SEQUENTIAL STUDIES OF SKELETAL CALCIUM RESERVES AND STRUCTURAL BONE VOLUME IN A COMMERCIAL LAYER FLOCK

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Summary

Production induced osteoporosis in caged laying hens has been speculated to represent a major constraint to continuing genetic development. Models need to be developed that describe the induction of osteoporosis, and its interaction with environmental and management factors. The current paper monitors bodyweight, egg production, femur calcium and bone histology in a commercial flock of ISA Brown layers from 16 through to 68 weeks of age.

Flock bodyweight declines between 35 and 45 weeks of age, which was correlated with a loss of skeletal calcium reserves (15-20%) and with the induction of osteoporosis. As egg production decreased between 42 and 68 weeks of age, birds were able to replete skeletal calcium to levels achieved in early egg production. It seems likely that better standardisation of the equilibrium between growth, skeletal reserves, feed intake and egg production can reduce osteoporosis, as well as improving the productive potential of modern laying strains.

I. INTRODUCTION

Research has demonstrated a high incidence of bone fragility in caged laying hens. This has been mainly attributed to the development of osteoporosis (Riddell, 1981), which has been speculated to represent a serious constraint to further genetic development in the commercial laying hen. In general terms osteoporosis is defined as a local or systemic deficiency in the quantity of fully mineralised structural bone (Thor, 1994), and has been described histologically as a reduction in the volume of structural trabecular and cortical bone within the skeleton. The vertebral skeleton, ribs and pelvis appear most susceptible to the development of osteoporosis, whilst the femur is the most susceptible part of the appendicular skeleton (Taylor and Moore, 1954; Riddell, 1981). Pathology characteristic of osteoporosis is clearly evident in the laying hen by about 40-45 weeks of age (Wilson et al., 1992), which corresponds to the period of peak egg mass output in mid egg production.

The potential for production induced osteoporosis has been largely disregarded in more recent research, despite historical evidence that flock management can play a critical role in influencing skeletal mineralisation. Early studies on cage layer fatigue indicated some predisposing management factors, including precocious egg production and egg production in under weight pullets in warm weather (Grumbles, 1959). The normal metabolic equilibrium in the fowl can therefore be disrupted by mismanagement, and disproportionately high levels of egg production can occur in birds which are underweight with low tissue reserves and low nutrient intakes. Furthermore, there is likely to be an important role for calcium nutrition and calcium turnover in determining the mineral content of the skeleton, but the relationship of calcium turnover to the development of osteoporosis is poorly understood.

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Maintenance of adequate skeletal calcium reserves is believed to be integral to sustaining production and shell quality, but there is little quantitative data on these parameters.

In an attempt to begin clarifying some of these relationships this paper reports on a flock of ISA Brown layers sequentially studied for growth, egg production, femur calcium reserves and bone histology.

II. METHODS

The ISA Brown flock was housed at commercial density (4 birds per cage) in a controlled environment shed where the temperature was maintained between 20-25°C. Birds were fed a commercial layer ration of 180 g/kg crude protein and 11.80 MJ/kg of metabolisable energy to 40 weeks of age, then 165 g/kg crude protein and 11.38 MJ/kg of metabolisable energy for the remainder of the experimental period. Calcium and phosphorous levels were included in the diet at 38 g/kg and 7 g/kg respectively.

Birds were monitored weekly for bodyweight up until 42 weeks of age, and then intermittently. Egg production was recorded weekly between 16 and 65 weeks of age.

Twenty left femur samples were obtained at 16, 23, 31, 42, 48 and 68 weeks of age and stored frozen until analysed for calcium content. The same twenty birds also had samples of the proximal tarsometatarsus removed for embedding and histological examination. The bone sections were examined blind and histomorphometry was used to quantify the percentages of medullary and trabecular bone (Wilson et al., 1992). At each sampling age the birds were examined for nodulation and deformity of the rib cage, with the incidence of osteoporosis calculated as a percentage of the twenty bird sample based on the subjective assessment of the rib cages.

III. RESULTS

![Graph showing bodyweight vs age](image)

Figure 1  Average Bodyweight of ISA Brown Flock from 16-66 Weeks of Age
(Note: following 42 weeks of age birds were weighed at 44, 50, 52, 56 and 65 weeks of age. Weights between were estimated assuming linearity)

The sequential studies of flock growth illustrated a period of sub-optimal growth in early egg production (21-28 weeks) followed by a period of weight loss between 34-38 weeks of age (Figure 1). This growth pattern has been recorded in a large number of commercial
layer flocks in Victoria, and is most notable in flocks housed in controlled environment shedding. The peak flock weight was 2.1 kg at 35 weeks of age.

Figure 2. Egg Production of ISA Brown Flock.

