Aerial perches and free-range laying hens: The effect of access to aerial perches and of individual bird parameters on keel bone injuries in commercial free-range laying hens

C. J. Donaldson,*† M. E. E. Ball,* and N. E. O’Connell†

*Agri-Food and Biosciences Institute, Hillsborough, Co. Down, BT26 6DR, United Kingdom; and †School of Biological Sciences, Queens University Belfast, BT9 7BL, United Kingdom

ABSTRACT The aim of this trial was to determine the effect of aerial perches on keel bone injuries and tibia bone characteristics in free-range laying hens. The relationship between keel bone injuries and individual bird parameters, such as weight, girth, wing:girth ratio, feather coverage, and tibia bone characteristics, was also assessed. Five commercial free-range houses, each containing between 7,000 and 8,000 birds, were used. The houses and range areas were divided in half; in half of the house, birds had access to aerial perches (P) and in the other half, they did not (NP). On 13 occasions between 17 and 70 wk of age, 20 birds per treatment were randomly selected from the slatted area and palpated for keel bone injury. At 72 wk of age, 30 birds per treatment in each of 4 houses were selected at random, weighed, and then euthanized. Girth and wing area and feather coverage were measured. The keel and left tibia bones were removed and keel bones were scored for injury. Tibia bones were weighed and diameter, length, breaking strength, and ash content recorded. Results indicated that access to aerial perches did not affect tibia bone measures (P > 0.05). Average palpated keel bone score increased with age of the hens (P < 0.001) but was not significantly affected by perch treatment (P > 0.05). There was a significant interaction between treatment and farm on keel bone injuries measured at dissection (P < 0.05), with the probability of birds having high keel-damage scores increasing in the perched treatment in some farms but not others. In general, as the keel bone injury score measured at dissection increased, the breaking strength (P < 0.001) and ash content (P < 0.05) of the tibia bone decreased. It is suggested that individual variation in bone strength contributes to differences in susceptibility to keel injury. No relationship existed between keel-injury score measured at dissection and individual parameters, such as weight, girth, or wing:girth ratio (P > 0.05), although feather coverage tended to decline with increasing keel damage (P < 0.06).

Key words: bone, breaking strength, keel bone injury, perch, welfare

INTRODUCTION

European Union legislation stipulates that laying hens must be provided with 15 cm of perch space per bird (European Council Directive, 1999). This legislation is interpreted differently between different member states within the European Union, and even between different parts of the United Kingdom. In Scotland and Northern Ireland, this legislation is interpreted to mean that distinct raised or aerial perches must be provided, whereas in England and Wales, raised slatted floors can currently be used as perches.
MATERIALS AND METHODS

Birds, Treatments, and Housing

One commercial free-range laying hen house on each of 5 farms was selected for use in this study. Farms 1, 2, and 5 contained 8,000 birds, farm 3 contained 7,000 birds, and farm 4 contained 7,800 birds (all Hy-Line Brown). The number of birds varied to meet the correct stocking density allowance (i.e., that it must not exceed 9 birds/m²). Each house was split across its width (including slatted and litter areas) and the range area was also divided to create 2 subflocks, each containing 4,000, 3,500, and 3,900 birds respectively. Each subflock within a house was assigned to 1 of 2 treatments: (1) access to aerial perches (allowing 15 cm of perch space per bird; perched, P) and (2) no access to aerial perches (nonperched, NP). In both treatments, the hens could perch on feeders and drinkers. The houses were placed in the houses at 16 wk of age with treatments already in place.

Birds were fed ad libitum on a sequence of commercial diets through rearing and production. Birds received formulated feed based on the recommended nutrient requirements indicated in commercial guidelines.

