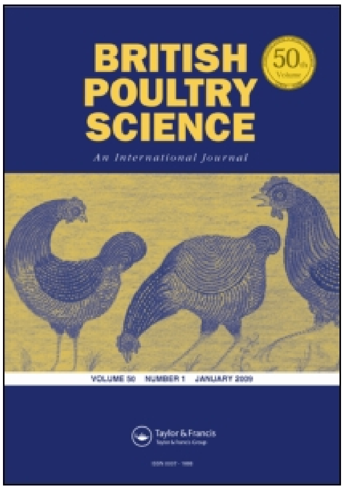


**British Poultry Science**
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713408216

# Comparison of the welfare of layer hens in 4 housing systems in the UK

C. M. Sherwin[a]; G. J. Richards[a]; C. J. Nicol[a]
[a] Animal Welfare and Behaviour Group, University of Bristol, Bristol, England

Online publication date: 30 September 2010

**To cite this Article** Sherwin, C. M. , Richards, G. J. and Nicol, C. J.(2010) 'Comparison of the welfare of layer hens in 4 housing systems in the UK', British Poultry Science, 51: 4, 488 — 499
**To link to this Article: DOI:** 10.1080/00071668.2010.502518
**URL:** http://dx.doi.org/10.1080/00071668.2010.502518

*British Poultry Science* Volume 51, Number 4 (August 2010), pp. 488–499

Taylor & Francis
Taylor & Francis Group

# Comparison of the welfare of layer hens in 4 housing systems in the UK

C.M. SHERWIN, G.J. RICHARDS AND C.J. NICOL

*Animal Welfare and Behaviour Group, University of Bristol, Bristol, England*



**Abstract** 1. The welfare of hens in 26 flocks (6 conventional cage, 6 furnished cage, 7 barn, 7 free-range) was assessed throughout the laying period using a combination of data on physical health, physiology and injurious pecking, collected by researchers on farm and during post-mortem analysis, and information submitted by producers.

2. There was an effect of housing system on 5 of the indicators recorded by researchers: gentle feather pecks given, feather damage score, proportion of hens with feather damage, proportion of the flock using perches, and faecal corticosterone.

3. Post-mortem analysis revealed several differences between housing systems in skin damage, plumage damage to the vent and abdomen, keel protrusion, bodyweight, and the proportion of hens that were vent pecked and that had old and recent keel fractures.

4. There was an effect of housing system on 5 indicators recorded by producers: proportion of egg shells with calcification spots, proportion of egg shells with blood stains, weight of hens found dead, temporal change in the proportion of egg shells with stains, and temporal change in proportion of hens found dead.

5. Each housing system had positive and negative aspects but overall, hens in barn systems had the highest prevalence of poor plumage condition, old fractures, emaciation, abnormal egg calcification, and the highest corticosterone. Hens in conventional cages sustained more fractures at depopulation than birds in other systems. Vent pecking was most prevalent in free-range flocks. The lowest prevalence of problems occurred in hens in furnished cages.

6. Although housing system had an influence on the hens' physical condition and physiological state, the high prevalence of emaciation, loss of plumage, fractures and evidence of stress is of concern across all housing systems, and suggests that the welfare of modern genotypes is poor.

## INTRODUCTION

The conditions under which layer hens are housed remain a major animal welfare issue for consumers, the egg production industry and legislators. Directive 1999/74/EC sets out minimum standards for the protection of layer hens in the EU. (European Commission, 1999). Thus, all conventional cages must now provide a minimum of 550 $cm^2$ per hen and be fitted with suitable claw shorteners. By 2012, conventional cages will no longer be permitted in the EU and hens will be housed in furnished cages providing nest boxes, perches, a pecking and scratching area and 750 $cm^2$ space per hen, or in alternative housing systems, such as barn and free-range. Some member states of the EU have unilaterally banned the use of furnished cages, but the UK position is that there is currently a lack of definitive evidence available to support a unilateral ban. Although there is increasing information about the welfare of hens housed in furnished cages (Jendral *et al.*, 2008; Rodenburg *et al.*, 2008; Barnett *et al.*, 2009; Tactacan *et al.*, 2009) the number of studies that have examined welfare under truly commercial conditions is limited. In the UK, approximately 33 million hens are kept for egg production and, despite

Correspondence to: Dr C.M. Sherwin, Animal Welfare and Behaviour Group, Department of Clinical Veterinary Science, University of Bristol, Dolberry Building, Langford, Bristol BS40 5DU, UK. E-mail: Chris.sherwin@bristol.ac.uk

Accepted for publication 22nd January 2010.

ISSN 0007–1668(print)/ISSN 1466–1799 (online)/10/040488–12 
DOI: 10.1080/00071668.2010.502518

recent increases in the proportion of the UK flock housed under free-range conditions, there has been little change in the number housed in barn systems and the majority of hens are still housed intensively in conventional cages. There is clearly a need to inform the debate regarding the welfare of layer hens in different housing systems.

Objectively comparing the welfare of animals housed in different systems is a difficult task (Rodenburg *et al.*, 2008). The concept of the Five Freedoms (Webster, 2001) has been highly influential and has served well to focus attention on the fact that animal welfare must embrace *all* aspects of the condition of life for animals. Housing systems that ignore any of the Five Freedoms will continue to be criticised and efforts must be made to improve any area where standards fall short. However, different housing systems are likely to have different strengths and weaknesses, and the welfare consequences of falling short of the ideal may not be equal across systems. It may never be possible to provide an ideal system because increasing the opportunities for behavioural freedom (for example) may unavoidably increase the risk of transmission of certain diseases, or the risk of injury. This imperfect, but realistic, scenario suggests that the costs and benefits of each housing system need to be carefully assessed, using measures which are directly comparable between husbandry systems. A balanced conclusion can then be drawn about which system maximises overall welfare, or which systems might compromise welfare.

