

# Specific characteristics of the aviary housing system affect plumage condition, mortality and production in laying hens

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**ABSTRACT** Feather pecking and high mortality levels are significant welfare problems in non-cage housing systems for laying hens. The aim of this study was to identify husbandry-related risk factors for feather damage, mortality, and egg laying performance in laying hens housed in the multi-tier non-cage housing systems known as aviaries. Factors tested included type of system flooring, degree of red mite infestation, and access to free-range areas. Information on housing characteristics, management, and performance in Belgian aviaries (N = 47 flocks) were obtained from a questionnaire, farm records, and farm visits. Plumage condition and pecking wounds were scored in 50 randomly selected 60-week-old hens per flock. Associations between plumage condition, wounds, performance, mortality, and possible risk factors were investigated using a linear model with a stepwise model selection procedure. Many flocks exhibited a poor plumage condition and a high prevalence of wounds, with considerable variation between flocks. Better plumage condition was found in wire mesh aviaries ( $P < 0.001$ ), in

aviaries with no red mite infestation ( $P = 0.004$ ), and in free-range systems ( $P = 0.011$ ) compared to plastic slatted aviaries, in houses with red mite infestations, and those without a free-range area. Furthermore, hens in aviaries with wire mesh flooring had fewer wounds on the back ( $P = 0.006$ ) and vent ( $P = 0.009$ ), reduced mortality ( $P = 0.003$ ), and a better laying performance ( $P = 0.013$ ) as compared to hens in aviaries with plastic slatted flooring. Flocks with better feather cover had lower levels of mortality ( $P < 0.001$ ). Red mite infestations were more common in plastic slatted aviaries ( $P = 0.043$ ). Other risk factors associated with plumage condition were genotype, number of diet changes, and the presence of nest perches. Wire mesh flooring in particular seems to have several health, welfare, and performance benefits in comparison to plastic slats, possibly related to decreased feather pecking, better hygiene, and fewer red mite infestations. This suggests that adjustments to the aviary housing design may further improve laying hen welfare and performance.

**Key words:** feather pecking, mortality, housing system, aviary, red mite

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## INTRODUCTION

The European Union Council Directive 1999/74/EC stipulates that from 2012 onwards, laying hens in the EU can only be housed in either furnished cages or non-cage systems (EU, 1999). As a result, over 160 million laying hens in the EU are currently kept in non-cage systems for commercial egg production (EuroStat, 2014). Non-cage housing systems have the potential to be more animal-friendly, mainly because they offer the hens more space and opportunities to perform natural behaviors than cage systems (Appleby and Hughes,

1991; Duncan, 2001; Shimmura et al., 2010; Rodenburg et al., 2012; Freire et al., 2013). In practice however, reasons for serious concern remain regarding the welfare of hens in commercial non-cage systems. Several recent studies have demonstrated that hens housed in non-cage systems have a higher risk for increased mortality and feather pecking compared with cage systems (Freire et al., 2003; Rodenburg et al., 2005, 2012; Fossum et al., 2009; Sherwin et al., 2010; Shimmura et al., 2010; Lay et al., 2011). Because non-cage systems are growing both in number and size, the related concern for layers' welfare is also growing (Tuytens et al., 2011).

Non-cage systems can be divided roughly into the traditional single-tier floor housing systems, and the more recently developed aviary systems. Aviaries are multi-tier systems that consist of a littered ground floor and a metal structure with up to four tiers

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(row-type aviaries). A portal-type aviary provides a single level on top of 2 stacks (Tauson, 2005a). Aviaries vary in design, although all systems typically have feeders, drinkers, and perches located on one or more tiers. Earlier aviary types have separate units for nest boxes, whereas in the more recent types the nest boxes are integrated into the tiers. The tiers' flooring is either constructed of wire mesh or plastic slats (LayWel, 2006). Access to the ground floor and multiple levels increases the surface accessible to the hens and allows them to perform natural behaviors such as running, wing flapping, flying, nesting, perching, and dustbathing when compared with cage environments (Leyendecker et al., 2005). According to EU Directive 1999/74/EC, up to 18 hens/m<sup>2</sup> house floor area can be kept, with a stocking density of 9 hens/m<sup>2</sup> on the useable area (including the tiers). Additionally, a covered veranda or a free-range area accessible through popholes may be provided. Free-range surface requirements are typically 4 m<sup>2</sup>/hen. Increased feather pecking and cannibalism, as well as poorer hygienic conditions and red mite infestations, have been suggested as causes for variability in egg production and mortality in aviary systems; these behaviors and living conditions are more unpredictable than for cage systems (Tauson et al., 1999; Tauson, 2002; Aerni et al., 2005; Lay et al., 2011; Sparagano et al., 2014). Furthermore, eggs laid outside the nest, so-called floor and system eggs, can be problematic in non-cage systems because of related increases in labor requirements and reductions in egg quality (Appleby, 1984).

