Chicken welfare is influenced more by housing conditions than by stocking density

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Intensive broiler (meat) chicken production now exceeds 800 million birds each year in the United Kingdom and 2 × 10^10 birds worldwide1, but it attracts accusations of poor welfare2,3. The European Union is currently adopting standards for broilers aimed at a chief welfare concern—namely, overcrowding—by limiting maximum ‘stocking density’ (bird weight per unit area). It is not clear, however, whether this will genuinely improve bird welfare because evidence is contradictory4–10. Here we report on broiler welfare in relation to the European Union proposals through a large-scale study (2.7 million birds) with the unprecedented cooperation of ten major broiler producers in an experimental manipulation of stocking density under a range of commercial conditions. Producer companies stocked birds to five different final densities, but otherwise followed company practice, which we recorded in addition to temperature, humidity, litter and air quality. We assessed welfare through mortality, physiology, behaviour and health, with an emphasis on leg health and walking ability. Our results show that differences among producers in the environment that they provide for chickens have more impact on welfare than has stocking density itself.

Table 1 Scoring of gait, hockburn, pad dermatitis and leg deviations

<table>
<thead>
<tr>
<th>Leg health measure</th>
<th>Score 0</th>
<th>Score 1</th>
<th>Score 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gait</td>
<td>Bird walks with ease, has regular and even strides and is well balanced</td>
<td>Bird walks with irregular and uneven strides and appears unbalanced</td>
<td>Bird is reluctant to move and is unable to walk many strides before sitting down</td>
</tr>
<tr>
<td>Hockburn*</td>
<td>No discoloration or lesions</td>
<td>&lt;5 mm lesion on pad</td>
<td>&gt;10% hock with lesion</td>
</tr>
<tr>
<td>Pad dermatitis†</td>
<td>No lesions</td>
<td>Inward bow at intertarsal joint so that the two legs meet &gt;22°</td>
<td>&gt;5 mm lesion on pad</td>
</tr>
<tr>
<td>Angle: in</td>
<td>Legs straight</td>
<td>Outward twist at intertarsal joint with ≥30° between the legs</td>
<td>&gt;10% hock with lesion</td>
</tr>
<tr>
<td>Angle: out</td>
<td>Legs straight</td>
<td>Rotation of the tibia shaft so that pads face each other &gt;15°</td>
<td></td>
</tr>
<tr>
<td>Rotation</td>
<td>Legs straight, pads facing away from handler</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Pink hocks were also recorded.
†Pervasively dirty pads also scored.

Across companies, there was a wide range of house sizes (455–1,901 m^2), house ages (5–40 yr) and numbers of birds per house (7,500–53,000); 75% of flocks were Ross 308 (see Supplementary Information). Each company contributed two houses to each target stocking density for a trial. With two companies, we repeated trials with the same ten houses in summer and winter to examine the effects of season. Within a company, houses were randomly assigned to stocking density (Supplementary Information), which was manipulated by altering the numbers of day-old chicks placed to achieve a projected ‘target’ maximum stocking density just before the birds were killed (39–42 d at 2–3 kg). The five target stocking densities were 30, 34, 38, 42 and 46 kg m^-2 (refs 1, 11, 12). Actual stocking density was measured as mean weight × number of birds per area of house. The same person (T.A.J.) made or checked all measurements with the help of trained assistants.

Welfare4–15 was assessed through mortality, physiology, behaviour and health, emphasizing leg health and walking ability16–20 (Table 1). We found that the effect of experimentally manipulating stocking density was overshadowed by much larger differences among companies (Table 2 and Fig. 1). Chickens grew more slowly at the highest stocking densities and jostled each other more, and fewer of them showed the best gaits (Table 3); however, for the most obvious measures of bird welfare—that is, the numbers of birds dying, being culled as unfit and showing leg defects—there was no effect of stocking density. There were, however, substantial differences among companies in almost all measures examined (Table 2). At no point was breed a significant explanatory factor in any outcome variables, suggesting that the differences were due to environmental influences.

Of the commercially relevant factors that seemed to allow some companies to ‘cope’ better than others with high stocking densities, the most likely candidates were those that affected litter moisture...
Litter moisture and ammonia, in turn, were related to bird health. Higher levels of both were correlated with more dirty pads (moisture, correlation coefficient, $r = -0.24$; ammonia, $r = 0.27$), more legs scored as angle-out (moisture, $r = 0.24$; ammonia, $r = 0.36$) and fewer birds with unblemished hocks (moisture, $r = -0.26$). In addition, birds had more hock lesions with wetter litter (score $2$, $r = 0.27$). High concentrations of ammonia were, unexpectedly, associated with lower mortality, but both litter moisture and air ammonia were correlated with higher faecal corticosteroid (a ‘stress’ hormone, see Supplementary Information). Eighty-four per cent of the variation in faecal corticosteroid concentrations were also correlated with mortality (Supplementary Information). Eighty-four per cent of the variation in faecal corticosteroid concentrations were also correlated with mortality (Supplementary Information). Eighty-four per cent of the variation in faecal corticosteroid concentrations were also correlated with mortality (Supplementary Information). Eighty-four per cent of the variation in faecal corticosteroid concentrations were also correlated with mortality (Supplementary Information). Eighty-four per cent of the variation in faecal corticosteroid concentrations were also correlated with mortality (Supplementary Information).