A schematic drawing of a typical free-range house used in this study is provided in Figure 1. The nest boxes were placed centrally on the slatted area running length-wise down the house. Birds had access to the nest boxes from both sides of the slatted area. The nest boxes had a space between them approximately every 15 m to allow birds to access both sides of the house. Parallel to the nest boxes on each side of the slatted area were the nipple drinkers and 3 feeder lines. However, farm 3 had a smaller slatted area, so it could only provide 2 feeder lines and bell drinkers. Each house differed in the size of the slatted and litter areas (Table 1). All farms had a maximum stocking density of 1,000 birds per hectare on the range at the time of the study, which conformed to RSPCA (2008) requirements. The birds had 10 h of artificial light per 24-h period at 16 wk of age, and this increased to 15 h of artificial light per 24-h period from approximately 24 wk of age.

All procedures were carried out under the Animals (Scientific Procedures) Act 1986 and with approval of the Agri-Food and Biosciences (Hillsborough) Ethical Review Committee.

Aerial Perches

Aerial perches were located on the slatted areas on both sides of the houses and were located next to the partitions that divided the slatted from the litter areas. However, when only 1 litter area was available, the other perches were mounted against the wall. Three different perch designs were used and each of these differed in terms of distance of rungs from the floor and from the partition or the wall. Perches consisted of 4 to 6 rungs arranged at a 45° angle from the partition or
the wall. Each rung of the perch was constructed of 3 cm of metal rungs [square (farms 1, 2, and 5) or circular (farms 3 and 4)]. Farm 3 contained 20 aerial perches in the perched treatment, whereas farms 2 and 4 had 22, farm 1 had 23, and farm 5 had 24 perches. Figures 2, 3, 4, 5, and 6 show the perch design for farms 1 to 5 respectively. Perches varied in length in each house as follows: 286 cm (farm 3), 287 cm (farms 1, 2, and 5), or 288 cm (farm 4).

**Experimental Birds and Parameters Measured**

**Keel Bone Palpation.** Twenty birds from each treatment were randomly selected from the slatted area of each house at 17, 18, 19, 20, 24, 28, 34, 40, 46, 52, 58, 64, and 70 wk of age. The keel bone of these animals was assessed for damage by palpation. The hen was restrained upside down for the duration of the examination. The palpation involved running 2 fingers down the side of the keel bone and feeling for calcium deposits or other malformations indicative of previous damage. During this procedure, particular attention was paid to the tip of the keel bone (Wilkins et al., 2004). The keel bone was scored as either 0 (healthy bone with no indication of damage) or 1 (bone is apparently fractured or deformed).

**Keel Bone Dissection.** Thirty birds were randomly selected from each treatment on each of 4 farms (farms 1, 2, 3, and 5), totaling 240 birds that were 72 wk of age (2 wk before the rest of the flock was slaughtered). The hens were caught in the slatted area under low light intensity to reduce escape behavior and injuries (Hester, 2005). The catcher walked through the house and picked up the bird closest to them at 3-m intervals from either the perching space above the feeder (only standing birds were chosen) or the floor. The birds were tagged with individual numbers and weighed (g). The birds were then humanely killed by cervical dislocation and held until all muscular contractions had ended in order to avoid bone damage.

The feather coverage of the birds was then scored using a 4-point scale devised by Tauson et al. (2004) from 4 (no feather loss) to 1 (extensive bald areas,}

### Table 1. Details of internal house characteristics at each farm

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Farm 1</th>
<th>Farm 2</th>
<th>Farm 3</th>
<th>Farm 4</th>
<th>Farm 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slatted area (m²)</td>
<td>604.43</td>
<td>841.56</td>
<td>418.76</td>
<td>491.98</td>
<td>519.83</td>
</tr>
<tr>
<td>Litter area (m²)</td>
<td>347.67</td>
<td>348.86</td>
<td>407.66</td>
<td>352.72</td>
<td>284.19</td>
</tr>
<tr>
<td>No. of litter areas</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Feeder track (m)</td>
<td>475</td>
<td>500.76</td>
<td>270.60</td>
<td>402</td>
<td>480</td>
</tr>
<tr>
<td>No. of nipple drinkers</td>
<td>840</td>
<td>808</td>
<td>70</td>
<td>820</td>
<td>820</td>
</tr>
</tbody>
</table>

1Farm 3 had bell drinkers.
severe feather loss). This was scored on 7 different regions of the bird, including the breast, back, thigh, vent, neck, wings, and tail (Nicol et al., 2003; Tauzon et al., 2004; Whay et al., 2007), giving a maximum score of 28 per bird. The total feather coverage from all 7 regions was calculated for each bird. Each bird

Figure 2. Three-dimensional diagram of the perch used in farm 1 with the height and distances between each rung of the perch and the feeders.

