were albumen height, Haugh units, yolk colour according to the La Roche scale (scores 1–15), blood and meat spots, shell deformation using a load of 500 g, and shell percentage. The thickness of the shell was calculated according to Tyler & Geake (1961) and shell weight (mg per cm^2) according to Mueller & Scott (1940).

Once every four weeks in Expt. 2 and once every eight weeks in Expt. 1 the location of hens in the aviary systems was recorded by direct visual observation in the light period (3 h and 6 h after light in Expt. 1 and 2, respectively) and in the night. Mortality was recorded on a group basis and all dead birds were autopsied at the National Veterinary Institute, Uppsala.

Recording of live weight and scoring of exterior appearance and health of randomly selected birds were carried out at 35 w and 55 w. In Expt. 1, 30 birds were scored in each of the aviary groups and 54 birds in each of the C groups. In Expt. 2, 20, 30 and 21 birds were scored in the L, M and C groups, respectively. The scoring comprised condition of plumage, feet (hyperkeratosis in the distal toe pad and abscesses in the foot pad, "bumble foot", and cleanliness), claws (excessive growth), keel bone lesions and wounds (pecks and scratches) on the comb and around the tail/back/cloaca region (rear wounds). The scoring was performed according to Tauson et al. (1984) implying a score of 1–4 points,

Table 3. Expt. 1. Effect of hybrid and housing system on extrior egg quality. Measured by hand-candling at the research station. Percentage of candled eggs

	LSL[1]			LB	Statistical significance	
	L	M	C	M	Hybrid	System
Dirty eggs	35.5a	16.7b	9.8c	20.4	0.07	**
Star	6.0a	2.0b	2.6b	3.6	**	*
Hair	1.34a	1.29ab	0.91b	1.36	N.S.	*
Pinhole	0.16a	0.05a	0.98b	0.14	N.S.	**
Other	3.4	1.5	2.1	2.7	N.S.	N.S.
Total cracks	10.6a	4.8b	6.6b	7.8	N.S.	*

[1] LSL = Lohmann Selected Leghorn; LB = Lohmann Brown; L = Lövsta; M = Marielund; C = conventional battery cage.

where Y_{jk} = observation for group k of hybrid j, μ = general mean, b_j = effect of hybrid j, and e_{jk} = random variation.

In Expt. 2 within the two aviaries the following statistical model was used:

$$Y_{ijk} = \mu + a_i + b_j + (ab)_{ij} + e_{ijk}$$

where Y_{ijk} = observation for group k in system i of hybrid j, μ = general mean, a_i = effect of system i, b_j = effect of hybrid j, $(ab)_{ij}$ = interaction effects and e_{ijk} = random variation.

Before analysis, the traits given in proportions (mislaid eggs, mortality, condition at slaughter, egg quality, birds' location in the aviary systems) were subjected to arcsin transformation (Snedecor & Cochran, 1986). In order to analyse differences between treatments, Fisher's protected least-significant-difference tests were used.

Results

Experiment 1

The results of production are given in Table 2. LSL had a higher laying percentage and lower egg weight as well as lower mortality than LB ($P < 0.05$). Within the LSL hybrid, the birds in C showed significantly higher egg mass per hen housed than the birds in L ($P < 0.05$). Hens in L had higher feed consumption ($P < 0.001$) and inferior feed conversion ratio than birds in M and C ($P < 0.01$). The percentage of mislaid eggs found did not differ significantly between aviaries. In L, the proportion of dirty eggs was significantly higher than in M, where in turn it was higher than in C in eggs graded at the egg packing plant ($P < 0.001$). In eggs candled at the research station (Table 3), the proportion of dirty eggs was generally found to be higher, but the relationship between the systems was the same ($P < 0.01$). LB was found to have more eggs with star cracks than LSL ($P < 0.01$). Within the LSL hybrid, birds in L had more star cracks than in M and C ($P < 0.05$). L gave more hair cracks than C ($P < 0.05$) and both aviaries had lower frequencies of pinhole cracks than C ($P < 0.01$). Regarding total cracks, L gave a higher proportion than the other two systems ($P < 0.05$). This was not, however, the case in the eggs candled at the egg packing plant.