Maladaptive pecking behaviors form serious animal welfare and economic problems in poultry production. Feather pecking is defined as pecking at and pulling out the feathers of conspecifics, whereas both cannibalistic behavior and vent pecking also damage the skin and underlying tissue of the conspecific. These behaviors may be associated with stress, pain, and fear, as well as increased mortality, and increased feed consumption due to heat loss (Bilcik and Keeling, 1999; Gunnarsson et al., 1999; Lambton et al., 2013). These undesirable behaviors are considered to be multifactorial and unpredictable problems that are present in all housing systems (Gunnarsson et al., 1999; Pöttsch et al., 2001; Lambton et al., 2010; Nicol et al., 2013; Rodenburg et al., 2013). Feather pecking is believed to be redirected ground pecking in relation to foraging behavior (Blokhuis, 1986; Huber-Eicher and Wechsler, 1997). Although aviary systems provide more opportunities to perform natural behaviors compared to cage systems, feather pecking remains a serious welfare issue (Huber-Eicher and Wechsler, 1997; Blokhuis et al., 2007; Rodenburg et al., 2013). When hens are kept in large groups, as in the aviary systems, feather pecking is more difficult to control, as a feather-pecker is more difficult to identify in a larger group versus a smaller one and can thus cause more damage (McAdie and Keeling, 2000; Rodenburg et al., 2005).

Feather pecking, variable production results, and relatively high mortality are still problems associated with laying hens housed in aviary housing systems. The aviary system has surpassed traditional floor housing as the most common non-cage housing system in Belgium and many other countries. The aims of this study were therefore (1) to quantify feather damage and pecking wounds, mortality, and egg production rates in laying hens housed in a cross-sectional sample of commercial aviary systems in Belgium, and (2) to identify risk factors within aviary systems for these outcome variables.

## MATERIALS AND METHODS

### *Flock Recruitment and Farm Visits*

The main stakeholders and representatives from the egg industry in Belgium were informed about the project aims and their public support of the project was requested. Egg producers were informed by presenting the project at agricultural fairs and an announcement in the main Belgian poultry stakeholders' magazine. Egg producers were then approached by telephone and asked for their participation in the study. Participation was encouraged by offering a financial compensation for their time and effort. A total of 47 henhouses with aviary housing on 33 commercial farms were included in this study. Farm visits were conducted between August 2012 and December 2013 by 2 observers from the Institute for Agricultural and Fisheries Research who jointly received extensive training in integument scoring prior to the start of the farm visits. Both observers of the present study received the training as part of the CORE organic II project HealthyHens in which both observers of the present study were involved ([www.coreorganic2.org](http://www.coreorganic2.org)). The laying hens were approximately 60-weeks-old at the time of the farm visit (ranging from 58 to 64 weeks of age).

### *Management, Production Results and Flock Mortality*

A questionnaire was sent to the farmer 2 weeks before the farm visit. It contained approximately 110 questions on management (e.g., light- and feeding regime, farm hygiene, manure disposal), aviary system characteristics (e.g., age, manufacturer, perch orientation, feeder and drinker types), housing enrichments, and laying hen information (e.g., hybrid, breeder, rearing, flock size). During each farm visit this questionnaire was checked to complete any missing answers. Egg production rate (expressed as the average number of eggs laid per day per hen present), percentage of second quality eggs, percentage of floor and system eggs, and percentage of cumulative mortality of the flock (percentage of dead hens since arrival on the production farm) were obtained from farm records. If the farm visit was conducted before or after the flock was 60-weeks-old, the production