Figure 3. Three-dimensional drawing of the perch used in farm 2 with the height and distances between each rung of the perch and the feeders.
Figure 4. Three-dimensional drawing of the perch used in farm 3 with the height and distances between each rung of the perch and the feeders.

Figure 5. Three-dimensional drawing of the perch used in farm 4 with the height and distances between each rung of the perch and the feeders.
was placed ventral-side up and the left wing was fully extended. The length across the top of the wing to the distal tips of the primary feathers (top wing) was measured (Figure 7). The girth of the bird (cm) was measured around the thorax, underneath the wings, and at the top of the keel bone (Figure 8). The wing:girth ratio was calculated by dividing the top-wing measure by the girth of the bird.

Figure 6. Three-dimensional drawing of the perch used in farm 5 with the height and distances between each rung of the perch and the feeders.

Figure 7. Location of top-wing measurement taken at dissection. Color version available in online PDF.
Ovarian activity was assessed to determine the reproductive state of the bird. This was carried out by displacing the gut and examining for large yellow follicles. If the bird was not reproductively active, these follicles were regressed and appeared as very small white follicles. Birds were scored as yes if large yellow follicles were present or no if not present. One bird from each treatment was found to be not reproductively active. Following this, the left tibia and keel bones were removed from each bird. Keel bones were removed in a manner similar to that described by Gregory and Wilkins (1989). Bones were cleaned of tissue, individually sealed in labeled bags, and stored at −18°C for a maximum of 4 wk.

**Analysis of Left Tibia Bone**

**Bone Strength Test.** Bones were thawed at room temperature overnight (14 h). Once thawed, the left tibia was weighed and bone length and diameter were measured using digital calipers (mm). A breaking-strength test was conducted on each bone, which involved subjecting the bones to a 100-kg load using a 3-point bending jig (Instron Testing Machine 5500R, Instron, High Wycombe, Bucks, UK), with a loading rate of 25 mm/min. The separation between centers of the outer pressure bars was 8 cm.

**Bone Ash Content.** All of the broken tibia bones were placed in individual silica dishes and dried at 104°C for 24 h. They were allowed to cool then reweighed to obtain the DM. Following this, bones were placed in a muffle furnace at 600°C for 48 h to obtain the bone ash content. Bones were cooled in desiccators for 30 min and weighed to obtain the ash weight.

**Assessment of Keel Bone Damage**

The keel bone was thawed at room temperature overnight (14 h). Bones were scored from 0 (no damage) to 4 (severe damage and multiple fractures; Wilkins, Department of Clinical Veterinary Science, University of Bristol, UK, personal communication; Figure 9). A bone with a score of 1 typically had one fracture, usually toward the tip of the keel. A bone with a score of 2 had between 2 and 3 fractures/callus formation or deformations along the ventral edge. A bone with a score of 3 had multiple fractures/callus formation plus slight deformation of the bone at the fracture sites, and a score of 4 meant multiple fractures/callus formation and severe deformations of the ventral edge.

**Statistical Analysis**

Data were analyzed using Genstat Version 12.1 (VSN International, Hemel Hempstead, UK). Residual values from all parametric analyses were plotted and visually assessed for normality. Nonnormal data were transformed where appropriate or analyzed using nonparametric statistics.