In the analysis of the interior egg quality (not in tables) at 36 w, no significant differences could be found between housing systems. Eggs from LB had the strongest yolk colour, thickest egg shells and highest shell weight ($P < 0.05$). At 72 w, LB had higher egg weight than LSL ($P < 0.05$).

At the scoring of birds' exterior appearance at 35 w (Table 4), LB were heavier than LSL ($P < 0.05$), showed less total foot damage ($P < 0.01$), mostly owing to less bumble foot ($P < 0.01$), and had lower scores for wounds on the comb ($P < 0.05$). At 55 w, LB were still heavier and had lower wound scores for comb, but had dirtier feet and better claw condition than LSL ($P < 0.05$). Within the LSL hybrid at 35 w, birds in C had better plumage than birds in M, which in turn had better plumage than hens in L ($P < 0.01$). C gave cleaner plumage ($P < 0.05$) and feet ($P < 0.001$) than either of the aviaries. Birds in C had the best total foot condition and M the worst ($P < 0.01$). The two most frequent foot lesions registered were bumble foot and toe pad hyperkeratosis. Bumble foot was not seen in C and was found to be most severe in M ($P < 0.01$), while toe pad hyperkeratosis occurred only in C ($P < 0.01$). Hens in C had the best keel bone health, while hens in L had worst

Table 5. Expt.1. Effect of hybrid and housing system on bird conditon at slaughter after plucking (80 weeks of age) as percentage of hens slaughtered. Bone breaking strength in Newtons

	LSL[1]			LB	Statistical significance	
	L	M	C	M	Hybrid	System
Ventral wounds	42.3a	49.2a	20.7b	35.4	*	**
Dorsal wounds	67.6a	39.0b	21.1b	48.4	N.S.	*
Bumble foot	14.2a	23.5a	0.82b	9.6	**	*
Tow pad hyperkeratosis	5.0a	2.7a	39.1b	5.4	0.06	**
Breast blisters	21.9a	14.7a	0.0b	5.7	*	***
Broken wings	10.1a	11.9a	30.7b	16.3	*	**
Broken legs	0.0	0.2	0.3	0.3	N.S.	N.S.
Keel bone deformation	30.4a	39.9a	4.2b	24.6	N.S.	**
Breaking strength tibia, N	233a	241a	182b	235	N.S.	**
Breaking strength humerus, N	222a	228a	111b	261	0.07	**

[1] LSL = Lohmann Selected Leghorn; LB = Lohmann Brown; L = Lövsta; M = Marielund; C = conventional battery cage.

Table 6. Expt. 1. Distribution of birds in various parts of the aviary systems as a percentage of hens in the pen

	LSL[1]		LB	Statistical significance	
	L	M	M	Hybrid	System
Day					
Litter floor	14.9	11.9	19.5	0.1	***
Feeding tiers	32.1	44.7	46.9	N.S.	*
Platforms outside nests	6.1	4.9	5.7	N.S.	N.S.
Nests	21.9	17.7	11.7	**	0.1
Upper tier, perches	23.4	20.3	15.4	N.S.	N.S.
Upper tier, total	25.0	20.8	16.2	N.S.	N.S.
Night					
Litter floor	0.1	0.2	11.4	N.S.	0.1
Feeding tiers	0.1	0.5	10.0	*	N.S.
Platforms outside nests	1.6	13.3	19.4	N.S.	0.06
Nests	5.4	0.6	0.3	N.S.	0.07
Upper tier, perches	88.3	80.7	57.9	N.S.	N.S.
Upper tier, total	92.8	85.4	58.9	N.S.	N.S.

[1] LSL = Lohmann Selected Leghorn; LB = Lohmann Brown; L = Lövsta; M = Marielund; C = conventional battery cage.