**Table 1.** Summary information on the aviary housing systems included in the study (N = 47 houses).

Factor	Feature	Frequency
Aviary type	Row	37/47 (79%)
	Portal	10/47 (21%)
Covered veranda	Yes	13/47 (28%)
	No	25/47 (53%)
Free-range area <sup>1,2</sup>	Yes	9/47 (19%)
	No	38/47 (81%)
Aviary system flooring	Wire mesh	31/47 (66%)
	Plastic slats	16/47 (34%)
Age of barn <sup>3</sup>	0 to 4 years	27/46 (59%)
	5 to10 years	5/46 (11%)
	≥ 11 years	14/46 (30%)
Age of aviary <sup>3</sup>	0 to 4 years	39/46 (85%)
	5 to10 years	7/46 (15%)
	≥ 11 years	0/46 (0%)
Nest perch	Yes	25/47 (53%)
	No	22/47 (47%)
Hens at start	0 to 20,000	11/47 (23%)
	20,001 to 40,000	24/47 (51%)
	40,001 to 60,000	10/47 (21%)
	≥ 60,001	2/47 (4%)
Hybrid	Lohmann Brown Classic	21/47 (45%)
	ISA Brown	13/47 (28%)
	Other	13/47 (28%)
Phases of feed	1	10/46 (22%)
	2	13/46 (28%)
	3	22/46 (48%)
	≥ 4	1/46 (2%)
Red mite infestation <sup>3</sup>	Absent	16/43 (37%)
	Mild infestation	20/43 (47%)
	Severe infestation	7/43 (16%)

<sup>1</sup>All henhouses with a free-range area also provided a covered veranda. These are not included in the 13/47 verandas.

<sup>2</sup>Two free-range farms were organic laying hen farms.

<sup>3</sup>Missing data on some farms.

results and mortality at 60 weeks of age were used for the statistical analyses by retrieving this information from the farm records provided or by contacting the farmer afterwards.

### Aviary System Characteristics

For each aviary system the manufacturer and specific aviary type were recorded. A distinction was made between row- and portal-type aviary systems, and whether or not the hens had access to a covered veranda or free-range area. Henhouses with both a free-range area and a covered veranda were considered to be free-range henhouses only. Further details of the aviaries (Table 1), such as flooring material of the aviary tiers (wire mesh vs. plastic slats), age of the barn, and the aviary system and presence or absence of a perch or platform in front of the nest were derived from the questionnaire and interview, or were recorded during the visit to the henhouse. Infestation of red mites was scored on an ordinal scale as either ‘absent’, ‘mild infestation’ (some red mites visible, but not in large quantities), or ‘severe infestation’ (clearly visible clumps or large quantities of red mites in cracks, crevices, and structural elements) (adapted from the WelfareQuality<sup>®</sup> protocol (Welfare Quality<sup>®</sup>2009)).

### Laying Hen Characteristics and Measurements

Information on hen age, hybrid, and rearing conditions were obtained from the questionnaire and interview. For animal-based parameters (plumage condition and wounds), 50 randomly selected laying hens per aviary henhouse were caught from all tiers of the aviary system, scored, then immediately released. Each observer scored approximately half of the hens per farm visit. If a covered veranda or a free-range area was present, an approximate representative number within the sample of 50 birds was scored in those areas. Plumage conditions of 5 body parts (neck, back, wings, tail, vent) were scored on an ordinal 4-point scale, adapted from the LayWel project (Tauson et al., 2005b; Blokhuis et al., 2007). For the wings, the wing with the worst plumage condition was scored. A score ranging from 1 to 4 was given to each body part, in which the highest score indicated the best plumage condition. For a total plumage score (TPS), the scores of the 5 individual body parts were summed to form a non-equidistant score. Thus the lowest TPS score was 5, representing an extremely poor plumage condition, and the highest TPS score was 20, which represents a more or less perfect plumage condition.

Wounds on the back and the vent area were scored per body part on a 4-point scale. A score 4 was given when no wounds or ≤2 small wounds were present, score 3 for >2 wounds with diameter <0.5 cm, score 2 for wound(s) present with a 0.5 to 2.2 cm diameter, and score 1 for presence of larger wound(s) >2.2 cm.

Cloacal discharge was scored on a binary scale (1 = present, 2 = absent).

### Data Analyses

Descriptive statistics for means, variation, and range were calculated for plumage condition, wounds, production, and mortality. Associations between animal-based measures (plumage condition and wounds), production (production rate, second quality eggs, floor and system eggs), mortality, and possible risk factors were investigated using linear models. For each dependent variable a separate model was built using a stepwise model selection procedure. The models employed the following factors as independent variables: all characteristics in Table 1 and times fed per day, nest entrance (perch vs. platform), daily time spent in henhouse by stockperson (minutes), daily time spent in henhouse by stockperson per 1,000 hens (minutes), and red mite infestation (absent, mild infestation, severe infestation). The flock was the experimental unit for the production results and mortality scores. The average of individual hen scores per flock was the experimental unit for plumage and wound scores. For hybrid as a risk factor, only the 2 predominant hybrids (respectively Lohmann Brown Classic and ISA Brown) were included. All other hybrids