**Parameters Measured at Dissection.** The influence of treatment on tibia bone weight, length, diameter, DM, ash content, and breaking strength were analyzed using ANOVA. This analysis used treatment within farm as a blocking factor. Keel-injury scores were assessed using ordinal logistic regression (with a multinomial distribution and a logit link function). The fitted terms in this analysis were farm, treatment, and farm × treatment. This analysis produced tables of probabilities together with bootstrapped SE values. Due to relatively low numbers of animals with keel injury scores of 3 or 4, these were collapsed into one category (3/4) in all analyses. An REML variance components analysis was used to determine the relationship between keel score and individual bird parameters, such as weight, girth, wing:girth ratio, feather coverage, tibia bone weight, length, diameter, breaking strength, DM, and ash content. Fixed effects in this analysis were treatment + keel score + keel score within treatment and the random effects were farm + treatment within farm. Feather coverage data were square-root transformed in this analysis. Individual birds were used as experimental units in all analyses.
Parameters Measured at Palpation. For the palpation data, birds were grouped into 3 age groups: prelay (17–20 wk of age), peak production (24–40 wk of age), and post-peak production (46–70 wk of age). The proportion of birds with a palpation score of 1 was calculated for each farm × treatment × age-group category. The influence of treatment, age, and farm were analyzed using ANOVA; the treatment effects were farm + treatment × age group, and the block effects were age group within treatment within farm.

RESULTS

Treatment and Age Effects on Keel Bone Injury Scores (Palpation)

Treatment did not have a significant effect on average palpated keel bone scores ($P = 0.336$, NP = 0.317, SEM = 0.0176; $F_{1,4} = 0.60; P > 0.05$), however age had a significant effect [standard error of the difference (SED) = 0.034; $F_{2,16} = 82.25; P < 0.001$; Figure 10]. Palpation scores did not differ between farms (farm 1 = 0.331, farm 2 = 0.270, farm 3 = 0.311, farm 4 = 0.294, and farm 5 = 0.427, SEM = 0.0279; $F_{4,4} = 4.67; P > 0.05$). There was no significant interaction between age and treatment on the palpated keel bone score (SED = 0.046; $F_{2,16} = 0.06; P > 0.05$).

Treatment and Farm Effects on Keel Bone Injury Scores (Dissection)

There were no significant main effects of treatment or farm on keel-injury scores, but there was a significant interaction between these factors ($P = 0.012$; Table 2). On one of the farms (farm 3), the probability of being scored with a keel injury score of 3/4 was considerably higher in the P treatment than in the NP treatment, but this was not the case in the other farms. In 2 of the farms, the probability of having a score of 3/4 was lower in the P than in the NP treatment.

Treatment Effects on Tibia Bone Parameters

Treatment did not have any significant effects on tibia bone parameters, such as weight, length, diameter, ash content, or breaking strength (all $P > 0.05$; Table 3).

Relationship Between Individual Factors and Keel Injuries

There was no significant relationship between individual keel-injury scores (measured at dissection) and either girth or BW ($P > 0.05$). In addition, there did not

Figure 9. Scale used to measure the severity of damage to the keel bone (left to right = score 0–4). Photos provided by L. J. Wilkins, Department of Clinical Veterinary Science, University of Bristol, Bristol, UK. Color version available in online PDF.

Figure 10. Average palpated keel bone scores at different time-points across the production cycle. a–c Bars with different letters differ significantly ($P < 0.001$). Twenty birds from each of the perched and nonperched treatments on each of 5 farms were assigned a score of 0 or 1. This occurred for a new selection of birds on 4 occasions between 17 and 20 wk and between 24 and 40 wk, and on 5 occasions it occurred between 46 and 70 wk. Values presented represent the average palpation score within different time periods.
not appear to be a relationship between keel-injury score and wing:girth ratio ($P > 0.05$). There was a tendency for total feather coverage to decrease with increasing keel-injury score ($P < 0.06$) (Table 4). Keel bone injury scores were significantly related to tibia bone strength and composition (Table 4). As keel score increased, there was a decrease in the percentage of ash content ($P < 0.001$) and in the breaking strength ($P < 0.05$) of the tibia bone.

