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Effects on Production, Health and Egg Quality of Varying Proportions of Wheat and Barley in Diets for Two Hybrids of Laying Hens Kept in Different Housing Systems

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A total of 2152 hens were fed one of two diets, with 25.0% wheat and 38.7% barley or 50.0% wheat and 13.7% barley. The hens were housed in battery cages with three hens per cage and in two aviary systems with tiered wire floors and litter–Lövsta with two tiers and Marielund with three tiers. Two hybrids were used: ISA Brown and Lohmann selected Leghorn.
Production, interior and exterior egg quality, health, plumage, keel bone and foot condition were studied. The high-wheat diet resulted in inferior plumage condition owing to feather pecking, especially in the Leghorn hybrid, which in turn probably caused the higher feed consumption recorded. No other effects on production or egg quality traits were observed. Mortality, cannibalism, keel bone condition and foot condition were far more affected by housing system and hybrid than by diet. The highest mortality, mainly caused by cloacal cannibalism, was registered for ISA Brown in aviaries.

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Key words: aviary; cage; cannibalism; feather pecking; foot condition.

Introduction

The behavioural repertoire of laying hens, as well as the movements of the birds in conventional cages, is very restricted. Hence, in several countries, and in north-western Europe especially, there have been calls for cages to be banned (see e.g. Craig & Swanson, 1994). Several different alternative housing systems, such as wire floor or tiered wire floor systems for large groups of birds, are therefore being developed in these countries (Gerken, 1994). However, feather pecking and cannibalism have often occurred (Hansen, 1993; Nørgaard-Nielsen et al., 1993; Abrahamsson & Tauson, 1995). The causes of cannibalism and feather pecking are believed to be multifactorial (Calet, 1965; Hughes & Duncan, 1972). They are two distinct phenomena (Allen & Perry, 1975), even though one may lead to the other or they may both be the results of the same cause. Cannibalism can result in large losses, especially in non beak trimmed birds and of brown medium-heavy hybrids, while feather pecking owing to extensive heat losses from naked skin implies considerable increases in feed

consumption (Tauson & Svensson, 1980). Hence, every possibility to minimize the occurrence of these problems must be considered.

The feed composition not only may have a significant effect on performance but has also been reported to affect health. For example, changes in diets during the production cycle for floor-kept laying hens have been followed by increased mortality (Curtis & Marsh, 1992). Diets low in protein may result in poor plumage condition in laying hens (Al Bustany & Elwinger, 1987). Methionine supplementation has been shown to suppress feather pecking and cannibalism in chicks (Neal, 1956). In young pheasants, these problems may decrease by increasing dietary protein and energy (Cain et al., 1984). However, even if all nutrient requirements are similar, different types of ingredients or different structure of the feed may lead to significant differences. Thus, pelleted feed has been shown to increase the risk of feather pecking (Heywang & Morgan, 1944; Huston et al., 1956; Lindberg & Nicol, 1994) probably owing to the decrease in time required for eating the daily amount of feed compared with an all-mash feed (Lanson & Smyth, 1955; Jensen et al., 1962). Al Bustany & Elwinger (1988) found that caged hens fed a diet based on ground cereals had better plumage condition than those fed a diet based on whole cereals. Among cereals used in diets for layers, oats have long been considered to be a valuable feed ingredient and have been shown to improve plumage condition (Al Bustany & Elwinger, 1988) and decrease cannibalism, attributed to the high fibre content in the hulls (Bearse et al., 1940). In practice, at least in Sweden, it has been recommended not to use large proportions of wheat in layer diets owing to risks of cannibalism (Jönsson, 1966). However, Petersen (1990) reported no significant effect on production, mortality or plumage condition when comparing diets with different grain proportions.

Most studies dealing with cannibalism and feather pecking in relation to feed composition originate from the time before cages were introduced. By keeping birds in very small groups in separate cages, cannibalism normally does not spread easily, as may often be the case in large groups, e.g. in floor pens (Hansen, 1993; Abrahamsson & Tauson, 1995). During recent decades, production capacity through genetic selection has also dramatically increased. The aim of the present study was to determine effects of large differences in the proportion of wheat and barley in layers diets on performance and health in hens of two different modern hybrids kept in aviaries still under development at the department (see Abrahamsson & Tauson, 1995) and in conventional cages. The study was focused on the possible effects on plumage condition and cannibalism.

