ABSTRACT

This study examined the long-term effects of housing system on several aspects of laying hen production. At 19 wks of age, 336 White Leghorn hens were placed, 3 birds per cage, into battery cages; 437 birds were assigned to an aviary with communal nests, ambulation areas, and three raised tiers with feeders and drinkers. Family groups were split between the two housing systems. The hens were housed in such a manner for over 3 yr (until the end of the 168th wk of age), with forced molts between 66 and 74 and between 119 and 125 wk of age. Feed consumption and conversion, egg weight, eggshell deformation, and hen-day productivity were assessed monthly in both systems. Although feed consumption and conversion tended to be higher in the aviary throughout the study, these variables differed significantly due to housing system only in Year 2 (P = 0.04). There were no differences in egg weight (P = 0.7), eggshell deformation (P = 0.85), egg cracking during shaking (P = 0.34), total hen-day productivity (P = 0.55), or egg mass produced per hen per month (P = 0.4). Although aviary systems have been criticized for egg losses due to floor laying, only 2.5% of eggs in the current study were laid on the floor in Year 1, and 0.3% in Years 2 and 3; 1.7% across all years. Hen mortality was variable across production and molt periods, and did not differ due to housing system (P > 0.05). The results of this study confirm that hen productivity in well-managed alternative housing systems can compare favorably with that in battery cages.

(Key words: layer, battery cages, aviary, productivity, welfare)

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INTRODUCTION

Battery cages for laying hens have been criticized by animal welfare organizations (e.g., Farm Animal Welfare Council, 1986) and scientists alike (e.g., Mickley and Fox, 1987; Wegner, 1990). The aviary housing system incorporates many of the requirements of the domestic hen that are currently not met by battery cage housing: increased physical space, greater environmental complexity, litter, perches, and egg-laying facilities (Folsch et al., 1988). However, the acceptance of alternative housing systems has been hindered by producers' perceptions that hen productivity in such systems is lower than in cages (Hill, 1986). Because a determination of the moral acceptability of any production system must incorporate the interests of all involved, any viable alternative to cages for laying hens must harmonize the interests of the consumer and the producer with those of the animal (Hurnik, 1990). To address such concerns, the current study undertook a long-term examination of the effects of housing system on several measures of laying hen productivity.

Keeping the same group of hens through three production cycles allowed the examination of the long-term effects of housing system on laying hen productivity. Although hens raised for egg production in Canada are generally not kept for more than a single laying cycle, the rationale for our decision to do so in the current study was to amplify any observable effects of housing system on hen performance, and to indirectly assess cumulative effects on hen quality of life (Hurnik and Lehman, 1988).

MATERIALS AND METHODS

Housing Systems

The two housing systems and the experimental animals have been described in detail by Tanaka and Hurnik (1991, 1992). To summarize, 763 female commercial-strain DeKalb2 White Leghorn layers were pedigree hatched and, at 1 d of age, allocated into littered floor pens (1.83 x 2.44 m) each with three roosts. Initial group size in the rearing environments was 70 pullets per pen (638 cm² per bird); at approximately 9 wk of age, the groups were each divided into two (1,276 cm² per bird). At 19 wk of age, the
hens were again divided, randomly splitting each family group. One group was assigned to a room with 112 battery cages (50 cm wide, 44 cm deep, 39 cm high in front, and 34 cm high in the rear), three birds to each cage (336 birds; 733 cm² per bird). The cage fronts and backs were comprised of three horizontal bars, spaced approximately 9 cm, and the sides were solid. The other group (437 birds) was placed in an identically sized room equipped as an aviary, with six communal nests along each side, two ambulation areas, and three central tiers with feeders and drinkers (1,310 cm² total floor area per bird). All birds had an equivalent 17 cm of feeder space, regardless of system, and had ad libitum access to feed and water. Hens were fed at approximately 0900 h, at which time they were also monitored for health and potential problems. Feed delivery was manual in the battery cages, and via chain feeder in the aviary. Ambient temperature in both was maintained at 20 to 22 °C, and the hens were exposed to a 14-h photoperiod (0600 to 1900 h). Eggs were collected daily between 1300 and 1400 h. Droppings boards (under all cages and under the three central tiers in the aviary) were scraped and the droppings removed weekly. The litter in the aviary was changed every 2 wk. No culling was performed, except to remove sick birds, and no replacements were made following hen deaths. Caged hens were beak trimmed at 22 wk of age, following an outbreak of cannibalism. This procedure was not necessary in the aviary at any point in the 3-yr study.