($P < 0.01$). Hens in the two aviary models had more wounds on the comb than C hens ($P < 0.05$). Most wounds around tail/back/cloaca region (rear wounds) were found in L and least in C ($P < 0.01$). Some of the differences in the exterior appearance and live weight of the birds recorded at 35 w had decreased at 55 w, while others showed increased incidence. The plumage was impaired at the higher age and the differences between housing systems were greater ($P < 0.001$). Hens in C had cleaner feet than hens in L, which in turn were cleaner than hens in M ($P < 0.001$). Birds in C still had more toe pad hyperkeratosis than aviary hens ($P < 0.01$) and fewer wounds in the tail/back/cloaca region than hens in L ($P < 0.05$).

At slaughter (Table 5), the LB hybrid showed a lower incidence of wounds on the ventral side ($P < 0.05$), bumble foot ($P < 0.01$) and breast blisters ($P < 0.05$) but more broken wings ($P < 0.05$) than LSL. LSL hens in the aviaries had more ventral wounds ($P < 0.01$), more bumble foot ($P < 0.05$), less toe pad hyperkeratosis ($P < 0.01$), more breast blisters ($P < 0.001$), fewer broken wings ($P < 0.01$) and more keel bone deformations ($P < 0.01$) than birds in C. Wounds on the dorsal side were significantly more common in L ($P < 0.05$) than in M or C. Both tibia and humerus were found to be stronger in hens in the aviary systems than in cages ($P < 0.01$).

Few significant differences between the hybrids were found in the distribution of birds in the aviaries (Table 6). However, in the daytime the LB hens were less often seen in the nests ($P < 0.01$), and at night there were more LB hens than LSL hens sleeping on the feeding tiers ($P < 0.05$). The LSL hens in L used the litter more ($P < 0.001$) and the feeding tiers less frequently ($P < 0.05$) during the daytime than those in M.

The autopsies of dead birds showed that the most frequent causes of death were salpingitis, wounds from pecks and scratches (most often cannibalism), hepatitis and lymphoid leucosis. Cloacal wounds, caused by cannibalism, and salpingitis seemed to correlate, i.e. in groups with many hens having cloacal wounds the incidence of salpingitis was also high. In LB, where the highest mortality was recorded, 14.0% of housed hens had salpingitis and 8.8% wounds, of which the vast majority were cloacal wounds, while in the LSL hybrid in M those proportions were only 2.2% and 0.2%, respectively. Some of the birds showed both types of lesions.

Experiment 2

Production, mortality and egg quality traits are shown in Table 7. LSL hens in aviaries showed higher egg mass per hen day ($P < 0.05$) and lower feed consumption ($P < 0.01$), implying a better feed conversion ratio ($P < 0.01$) than DK. There was no significant difference between the hybrids in the proportion of mislaid eggs but a tendency for DK to show a higher frequency of mislaid eggs than LSL ($P < 0.06$). When comparing the two aviary systems, hens in M showed a higher laying percentage ($P < 0.05$), higher egg mass both per hen housed and per hen day ($P < 0.05$), and a lower daily feed intake ($P < 0.05$), which implied a better feed conversion

Table 7. Expt. 2. Effect of hybrid, aviary (L and M) and housing system (L, M and C within LSL) on production, mortality and egg quality. Cracked and dirty eggs graded at the egg packing plant

	DK[1]		LSL			Statistical significance			
	L	M	L	M	C	Hybrid	Aviary	System	Hybrid × aviary
Laying %/hen day	73.3	81.2	78.7a	81.9b	82.3b	0.06	*	*	0.1
Egg weight, g	62.9	63.3	63.9	63.7	64.9	0.09	N.S.	N.S.	N.S.
Egg mass, kg/hen housed	17.4	20.2	18.6	20.9	21.1	N.S.	*	N.S.	N.S.
Egg mass, g/hen day	46.1	51.4	50.3	52.1	53.4	*	*	0.07	0.09
Feed consumption, g/hen day	136.5	131.3	127.7	126.9	127.7	**	*	N.S.	N.S.
Feed conversion ratio, kg/kg	2.96	2.55	2.54	2.44	2.39	**	**	N.S.	*
Mortality, %	15.4	9.1	16.3	6.7	8.1	N.S.	*	N.S.	N.S.
Mislaid eggs, %	11.0	3.1	6.0	3.1	–	0.06	**	–	N.S.
Cracked eggs, %	4.1	4.8	3.3a	5.2b	4.5b	N.S.	**	*	*
Dirty eggs, %	8.1	6.6	7.4a	7.4a	3.3b	N.S.	N.S.	*	N.S.