Materials and methods

Birds, diets and systems

The experiment was carried out between March 1993 and May 1994 and comprised 2152 hens. Two commercial hybrids were used, ISA Brown and Lohmann Selected Leghorn (LSL). Until 17 weeks (w) of age the pullets were fed a grower's all mash containing 15.0% crude protein (CP), 10.9 MJ metabolizable energy per kg, 1% Ca and 0.7% P. During the complete following period until slaughter at 80 w the hens were fed a layer's all mash (crumbles). Two diets were used: BARLEY with 25% wheat and 38.7% barley, and WHEAT with 50% wheat and 13.7% barley. The composition of the diets and the nutrient contents are given in Table 1. Owing to grains from the new harvest coming into the rations at 48 w, the nutrient content was slightly changed. During the experiment, the diets were regularly chemically analysed for dry matter content, ash and crude protein.

Three different housing systems, all in the same building, were used: battery cages in three tiers (C) and two aviary systems with tiered wire floors and litter (wood shavings) – Lövsta (L) and Marielund (M). The systems were the same as in an earlier study (Abrahamsson & Tauson, 1995).

The L system had two tiers, the lower tier with feed troughs and the upper resting tier with perches. Each pen measured 6.0 × 2.7 m. The nests were made of black plastic with "rubber finger" mat linings.

The M system consisted of three tiers. The two lower tiers had feed troughs and the top resting tier had perches. Each pen measured 5.8 × 2.8 m. The nests used were of plastic bowl design with a perforated bottom (Facco). The perches on the highest tier (resting area) in both L and M were made of European beech hardwood.

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. Egg collection was carried out once a day. Floor eggs in the aviaries were collected five times a a day in the first months of lay and then three times a day.

There were four L-pens (groups), two with 150 ISA birds and two with 175 LSL birds in each. This implied 9.2 ISA hens and 10.7 LSL hens per m^2 ground floor, 6.2 ISA hens and 7.2 LSL hens per m^2 available area and 20.0 cm perch length per ISA and 17.1 cm perch length per LSL bird. There were four M-pens (groups), two with 245 ISA birds and two with 290 LSL birds. This implied 15.0 ISA hens and 17.7 LSL hens per m^2 ground floor, 7.8 ISA hens and

Table 1. Compositions of the diets used

	Until 48 w		From 48 w	
	BARLEY	WHEAT	BARLEY	WHEAT
Ingredients				
Wheat	25.00	50.00	25.00	50.00
Barley	38.70	13.70	38.70	13.70
Oats	10.00	10.00	10.00	10.00
Wheat bran	1.00	1.00	1.00	1.00
Alfalfa meal	2.80	2.80	2.80	2.80
Soybean meal	2.00	2.00	7.00	7.00
Rapeseed meal	5.00	5.00		
Fish meal	3.00	3.00	3.00	3.00
Meat and bone meal	1.00	1.00	1.00	1.00
Animal fat	1.50	1.50	1.50	1.50
Vitamin and trace element mixture	1.00	1.00	1.00	1.00
Calcium carbonate	7.80	7.80	7.80	7.80
Sodium chloride	0.20	0.20	0.20	0.20
Mono-calcium phosphate	0.70	0.70	0.70	0.70
DL-methionine	0.17	0.17	0.17	0.17
Lysine-HCl	0.13	0.13	0.13	0.13
	100.00	100.00	100.00	100.00
Calculated content				
Energy, MJ/kg	11.0	11.1	10.9	11.1
Protein, g/kg	150	150	144	143
Lysine, g/kg	7.4	7.2	7.7	7.6
Methionine, g/kg	4.2	4.2	4.4	4.3
Methionine + Cysteine, g/kg	7.0	7.2	7.2	7.1
Lipids, g/kg	41	39	39	37
Linolic acid, g/kg	9.9	9.4	8.8	8.3
Crude fibre, g/kg	46	40	40	36
Ca, g/kg	34.7	34.7	34.4	34.5
P, g/kg	6.0	6.0	5.7	5.7
Na, g/kg	1.5	1.5	1.4	1.4
Analysed content (mean)				
Crude protein, g/kg	153	150	147	145
Ash, %	12.6	12.7	13.0	12.5
Dry matter, %	90.0	90.3	90.1	90.3

9.2 LSL hens per m^2 available area and 16.6 cm perch length per ISA and 14.0 cm perch length per LSL bird. There were six C-groups, each with 72 birds, three of each hybrid. One group of each diet (BARLEY or WHEAT) was used as replicate in each combination of system and hybrid, except in C (owing to the six groups) where there were two replicates of ISA × BARLEY and two of LSL × WHEAT.