The hens were housed in such a manner for over 3 yr (until the end of the 168th wk of age), with forced molts between 66 and 74 and between 119 and 125 wk of age. Molting was induced by a combination of short photoperiod (6 h) and intermittent feed deprivation (two 4-d periods off feed separated by 1 d with feed, followed by seven 2-d periods off feed, all separated by 1 d with feed). Hens had ad libitum access to water throughout the molt process.

Production Variables

Feed Consumption. The amount of feed consumed in each system was assessed for 2 d, every 4 wk. On Day 1 of the measurement period, the feeders were completely emptied (cages) or vacuumed out (aviary). A weighed amount of feed was provided, and the orts weighed on Day 2. A second weighed amount of feed was given on Day 2, and the orts again weighed on Day 3. Feed consumption was averaged across the 2 d. Feed consumption per bird was determined by dividing the amount of feed consumed by the number of birds (aviary: entire flock; cages: number of birds in cage). The monthly (28 d) feed conversion was calculated by multiplying the number of hens present by the average daily feed consumption, and dividing by the number of eggs laid in the same period multiplied by average egg weight (Table 1).

Egg Weight and Shell Strength. Every 4 wk, 100 eggs from each side of the aviary and 100 eggs from each row of battery cages were randomly selected (200 eggs from each system) and individually weighed. Only eggs determined by candling to be uncracked were used. Eggshell deformation³ in response to a 500-g weight applied to the widest diameter of the egg was used as an indirect measure of shell strength (Hamilton, 1982). The deformation was measured twice per egg, on opposite sides of the egg, and the values averaged. Eggs that cracked during deformation testing were counted and discarded. To simulate handling stress, the remaining eggs were subjected to 3 min of vigorous horizontal shaking⁴ at 75 rpm. Following shaking, the number of cracked eggs was assessed by candling.

Hen Productivity. Eggs from both systems were collected and counted daily. Every 28 d, the number of eggs produced was divided by the total number of hens present to determine the percentage productivity. Cumulative egg mass production was calculated monthly, on a per bird basis. In the aviary, floor eggs were collected daily and are included in all egg yield totals.

Statistical Analysis

The production data of the two systems were compared using the Wilcoxon signed-rank test. The effect of production years on the various production parameters was assessed using the Kruskal-Wallis test. All tests were performed using SAS® computer software (Schlotzhauer and Littell, 1987).

RESULTS

Summary results for all measured production variables are presented in Table 1; relative hen mortality is given in Table 2. Production performance data for Year 1 have been previously reported (Tanaka and Hurnik, 1992), but are excerpted here for comparison with the following years of this study.

Feed Consumption and Conversion

Although aviary hens tended to consume more (Table 1), feed consumption did not differ significantly with system in Years 1 or 3. In Year 2, the aviary hens consumed significantly more feed than those in the battery cages (119.1 vs 109.9 g per bird per d; P = 0.04). When feed consumption data for all 3 yr were combined, there was no effect of housing system (121 vs 116 g per bird per d; P = 0.16). Feed consumption varied with year in both systems (P < 0.05).

Feed conversion rates paralleled consumption patterns, differing due to housing system only in Year 2 (P < 0.05), but not overall (P = 0.11). Feed conversion increased with production year in both housing systems (P < 0.05).

³Marius N.V., Hollantleen 18, Utrecht, The Netherlands.
⁴Lab-Line Orbit Shaker, Lab-Line Instruments Inc., Melrose Park, IL 60160.
Hens kept in alternative systems have previously been reported to consume more feed (e.g., Bailey et al., 1959; Hill, 1981), due either to wastage or changes in nutritional requirements as a result of increased physical activity (Hill, 1981). The results of the current study, however, indicate that alternative housing systems do not necessarily lead to significantly higher feed consumption (or wastage) and therefore increased feed costs.