[1] DK = Dekalb XL; LSL = Lohmann Selected Leghorn; L = Lövsta; M = Marielund; C = conventional battery cage.

ratio ($P < 0.01$) than hens in L. Birds in M also showed lower mortality ($P < 0.05$), a lower percentage of mislaid eggs ($P < 0.01$), but a higher percentage of cracked eggs ($P < 0.01$) than hens in L. Significant interaction effects between hybrid and aviary were found in feed conversion ratio and proportion of cracked eggs ($P < 0.01$). Within the LSL hybrid, hens in L had a lower laying percentage ($P < 0.05$) and a lower proportion of cracked eggs ($P < 0.05$) than those in M and C. The aviaries gave a higher proportion of dirty eggs than C ($P < 0.05$).

At 36 w, the yolks were of a stronger colour in eggs from the DK hybrid ($P < 0.05$) than in LSL. Higher proportion of meat spots was found in M ($P < 0.05$) than in L (not in tables). No significant differences in interior egg quality or shell strength traits were found at 72 w.

At the scoring of birds' exterior appearance (Table 8) at 35 w, LSL had better plumage scores ($P < 0.01$) but dirtier plumage ($P < 0.01$) and slightly worse foot condition ($P < 0.05$) than DK. However, the total foot condition scores were reversed in M. At 55 w, LSL still had higher plumage scores ($P < 0.05$) and at this age also better claw condition ($P < 0.01$) but more comb wounds ($P < 0.05$) than DK. When comparing the two aviary systems at 35 w, hens in L showed better claw condition and better foot condition regarding bumble foot ($P < 0.05$) than hens in M. However, in these traits significant interactions were found between hybrids and aviaries ($P < 0.05$) since in LSL there was a higher incidence of bumble foot in L and in DK there were shorter claws in M. At 55 w, hens in L still had the best claw condition ($P < 0.01$) but also significantly more wounds on the combs ($P < 0.05$).

Within the LSL hybrid at 35 w, hens in C were heavier ($P < 0.05$), had cleaner feet ($P < 0.05$) and had less bumble foot ($P < 0.01$) than birds in the two aviaries. Birds in C also showed better claw condition than in M ($P < 0.01$). At 55 w, the LSL hens in C were still heaviest ($P < 0.01$) and had the cleanest feet ($P < 0.01$). At this age, the lowest mean score for bumble foot was recorded in M and the highest (no bumble foot) in C ($P < 0.01$). However, regarding toe pad hyperkeratosis, there was a significantly lower mean score in C hens compared with those in the aviaries ($P < 0.01$). In the aviaries, there was a lower mean score for keel bone lesions and rear wounds than in C ($P < 0.05$).

At slaughter (Table 9), LSL showed a higher incidence of keel bone deformation ($P < 0.05$) and bumble foot ($P < 0.01$) than DK. In both hybrids, M showed a higher level of keel bone deformation than L ($P < 0.05$). Within LSL birds the aviaries gave a higher level of breast blisters ($P < 0.01$) and broken claws ($P < 0.05$) than in C.