Rearing and lighting

From day old to 16 w the chickens were reared by hybrid in two groups in a separate unit in a two-tier aviary system with litter, and with water and feed on the lower tier and perches on the upper. The birds had access to the litter floor from 5 w. No birds were beak trimmed. The plumage condition at 16 w of all pullets was regarded as intact. At this age the pullets were transferred into the laying house and given $8\frac{1}{2}$ h of light per day. Light was then successively increased to 15 h per day at 30 w. Owing to very high mortality in the two groups of ISA hens in L the light over the feeding tier was dimmed at 35 w. In order to prepare birds for activities associated with light and dark periods, such as finding food and water at the beginning of a light period and finding resting perches on the top tier at the beginning of a dark period, the light was turned on/off with an artificial dawn and dusk (Tanaka & Hurnik, 1991).

Recording and statistical analysis of data

Production, feed consumption and mortality were recorded on a group basis from 20 w to 80 w. All dead birds were autopsied at the National Veterinary

Institute, Uppsala. The weight of eggs was recorded one day every week. During periods of five days on seven occasions (at 26, 31, 43, 51, 56, 66 and 75 w), eggs were collected for candling at a commercial egg packing plant in order to record the proportions of cracked and dirty eggs in accordance with commercial egg grading procedures. At 38 and 72 w, a sample of 10 eggs from each group was collected in order to record the interior quality and shell strength. The traits recorded were albumen height, Haugh units according to Haugh (1937; cited in Stadelman & Cotterill, 1973), yolk colour according to the La Roche scale (scores 1–15), blood spots, meat spots and shell percentage. Shell deformation was calculated from the average value of measurements on three different points across the egg equator when a load of 500 g was applied to the egg with a Marius apparatus (TESA, Renens, Lausanne, Switzerland). 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 eight weeks the location of hens in the aviary systems was recorded by direct visual observation in the light period 6 h after lights on and in the night 1 h before lights on. On one day at both 26 and 56 w dust bathing behaviour was studied by a person sitting outside the aviary pen or in front of six cages per battery cage group. The number of hens dust bathing was recorded once every 5 min from 2 to 4 h and from 7 to 9 h after lights on. Hens were registered as bathing if they were either wing shaking, lying on their side, side rubbing, head rubbing or bill raking (van Liere, 1992). Consequently, sham dust bathing of hens in C was registered as dust bathing.

The recording of live weight and the scoring of exterior appearance and health of randomly selected birds were carried out at 35 and 55 w. In L and M, 20 and 30 randomly selected birds per group, respectively, and in C all hens from three randomly selected cages per group, were scored. The scoring comprised condition of plumage, feet (hyperkeratosis in the distal toe pad, 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, where 4 meant an intact and 1 a very poor condition. Regarding bumble foot, 1 indicated an acute inflammation and 3 minor damage to the food pad or total healing at the end of the inflammatory process. The plumage condition was recorded separately on the neck, breast, back, wings, tail and cloaca/abdomen region. The six plumage scores were added together, giving a total score ranging from a minimum of 6 to a maximum of 24 points.

Statistical analyses were performed using the General Linear Models of the statistical analysis system SAS (SAS Institute Inc., 1989). All main effects were considered fixed. For exterior egg quality and bird location, the mean of the different proportions, recorded on each occasion, was calculated for each group before analysis. In order to analyse differences between the systems, Fisher's protected least-significant-difference test was used.

The following statistical model was used;

$$Y_{ijkl} = \mu + a_i + b_j + c_k + ab_{ij} + ac_{ik} + bc_{jk} + e_{ijkl},$$

where Y_{ijkl} = observation for group 1 in system i of hybrid j with diet k, μ = general mean, a_i = the effect of system i, b_j = the effect of hybrid j, c_k = the effect of diet k, ab_{ij} ac_{ik} bc_{jk} = interaction effects and e_{ijkl} = random variation.