were pooled together to form a diverse group consisting of 5 hybrids (respectively Lohmann Brown Lite, Hy-line Brown, Bovans Brown, Novogen Brown, and Dekalb White) which included both white and brown hybrids. This group was included as a separate hybrid in the risk factor analysis, but due to the diversity of hybrids within this group, it was excluded from any further interpretation of results. Only significant risk factors were included in the final model per outcome variable (significance level of 5%). The means provided for the scores in the text are the least squares means ( $\pm$  SE). The analyzed data were considered sufficiently normally distributed, based on the graphical evaluation (histogram and QQ-plot) of the residuals. In case of post-hoc pairwise testing, p-values were corrected with the Tukey-Kramer adjustment for multiple comparisons. Analyses were performed using R 3.0.1 for Windows (R Foundation for Statistical Computing, Vienna, Austria) and StatSoft. Inc. (2012) STATISTICA, version 11 (Stat Soft Inc, Tulsa, USA).

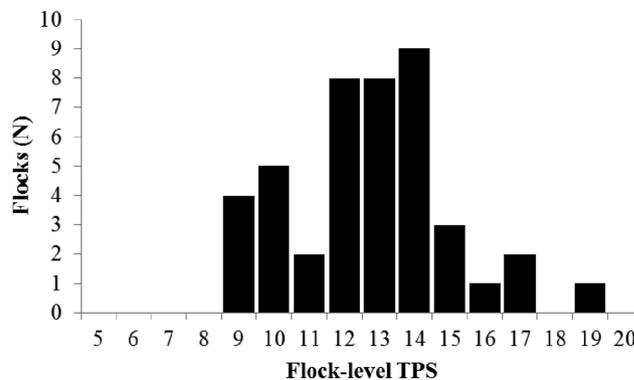
## RESULTS

### **Flock, Farm, Aviary and Management Information**

The hens in this study sum to 1,479,036 commercially held laying hens in Belgian aviaries, which corresponds to 44.4% of all registered non-cage laying hens in Belgium in December 2013 (EuroStat, 2014). Because floor systems are also registered as non-cage systems, the actual percentage of all laying hens kept in Belgian aviaries that were reached in this study in fact is much higher than 44.4%.

General flock and farm information is summarized in Table 1. The average flock age during the visit was  $60.7 \pm 0.3$  weeks. At 60 weeks of age, the average cumulative mortality was 4.1% (range, 0.9 to 12.8%) and average laying rate was 87.6% (range, 72.0 to 94.1%), with 2.2% second quality eggs, and 1.0% floor and system eggs (range, 0.9 to 12.8%). The main causes of mortality, as reported by the farmers, were feather pecking and cannibalism, salpingitis, *Escherichia coli* infections, and smothering. The highest mortality (12.8%) found in the present study was due to an outbreak of infectious laryngo tracheitis at 32 weeks of age. The examined laying hen hybrids were Lohmann Brown Classic (N = 21 flocks) and ISA Brown (N = 13), plus 5 other hybrids. Beak trimming is commonly applied in Belgian laying hen husbandry. Of the 47 flocks in the study, 46 had trimmed beaks, while one organic flock had intact beaks.

The farmers were on average  $42.1 \pm 1.0$  years of age (range, 24 to 54 years) with  $18.7 \pm 1.3$  years of experience in laying hen farming. The average corridor width between rows (portal-type aviaries were excluded from this measurement) was  $163 \pm 10$  cm. On average the hens were fed  $5.4 \pm 0.1$  times per day and had been fed  $2.3 \pm 0.1$  different diets since arrival on the production



**Figure 1.** Distribution of TPS at flock level as scored on 50 hens per flock. TPS is the cumulative score from 5 body parts which are given a score between 1 (heavily deteriorated plumage condition) and 4 (no feather damage).

farm. Red mites were found in 63% of the henhouses and were found in varying quantities on supporting beams, in nest boxes, or near perches. Red mites were rarely detected on the birds. The self-reported average time spent daily in the henhouse amongst the hens (for e.g., collecting floor eggs and carcasses, system maintenance, etc.) by the farmer or stockperson was  $108 \pm 9$  minutes per flock per day. Weighted for flock size, the time spent for every 1,000 hens placed was on average  $3.9 \pm 0.3$  minutes per day.