This paper describes a study on the welfare of layer hens in a range of 4 housing systems currently used in the UK. This was achieved by assessing the condition of the hens at the beginning, middle and end of the laying period, post-mortem analysis of 150 hens from each flock, a full objective description of each housing system, management and environment, and weekly feedback questionnaires from the producers. The methods of assessing welfare were the same across all 4 housing systems which, to the best of our knowledge, has not been attempted previously other than using mortality as an indicator of welfare (EFSA, 2005; Blokhuis *et al.*, 2007).

## MATERIALS AND METHODS

All questionnaires, forms, appendices and photographic scales have been placed in Supplementary Information on the Journal website (http://www.informaworld.com/smpp/title~content=t713408216~db=all~tab=issueslist~branches=40–v40).

### Flock recruitment

Producers were written to explaining the aims and purpose of the study, and what would be requested from them. This was followed with a phone call approximately one week later. In addition, an advertisement was placed in "The Ranger" (a newsletter for free-range egg producers) requesting interested independent producers to enrol in the study. The study was conducted on 26 flocks of a range of sizes and strains housed on 15 commercial layer units across the UK (Tables 1 and 2). Flocks entered the study at between 16 to 20 weeks of age, and stayed within the study for a mean of 49 weeks (47 weeks for Barn (B) and Conventional Cage (CC) systems, 50 weeks for Free Range (FR), and 53 weeks for Furnished Cages (FC)). The term Barn is widely used in the UK but this system can also be termed an indoor single-tier aviary (www.laywel.eu).

### Data collected by researchers

Each flock was visited three times during the laying period, at approximately one week after placement, 30 and 70 weeks of age. During Visit 1 only, researchers completed a Background questionnaire regarding the history of the hens prior to placement, and the housing and husbandry was characterised in detail by completing a Housing questionnaire. On Visits 1, 2 and 3, the researchers also completed a Current Husbandry, Environment, Welfare and Health questionnaire of a further 120 questions.

On all three visits, behavioural observations, a health check, assessment of fear, and faecal samples were collected as welfare indicators. Behavioural observations focussed on the occurrence of any injurious behaviours and vocalisations indicative of frustration. The observations comprised continuous sampling for 1 min on each of 30 focal hens randomly selected from all areas of the house and range. For free-range flocks, 15 hens were observed indoors and 15 hens outdoors. All behavioural observations began after 12:00 h to reduce nesting and laying behaviours biasing the data. The frequency of "gakel" calls (frustration vocalisations), gentle feather pecks (received or given), aggressive pecks (received or given), severe feather pecks (received or given) and cannibalistic pecks (received or given) were recorded. The health of each focal hen was assessed without handling the hen, by recording data on feather and skin damage on 10 areas of the body, and other indicators of general health (such as posture, abnormal scratching). Damage was scored on a 4-point scale from 0 being "no damage" to 3 being "very much damage". Also on each visit,

**Table 1.** *Summary information of the flocks in the study*

| Housing system | Post-mortem | Strain | Rearing system | Beak trimmed | Time in study (weeks of age) |
|---|---|---|---|---|---|
| CC | Yes | Lohmann | Litter | Yes | 20–68 |
| CC | Yes | Lohmann | Cage | Yes | 19–70 |
| CC | No | Hisex | Litter | Yes | 17–70 |
| CC | No | Hyline + Lohmann | Litter | Yes | 16–39 |
| CC | No | Lohmann | Litter | Yes | 16–68 |
| CC | Yes | Lohmann | Litter | Yes | 16–72 |
| FC | Yes | Hyline | Litter | Yes | 18–71 |
| FC | Yes | Hyline | Litter | Yes | 18–71 |
| FC | Yes | Hyline | Litter | Yes | 18–71 |
| FC | Yes | Bovan Goldline | Litter | Yes | 20–79 |
| FC | Yes | Hyline | Litter | Yes | 20–72 |
| FC | Yes | Isa Brown | Litter | Yes | 16–64 |
| B | Yes | Hyline | Litter | Yes | 19–69 |
| B | No | Hyline | Litter | Yes | 17–57 |
| B | Yes | Hyline | Litter | Yes | 19–69 |
| B | Yes | Hyline | Litter | Yes | 19–73 |
| B | Yes | Hyline | Litter | Yes | 19–73 |
| B | Yes | Hyline | Litter | Yes | 19–61 |
| B | Yes | Hyline | Litter | Yes | 19–61 |
| FR (mobile) | No | Hyline | Litter | No | 18–66 |
| FR (mobile) | Yes | Lohmann | Litter | No | 17–72 |
| FR (static) | No | Hyline + Lohmann | Litter | Yes | 17–56 |
| FR (static) | Yes | Hyline | Litter | Yes | 17–71 |
| FR (static) | No | Lohmann | Litter | Yes | 17–66 |
| FR (static) | Yes | Hyline | Litter | Yes | 18–70 |
| FR (static) | Yes | Hyline | Litter | Yes | 17–71 |

**Table 2.** *Summary information of the housing systems in the study*

| System | Shed size ($m^2$) | | Flock size | | Stocking density | | Age of system (years) | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| CC | 2490 | 1279–4514 | 76,462 | 39,760–107,581 | 5·0/cage | 5·0–5·0 | 11·9 | 7·0–18·0 |
| FC | 770 | 508–1292 | 19,524 | 1056–45,450 | 48·3/cage | 8·0–60·0 | 2·9 | 1·0–6·0 |
| B | 1078 | 373–1363 | 11,392 | 5740–15,000 | 10·86/$m^2$ | 7·9–11·7 | 13·4 | 6·0–16·0 |
| FR | 701 | 164–1226 | 7120 | 2000–13,248 | 9·72/$m^2$ | 6·0–11·7 | 5·9 | 1·0–15·0 |



between 6 and 10 fresh, uncontaminated faecal samples were collected. For cage systems, samples were collected from each tier, and for free-range flocks, 4 samples were collected from inside and four from outside the house. Faecal samples were freeze-dried, ground and sieved, weighed, added to a methanol mix (90% methanol, 10% distilled water), vortexed and then centrifuged at $750 \times g$ for 30 min. The extracted supernatant samples were analysed for corticosterone content using an ImmuChem™double antibody corticosterone 125RIA kit.