Egg production peaked at 90% in weeks 28 and 30-33, but decreased in association with the decrease in bodyweight between 34 and 38 weeks of age (Figure 2).

Figure 3. Average Femur Calcium Content (grams/bone) of ISA Brown Flock from 16-68 Weeks of Age (Mean (SE)).

Femur calcium content increased by over 50% from 16-23 weeks of age as the birds began egg production, and peaked at 31 weeks of age. The femur calcium then declined significantly (P< 0.05) by 42 weeks of age. The decline in femur calcium appeared correlated with the loss of bodyweight and the decline in egg production occurring in mid-lay. The loss of bodyweight (5%) and femur calcium (20%) corresponded to the theoretical peak egg mass output (35-45 weeks of age). From 48 to 70 weeks there is a rise in femur calcium associated with the decrease in egg production.

The comparison between femur calcium content and bone density parameters (trabecular bone volume and medullary bone volume) indicates that the shift in calcium
balance is well correlated with the change in both structural and mobilisable bone volumes of the proximal tarsometatarsus (Table 1). In the period from 31-42 weeks of age trabecular bone volume decreased by 50% and medullary bone decreased by 75%, followed by an increase to 48 weeks of age (Table 1).

Table 1. Sequential Determination of Femur Calcium (grams/bone), Trabecular Bone Volume (TBV%) and Medullary Bone Volume (MBV%) in the Proximal Tarsometatarsus of the ISA Flock (± standard error).

<table>
<thead>
<tr>
<th>Age (weeks)</th>
<th>Femur Calcium (grams/bone)</th>
<th>Trabecular Bone Volume (%)</th>
<th>Medullary Bone Volume (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SE)</td>
<td>Mean (SE)</td>
<td>Mean (SE)</td>
</tr>
<tr>
<td>16</td>
<td>0.65 ± 0.01</td>
<td>21.90 ± 1.40</td>
<td>2.38 ± 0.28</td>
</tr>
<tr>
<td>23</td>
<td>0.95 ± 0.04</td>
<td>15.06 ± 0.92</td>
<td>2.94 ± 0.42</td>
</tr>
<tr>
<td>31</td>
<td>1.05 ± 0.06</td>
<td>11.37 ± 0.91</td>
<td>7.24 ± 0.59</td>
</tr>
<tr>
<td>42</td>
<td>0.93 ± 0.03</td>
<td>5.24 ± 0.58</td>
<td>1.73 ± 0.19</td>
</tr>
<tr>
<td>48</td>
<td>0.95 ± 0.03</td>
<td>12.21 ± 0.77</td>
<td>4.66 ± 1.64</td>
</tr>
<tr>
<td>68</td>
<td>1.16 ± 0.05</td>
<td>*</td>
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</tr>
</tbody>
</table>

The nodulation and deformation of the rib cage, characteristic of osteoporosis, was initially evident at 42 weeks of age with 80% of birds affected. At 68 weeks of age both the incidence of rib abnormalities and the severity of the rib nodulation and deformity remained unchanged.

IV. DISCUSSION

In the model presented in this research it is clear that there was a profound shift in skeletal calcium reserves in mid-lay (31-42 weeks of age). The onset of osteoporosis is likely to occur in this period when skeletal calcium reserves are at their lowest. Histological evidence indicates that trabecular bone volume had declined by approximately 50% in a similar time frame, suggesting that the birds had used structural bone to sustain production, thereby increasing their susceptibility to osteoporosis. Under the pressure of continuously high egg mass output, the flock lost approximately 80-100 grams live weight (5%) and approximately 15-20% of total femur calcium content. If the femur calcium loss is representative of the whole skeleton then approximately 50% of the mobilisable pool of calcium (4.5 grams calcium) had been depleted between 31-42 weeks of age. As the pressure of egg mass output declined, the skeleton was able to replenish calcium stores and both trabecular and medullary bone (Rennie et al., 1997).

Clearly there are likely to be large shifts in skeletal mineral content occurring in mid-lay which are proportionally larger than the shifts in liveweight. The model developed is likely to be representative of commercial flocks and can form standards for additional analysis. Evidence collected in more recent studies indicates that the magnitude of the suppression of liveweight gain in early and mid-lay may not always be as severe as in these studies, but the age of the growth depression was very consistent across flocks.

Considering the magnitude of the shifts in skeletal mineralisation that could be occurring in mid-lay, there may be a relationship between the persistency of production, shell quality and calcium metabolism which could be moderated by new nutritional approaches. Furthermore, the close association between the development of the osteoporosis in mid-lay
and the drain of production, supports the premise that the production induced osteoporosis is much more significant in the induction of bone fragility in caged hens than the confinement and reduced mobility associated with the cage system. In future, comparisons of bone fragility or density should be carefully standardised for egg mass output.

REFERENCES