Interactions that were found not to be significant at the 90% level ($P < 0.10$) in the first analysis were excluded from the model. This procedure was performed to increase the degrees of freedom of the error term (random variation) in the model. Before analysis, the traits given as proportions (mislaid eggs, mortality, exterior egg quality, dust bathing behaviour, birds' location in the aviary systems) were subjected to arcsin transformation (Snedecor & Cochran, 1968).

Results

Production, mortality and egg quality

The results for production are given in Table 2. Hens fed WHEAT consumed more feed per hen day than hens fed BARLEY ($P < 0.05$). A significant interaction ($P < 0.01$) was found between diets and systems owing to the very high consumption in L with diet WHEAT (140 g/hen day). No other significant differences were found between the diets regarding production traits. Hens in C had higher egg weight than hens in L ($P < 0.05$) and a higher laying percentage ($P < 0.05$), a higher egg mass per hen day ($P < 0.05$) and a better feed conversion ratio ($P < 0.001$) than both aviaries. A significant interaction ($P < 0.05$) was found regarding feed conversion between systems and hybrids owing to a much larger difference between the aviaries and C among ISA than among LSL hens. Hens in C had higher egg mass per hen housed than both aviaries, while hens in M had higher egg mass per hen housed than hens in L ($P < 0.01$), but a non-significant interaction effect ($P < 0.07$) between systems and hybrids indicated that this difference concerned only the ISA hybrid. Overall, daily feed consumption in C was lower than in the aviaries, while feed consumption was lower in

M compared with L ($P < 0.01$). However, a significant interaction ($P < 0.01$) was found between systems and hybrids regarding feed consumption owing to LSL in L actually having a lower feed consumption than LSL in M but also owing to a very high consumption among ISA birds in L (142 g/hen day). The mortality in L was higher than in C ($P < 0.05$). The highest mortality, 45.3%, was found in ISA birds in L, and most of this was due to a very high mortality (2.9% per week) in the weeks before 35 w. The mortality decreased after the light was dimmed at 35 w to 1.3% per week and thereafter it returned to a more normal level. In L, the proportion of cracked eggs was lower than in the other systems ($P < 0.01$). The proportion of dirty eggs was higher in M than in both L and C, and higher in L than in C ($P < 0.001$). However, a significant interaction was found regarding dirty eggs between systems and hybrids owing to M giving higher proportions of dirty eggs than both the other systems among LSL but only higher than C among ISA birds ($P < 0.01$). The LSL hybrid compared with ISA, had a higher laying percentage ($P < 0.01$), higher egg mass per hen housed ($P < 0.001$), higher egg mass per hen day ($P < 0.01$), lower feed consumption ($P < 0.01$), better feed conversion ratio ($P < 0.001$), lower mortality ($P < 0.001$) and a lower proportion of cracked ($P < 0.001$) and dirty eggs ($P < 0.001$).

There were no clear differences found between the diets regarding causes of death. The most common diagnosis at autopsy was cannibalism, being highest among ISA birds with 30.0%, 16.1% and 4.6% of housed hens in L, M and C, respectively, while this was rare in LSL birds, reaching 1.4%, 0.7% and 0.5%, respectively. Almost all hens that died from cannibalism were pecked in or around the cloaca. Several were so badly pecked that hardly any intestines were left. Other common diagnoses were salpingitis (6.8% of ISA birds and 0.9% of LSL birds) and hepatitis (1.1% of ISA birds and 0% of LSL birds).

At 36 w, no significant differences were recorded between diets regarding interior egg quality or shell strength. At this age, eggs from the aviaries, compared with C, had lower shell deformation (L, 19.8; M, 19.7; C, 21.6 µm, $P < 0.01$), thicker shell (L, 0.349; M, 0.350; C, 0.338 mm, $P < 0.05$), higher shell percentage (L and M, 9.8; C, 9.3%, $P < 0.01$), higher shell weight (L, 83.4; M, 83.7; C, 80.8 mg per cm^2, $P < 0.05$) but more meat spots (L, 5.0; M, 7.5; C, 0.0%, $P < 0.01$). More eggs from ISA hens (18.3%) than from LSL (1.2%) had blood spots ($P < 0.05$) but fewer had meat spots (0.1 vs. 8.3%, $P < 0.01$). At 72 w these differences between the systems had disappeared, but hens fed WHEAT laid a larger proportion of eggs with blood spots (23.6%) than hens fed BARLEY (8.2%, $P < 0.01$). Eggs from the aviaries