There were no significant interactions between keel score and treatment in individual bird parameters.

### DISCUSSION

The primary aim of this trial was to determine if access to aerial perches on commercial free-range farms increased keel bone injury levels in laying hens. The results showed no clear effect of access to perches on keel injury levels. Even though no treatment differences were seen with the palpated keel scores, there was an interaction between treatment and farm in keel injuries measured through dissection. Marked increases in the probability of birds receiving high keel-injury scores were observed when perches were provided in farm 3. Differences in house and perch design between farm 3 and other farms could have accounted for this effect. Stocking density was similar across all farms; however, the reduced floor space in the slatted area of farm 3, coupled with a reduced number of feeder lines, could have led to increased crowding on the perches, causing more inaccurate jumps. This agrees with research by Moinard et al. (2005), who found that having obstructions on perches can lead to less-successful jumps. In addition, the perch on farm 3 consisted of 6 rungs arranged in a different manner to perches on farms 1, 2, and 5, and rungs were circular in shape. Duncan et al. (1992) found that birds preferred rectangular to circular perches. A circular perch is likely to be slipperier as there are no edges to grip (Duncan et al., 1992), meaning that the bird is unable to use the tendon locking mechanism (Tauson and Abrahamsson, 1994). This may limit the ability of the bird to land or perch safely. The design of the current trial meant that it was not possible to tease-out precise causal factors of increased injury levels. However, the results support previous research, suggesting that poor perch and housing design are key risk factors for keel injuries (Scott and Parker, 1994; Scott et al., 1999; Sandilands et al., 2009; Struelens and Tuyttens, 2009).

The keel bone palpations showed that the number of birds with keel injuries increased over the lay cycle. Gregory and Wilkins (1996) conducted a similar study using full dissection and found no birds with broken bones (old or new fractures) before 45 wk of age; however, after this age, injury levels increased. The results of the present study suggest that keel damage existed in the early stages of the lay cycle (prelay) and continued to increase through peak production and the second half of the lay cycle. It is possible that birds injured themselves in the early part of the lay cycle as they became accustomed to the equipment within the house. This indicates the importance of correct house and perch design to minimize the incidence of injuries occurring in the early part of the lay cycle. The in-

### Table 2. Probabilities of birds receiving different keel scores in perched and nonperched treatments on 4 different farms

<table>
<thead>
<tr>
<th>Farm</th>
<th>Treatment</th>
<th>Keel score</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3/4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Perched</td>
<td>0.4166</td>
<td>0.2872</td>
<td>0.1842</td>
<td>0.1121</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nonperched</td>
<td>0.2752</td>
<td>0.2829</td>
<td>0.2501</td>
<td>0.1918</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Perched</td>
<td>0.3917</td>
<td>0.2900</td>
<td>0.1955</td>
<td>0.1227</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nonperched</td>
<td>0.2297</td>
<td>0.2683</td>
<td>0.2700</td>
<td>0.2320</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Perched</td>
<td>0.1375</td>
<td>0.2090</td>
<td>0.2923</td>
<td>0.3612</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nonperched</td>
<td>0.3109</td>
<td>0.2892</td>
<td>0.2334</td>
<td>0.1665</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Perched</td>
<td>0.2414</td>
<td>0.2728</td>
<td>0.2651</td>
<td>0.2207</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nonperched</td>
<td>0.3654</td>
<td>0.2916</td>
<td>0.2077</td>
<td>0.1353</td>
<td></td>
</tr>
</tbody>
</table>

1Thirty birds in each treatment on each of 4 farms (240 in total) were examined.