### **Plumage Condition and Wounds**

The inter-observer reliability between the 2 observers for scoring plumage condition and wounds were 0.55 and 0.71, respectively, measured by prevalence adjusted bias adjusted kappa.

The plumage condition of a total of 2,150 hens from 43 flocks was scored (Table 2). Four flocks were not scored for plumage condition due to induced molting before or during the farm visit. Signs of feather pecking and/or feather damage were present on all observed farms. The maximum TPS of 20 points (no damage) was observed in 22 (1.0%) of the 2,150 observed hens, and the minimum TPS of 5 (severe damage) was observed in 11 hens (0.5%). The average TPS at flock level was  $13.4 \pm 0.4$  with the worst flock having a TPS of  $9.1 \pm 0.4$  and the best flock having a TPS of  $19.3 \pm 0.1$  (Fig. 1). Table 2 displays the average prevalence of plumage damage and wounds to the different body parts as well as variation within and between flocks for the different scores for feathers and wounds. The mean flock prevalence range was considerable: some flocks had hardly any feather damage or wounds, whereas in other flocks (almost) all birds had feather damage or wounds. Within-flock variation was almost equal between the feather scores for the different body parts and also between the wound scores. Between-flock variation was the largest for feather scores on the back and the vent. Cloacal discharge was found in only 1.0% of all observed hens.

**Table 2.** Mean flock level prevalence of feather damage and wounds, average score for plumage and wounds (1 = worst score, 4 = best score), and variation within- and between-flocks.

Feathers	N flocks <sup>1</sup>	Mean flock prevalence <sup>2</sup> (%)	Range (%)	Mean flock score <sup>3</sup>	Within-flock variation <sup>4</sup>	Between-flock variation <sup>5</sup>
Neck	43	80.0 ± 2.8	14 to 100	2.77 ± 0.02	0.73	0.47
Back	43	70.1 ± 4.5	2 to 100	2.62 ± 0.02	0.78	0.83
Wings	43	66.8 ± 3.0	2 to 92	3.05 ± 0.02	0.75	0.37
Tail	43	91.6 ± 1.8	38 to 100	2.06 ± 0.02	0.80	0.50
Vent	43	56.4 ± 4.7	2 to 100	2.83 ± 0.03	0.81	0.93
TPS <sup>6</sup>				13.4 ± 0.4	2.50	2.34
Wounds						
Back	47	29.9 ± 3.5	0 to 80	3.61 ± 0.01	0.58	0.35
Vent	47	26.5 ± 3.5	0 to 94	3.61 ± 0.02	0.62	0.42

<sup>1</sup>Only 43 from 47 flocks could be scored for plumage because 4 flocks underwent induced molting.

<sup>2</sup>Percentage of hens per flock with affected plumage or wounds (hens scored with either a score 1, 2, or 3).

<sup>3</sup>Mean score (± S.E) on ordinal 4-point scale (1 to 4) at flock level.

<sup>4</sup>Within-flock variation calculated by random effects model.

<sup>5</sup>Between-flock variation calculated by random effects model.

<sup>6</sup>TPS: Total Plumage Score, the scores of the 5 individual body parts were summed to form a non-equidistant score.

**Table 3.** Effect of wire mesh vs. plastic slats flooring on plumage score, wound score, egg production rate, and mortality at 60 weeks of age.

Feather score	Wire mesh LSM ± se	Plastic slats LSM ± se	<i>P</i> -value
Neck			NS
Back	2.91 ± 0.18	2.52 ± 0.21	0.006
Wing	3.20 ± 0.06	2.88 ± 0.07	0.002
Tail			NS
Vent	2.92 ± 0.17	2.52 ± 0.24	0.010
TPS	13.8 ± 0.4	12.4 ± 0.6	<0.001
Wounds score			
Back	3.78 ± 0.07	3.49 ± 0.09	0.010
Vent	3.72 ± 0.07	3.39 ± 0.10	0.009
Egg production rate (%)	88.3 ± 0.7	85.3 ± 0.9	0.009
Mortality (%)	3.3 ± 0.4	5.4 ± 0.5	0.003

LSM = Least Squares Means; NS = Not significant; TPS = Total Plumage Score.