*Climate variables*

To collect long-term climate data, "Hobo" data loggers (Tempcon Instruments) were placed in a site representative of conditions experienced by the hens. These were programmed to record air temperature and relative humidity at 1 h intervals. Data loggers were installed during Visit 1 and replaced by a second logger at Visit 2 which ensured climate data were collected for the duration of the laying period. Data were downloaded from the loggers using the Greenline™ software. Also on each visit, the researchers recorded the ammonia concentration (Draeger tubes) at various sites representative of the conditions experienced by the hens.

*Post-mortem examination*

At the end of the laying period, 150 hens from each flock underwent post-mortem examination. After the hens had been commercially culled by gas, they were immediately chilled (4°C) and examined the following day by a team of 5 trained staff. The hens were weighed, numbered, and their feet washed for examination. They were assessed for beak deformities, skin damage,

**Figure 1.** *Examples of the photographic scales used to standardise post-mortem scoring.*



parasites, plumage damage, plumage soiling, vent damage (not from pecking), evidence of vent pecking, foot condition (including bumble-foot), keel protrusion, keel deformation, and fractured keels. Damage was scored on a 4-point scale with 0 being "no damage" to 3 being "very much damage", and breaks were classified as recent (no evidence of healing) or old (some evidence of healing). Photographic scales were prepared and used to standardise scores; examples are given in Figure 1.

### Data collected by producers

During Visit 1, the producers were asked to complete and return each week a Weekly Welfare Assessment form. This contained questions on a range of welfare indicators such as mortality, the prevalence of red-mites, the number of hens performing injurious pecking, and also changes in husbandry. The producers were asked to examine a maximum of 10 hens found each week and provide information on a range of welfare indicators and possible causes of death. They were provided with full verbal and written instructions on how to complete the forms and a set of photographic scales for standardising scores of variables such as feather damage. Under conditions of stress, hens sometimes delay laying eggs which results in additional calcium carbonate being deposited on the egg shell or egg shell deformations (Hughes *et al.*, 1986; Mills *et al.*, 1987; Reynard and Savory, 1999). In addition, if the hen's vent prolapses or is torn due to laying an overly large egg, this can sometimes result in blood stains being visible on the shells. Therefore, the producers were also asked to examine 100 eggs, prior to grading, and record the number of egg shells with calcification spots or rings, or, blood stains. A written description of the appearance of calcification spots was given on the form, and this was also discussed with the producer on the first visit. In addition, the producers were asked to complete at 30, 50 and 70 weeks of age, a more detailed assessment of possible causes of mortality. Data were validated by cross-checking with information given previously by the producer and other flocks of the same system with hens of the same age. Any possible inconsistencies, for example, prevalence of red-mites being recorded as high one week and low the next but with no indication of a treatment being given, were checked by telephoning the producer and requesting clarification.

### Statistical methods

Average scores for feather damage to the head, neck (front), neck (back), breast, back, wings, tail-tip, tail-base, top of the legs, and, vent/abdomen were all recorded. These were highly significantly correlated ($N = 75$, $P < 0{\cdot}001$, Kendall's Tau b), therefore a mean feather damage score was calculated for entering into the repeated measures ANOVA. Similarly, the proportion of focal hens with feather damage to the head, neck (front), neck (back), breast, back, wings, tail-tip, tail-base, top of the legs, and, vent/abdomen were all recorded. These were also highly significantly correlated ($N = 75$, $P < 0{\cdot}001$, Pearson's correlation), therefore a mean proportion of the flock with feather damage was calculated for entering into the repeated measures ANOVA. Data for CC were omitted from some analyses as none of these flocks had perches.

The data on welfare indicators collected on each of the three visits by researchers were analysed by repeated measures ANOVA with housing type as the between-subjects variable, and mean flock value of the welfare indicator for the visit as the within-subjects variable.

For each flock, means of the climate data over the laying period were calculated and these flock-means used to test for differences between housing systems by ANOVA.

For the post-mortem analysis, a flock-mean was calculated for each of the welfare indicators assessed during post-mortem and these flock-means analysed by non-parametric Kruskal–Wallis test where the data were measured on an ordinal scale, or by ANOVA where the data were measured on a ratio scale

Data from the producers were provided on a weekly basis, however, it would be pseudo-replication to analyse these weekly data-points as statistically independent units. Moreover, Kolmogorov–Smirnov tests indicated that the raw data of all the producer-collected welfare indicators were non-normally distributed. Therefore, a flock-mean representing the welfare indicator over the duration of the laying period was calculated for each flock, and a Kruskal–Wallis analysis conducted on these means testing for differences between housing systems. The change in some of the welfare indicators with age was also of interest. Therefore, regression coefficients were calculated for each flock. These were not normally distributed, therefore they were entered into a non-parametric Kruskal–Wallis analysis to test for differences between housing systems.

We also examined temporal effects in the data submitted by producers. The data were considered as 6 periods (16–25, 26–35, 36–45, 46–55, 56–65 and 66–72 weeks of age). For each flock, a mean representing each period was calculated for each welfare indicator. These data met the assumptions required for parametric analysis of non-transformed data, and a repeated measures ANOVA was conducted on these means with housing type as the between-subjects variable, and the mean value of the welfare indicator for the time-period as the within-subjects variable. For each housing system, the data were also tested to determine whether temporal changes in welfare indicators were best approximated by a linear or quadratic relationship using the curve estimation function in SPSS. This was done using each flock's raw data for each period, thus for most weeks there were 7 data-points each for FR and B (one for each flock), and 6 data-points each for CC and FC (again, one for each flock).