### Table 3. Treatment effects on bone parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Perched</th>
<th>Nonperched</th>
<th>SEM</th>
<th>$F_{(1,3)}$</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bone weight (g)</td>
<td>12.41</td>
<td>12.63</td>
<td>0.077</td>
<td>3.79</td>
<td>NS</td>
</tr>
<tr>
<td>DM (%)</td>
<td>68.22</td>
<td>68.55</td>
<td>0.289</td>
<td>0.64</td>
<td>NS</td>
</tr>
<tr>
<td>Ash weight (g)</td>
<td>3.73</td>
<td>3.77</td>
<td>0.034</td>
<td>0.51</td>
<td>NS</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>30.18</td>
<td>30.00</td>
<td>0.211</td>
<td>0.36</td>
<td>NS</td>
</tr>
<tr>
<td>Ash DM basis (%)</td>
<td>44.27</td>
<td>43.77</td>
<td>0.238</td>
<td>2.19</td>
<td>NS</td>
</tr>
<tr>
<td>Bone length (mm)</td>
<td>115.40</td>
<td>115.84</td>
<td>0.210</td>
<td>2.13</td>
<td>NS</td>
</tr>
<tr>
<td>Bone diameter (mm)</td>
<td>6.70</td>
<td>6.71</td>
<td>0.063</td>
<td>0.03</td>
<td>NS</td>
</tr>
<tr>
<td>Breaking strength (kg)</td>
<td>27.76</td>
<td>26.75</td>
<td>0.434</td>
<td>2.69</td>
<td>NS</td>
</tr>
</tbody>
</table>
Table 4. Relationship between keel bone score and individual bird parameters¹

<table>
<thead>
<tr>
<th>Parameter</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3/4</th>
<th>SEM</th>
<th>F-value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (g)</td>
<td>1,932</td>
<td>1,892</td>
<td>1,922</td>
<td>1,902</td>
<td>29.48</td>
<td>F₃,228 0.87</td>
<td>NS</td>
</tr>
<tr>
<td>Girth (cm)</td>
<td>30.26</td>
<td>29.76</td>
<td>30.10</td>
<td>30.05</td>
<td>0.319</td>
<td>F₃,229 1.19</td>
<td>NS</td>
</tr>
<tr>
<td>Wing:girth ratio</td>
<td>0.95</td>
<td>0.97</td>
<td>0.98</td>
<td>0.98</td>
<td>0.019</td>
<td>F₃,227 1.89</td>
<td>NS</td>
</tr>
<tr>
<td>Total feather coverage²</td>
<td>3.242 (10.51)</td>
<td>3.178 (10.10)</td>
<td>3.076 (9.46)</td>
<td>3.064 (9.39)</td>
<td>0.077</td>
<td>F₃,226 2.56</td>
<td>0.056</td>
</tr>
<tr>
<td>Bone weight (g)</td>
<td>12.77</td>
<td>12.43</td>
<td>12.44</td>
<td>12.37</td>
<td>0.014</td>
<td>F₃,231 1.64</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>DM weight (g)</td>
<td>8.78</td>
<td>8.44</td>
<td>8.40</td>
<td>8.38</td>
<td>0.017</td>
<td>F₃,232 3.82</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Ash weight (g)</td>
<td>3.941</td>
<td>3.736</td>
<td>3.695</td>
<td>3.552</td>
<td>0.082</td>
<td>F₃,230 7.82</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>30.96</td>
<td>30.17</td>
<td>29.86</td>
<td>29.71</td>
<td>0.049</td>
<td>F₃,228 8.34</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Ash DM basis (%)</td>
<td>44.82</td>
<td>44.29</td>
<td>43.95</td>
<td>43.72</td>
<td>0.548</td>
<td>F₃,229 7.68</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Bone length (mm)</td>
<td>115.7</td>
<td>115.7</td>
<td>115.1</td>
<td>116.0</td>
<td>0.533</td>
<td>F₃,230 1.07</td>
<td>NS</td>
</tr>
<tr>
<td>Bone diameter (mm)</td>
<td>6.66</td>
<td>6.73</td>
<td>6.73</td>
<td>6.70</td>
<td>0.077</td>
<td>F₃,230 0.38</td>
<td>NS</td>
</tr>
<tr>
<td>Breaking strength (kg)</td>
<td>28.19</td>
<td>27.09</td>
<td>27.73</td>
<td>25.47</td>
<td>0.083</td>
<td>F₃,226 3.78</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