Table 8. Expt. 2. Effect of hybrid, aviary (L and M) and housing system (L, M and C within LSL) on live weight and exterior appearance at 35 and 55 weeks of age. Maximum plumage score = 24 points, minimum = 6 points. All other parameters, maximum = 4 points and minimum = 1 point

	DK[1]		LSL			Statistical significance			
	L	M	L	M	C	Hybrid	Aviary	System	Hybrid × aviary
Age 35 w									
Live weight, g	1673	1713	1689a	1708a	1829b	N.S.	N.S.	*	N.S.
Body plumage, score	10.7	12.3	15.1	14.0	18.2	**	N.S.	0.07	0.1
Cleanliness plumage	3.75	3.75	3.58	3.37	3.71	**	N.S.	0.08	N.S.
Cleanliness feet	2.78	2.78	2.88a	2.57a	3.90b	N.S.	N.S.	*	N.S.
Foot, total score	3.80	3.45	3.60	3.58	3.71	*	0.06	N.S.	0.08
Bumble foot	3.83	3.53	3.60a	3.62a	4.00b	N.S.	*	**	*
Toe pad hyperkeratosis	4.00	3.92	4.00	4.00	3.86	N.S.	N.S.	0.06	N.S.
Claw condition	3.63	3.75	3.92a	3.38b	3.93a	N.S.	*	**	*
Keel bone lesions	3.00	3.18	3.58	3.30	3.83	N.S.	N.S.	N.S.	N.S.
Comb wounds	3.03	3.53	3.25	2.97	3.67	N.S.	N.S.	0.07	*
Rear body wounds	2.98	2.88	3.40	3.02	3.86	N.S.	N.S.	0.07	N.S.
Age 55 w									
Live weight, g	1748	1765	1783a	1779a	.1911b	N.S.	N.S.	**	N.S.
Body plumage, score	8.9	9.5	10.5	9.9	11.9	*	N.S.	N.S.	0.07
Cleanliness plumage	3.80	3.85	3.70	3.78	3.86	N.S.	N.S.	N.S.	N.S.
Cleanliness feet	2.75	2.80	2.88a	2.77a	4.00b	N.S.	N.S.	**	N.S.
Foot, total score	3.73	3.82	3.70	3.60	3.62	N.S.	N.S.	N.S.	N.S.
Bumble foot	3.73	3.82	3.73a	3.62b	4.00c	N.S.	N.S.	**	N.S.
Toe pad hyperkeratosis	4.00	4.00	3.98a	4.00a	3.74b	N.S.	N.S.	**	N.S.
Claw condition	3.58	3.17	3.80	3.43	3.76	*	**	0.1	N.S.
Keel bone lesions	3.05	3.28	3.10a	3.18a	3.93b	N.S.	N.S.	*	N.S.
Comb wounds	3.48	3.73	3.40	3.45	3.60	*	*	N.S.	N.S.
Rear body wounds	3.50	3.72	3.73a	3.60a	3.93b	N.S.	N.S.	*	*

[1] DK = Dekalb XL; LSL = Lohmann Selected Leghorn; L = Lövsta; M = Marielund; C = conventional battery cage.

Table 9. Expt. 2. Effect of hybrid, aviary (L and M) and housing system (L, M and C within LSL) on bird condition at slaughter (80 weeks of age) as a percentage of hens slaughtered

	DK[1]		LSL			Statistical significance			
	L	M	L	M	C	Hybrid	Aviary	System	Hybrid × aviary
Breast blisters	28.4	24.5	30.0a	27.5a	0.0b	N.S.	N.S.	**	N.S.
Keel bone deformation	5.7	9.1	9.9a	21.3b	1.8c	*	*	**	N.S.
Broken claws	12.9	6.5	5.7a	10.0a	0.3b	N.S.	N.S.	*	*
Bumble foot	7.8	5.7	9.9a	12.9b	0.0c	**	N.S.	***	*
Rear body wounds	3.0	1.1	3.5	3.1	1.5	N.S.	N.S.	N.S.	N.S.

[1] DK = Dekalb XL; LSL = Lohmann Selected Leghorn; L = Lövsta; M = Marielund; C = conventional battery cage.

The highest incidence of keel bone deformation was found in M and the least in C ($P < 0.01$), being similar to the differences found in the incidence of bumble foot ($P < 0.001$).