**Egg Weight**

There was no difference in average egg weight due to system in any of the 3 production yr, or overall (P = 0.7). Average egg weight increased significantly with successive years of production in both systems (P < 0.05). This finding is consistent with the report of Appleby et al. (1988), and the general conclusion of Hill (1986) that there is no difference in egg weight between cage and alternative housing systems. Other studies have reported small advantages to both cage (Bailey et al., 1959) and loose-housed systems (McLean et al., 1986).

**Eggshell Strength**

Eggshell deformation did not differ between housing systems in any of the 3 yr of the study, or overall (P = 0.85); nor did it differ within housing system due to production year. The percentage of eggs cracked during the shaking test increased with year (P < 0.05), but did not differ due to housing system in any single year, or overall (P = 0.34). Eggshell quality has not elsewhere been shown to differ with housing system (e.g., Wegner, 1983).

**Hen Productivity**

Previous reports have suggested that caged laying hens produce more eggs than hens kept in alternative housing systems, including floor pens (Bailey et al., 1959), deep litter pens (Bareham, 1972; Appleby et al., 1988), and a perchy (McLean et al., 1986). However, results have been variable. A review by Appleby and Hughes (1991) concluded that there is no strong evidence that productivity is necessarily better in cages. The results of the current study confirm this assertion; there was no difference in percentage egg yield in any of the 3 yr of this study (Figure 1), or overall (P = 0.55). Similarly, weekly egg mass production did not differ due to housing system (P = 0.4). However, hen productivity and weekly egg mass in both systems decreased significantly (P < 0.05) with increasing production year.

**TABLE 1. Performance of laying hens housed for 3 yr in an aviary or battery cages**

<table>
<thead>
<tr>
<th>Housing</th>
<th>Year</th>
<th>Average feed consumption¹</th>
<th>Monthly feed conversion³</th>
<th>Average egg weight</th>
<th>Eggshell deformation</th>
<th>Cracked eggs⁴</th>
<th>Hen-day productivity</th>
<th>Egg mass per bird per week</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(g/hen/d)</td>
<td>(g/g)</td>
<td>(g)</td>
<td>(µm)</td>
<td>(%)</td>
<td></td>
<td>(g)</td>
</tr>
<tr>
<td>Aviary</td>
<td>1</td>
<td>127.8</td>
<td>2.5</td>
<td>59.2</td>
<td>25.8</td>
<td>25.1</td>
<td>86.5</td>
<td>357.1</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>119.0³</td>
<td>2.6³</td>
<td>63.7</td>
<td>25.7</td>
<td>35.1</td>
<td>73.5</td>
<td>328.5</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>117.9</td>
<td>3.2</td>
<td>64.5</td>
<td>26.8</td>
<td>45.6</td>
<td>59.6</td>
<td>270.0</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>120.6</td>
<td>2.8</td>
<td>62.1</td>
<td>26.1</td>
<td>33.5</td>
<td>70.9</td>
<td>317.4</td>
</tr>
<tr>
<td>Battery</td>
<td>1</td>
<td>127.8</td>
<td>2.4</td>
<td>59.1</td>
<td>25.2</td>
<td>25.1</td>
<td>88.8</td>
<td>368.2</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>109.9³</td>
<td>2.4³</td>
<td>63.7</td>
<td>26.0</td>
<td>39.3</td>
<td>74.7</td>
<td>335.5</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>116.4</td>
<td>3.0</td>
<td>64.6</td>
<td>27.2</td>
<td>49.4</td>
<td>60.9</td>
<td>272.5</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>115.7</td>
<td>2.6</td>
<td>62.1</td>
<td>26.1</td>
<td>36.9</td>
<td>72.7</td>
<td>327.3</td>
</tr>
</tbody>
</table>

¹Means within a column within a year with no common superscript differ significantly within housing system (P < 0.05).
²Values given are averages of monthly totals for that production year (n = 10 mo in Year 1; n = 11 mo in Years 2 and 3). All variables except eggshell deformation varied significantly (P < 0.05) with year, within housing system.
³Taylor and Humik (1994).
⁴Feed conversion calculated using the formula: FC = (number of hens x 28 d x average daily feed consumption)/(number of eggs/mo x average egg weight).
⁵The percentage of eggs that cracked during experimental shaking for 3 min at 750 rpm.
⁶First-year data have already been reported in Tanaka and Humik (1992).