## Risk Factors

System flooring material was identified as a risk factor for plumage condition, wound severity, laying rate, and mortality (Table 3). Hens housed in systems with wire mesh flooring instead of plastic slatted flooring showed better feather scores on the back ( $P = 0.006$ ), the wings ( $P = 0.002$ ), and the vent ( $P = 0.010$ ). Consequently, the TPS was also better for wire system flooring compared to plastic system flooring ( $P < 0.001$ ). Hens in systems with wire mesh flooring had less severe wounds on the back ( $P = 0.01$ ) and the vent ( $P = 0.009$ ). In systems with wire mesh flooring, the egg laying rate was higher ( $P = 0.013$ ) and mortality lower ( $P = 0.003$ ).

Red mite infestation was identified as a risk factor for plumage condition, cloacal discharge, and mortality (Table 4). Flocks in henhouses with no red mite infestation had a better plumage condition, as indicated by a higher TPS, than flocks with a mild or severe red mite infestation. Cloacal discharge score and mortality were worse in flocks with mild red mite infestation compared to flocks with no or severe red mite infestation. A red mite infestation was more frequently found in systems

with plastic slatted flooring than in systems with wire mesh flooring (85.7% vs. 51.7%,  $P = 0.043$ ).

Hens with access to a free-range area had better feather scores on the back ( $2.86 \pm 0.25$  vs.  $2.57 \pm 0.15$ ,  $P = 0.029$ ) and better TPS scores ( $14.7 \pm 0.7$  vs.  $12.6 \pm 0.4$ ,  $P = 0.011$ ) compared to hens without access to a free-range area. Better plumage scores for the tail were found with a platform in front of the nest perch rather than only a perch in front of the nest ( $2.32 \pm 0.10$  vs.  $2.02 \pm 0.10$ ,  $P = 0.016$ ). Hens housed in row-type aviaries when compared to hens in portal-type aviaries showed better neck plumage scores ( $2.93 \pm 0.07$  vs.  $2.26 \pm 0.13$ ,  $P < 0.001$ ). The score for vent plumage improved with increasing time per day spent in the henhouse by a stockperson ( $F_{4,34} = 4,858$ ,  $P = 0.043$ ). Mortality decreased with a better TPS ( $F_{1,40} = 20.05$ ,  $P < 0.001$ ) and egg production rate increased with better neck plumage scores ( $F_{1,41} = 10.61$ ,  $P = 0.002$ ).

The percentage of second quality eggs increased with increasing age of the barn ( $F_{1,29} = 11.97$ ,  $P = 0.002$ ). Increasing numbers of feed changes during the first 42 weeks of the flocks' production period on the laying farm (e.g., transition feed, pre-start feed, peak-of-lay feed) resulted in a better plumage score in the neck ( $F_{1,39} = 7.93$ ,  $P = 0.008$ ). Lohmann Brown Classic hens showed a higher production rate than ISA Brown hens ( $88.5 \pm 0.9\%$  vs.  $84.0 \pm 1.0\%$ ,  $P = 0.005$ ). ISA Brown showed a better plumage score on the wings than Lohmann Brown Classic ( $3.08 \pm 0.08$  vs.  $2.76 \pm 0.07$ ,  $P = 0.013$ ).

We found no significant effects or interactions of the outcome variables with number of feedings per day, years of farming experience, presence of a covered veranda, age of the aviary system, or flock size on any of the indicators measured.

## DISCUSSION

This study shows that some health and welfare aspects for laying hens in aviaries are often not

**Table 4.** Effect of red mite infestation on plumage score, cloacal discharge, and mortality at 60 weeks of age.

	No infestation	Mild infestation	Severe infestation	<i>P</i> -value
	LSM ± se	LSM ± se	LSM ± se	
Back	3.14 ± 0.20 <sup>a</sup>	2.32 ± 0.20 <sup>b</sup>	2.32 ± 0.30 <sup>a</sup>	0.020
Vent	3.25 ± 0.23 <sup>a</sup>	2.49 ± 0.19 <sup>b</sup>	2.43 ± 0.33 <sup>a</sup>	0.045
TPS	14.7 ± 0.5 <sup>a</sup>	12.4 ± 0.4 <sup>b</sup>	12.2 ± 0.8 <sup>b</sup>	0.004
Cloaca discharge	1.998 ± 0.005 <sup>a</sup>	1.982 ± 0.004 <sup>b</sup>	1.999 ± 0.007 <sup>a</sup>	0.032
Mortality (%)	3.1 ± 0.4 <sup>a</sup>	4.6 ± 0.4 <sup>b</sup>	2.8 ± 0.7 <sup>a</sup>	0.015

LSM = Least Squares Means; TPS = Total Plumage Score.