Table 2. Effects of diet, housing system and hybrid (ISA, LSL) on production, mortality and egg quality

	ISA					LSL					Statistical significance			
	Diet		System			Diet		System						
	BARLEY	WHEAT	L	M	C	BARLEY	WHEAT	L	M	C	Diet	System[1]	Hybrid	Interactions used in model
Laying, %/hen day	75.1	75.0	75.5	70.5	79.4	82.4	83.6	79.7	84.0	85.3	NS	*	**	D × S 0.07, S × H 0.07
Egg weight, g	64.8	64.6	64.3	64.5	65.4	64.2	64.3	63.5	64.2	65.0	NS	*	NS	–
Egg mass, kg/hen housed	17.6	17.4	14.8	17.0	20.8	22.0	22.2	20.8	22.5	23.1	NS	**	***	S × H 0.07
Egg mass, g/hen day	48.7	48.5	48.6	45.5	51.9	53.0	53.8	50.6	53.9	55.4	NS	*	**	D × S 0.08, S × H 0.1
Feed consumption, g/hen day	131.1	132.3	141.9	128.9	124.5	123.5	129.0	125.9	127.4	125.4	*	**	**	D × S**, D × H 0.06, S × H**
Feed conversion ratio, kg/kg	2.71	2.74	2.92	2.83	2.42	2.33	2.40	2.48	2.36	2.26	NS	***	***	S × H*
Mortality, %	29.6	27.7	45.3	30.2	11.4	3.3	3.9	4.9	3.1	2.5	NS	*	***	S × H 0.07
Mislaid eggs, %	5.9	8.4	6.4	7.9	–	5.8	1.4	6.7	0.5	–	NS	0.07	0.06	D × S 0.07, D × H 0.08, S × H 0.06
Cracked eggs, %	6.1	6.9	5.6	6.4	7.5	4.5	4.2	3.1	4.4	5.5	NS	**	***	–
Dirty eggs, %	7.8	7.6	8.9	9.2	5.0	5.4	5.4	4.0	7.2	5.0	NS	***	***	S × H**

L = Lövsta, M = Marielund, C = conventional battery cage.
NS: non-significant; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.
[1] For differences between the individual systems see text.

had the brightest yolk colour (L and M, 7.5; C, 7.0 points, $P < 0.05$). Compared with LSL hens, ISA hens laid eggs with lower albumen height (6.2 vs. 7.3 mm, $P < 0.01$), and also lower Haugh units (74.2 vs. 82.9, $P < 0.001$), brighter yolk colour (7.6 vs. 7.1 points, $P < 0.05$) and more blood spots (29.9 vs. 2.0%, $P < 0.001$).

Live weight and exterior appearance

The results of the scoring of exterior appearance are given in Table 3. The WHEAT diet gave inferior body plumage at both 35 w ($P < 0.01$) and 55 w ($P < 0.05$). An interaction at 35 w between hybrids and diets ($P < 0.01$) was due to LSL being highly affected by diet (BARLEY, score 22.0, and WHEAT, score 18.3) but not ISA (BARLEY, score 20.5, and WHEAT, score 20.2). A non-significant tendency remained at 55 w. Regarding bumble foot, an interaction was found between systems and diets owing to WHEAT giving higher scores in L but lower in M and similar in C compared with BARLEY ($P < 0.01$). No other significant effects of diet were registered at the scoring at 35 of 55 w.

At 35 w, hens in C had higher live weight ($P < 0.01$) better plumage condition ($P < 0.001$), cleaner feet ($P < 0.001$) but more toe pad hyperkeratosis ($P < 0.05$) than hens in the aviaries. However, an interaction between hybrids and systems regarding live weight ($P < 0.01$) was due to ISA in C being heavier than ISA in the aviaries while LSL hens were not affected by housing system. An interaction between hybrids and systems regarding plumage condition was due to ISA in M having better plumage condition than LSL, while there was no difference in the other systems ($P < 0.05$). There was more bumble foot found in M than in the other systems and more in L than in C ($P < 0.001$). The claw condition was worse in M than in the other systems ($P < 0.05$). There were less comb wounds in C than in L ($P < 0.05$). The ISA hens were heavier ($P < 0.001$), had higher score for cleanliness of plumage ($P < 0.05$), less bumble foot ($P < 0.001$), better claw condition ($P < 0.001$) and less comb wounds ($P < 0.01$) than LSL. Regarding bumble foot, an interaction was found between systems and hybrids owing to LSL being much more affected by this syndrome than ISA in the aviaries ($P < 0.001$).