# RESULTS

## Data collected by researchers

There were significant differences between housing systems in 5 of the welfare indicators collected by the researchers (Table 3). The rate of gentle feather pecks given was highest in the FR hens, however, these hens had the lowest feather damage score and the lowest proportion of the flock with feather damage. Although not statistically significant, the prevalence of severe feather pecks received was numerically greatest in B hens ($1{\cdot}3 \pm 0{\cdot}4$, $0{\cdot}6 \pm 0{\cdot}4$, $0{\cdot}5 \pm 0{\cdot}4$ and $0{\cdot}2 \pm 0{\cdot}4$ pecks/hen for B, FC, FR and CC, respectively) which corresponds with B hens also having the highest feather damage score and greatest prevalence of hens with feather damage. B hens also had the greatest faecal corticosterone concentrations – almost twice those of the lowest concentration found in FC hens. Hens from FC had the second lowest frequency of gentle feather pecking given and feather damage score, used the perches the most, and had the lowest faecal corticosterone.

### *Climate variables*

The housing systems differed significantly in several of the climate variables (Table 4).

CC had the highest and B the lowest mean air temperature. There was no significant difference between housing systems in the maximum or minimum air temperatures although B had the highest (equal with FC) recorded maximum air temperature, lowest recorded minimum temperature and the greatest ranges of maximum, minimum and mean temperature.

FC had the greatest maximum relative humidity and B had the greatest mean relative humidity. The ranges of values show that highest recorded max and mean relative humidity were both in the FC. CC had the lowest maximum and mean relative humidity.

B had the greatest maximum, minimum and mean ammonia concentrations, and was equal with FR for the greatest range in maximum concentration. FC had the lowest maximum and mean ammonia concentrations, and also the smallest ranges of both these measures.

### *Post-mortem examinations*

Table 5 presents the results of the post-mortem variables scored on ordinal scales. There were significant differences between systems in skin damage, vent/abdomen plumage damage and keel protrusion. Skin damage and keel protrusion were worst in FR hens, with vent and abdomen plumage damage worst in B hens.

**Table 3.** *Mean (±SEM) scores for welfare indicators recorded by researchers*

| System | Gentle feather pecks given (pecks/hen/min) | Feather damage score[1] | Proportion flock with feather damage[2] (%) | Perch use[3] (% flock) | Faecal corticosterone (ng/g dry matter) | Body weight (kg) | Hens that had been vent pecked (%) | Hens with old keel fractures (%) | Hens with recent keel fractures (%) | Egg shells with calcification spots (%) | Egg shells with blood stains (%) | Weight of hens found dead (kg) | Temporal change in egg shells with blood stains (regression coefficient) | Temporal change in proportion of hens found dead (regression coefficient × $10^{-4}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CC | $0·01^{a}$ (0·09) | $0·5^{b}$ (0·1) | $24·7^{b}$ (2·3) | n/a | $14·0^{b}$ (2·4) | $1·95^{ab}$ (0·05) | $6·2^{b}$ (5·6) | $17·7^{a}$ (6·1) | $24·6^{a}$ (3·8) | 3·5 (4·0) | 1·0 (1·6) | 1·87 (0·13) | 0·13 (0·30) | 0·30 (0·27) |
| FC | $0·06^{a}$ (0·08) | $0·5^{b}$ (0·1) | $24·9^{b}$ (2·1) | $26·6^{a}$ (0·9) | $10·7^{b}$ (2·4) | $1·80^{cd}$ (0·04) | $1·6^{b}$ (4·0) | $31·7^{a}$ (4·3) | $3·6^{b}$ (2·7) | 1·2 (1·3) | 0·8 (0·5) | 1·58 (0·17) | 0·05 (0·04) | 0·26 (0·08) |
| B | $0·16^{ab}$ (0·08) | $0·5^{b}$ (0·1) | $26·9^{b}$ (2·1) | $2·1^{b}$ (0·8) | $21·8^{a}$ (2·6) | $1·72^{d}$ (0·04) | $10·0^{ab}$ (4·0) | $69·1^{b}$ (4·3) | $1·2^{b}$ (2·7) | 4·1 (1·9) | 2·1 (0·6) | 1·66 (0·12) | 0·19 (0·11) | 1·03 (0·49) |
| FR | $0·38^{b}$ (0·08) | $0·3^{a}$ (0·1) | $15·5^{a}$ (2·1) | $2·5^{b}$ (0·8) | $15·6^{ab}$ (2·2) | $1·86^{abc}$ (0·05) | $22·5^{ab}$ (4·9) | $59·8^{b}$ (6·1) | $1·3^{b}$ (3·8) | 1·7 (1·2) | 1·4 (1·4) | 1·77 (0·12) | –0·02 (0·08) | 0·48 (0·30) |
| Housing | $P=0·045$ | $P=0·005$ | $P=0·006$ | $P<0·001$ | $P=0·047$ | $P=0·019$ | $P=0·03$ | $P<0·001$ | $P<0·001$ | $P=0·029$ | $P=0·038$ | $P=0·008$ | $P<0·02$ | $\chi^2_3=12·1$ |
| | $F_{3,19}=3·2$ | $F_{3,19}=5·9$ | $F_{3,19}=5·7$ | $F_{2,15}=269·7$ | $F_{3,16}=3·31$ | $F_{3,18}=4·5$ | $F_{3,18}=3·83$ | $F_{3,18}=22·0$ | $F_{3,18}=9·64$ | $\chi^2_3=9·05$ | $\chi^2_3=8·43$ | $\chi^2_3=11·7$ | $\chi^2{}_3=9·87$ | $P=0·007$ |
| Visits | $P=0·54$ | $P<0·001$ | $P<0·001$ | $P=0·36$ | $P=0·38$ | | | | | | | | | |
| | NS | $F_{2,38}=267·4$ | $F_{2,38}=254·6$ | NS | NS | | | | | | | | | |

Means within columns with different superscripts differ significantly ($P<0·05$).