### Methods

#### Management and husbandry

We recorded the following information: house age; ownership (company or contract grower); size; orientation; fabric; light pattern and source; dawn/dusk dimming; percentage of wheat feed; feeder type and number; drinker type and number; heater type, number and position; type of ventilation system; misting systems; floor and litter type; number of stockmen and number of visits per house; vaccination programme; feed withdrawal; and thinning or clearance programme.

#### Environment

We recorded temperature and relative humidity every hour throughout the growth cycle.
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(by using four randomly positioned Tiny Talk data loggers in each house at a height of 60 cm); and atmospheric ammonia (by a Gastec GV-1005 pumpset), light at bird height (ISO-Tech digital light meter) and litter moisture content ([sample weight difference after drying/sample weight] × 100) at target density.

**Birds**

We recorded the source, breed, sex (all-male, all-female or mixed), age of parent flock, date and time of arrival, position of chicks on delivery lorry, type of vehicle (rigid or articulated), ventilation (fans, vents) and on-board temperature. The numbers of trays of chicks per house and chicks per tray were audited.

**Leg health**

At target density, a single bird chosen from each of ten points in each house, was observed walking for at least ten paces before being scored for gait ([Table 1, n = 1,140 birds]). Groups of ten birds were subsequently caught at four random points per house; individuals were inverted (ventral side facing handler), held by the legs with the handler’s thumbs just below the intertarsal joint and assessed for leg straightness ([Table 1, n = 4,370], weighed and then released.

**Corticosterone measurements**

Fresh faecal samples were collected at five random positions in each house, dried at 40 °C and analysed for corticosterone[13,14].

**Behaviour**

Four battery-operated video cameras radio-linked to a VCR (Tracksys) were placed in each house at a height of 155 cm. Eight 10-min sequential records of each camera view were made between 10:00 and 12:00 at target density. One randomly chosen focal bird from each 10-min section of video was analysed for 5 min for frequency and duration of stand, lie, feed, drink, preen, rest (eyes closed) and be stretched out; frequency of walking (including number of strides) and peck litter, peck other bird, scratch litter, scratch head, stretch head, wing or leg, shake body, shake head, dust bathe, wing flap, aggressive interactions and perch; changes of posture (up or down); jostling or being jostled by other birds; and being disturbed or walked on by other birds (n = 741 from 107 houses).

**Production**

We recorded mortality (numbers of birds found dead plus numbers of birds culled because of illness or leg problems), feed conversion ratio, water intake, date, numbers and weights of birds removed from the house (thinned or cleared) and number of birds rejected at the processing plant. Growth rate was calculated as: individual weight (average chick weight) × number of days.

**Statistical analysis**

The independent statistical unit was house. Where many measurements were made per house, a single mean–per-house value was used in the analysis. Variables were first analysed for effects of target stocking density, actual stocking density and company by analysis of variance. Where actual density effects were significant, they were further analysed by regression analysis ([fitted line model] and post-hoc Tukey comparison).

Univariate linear correlations were examined between outcome variables and predictors treated as continuous variables. Multivariate linear models were constructed using a stepwise model selection procedure (starting from a model with no predictors) with possible predictors, including those continuous predictors with substantial linear correlations (< -0.2 or > 0.2) and categorical predictors. We discuss only effects where P < 0.01.

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1. Scientific Committee on Animal Health and Animal Welfare

2. Webster, J. Animal Welfare: a Cool Eye Towards Eden


4. thumbs just below the intertarsal joint and assessed for leg straightness ([Table 1, n = 4,370], weighed and then released.

5. Hall, A. The effect of stocking density on the welfare and behaviour of broiler chickens reared


12. Royal Society for the Prevention of Cruelty to Animals

13. Ekstrand, C., Carpenter, T. E. & Donald S. Burke


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Travelling waves in the occurrence of dengue haemorrhagic fever in Thailand

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Dengue fever is a mosquito-borne virus that infects 50–100 million people each year. Of these infections, 200,000–500,000 occur to the severe, life-threatening form of the disease, dengue haemorrhagic fever (DHF)1. Large, unanticipated epidemics of DHF often overwhelm health systems. An understanding of the spatial-temporal pattern of DHF incidence would aid the