At 55 w, hens in C were heavier than hens in M, which were heavier than hens in L ($P < 0.01$). However, as at 35 w, there was a significant interaction between systems and hybrids ($P < 0.05$), indicating that this concerned only ISA hens. Hens in C also had cleaner plumage than hens in M ($P < 0.05$). Hens in C had cleaner feet than hens in the aviaries while hens in L had cleaner feet than hens in M ($P < 0.001$). Bumble foot was found in the aviaries but not in C ($P < 0.001$), while toe pad hyperkeratosis was found in C but not in the aviaries ($P < 0.05$). More keel bone lesions were found in L than in M, where, in turn, more were found than in C ($P < 0.001$). C hens had less comb wounds ($P < 0.001$) and less rear body wounds ($P < 0.01$) than hens in the aviaries. ISA hens were heavier ($P < 0.001$), had higher scores for cleanliness of plumage ($P < 0.01$), less bumble foot ($P < 0.001$), shorter claws ($P < 0.001$) and less keel bone lesions ($P < 0.001$) than LSL. Regarding bumble foot and keel bone lesions, there were significant interactions between systems and hybrids owing to LSL being much more affected by these lesions in the aviaries than ISA ($P < 0.01$ for both traits).

Bird location and dust bathing

When recording the birds' locations during the day, 6 h after lights on, it was noted that often there were groups of hens standing very close together on the litter floor, often at one end of the pen or beneath one of the lamps on the first feeding tier. Although not recorded separately, much preening behaviour was observed among hens on the top resting tier. More ISA hens than LSL hens (15% vs. 9%) were on the litter floor ($P < 0.01$) but fewer were on the top resting tier (26% vs. 31%, $P < 0.001$). When comparing the systems, fewer hens in L than in M were on the feeding tier (35% vs. 47%, $P < 0.01$) but more were on the top resting tier (34% vs. 23%, $P < 0.001$). During the night, the use of perches on the top resting tier was extensive but varied considerably between pens, from 61% to 96%, with an average of 73%. In M, 10% of the hens used the platforms outside the nests for roosting while fewer than 1% in L did so ($P < 0.01$). Only 3% of the hens stayed in the nests and fewer than 1% on the litter. The proportion of hens using the feeding tiers during the night varied very much between pens, from less than 1% to 32%, with an average of 13%.

Dust bathing behaviour at 26 and 56 w was more often performed by LSL hens than by ISA hens ($P < 0.01$). The values (mean of hens simultaneously dust bathing during observation periods) for ISA in L, M and C were 2.1%, 1.6% and 1.1% respectively, while for LSL these values were 2.3%, 2.3% and 3.6%, respectively. This also implied an interaction between systems and hybrids ($P < 0.05$) due to the large difference found between the hybrids in C.

Discussion

In general the production traits were not affected very much by the proportion of wheat/barley, which is in

Table 3. Effects of diet, housing system and hybrid on live weight and on scores (1–4, except plumage 6–24) for exterior appearance. Higher scores mean better condition