**Table 4.** *Mean and range of climate variables recorded by researchers*

| System | Max | | Min | | Mean | |
|---|---|---|---|---|---|---|
| | Mean | Range | Mean | Range | Mean | Range |
| | | | Temperature (°C) | | | |
| CC | 31·8 | 26·3–34·5 | 10·3 | 3·1–14·5 | 20·5 | 18·2–22·5 |
| FC | 33·5 | 24·3–38·2 | 6·8 | 3·9–9·2 | 17·0 | 15·2–18·5 |
| B | 33·4 | 22·4–38·2 | 6·0 | −2·6–14·4 | 16·1 | 12·9–19·4 |
| FR | 32·3 | 30·7–35·3 | 4·9 | 1·1–10·9 | 16·5 | 14·1–19·9 |
| | | | | | $P<0{\cdot}001$ | |
| | NS | | NS | | $F_{3,24}=7{\cdot}4$ | |
| | | | Relative humidity (%) | | | |
| CC | 81·8 | 71·5–85·7 | 33·8 | 22·0–39·0 | 60·7 | 53·6–66·6 |
| FC | 90·9 | 82·1–98·9 | 32·2 | 23·8–42·2 | 67·1 | 58·8–75·4 |
| B | 90·2 | 82·9–96·3 | 32·6 | 13·4–48·6 | 71·5 | 68·6–73·1 |
| FR | 86·9 | 76·1–94·6 | 33·9 | 28·4–43·2 | 66·2 | 50·4–70·1 |
| | $P=0{\cdot}044$ | | | | $P=0{\cdot}031$ | |
| | $F_{3,24}=3{\cdot}2$ | | NS | | $F_{3,24}=3{\cdot}6$ | |
| | | | Ammonia (ppm) | | | |
| CC | 8·16 | 4·0–12·0 | 2·08 | 1·0–4·0 | 4·79 | 2·5–8·6 |
| FC | 3·16 | 1·0–5·0 | 0·33 | 0·0–1·0 | 1·41 | 0·3–3·0 |
| B | 16·85 | 10·0–25·0 | 2·14 | 0·0–4·0 | 8·94 | 5·5–9·8 |
| FR | 9·42 | 5·0–20·0 | 1·71 | 0·0–5·0 | 5·08 | 2·3–9·0 |
| | $P<0{\cdot}01$ | | | | $P<0{\cdot}001$ | |
| | $F_{3,25}=8{\cdot}9$ | | NS | | $F_{3,24}=10{\cdot}1$ | |

Differences between housing systems were tested by ANOVA.



The post-mortem variables scored on ratio scales are presented in Table 3. There were significant differences between systems in bodyweight, % of hens vent pecked, hens with old keel fractures and hens with recent keel fractures.

## Data collected by producers

Overall, 6·8% of hens placed at the start of lay were found dead or were culled. There was a significant effect of housing system on the proportion of hens placed found dead when the data were pooled for 6 time periods (see Statistical methods) and analysed by repeated measures ANOVA ($F_{3,16}=5{\cdot}2$; $P=0{\cdot}011$) (see Figure 2). Overall, all the 4 housing systems showed an increase in mortality rate with age, that is, in the proportion of hens placed found dead (Figure 2).

There were significant differences between housing systems in the proportion of egg shells with calcification spots, the proportion of egg shells with blood stains, the weight of hens found dead (Table 3) and the proportion of hens with red-mite ($F_{3,12}=4{\cdot}00$; $P=0{\cdot}034$: Figure 3).

The following welfare indicators had a strongly significant relationship with time. They all increased with age and showed a similar relationship in all housing systems, unless stated otherwise; the proportion of egg shells with calcification spots, proportion of egg shells with blood stains, and the proportion of hens culled and found dead (due to injurious pecking or unclear causes), the proportion of hens with red mite, and, the severity of red mite. There were 4 exceptions to this: (1) for FC hens the proportion of egg shells with calcification spots decreased linearly with age, but for the other three systems there were "U" type relationships, (2) the proportion of egg shells with blood stains did not change with time in FR hens, but it increased linearly in the other systems, (3) the proportion of FC hens culled did not change with time, but increased linearly with age in the other three systems, and (4) the proportion of FC hens that died due to injurious pecking showed a shallow curvilinear inverted "U" relationship with age, but increased linearly for all the other three systems.

# DISCUSSION

## General

Despite studying relatively small numbers of flocks with a slightly different breed profile represented in each housing type, significant differences between systems were detected. It is possible that other confounding factors in the data existed, such as rearing or the frequency of contact with humans, but the systems that were studied are typical of modern commercial practice. For the purposes of our discussion, we recognise that we cannot separate the influence of genetics, the environment and any of their

**Table 5.** *Median values of post-mortem welfare indicators recorded by researchers*

| Housing System | Skin damage | Plumage damage | | | | | Severity of vent damage | Other vent damage (prolapse) | Footpad dermatitis | Keel protrusion | Beak deformity | Plumage soiling |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Neck | Back | Wings | Tail | Vent and abdomen | | | | | | |
| CC | 0·59 | 2·00 | 1·80 | 2·11 | 1·67 | 1·96 | 0·05 | 1·41 | 1·91 | 0·91 | 0·12 | 1·11 |
| FC | 1·05 | 1·94 | 2·40 | 1·93 | 1·84 | 2·19 | 0·01 | 1·81 | 1·55 | 1·00 | 0·11 | 0·80 |
| B | 1·31 | 2·26 | 2·73 | 1·89 | 1·93 | 2·55 | 0·10 | 1·38 | 1·37 | 1·12 | 0·09 | 0·90 |
| FR | 1·68 | 1·64 | 2·73 | 1·44 | 1·79 | 2·15 | 0·29 | 1·70 | 2·17 | 1·21 | 0·09 | 0·89 |
| | $\chi^2 = 8{\cdot}29$ $P < 0{\cdot}05$ | NS | NS | NS | NS | $\chi^2 = 8{\cdot}43$ $P < 0{\cdot}05$ | NS | NS | NS | $\chi^2 = 8{\cdot}80$ $P < 0{\cdot}05$ | NS | NS |

Differences between housing systems were tested by Kruskal–Wallis.