**TABLE 2. Mortality of laying hens through 3 yr of production, including two forced molts**

<table>
<thead>
<tr>
<th>Housing system</th>
<th>Year 1</th>
<th>Molt 1</th>
<th>Year 2</th>
<th>Molt 2</th>
<th>Year 3</th>
<th>Total³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aviary</td>
<td>5.9</td>
<td>1.2</td>
<td>5.9</td>
<td>0.8</td>
<td>6.8</td>
<td>19.2</td>
</tr>
<tr>
<td>Battery cages</td>
<td>5.1</td>
<td>1.3</td>
<td>4.8</td>
<td>1.7</td>
<td>10.2</td>
<td>21.1</td>
</tr>
</tbody>
</table>

¹Hen mortality across periods did not differ with housing system (P > 0.05; Wilcoxon signed rank test).
²The percentage of birds beginning that production period or molt that died during the period.
³The percentage of birds beginning the study that died at any time throughout the 3 yr.
Another common criticism of alternative housing systems for laying hens is the occurrence of floor eggs (Hill, 1981; Wegner, 1983). Floor eggs increase labor costs for egg collection, and decrease hatchability or marketability due to contamination (Appleby, 1984). The incidence of floor eggs in alternative housing systems appears to be very variable, and has been reported to range from 3.5 to 30% of eggs laid (Appleby, 1984). Floor eggs are most common at the start of the laying period, and have been reported to reach levels over 60% at this time (Hill, 1986).

The occurrence of floor eggs in the aviary in this study was highest during the 1st mo (7%), but immediately dropped to less than 2.5% in the 2nd mo. The average percentage of floor eggs was 2.5% in Year 1; 0.3% in both Years 2 and 3, and 1.7% across all years. These levels are considerably lower than have been reported elsewhere, and may be attributed to several design features of the Guelph aviary. First, nest fronts were partially closed, to increase their attractiveness to hens, which often seek secluded areas for oviposition (Hurnik and Walker, 1972; Folsch et al., 1988). Second, all nest fronts were painted alternately red, yellow, blue, or green. It was hypothesized that this would allow the hens to differentiate individual nests by color as well as location, thereby permitting them to establish nest preferences and reduce competition (Hurnik et al., 1973). Finally, the lower walls and all partitions were painted white to maximize brightness, thereby minimizing their seclusion relative to the nests. It would appear that these strategies were successful in minimizing egg losses due to floor laying. However further replication of these results is necessary to confirm this hypothesis.

The mortality of the birds during each of the production years and the two forced molt periods is given in Table 2. Hen mortality across production and molt periods was variable, but did not differ consistently due to housing system (P > 0.05). Mortality rates have been reported elsewhere to be higher in battery cages than in alternative systems (e.g., McLean et al., 1986) and vice versa (e.g., Dun et al., 1991). As a result, some authors have concluded that the housing systems themselves do not directly affect rates of hen death (Appleby and Hughes, 1991; Bailey et al., 1959).

For some variables (egg yield, average egg weight, cumulative egg mass produced per hen, and eggshell quality), hen performance in subsequent years confirmed the findings in Year 1. Other variables, however, were less consistent in their response over time. For example, feed consumption and conversion tended to be higher in the aviary than in cages throughout the study, yet this was confirmed statistically only in the 2nd production yr.

The results of the current study clearly indicate that the productivity (feed consumption and conversion, egg weight, eggshell deformation, and percentage hen-housed egg yield) of laying hens kept in alternative housing systems can compare favorably with that achieved in battery cages. Floor eggs, frequently cited as a major drawback of alternative housing for laying hens, proved very manageable under the conditions of this study. Further, it has been reported elsewhere that several aspects of the physical condition (feather cover, claw
length, and toe lesions) of the aviary hens have been shown to be significantly superior to the caged hens at the end of this 3-yr study (Taylor and Hurnik, 1994). Therefore, it may be concluded that, under appropriate management, an aviary system such as the one evaluated here has the potential to be a practical and competitive alternative to battery cage housing for laying hens. It is difficult to predict the relative costs of installing an aviary vs a battery cage system under commercial conditions. However, the cost of installing the two experimental systems used in these studies was comparable. In addition to protecting producers' interest in maintaining high levels of productivity given an appropriate level of management, an aviary system can address some of consumers' greatest concerns about laying hen well-being and overall quality of life.

**ACKNOWLEDGMENTS**

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