	Diet		System[1]			Hybrid		Statistical significance			
	BARLEY	WHEAT	L	M	C	ISA	LSL	Diet	System	Hybrid	Interactions used in model
Age 35 w											
Live weight, g	1823	1811	1769^{b}	1804^{b}	1878^{a}	1944	1690	NS	**	***	S × H**
Body plumage, score	21.3	19.3	19.0^{b}	19.1^{b}	22.6^{a}	20.4	20.2	**	***	NS	D × S 0.09, D × H**, S × H*
Cleanliness plumage	3.85	3.83	3.83	3.79	3.91	3.97	3.71	NS	NS	*	–
Cleanliness feet	3.05	3.05	2.65^{b}	2.56^{b}	3.92^{a}	3.03	3.07	NS	***	NS	D × S 0.07, D × H 0.09
Bumble foot	3.76	3.76	3.73^{b}	3.55^{c}	4.00^{a}	3.96	3.56	NS	***	***	D × S**, S × H***
Toe pad hyperkeratosis	3.97	3.90	4.00^{a}	4.00^{a}	3.81^{b}	3.92	3.96	NS	*	NS	–
Claw condition	3.73	3.77	3.80^{a}	3.67^{b}	3.78^{a}	3.97	3.53	NS	*	***	H × D 0.08
Keel bone lesions	3.90	3.84	3.71	3.91	3.98	3.90	3.84	NS	0.07	NS	–
Comb wounds	3.63	3.61	3.45^{b}	3.61^{ab}	3.80^{a}	3.81	3.43	NS	*	**	–
Rear body wounds	3.81	3.67	3.54	3.78	3.89	3.67	3.81	NS	NS	NS	–
Age 55 w											
Live weight, g	1886	1867	1793^{c}	1879^{b}	1957^{a}	2010	1743	NS	**	***	S × H*
Body plumage, score	15.2	12.4	12.8^{b}	10.7^{b}	17.8^{a}	13.4	14.1	*	**	NS	D × H 0.1
Cleanliness plumage	3.72	3.76	3.70^{ab}	3.63^{b}	3.91^{a}	3.90	3.58	NS	*	**	–
Cleanliness feet	2.99	2.96	2.58^{b}	2.38^{c}	3.98^{c}	2.98	2.98	NS	***	NS	–
Bumble foot	3.84	3.88	3.75^{b}	3.83^{b}	4.00^{a}	3.98	3.74	NS	***	***	S × H**
Toe pad hyperkeratosis	3.93	3.89	4.00^{a}	4.00^{a}	3.72^{b}	3.94	3.87	NS	*	NS	–
Claw condition	3.61	3.71	3.79	3.53	3.66	3.97	3.35	NS	0.09	***	D × H 0.08, S × H 0.1
Keel bone lesions	3.64	3.54	3.19^{c}	3.63^{b}	3.96^{a}	3.73	3.45	0.08	***	***	S × H**
Comb wounds	3.59	3.51	3.28^{b}	3.42^{b}	3.94^{a}	3.63	3.46	NS	***	NS	–
Rear body wounds	3.58	3.54	3.49^{b}	3.22^{b}	3.96^{a}	3.48	3.63	NS	**	NS	–

L = Lövsta, M = Marielund, C = conventional battery cage.

NS: non-significant; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

[1] Regarding systems values in the same row that do not share a superscript letter are significantly different at least at the 95% level ($P < 0.05$).

accordance with Al Bustany & Elwinger (1988), Classen et al. (1988) and Petersen (1990). The only significant effect was found on feed consumption, but this in turn did not affect egg production or feed conversion ratio. Since the nutrient contents were similar in both diets, considerable differences in production were not expected. The higher feed consumption in WHEAT was probably due to differences in plumage condition and hence in heat loss (Tauson & Svensson, 1980). However, the differences found between hybrids and systems were greater. Many of the differences between the hybrids can be explained by the very high mortality, due to cannibalism, in the ISA hybrid. For brown hybrids kept in aviaries a higher mortality has earlier been reported by Abrahamsson & Tauson (1995). Mortality and cannibalism were generally lower in the cages, particularly in ISA but to a minor degree in LSL. A cage with a small number of birds obviously limits the risk of cannibalism, which can spread more easily in a large group. The mortality levels of LSL would be considered low even in the aviaries. A somewhat higher mortality in ISA compared with LSL has also been recorded in battery cages and modified cages (Abrahamsson et al., 1996).

The fact that most hens that died from cannibalism were pecked in or around the cloaca implies that this was probably not due to aggressiveness. Instead, it might possibly be a result of curiosity, where hens peck those that lay eggs on the floor. The contrast in colour between the egg shell and the red mucous membrane of the cloaca may contribute to attracting pecking. This was indicated by a rapid decrease of mislaid eggs in these groups (the values in Table 2 show only the average over the total laying period). To reduce the high mortality the light was dimmed over the feeding tiers, since most hens that died from cannibalism were found there. The possibility of stopping the experiment was also considered, but since most cases of cannibalism occurred at the beginning of the experiment, and thereafter mortality returned to a more normal level, the experiment was allowed to continue.