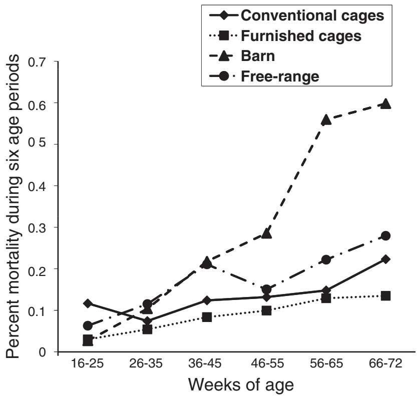


**Figure 2.** *The proportion of hens placed found dead throughout the laying phase in 4 different housing systems, as reported by producers in weekly questionnaires.*

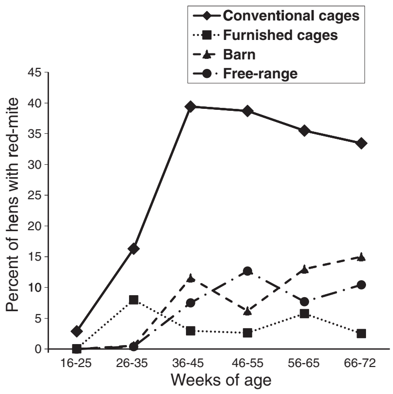


**Figure 3.** *The percent of hens with red-mite throughout the laying phase in 4 different housing systems, as reported by producers in weekly questionnaires.*

interactions, nonetheless, we draw conclusions about housing systems acknowledging that some systems use particular breeds and particular husbandry. Thus, the combined genetics and environment are inherent characteristics of each system. Table 1 shows that only one conventional cage flock was reared in cages, and that breeds were relatively well distributed across the different housing systems. Few previous studies have compared the welfare of hens in more than two housing systems; most have compared either one intensive and one extensive system, or variations (for example in stocking density) within one system. Furthermore, to the best of our knowledge, this is the first study to use the same broad range of welfare measures at the same stages of the laying phase across different flocks in different systems. These welfare measures were chosen to be valid and fair, but they were not comprehensive. In particular we did not assess the full behavioural repertoire of the birds. It is already known that important behaviours are severely constrained or prevented in conventional cage systems, and limited in some aspects in furnished cages (Weeks and Nicol, 2006).

## Novel indicators

We used several welfare indicators in this study that have not been used previously to look at the effects of housing on layer hens in commercial conditions. We asked producers to report the proportion of egg shells with calcification spots or "dusting". Under conditions of stress, hens will delay laying eggs which results in additional calcium carbonate being deposited on the egg shell or deformed shells (Hughes *et al.,* 1986; Mills *et al.,* 1987; Reynard and Savory, 1999). This method was successful in that it indicated differences between systems consistent with other welfare indicators. Thus, the B hens, which had the highest corticosterone and the highest prevalence of emaciation, keel fractures, and plumage loss (see below), also had the most egg shells with calcification spots, almost 4 times as many as for hens in FC (Table 3). Notably, calcification spots for the FC hens decreased linearly but in the other systems followed a "U" shaped response during the laying phase. This latter response indicates that earlier and later phases of the laying period were perhaps most stressful for layer hens housed in CC, FR and B – the systems that are currently the most widely used. We also asked producers to record the number of egg shells with blood stains. Blood stains might be found on egg shells for a number of reasons including the eggs being too large for the cloaca, prolapse, disease or vent pecking, all of which indicate either a direct or an indirect reduction in welfare due to an increased potential for further disease or infection. Again this measure was consistent with other measures of welfare in that B hens had both the greatest proportion of egg shells with blood stains (Table 3), and showed the greatest increase in prevalence of this problem with age. Asking producers to record calcification spots or blood stains on egg shells may be reliable, non-invasive, practicable, on-farm measures which both producers and researchers can use to monitor welfare.

Another welfare indicator that has not been used previously to compare the effects of different housing systems on commercial layer hens within the same study is faecal corticosterone concentrations. Nicol *et al.* (2006) used this method to examine stress levels in laying hens housed at different stocking densities within commercial barn systems, reporting a mean concentration of 28 ng/g dry matter. This value is approximately twice that of CC, FC and F hens reported in this present study (Table 3) but is similar (just 25% higher) to the B hens in the current study. Concern about the high levels of stress in birds in indoor single-tier aviary systems was raised by Nicol *et al.* (2006) and our results suggest that this issue has not yet been resolved. Plasma corticosterone has been used previously as an indicator of housing effects on welfare (Pavlik *et al.,* 2008; Barnett *et al.,* 2009; Tacatan *et al.,* 2009) although these studies failed to find significant differences between housing systems; possibly, due to the rapid response of the adrenal system, corticosterone collected in this manner might indicate the birds' response to handling and capture, rather than to housing per se. Other possible methods of integrated non-invasive corticosterone assessment are measuring quantities within the egg (Royo *et al.,* 2008; Barnett *et al.,* 2009) or feathers (Bortolloti *et al.,* 2008) although these have yet to be used on commercial flocks of layer hens.

## Plumage damage and injurious pecking

There were significant differences in the feather pecking activity of hens in the different housing systems. The rate of gentle feather pecks given was highest in the FR hens, however, these hens had the lowest feather damage score and the lowest proportion of the flock with feather damage (Table 3). This lack of correlation between feather-pecking activity and feather loss has been reported previously (Bilcik and Keeling, 1999), and reflects the probability that it is severe feather pecking, not gentle feather pecking, that results in damage. The prevalence of severe feather pecks received was numerically greatest in B hens, which corresponds with B hens also having the highest feather damage score and greatest prevalence of hens with feather damage (Table 3). Both the mean feather damage score and the proportion of the flock with feather damage increased over the duration of the study. This is not particularly surprising as both abrasion and feather pecking are likely to increase during the laying period, rather than decrease. The proportion of hens that were vent pecked was twice as great in the FR system compared with the other three housing systems, perhaps reflecting a greater freedom of movement to perform this behaviour, or the possibility that the perch positions provided an optimum exposure of the vent for this behaviour to occur. It has recently been found that allowing access to the range immediately prior to onset of lay increases the risk of vent pecking (Lambton *et al.,* 2009). In summary, both the proportion of hens with plumage and vent damage differed between housing systems, but were prevalent at a high incidence in all four systems by the end of the laying period.