Shared superscripts indicate no significant difference ( $P > 0.05$ ).

optimal and that a large variation in plumage condition, wounds, mortality, and production exists between farms. The variation ranging from hardly any affected hens on a single farm up to all hens affected on another farm implies that there is room for improving several welfare aspects in commercial aviary farms. Previous studies of non-cage systems had also reported large variations ranging from very low to extremely high prevalence of the measured health and welfare problems (Bilcik and Keeling, 1999; Gunnarsson et al., 1999; Bestman and Wagenaar, 2003; Lambton et al., 2010; Nicol et al., 2013). We were able to confirm some previously described risk factors, but we have also identified new risk factors for plumage condition, egg production, and mortality linked to the housing system and management.

To demonstrate the prevalence and variation of the investigated variables between farms, this study examined a representative cross-sectional sample population of Belgian henhouses with aviaries. In our study, the aviary systems were installed on average less than 3 years before the start of this study, indicating that this study mainly represents the newer henhouses in Belgium.

The average mortality of 4.1% at 60 weeks of age found in the present study is almost half of the 8.1% mortality recorded by a Belgian field study conducted in 2005 and 2006 (Rodenburg et al., 2008), although the study of Rodenburg et al. studied a much smaller sample population. However, the mortality rate found in the present study is also lower than the mortality rate (%/hen housed/age) found in the systematic review by Aerni et al. (2005). This may indicate that mean mortality in aviaries has now declined to a level comparable to cage systems (Weitzenbürger et al., 2005; Tactacan et al., 2009). The comparatively low mean cumulative mortality found in the present study most likely has multi-factorial causes, such as better disease control, adjusted rearing conditions, reduced feather pecking and cannibalism, improved feeds, and improved management by farmers due to increasing experience with the system.

The present study confirmed that feather pecking is still a very common problem with large variations between different henhouses, a result which is similar to many other studies as reviewed by Nicol et al. (2013). The farmers in our study reported that feather pecking

and cannibalism were the main causes of hen mortality, which corresponds with the association we found, i.e., that better plumage condition was associated with decreased mortality. This finding is in accordance with other studies (Green et al., 2000; Whay et al., 2007). Although plumage condition is strongly correlated with feather pecking behavior (Bilcik and Keeling, 1999), missing or damaged feathers are not necessarily solely the result of feather pecking. Abrasion due to different parts of the environment may also lead to wear, feather damage, feather loss, and increased feather pecking (Tauson, 1998; McAdie and Keeling, 2000; Tactacan et al., 2009; Guinebretière et al., 2013). The feather damage we found on the neck, back, tail, and vent however can more confidently be attributed to pecking (Bilcik and Keeling, 1999; Uitdehaag et al., 2008). The high between-flock variation for feather scores on the back and the vent (Table 2) indicates that those body parts are possibly most affected by the different risk factors encountered as compared to the lower between-flock variation observed for the other scored body parts which apparently had more similar scores among all flocks. Wounds on the vent and the surrounding skin are typically caused by injurious vent pecking, a behavior closely related to feather pecking that is associated with stress (Gunnarsson et al., 1999; Pötzsch et al., 2001). Even though beak trimming is the main method for reducing feather damage caused by feather pecking (Nicol et al., 2013), our results prove that this method is far from sufficient to prevent severe injury.

The present study demonstrated that wire mesh as flooring material in the aviary was associated with better plumage scores, fewer wounds, higher production rates, and lower mortality compared to plastic slats as flooring material. Whay et al. (2007) reported increased feather loss in single-tier floor housing systems with plastic slats compared to wire and wooden slatted floors. However, that study pooled data from wooden and wire floors, as the authors assumed there was no difference between these 2. Pötzsch et al. (2001) found that feeders located on wire mesh and drinkers located on plastic slats were risk factors for increased feather pecking and vent pecking in non-cage systems. However, the comparison between wire mesh and plastic slats alone, without feeder or drinker location, was not analyzed. Differences found in plumage scores between

different housing systems, as found in previous studies (Sherwin et al., 2010; Shimmura et al., 2010; Lay et al., 2011; Freire and Cowling, 2013), may not be solely due to being housed in either a non-cage system or a cage system, but might be caused by being housed on different flooring materials. In the quantitative comparison review by Freire and Cowling (2013), the authors state that hens in furnished cages are predominantly held on wire mesh floors, whereas plastic slatted flooring in cages is rare. In contrast to their findings, our study of Belgian aviary systems revealed that plastic slatted flooring in aviaries was fairly common, with one-third of all studied aviary systems having plastic slatted flooring. Previous studies might have unknowingly underestimated the effect of flooring type in the housing systems that were compared. However, the findings of Nicol et al. (2003), albeit on single-tier floor housing, were not in agreement with the present study as they demonstrated a tendency for less feather pecking in systems with plastic flooring compared to systems with wire flooring.