Table 10 shows the distribution of birds within the systems. DK hens were found to locate themselves more on the perches during daytime ($P < 0.01$). Hens in M stayed more on the feeding tiers ($P < 0.001$) compared with L during the day, while hens in L were more often observed in the nests, on perches as well as on the upper tier totally ($P < 0.001$). At night, slightly more birds in M than in L stayed on the floor ($P < 0.05$). More birds stayed outside the nests ($P < 0.001$) and there were fewer in the nests ($P < 0.001$), on perches ($P < 0.05$) and on the upper tier totally ($P < 0.01$) in M than in L.

The most common causes of death were salpingitis, wounds from pecks (usually cannibalism), hepatitis and lymphoid leucosis. The highest mortality rates for both hybrids were found in L, where also the highest proportions of hens were found that had been given the diagnosis "wounds from pecks", being 8.9% of hens housed in LSL and 4.3% in DK. In M, 2.1% of LSL and 1.0% of DK had wounds and, in C, 3.2% of the LSL hens had wounds.

Discussion

Production and egg quality

Although similar differences between keeping systems were found in several traits studied in both experi-

Table 10. Expt. 2. Distribution of birds in various parts of the aviary systems as a percentage of hens in the pen

	DK[1]		LSL		Statistical significance		
	L	M	L	M	Hybrid	Aviary	Hybrid × aviary
Day							
Litter floor	10.1	7.6	8.7	9.5	N.S.	N.S.	0.09
Feeding tiers	28.9	48.2	30.0	47.7	N.S.	***	N.S.
Platforms outside nests	3.4	4.2	3.9	3.9	N.S.	0.08	N.S.
Nests	14.4	12.1	14.9	11.6	N.S.	***	N.S.
Upper tier, perches	37.8	25.7	35.7	24.7	**	***	N.S.
Upper tier, total	43.2	27.9	42.6	27.3	N.S.	***	N.S.
Night							
Litter floor	0.07	0.33	0.02	0.17	0.1	*	N.S.
Feeding tiers	4.3	6.2	0.4	2.5	0.1	N.S.	N.S.
Platforms outside nests	0.0	13.3	0.2	19.0	N.S.	***	N.S.
Nests	0.97	0.0	0.96	0.01	N.S.	***	N.S.
Upper tier, perches	84.6	73.4	88.2	68.9	N.S.	*	N.S.
Upper tier, total	94.6	80.0	98.4	78.3	N.S.	**	N.S.

[1] DK = Dekalb XL; LSL = Lohmann Selected Leghorn; L = Lövsta; M = Marielund; C = conventional battery cage.

ments, especially regarding some production traits, these were not always significant, probably owing to the limited number of replicates.

Although showing a lower average in both experiments, M seemed to compete best with battery cages regarding production and feed conversion. This confirms data reported by Hansen (1993) comparing three different aviary models. Although, in L, group size was smaller and, in Expt. 2, also a further reduction in stocking density and group size was used compared with M, production was significantly lower. Hence, the lower production level in L is difficult to explain and its cause is probably multifactorial. Obviously, the general structure of the M aviary might well compensate for the effects of higher stocking density and larger group size, at least in white hybrids. However, the increased mortality rates in L compared with M, often caused by cannibalism, especially in Expt. 2, negatively influenced the egg mass produced per hen housed. It is also possible that a larger proportion of mislaid eggs in L were eaten by hens or lost on the manure belts, and therefore could not be recorded.

The high feed consumption in L (Expt. 1) and in DK (Expt. 2) can be explained by poor plumage condition (Tauson & Svensson, 1980; Peguri & Coon, 1993). This effect probably exceeded any possible effect on feed consumption due to greater locomotive activity of the hens in the aviaries compared with that in C.

The exterior egg quality is an important trait because dirties and cracks reduce the price of the eggs as well as the food hygiene. The higher proportion of star cracks in LB could be explained by the greater weight of those eggs increasing the force when they roll out of the nests and occasionally collide with other eggs on the belt. The hybrids used did not seem to affect any other kinds of cracks. The high proportion of pinhole cracks in C agrees with Elson (1978), who claimed that such cracks could be caused by the bird's beak or claws in eggs not having rolled out efficiently in cages. The aviaries competed very well with cages regarding proportions of cracked eggs but not dirties. The possible negative effect on egg quality traits in the aviaries from the use of automatic egg collection was probably of minor importance because of the very short length of the belts.