## Keel bone fractures

In the present study, 55·7% of all the hens experienced a fracture, of which 84·8% were old fractures, that is, 47% of all hens experienced a keel break during their laying period – this lies at the lower end of the range reported by Wilkins *et al*. (2004) reflecting the slightly lower risk in cage systems. Recent keel bone fractures were nearly 5 times more common in CC hens than hens from other systems (Table 3) although this problem was particularly high in one flock of this system. These fractures were almost certainly caused by the keels being broken during depopulation, handling and transport, exacerbated by osteoporosis due to low mobility in this housing system. The high incidence of bone breakages during depopulation of hens from intensive cage systems was first revealed by Fleming *et al.* (1994) but the present paper indicates that recent breakages remain a welfare problem which can perhaps be best addressed by suitable training of catching teams.

In previous work the prevalence of old fractures in the keel and furculum has been assessed as between 50 and 78% in non-cage systems (Wilkins *et al.,* 2004) with no difference between barn and free-range hens, and at 60% in a study of 36 barn flocks (Nicol *et al.,* 2006). The type of housing system had a great effect on the prevalence of old keel bone fractures, with the value in the worst system (B) being almost twice that of the cage systems. However, even in the very confined conditions of a conventional cage, old keel fractures occurred at rates that raise welfare concerns and suggest that current layer hen genotypes are not sufficiently robust to withstand production demands (Table 3).

## Body condition

Bodyweight and keel protrusion are indicators of possible emaciation. B hens were the lightest at post-mortem (Table 3) and had the greatest prevalence of severe keel protrusion. However, the greatest proportion of hens with some degree of keel protrusion was recorded in the FR flocks (Table 4). Hens from CC were the heaviest at post-mortem and also had lowest prevalence of severe keel protrusion, however, it was noted on many occasions that hens (not only from CC) had central fat deposits visibly larger than we expected. In chickens, physiological stress can cause lipid accumulation in the liver (Puvadolpirod and Thaxton, 2000), and more generally, chronic elevation of glucocorticoid hormones can result in a redistribution of fat reserves, with increased central fat accumulation (Macfarlane *et al.,* 2008) leading us to speculate on a possible relationship between housing system, stress and fat deposition. The type of housing system had large effects on emaciation (Table 5), but all 4 housing systems produced hens that had protruding keel bones and were underweight (except for CC) compared to breed standards published on the internet (Hisex, 2·0 kg; Bovan Brown, 2·0 kg; Lohmann Brown, 1·9-2·1 kg; Hyline, 1·94 kg; ISA Brown, 2·0 kg)

## Mortality

Mortality rates in layer flocks have previously been reported as between 2·9 and 9·0% in furnished cages (Appleby *et al.,* 2002), 6·9% in a survey of 25 free-range farms (Whay *et al.,* 2007), and between 6 and 7% in conventional cages and furnished cages (EFSA, 2005). However, higher values have been reported such as between 5 and 20% mortality in barns (Nicol *et al.*, 2006) and 8·3% for conventional cages, 7·1 to 15·5% for furnished cages (a figure possibly elevated by including data from countries that have adopted furnished cages also practicing less beak trimming than the UK) and 11·8% for non-cage systems (Blokhuis *et al.*, 2007). These indicate that mortality in the present study was lower than previously reported, possibly because the willing participants in this study may have been particularly good producers, or because UK husbandry standards are improving. The slopes for the increased rates of mortality with age were small, indicating the proportions did not increase rapidly, but they do indicate that welfare for the hens progressively decreased throughout the laying phase. The greatest increase in mortality with age was found for the B hens (Figure 2, Table 3), which was almost 4 times greater (steeper) than the lowest value recorded from the FC hens. It is again noted that although there were significant differences in mortality between housing systems, with the exception of the FC system, mortality was prevalent at rates above those published in breed standards.

## Overall

The major aim of this study was to collect data to allow a balanced conclusion to be drawn about which housing systems maximise or compromise overall welfare for layer hens. It is clear from this study that all 4 systems offer both positive and negative welfare aspects for layer hens: the non-free range systems offer increased protection from predators, but also a reduced opportunity for extensive locomotion. Combining indicators to draw overall conclusions about welfare is an exercise fraught with difficulty (Rodenburg *et al.*, 2008) but, in this case, however the assessment was conducted (whether it included all welfare indicators irrespective of a difference between housing systems, only those indicators that differed significantly between housing systems, grouping related non-independent welfare indicators to provide just one input, or only the indicators with the greatest potential impact on welfare) the same conclusion emerged. The welfare of the birds in the FC system was better than that of birds in the other systems. FC hens had the lowest faecal corticosterone, fewest hens with overall (old or recent) keel fractures, fewest hens with vents pecked, lowest numbers of egg shells with blood stains or egg shells with calcification spots, and the shallowest slope for the regression of the proportion of hens placed found dead as this changed with age. This could indicate that overall welfare was perhaps best for the hens in the FC, however, it is possible that the relative novelty of these systems means these were run as ‘‘experimental’’ systems, possibly attracting more attention and diligence from the producers than the other less novel systems. In addition, of the 6 FC flocks studied here, 4 were on the same site and sometimes managed by the same staff. Notwithstanding these minor concerns, these data do not support the arguments being made by some countries that the welfare of hens in furnished cages is poor and that this housing system should be banned.

In general, the CC, FC and FR systems were ranked similarly in terms of overall welfare. However, several of the indicators which appear to show good welfare in CC, such as keel protrusion, bodyweight, bodyweight when found dead, were almost certainly correlated and probably related to altered pattern of fat deposition, which in itself might indicate poor welfare. FR hens scored well for feather score and a decrease in egg shells with blood stains as they got older, but had middle or poor scores for all the other indicators. The welfare of birds in Barn systems was of particular concern in terms of stress, mortality and rates of old fractures.