¹Sixty birds on each of 4 farms were assessed (30 perched and 30 nonperched); keel score 0, n = 71; keel score 1, n = 66; keel score 2, n = 57; and keel score 3/4, n = 46.
²Square-root transformed, values presented in brackets are back-transformed values.

jury levels at the end of the lay cycle were significantly higher than those during the mid and early lay cycle. This could be related to the sustained egg production, leading to more brittle bones (Gregory and Wilkins, 1996) as a result of calcium depletion (Riczu et al., 2004). Furthermore, it could be speculated that an age-related reduction in feather coverage led to more poorly controlled flights and landings (Wilkins et al., 2005), and thus more injuries. The fact that there was no significant main effect of treatment on keel-injury scores measured by palpation agrees with data recorded during dissection.

The effect of aerial perches on leg bone strength was also of interest in this study, as it has been shown that access to perches may lead to stronger bones due to increased exercise (Hughes et al., 1993; Alvey and Tucker, 1994; Barnett et al., 1997). The results of the present study showed that there was no effect of providing aerial perches onibia strength. This may have been due to the fact that the hens were housed in alternative systems and therefore that birds in the nonperched treatment had sufficient opportunity to exercise and improve leg health. This may have been achieved by jumping on to and off the feeders and slatted areas (Gregory et al., 1991; Leyendecker et al., 2005).

As the keel-injury score increased, the tibia bone ash content and breaking strength decreased. This would indicate that birds with higher injury scores had weaker bones. This concurs with earlier work that found that birds with the lowest bone ash content had weaker bones and were prone to injury (Thorp and Waddington, 1997). This may reflect the fact that bones with low ash content are poorly mineralized and have low medullary bone content (Rath et al., 2000; Clark et al., 2007). There are a number of factors that could potentially cause individual variation in bone strength. It is possible that differences could reflect direct genetic effects on bone strength (Hocking et al., 2003) or differences in egg productivity that could indirectly affect bone strength. However, nutritional aspects may also be important, and individual differences in calcium absorption from the gut may have contributed to differences in bone strength (Fleming et al., 2006). Feed intake was not assessed within the current study; however, the fact that no relationship existed between BW and keel-injury score suggests that differences in feed intake may not have been a cause of bone weakness and injury.

Individual bird parameters, such as weight, girth, and wing:girth ratio did not appear to be related to keel bone injury level. The results suggest that those birds with more severe keel injuries were not the larger, heavier birds or those with a lower wing-to-girth ratio, which contradicts suggestions by Knowles et al. (1993) and Tobalske and Dial (2000). It is possible, however, that there was not sufficient variation in individual conformational parameters in the current study to clearly assess relationships with keel-injury scores. As keel-injury score increased, feather coverage tended to decrease. As birds become more injured, they are likely to suffer from increased pain and discomfort, resulting in reduced mobility (Webster, 2004; Wilkins et al., 2004), and therefore, would be more prone to bouts of feather pecking from other hens (Bright, 2007). It is also possible that birds with keel injuries lose more feathers due to factors such as stress (Campo et al., 2001), or that birds with feather loss are more prone to sustaining injuries. The lack of statistical significance in the relationship between keel damage and feather coverage possibly reflects the fact that feather loss has several causal factors.

Conclusions

The use of aerial perches in commercial free-range laying hen systems does not uniformly contribute to increased keel bone injuries. The results of the current study suggest that where they occur, they are likely to be related to poor house and perch design. Palpation results suggested that keel injuries occurred at
very early stages in the lay cycle, suggesting that ease with which birds are likely to adapt to large alternative housing systems should be considered in house design. Further research involving assessment of dissected bones of birds early in the lay cycle would be beneficial to validate these results. The results suggested that individual parameters, such as BW and the wing:girth ratio were not key in leading to increased keel-injury levels. Finally, the lack of significance in the relationship between keel damage and feather coverage suggest that it is not a robust indicator of keel damage.

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