An improper (gliding) installation of the nest bottoms in L in Expt. 1 may explain the high proportions of cracked eggs, especially star cracks, and the defecated Astro-turf material explains the high proportion of dirty eggs. Changing the nest design in Expt. 2 to a better installed nest bottom made of "rubber fingers", keeping much cleaner than the Astro-turf, improved egg quality. However, instead, the proportion of mislaid eggs increased, possibly because the hens did not like the bottoms of the nests, alternatively the white plastic nests were too light compared with the metal sheet used in Expt. 1. The effect of light on the choice of nests is not, however, very clear (Appleby et al., 1984). The low usage of the nests in Expt. 2 could not be confirmed by the recording of birds' location in the systems (Tables 6 and 10). Probably the hens that actually laid the eggs in the nests in L stayed in the nests for a longer period than those in M.

Mislaid eggs, especially if laid in the litter, are usually dirty. Further improvement of nest design may make nests more attractive for the hens and the proportion of dirty eggs would decrease. Apart from poor nest design, a large proportion of mislaid eggs could be caused by unsuitable location of the nests. In L pens there were wire netting walls under and above the nests separating the groups, while in M there were boards. Hence, when birds in L approached the nests the sight of hens in the neighbouring pen might have distracted them. Also the rearing method (Appleby et al., 1988) is important for the proportion of mislaid eggs. The rearing methods used in the present study focused on being adapted to aviaries in particular, as pointed out by Oester & Fröhlich (1986). Thus, not only were birds reared on litter but they also had access to elevated wire floors and perches. There might also be a genetic effect, as shown by Sørensen (1992), since LSL laid more eggs in nests than did DK and LB, even if this could not be confirmed by the statistical analysis. Low proportions of mislaid eggs are important not only for reasons such as production and egg quality, but also for ergonomical reasons, particularly when having to collect them in large flocks.

The lack of differences in interior egg quality found between eggs from the different systems could be explained by the fact that the composition of the egg is highly influenced by the genotype of bird and feed, and probably to a much lesser extent by the housing system (Scholtyssek et al., 1984). The occasional difference between the aviaries at 36 w in Expt. 2 in proportion of meat spots was not repeated and might have been caused by individual eggs from a rather small sample. The only significant interior egg quality trait differences registered were found between hybrids, being more frequent between LSL and LB than between LSL and DK, probably caused by the greater genetic difference between leghorn and brown hybrids.

Behaviour and health

Detailed behaviour studies might have helped explain part of the difference found, e.g. in cannibalism between systems and bird material. However, it was not found possible to carry out such studies with enough accuracy in the aviaries because of difficulties in recording individual birds for a longer period in structures of this design, especially avoiding the effect of an observer in direct visual observation.

The importance of making a distinction between the two behaviours "feather pecking" and "cannibalism" is, however, clearly shown by the fact that birds in groups suffering from cannibalism did not show poorer plumage scores than the others (Tables 4 and 8). Feather pecking is believed to be a redirected food pecking (Blokhuis, 1989) or caused by the hens using feathers as a dust bathing substrate (Vestergaard, 1989). However, in agreement with Hansen (1993), the feather damage in the present studies was most severe in the aviaries, where the hens had access to litter. Furthermore, a general observation was that individuals pecking feathers were not seen dustbathing. The possible effect of rearing method and access or not to litter on the degree of feather damage is hard to find in the present study since the rearing was especially adapted to the aviary birds. Furthermore, the birds in C showed a better plumage still if they were transferred from litter rearing into a non-litter condition at 16 w. Wood shavings are a widely used litter material in floor-kept laying hens. According to Nørgaard-Nielsen et al. (1993b) other litter materials such as sand or peat during rearing or additional straw in the laying environment may reduce feather pecking. However, in their study wood shavings were not included as a comparison. The low incidence of wounds on the combs in hens in C can be explained by the fact that a small group of birds more easily develops a stable pecking order in contrast to the aviary birds, which were seen more frequently pecking and fighting with each other, even at higher ages.