The finding in this study of perhaps greatest concern is that measures used which almost certainly indicate reduced welfare (egg shells with calcification spots or blood stains, keel bone breaks, plumage damage, vent pecking, vent prolapse, emaciation, and, mortality) were all prevalent at high rates in all 4 types of housing system. This raises a vexing ethical question about whether the modern layer hen is robust enough to withstand the demands of production within any of these types of housing system, or, whether changes to any of these 4 housing systems could reduce the prevalence of these welfare issues

## ACKNOWLEDGEMENTS

Most of the flocks were recruited with the kind assistance of Noble Foods and we gratefully acknowledge their enormous contribution, that of their producers and all other independent producers and farm staff who participated so willingly, enthusiastically and professionally in this study. The work was funded by Defra (AW1132).

## REFERENCES

Appleby, M.C., Walker, A.W., Nicol, C.J., Lindberg, A.C., Friere, R., Hughes, B.O. & Elson, H.A. (2002) Development of furnished cages for laying hens. *British Poultry Science*, **43**: 489–500.

Barnett, J.L., Tauson, R., Downing, J.A., Janardhana, V., Lowenthal, J.W., Butler, K.L. & Cronin, G.M. (2009) The effects of a perch, dust bath, and nest box, either alone or in combination as used in furnished cages, on the welfare of laying hens. *Poultry Science*, **88**: 456–470.

Bilcik, B. & Keeling, L.J. (1999) Changes in feather condition in relation to feather pecking and aggressive behaviour in laying hens. *British Poultry Science*, **40**: 444–451.

Blokhuis, H.J., Fiks Van Niekerk, T., Bessei, W., Elson, A., Guémené, D., Kjaer, J.B., Maria Levrino, G.A., Nicol, C.J., Tauson, R., Weeks, C.A. & van de Weerd, H.A. (2007) The LayWel project: welfare implications of changes in production systems for laying hens. *World's Poultry Science Journal*, **63**: 101–114.

Bortolloti, G.R., Marchant, T.A. & German, T. (2008) Corticosterone in feathers is a long-term, integrated measure of avian stress physiology. *Functional Ecology*, **22**: 494–500.

European Commission (1999) Council Directive 1999/74/EC of 19 July 1999 laying down minimum standards for the protection of laying hens. *Official Journal of the European Union*, **L203**: 0053–0057.

European Food Safety Authority (EFSA) (2005) Welfare aspects of various systems for keeping laying hens. *European Food Safety Authority Journal*, **197**: 1–23.

Fleming, R.H., Whitehead, C.C., Alvey, D., Gregory, N.G. & Wilkins, L. (1994) Bone structure and breaking strength in laying hens housed in different husbandry systems. *British Poultry Science*, **35**: 651–662.

Hughes, B.O., Gilbert, A.B. & Brown, M.F. (1986) Categorisation and causes of abnormal egg shells: relationship with stress. *British Poultry Science*, **27**: 325–337.

Jendral, M.J., Korver, D.R., Church, J.S. & Feddes, J.J.R. (2008) Bone mineral density and breaking strength of white leghorns housed in conventional, modified, and commercially available colony battery cages. *Poultry Science*, **87**: 828–837.

Lambton, S.L., Knowles, T.G., YORKE, C. & Nicol, C.J. (2009) Risk factors affecting the development of vent pecking and cannibalism in loose housed laying hen flocks. *Proceedings of the 8th European Symposium on Poultry Welfare*, Cervia, Italy, pp. 13.

Macfarlane, D.P., Forbes, S. & Walker, B.R. (2008) Glucocorticoids and fatty acid metabolism in humans: fuelling fat redistribution in the metabolic syndrome. *Journal of Endocrinology*, **197**: 189–204.

Mills, A.D., Marche, M. & Faure, J.M. (1987) Extraneous egg shell calcification as a measure of stress in poultry. *British Poultry Science*, **28**: 177–181.

Nicol, C.J., Brown, S.N., Glen, E., Pope, S.J., Short, F.J., Warriss, P.D., Zimmerman, P.H. & Wilkins, L.J. (2006) Effects of stocking density, flock size and management on the welfare of laying hens in single-tier aviaries. *British Poultry Science*, **47**: 135–146.

Pavlik, A., Jezova, D., Zapletal, D., Bakos, J. & Jeilnek, P. (2008) Impact of housing technology on blood plasma corticosterone levels in laying hens. *Acta Veterinaria Hungarica*, **56**: 515–527.

Puvadolpirod, S. & Thaxton, J.P. (2000) Model of physiological stress in chickens 1. Response parameters. *Poultry Science*, **79**: 363–369.

Reynard, M. & Savory, C.J. (1999) Stress-induced oviposition delays in laying hens: duration and consequences for eggshell quality. *British Poultry Science*, **40**: 585–591.

Rodenburg, T.B., Tuyttens, F.A.M., De Reu, K., Herman, L., Zoons, J. & Sonck, B. (2008) Welfare assessment of laying hens in furnished cages and non-cage systems: assimilating expert opinion. *Animal Welfare*, **17**: 355–361.

Royo, F., Mayo, S., Carlsson, H.E. & Hau, J. (2008) Egg corticosterone: a non-invasive measure of stress in egg-laying birds. *Journal of Avian Medicine and Surgery*, **22**: 310–314.

Tactacan, G.B., Guenter, W., Lewis, N.J., RODRIGUEZ-Lecompte, J.C. & House, J.D. (2009) Performance and welfare of laying hens in conventional and enriched cages. *Poultry Science*, **88**: 698–707.

Webster, A.J.F. (2001) Farm animal welfare: the five freedoms and the free market. *The Veterinary Journal*, **161**: 229–237.

Weeks, C.A. & Nicol, C.J. (2006) Behavioural needs, priorities and preferences of laying hens. *World's Poultry Science Journal*, **62**: 296–307.

Whay, H.R., Main, D.C.J., Green, L.E., Heaven, G., Howell, H., Morgan, M., Pearson, A. & Webster, A.J.F. (2007) Assessment of the behaviour and welfare of laying hens on free-range units. *Veterinary Record*, **16**: 119–128.

Wilkins, L.J., Brown, S.N., Zimmerman, P., Leeb, C. & Nicol, C. (2004) Investigation of palpation as a method for determining the prevalence of kell and furculum damage in laying hens. *Veterinary Record*, **155**: 547–549.