The recommendation to use only low proportions of wheat in layer diets (Jönsson, 1966), because of the risk of cannibalism, could not be confirmed in the present study. Instead, the diet had a significant effect on plumage condition, particularly in the LSL hybrid, while ISA was less affected. This, however, does not agree with Al Bustany & Elwinger (1988) or Petersen (1990), who were unable to show any differences in plumage in caged layers fed barley or wheat diets. Apart from those studies carried out in cages only, and the present study showing less plumage deterioration in cages generally than in aviaries, a possible explanation of the effect of wheat in the present study could be that the wheat diet was lower (10%) in fibre content. Diets containing large proportions of fibre from oat hulls have been shown to decrease cannibalism and feather pecking (Bearse et al., 1940). There might also be other factors in wheat that trigger pecking but that remain to be identified. It is unlikely that low protein or energy levels caused feather pecking in the present study since both diets had very similar levels. A poor feather coverage can decrease layers' production (Peguri & Coon, 1993), but the poor feather coverage in hens fed WHEAT in the present study was probably compensated by the increased feed intake. The larger effect of WHEAT on feather coverage in the LSL hybrid than in ISA was in accordance with the larger difference in feed intake between the diets in LSL compared with ISA. The other traits of external appearance were more affected by housing systems, for example foot and keel bone condition, and wounds caused by pecking, and this agrees with Engström & Schaller (1993), Hansen (1993) and Abrahamsson & Tauson (1995). The fact that signs of aggressiveness, especially pecking wounds on the comb, were found less in cages than in aviaries but were not affected by diet also reveals the major importance of housing system for this behaviour.

The inferior performance in aviaries compared with cages is in accordance with earlier results where similar or the same aviaries were used (Hansen, 1993; Abrahamsson & Tauson, 1995). However, the production by LSL in M should probably be considered very satisfactory, especially if such eggs fetched a better price than ordinary cage eggs. The overall hygienic properties of the aviaries, with hens having access to litter, increase the proportion of dirty eggs compared with conventional cages. However, in this sense the rubber nest linings used in L were an improvement compared with the nests in M. The proportion of cracked eggs is, in agreement with Abrahamsson & Tauson (1995), not higher in aviaries and may, as in L, even be significantly lower than in cages.

Scholtyssek et al. (1984) noticed a tendency for better interior egg quality and shell strength in eggs from caged hens than from hens kept on litter, but no such effect could be detected in the present study. The few differences between the systems were not consistent over time. Some differences appeared between the hybrids regarding yolk colour, blood spots and properties of the albumen, which are probably inherited. The fact that no differences were found between diets as regards albumen height or shell percentage agrees with Al Bustany & Elwinger (1988) and Petersen (1990). The only effect of diet was that WHEAT gave more eggs with blood spots at 72 w. However, this was the opposite of the results at 36 w and might therefore be a random effect.

During the light period of the day, the hens in the aviaries seem to have been rather well distributed

over the system. The differences in use of feeding and resting tiers between L and M illustrate the differences in available area of these systems. The reason for the platforms outside the nests in L being less used than in M for roosting during the night is probably a combination of these being positioned much lower (less attractive) than the perches of the top tier compared with those in M, the much steeper angle of the top tier perches and the greater available perch length per hen in L.

In the dust bathing study, LSL hens performed more of this behaviour than ISA hens and this confirms the results obtained in a parallel study of modified cages (Abrahamsson et al., 1995). According to Vestergaard (1982) there is a marked peak in dust bathing behaviour around mid-day. Hence, the recorded proportions of birds dust bathing are very much dependent on the time schedule of the data collection, making it hard to compare data from different studies. However, Vestergaard (1982) found that on average White Leghorn hens performed one 27 min bout of dust bathing every second day. This would result in a total average of 1.6% of dust bathing during the light period, which agrees well with the present study.

Conclusion

A very large proportion of wheat in the feed cannot be recommended for layers owing to the increased risk of feather pecking. However, differences between bird material occur. The inferior plumage condition of hens fed the diet high in wheat increased feed consumption, probably due to heat loss from the body of the birds. However, the proportion of wheat and barley had no significant effect on production, egg quality, mortality or cannibalism. These traits seem to be far more affected by housing system and hybrid.

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