Cleanliness of the plumage as well as of the feet decreased in the aviaries much more rapidly than in C, owing to access to litter on the floor and the overall inferior hygiene found in the aviaries. However, it should be noted that it is much harder to detect defecation of the plumage of LB hens, because of the brown colour. LB hens also have much smaller combs, which makes it harder for other hens to peck at.

The effect of keeping system on foot condition was very clear. Thus, bumble foot hardly ever occured in hens kept in cages, while toe pad hyperkeratosis occurred almost only in cages. The incidence of bumble foot has been shown to be highly influenced by the presence and design of a perch (Siegwart, 1991; Tauson et al., 1992; Tauson & Abrahamsson, 1994). Also, LSL seems to be more sensitive to bumble foot than LB, implying a genetic predisposition for bumble foot, which confirms earlier results by Tauson & Abrahamsson (1994). The presence of perches could also explain the higher incidence of keel bone lesions in the aviaries as shown by Abrahamsson & Tauson (1993). Claw length seemed to be correlated to the frequency of broken claws at slaughter at 80 w, i.e. long claws increase the risk of breaking. The shorter claws in L compared with M can be explained by the larger proportion of litter and of available area in L, and the short claws in C by the use of abrasive tapes (Tauson, 1986).

The high mortality rates found in L (LSL) and M (LB) caused by cannibalism well illustrates the effects this behaviour may have on bird welfare and production in flocks of non beak trimmed hens especially, as also reported by Nørgaard-Nielsen et al. (1993a). These authors also showed the effect of reducing cannibalism by beak trimming. However, this measure is prohibited in Sweden. In the groups with a high incidence of canniblaism there were also many cases of salpingitis. Either this salpingitis could have developed as an infection through wounds after the hens had been pecked at the cloaca, or the salpingitis developed first, which then encouraged other hens to peck.

More frequent use of the feeding tiers by the hens in M in the daytime could be explained by the fact that the feeding tiers in this system, compared with L, made up a larger proportion of the total available area. This also implied that in both experiments the birds in L used the resting upper tier with perches more (in Expt. 1 not significant) than birds in M. However, the greater differences in height and distance between the perches in the resting tier of L, which gave the birds an image of more "space", and the greater perch length per hen, could also have contributed to the more frequent use of the perches. The higher sloped resting tier in L also facilitated inspection of birds at the top. In M, many hens used the platforms and perches outside the nests during the night. The greater locomotive possibility in the aviaries compared with that of C had a clear effect on the strength of both tibia and humerus in Expt. 1. At slaughter, however, the high incidence of broken wings in all treatments was caused by an improperly installed neck cutter at the slaughter plant.

Conclusion

The overall impression of production and health of birds in the present study is that, in a good aviary system, egg production, although being less predictable, may be similar to that in cages, while hygiene and bird health are still in several respects better in cages than in new aviary tiered floor systems. The access to nests, perches and litter as well as the stronger skeleton in birds in aviaries imply benefits over conventional cages. However, feather pecking, cannibalism and mislaid eggs are the main problems that need to be solved in large group aviaries before commercial use on a larger scale can be advisable. Since the effect of hybrid seems considerable, future studies of keeping systems for laying hens must continue to consider not only the design of systems but also genetic material and, if large groups on litter are kept, possibly genetic selection for less cannibalism, feather pecking and mislaid eggs.

Acknowledgements

The present studies were made possible by financial support from the Swedish Farmers' Foundation for Agricultural Research and the National Board of Agriculture. AB Bröderna Victorsson and Big Dutchman Deutschland GmbH are thanked for providing the two aviary models. The Centre for Rural Building at the North of Scotland College of Agriculture in Aberdeen and the National Veterinary Institute in Uppsala are thanked for carrying out the measurements of bone breaking strength and autopsy of birds, respectively.

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