The effect of flooring material in the present study may have multiple explanations which include differences in red mite infestation, dustbathing behaviour, in bird and system hygiene, or a combination of these factors. Deep-litter systems such as the aviary system have a high risk for infestation with the red mite ectoparasite, *Dermanyssus gallinae*; in many countries this pest has become endemic (Sparagano et al., 2009, 2014). The presence of red mites is associated with feather pecking, increased mortality due to cannibalistic behaviors, anemia, and the mites can also be vectors for several poultry diseases (Chauve, 1998; Wall and Tauson, 2013; Sparagano et al., 2014). The complex environment of an aviary is more difficult to disinfect between rounds, also providing more refuge places for the red mites as compared to cage systems (Höglund et al., 1995; Chauve, 1998; Lay et al., 2011). We found that 63% of all hen-houses had a red mite infestation. Our results confirm the association between feather pecking, disease, and mortality with red mite infestation, as hens in housing with red mite infestations had poorer plumage condition, increased cloacal discharge, and increased mortality. Red mites can more easily find refuge under plastic slats than under wire mesh, thus rendering control more difficult (Zoons, 2015, personal communication). Our results show that red mite infestations were more prevalent in aviaries with plastic slatted flooring compared to wire mesh flooring.

Although the natural desire for laying hens to dustbathe is better satisfied in aviary systems than in cage systems, sham-dustbathing in the presence of litter still occurs (Lindberg and Nicol, 1997; Olsson et al., 2002; Colson et al., 2007). Sham-dustbathing on structural components of the housing system instead of in loose litter may cause abrasion of the feathers. Plastic slats are perceived to be more comfortable and give more support (Tauson, 1998), therefore sham-dustbathing may have occurred more often in those systems compared

to wire mesh flooring systems, resulting in a poorer plumage condition of mainly the wings and the ventral part of the body. McAdie and Keeling (2000) demonstrated that conspecifics are more likely to peck at damaged feathers than intact feathers. Hence increased feather damage in plastic slatted systems, caused by abrasion, may lead to increased feather pecking and thereby a worse plumage condition compared to the plumage condition of hens in wire mesh systems.

The hygiene of wire mesh flooring systems is better because manure is more effectively trampled through the wire mesh onto the manure belt, whereas in more solid flooring types (wood, plastic) manure sticks more to the flooring surface (Hughes and Black, 1973; Akpobome and Fanguy, 1992). Hens kept on plastic slats might therefore have dirtier plumage. This would be in line with Simpson and Nakaue (1987) who showed that broilers kept on wire flooring showed less feather soiling than broilers kept on plastic-coated expanded metal. Further research is needed to demonstrate if dirty plumage indeed leads to increased dustbathing, excessive preening behavior, or makes feathers more attractive to be pecked at by conspecifics. Our study could not demonstrate this as neither dustbathing and feather pecking behavior or plumage cleanliness were measured during the farm visits. Poorer hygiene may also contribute to the higher mortality found in systems with plastic slatted flooring as these systems are more difficult to clean and disinfect between successive production rounds (Shields and Greger, 2013). Comparing dustbathing and preening behavior in systems with different flooring types in correlation to plumage cleanliness and plumage condition could elucidate the hygiene and the previously mentioned (sham) dustbathing hypotheses.

Another aspect we investigated was the presence of a free-range area. A free-range area reduces stocking density in the henhouse and also provides more opportunities to perform species-specific behaviors, such as exploratory behaviors and foraging, thereby reducing the motivation to feather peck (Bestman and Wagenaar, 2003; Lambton et al., 2010; Sherwin et al., 2010). Our study confirms that providing access to a free-range area had a positive effect on plumage condition. Contrary to Sherwin et al. (2010), we found no indications of a negative effect of a free-range area on the prevalence of vent pecking. In fact, we found wounds on the back to be less frequent in free-range systems. Our study did not show increased mortality due to the presence of a free-range area as reported in the review of Tauson (2005a).

Another novel housing effect we identified is the presence of a perch versus a platform in front of the nests. Hens in systems with a platform in front of the nests had better tail feather scores, suggesting that hens peck less at the tail when kept in those systems. Hens are strongly motivated to explore the nest site prior to egg-laying. Agonistic and frustration behaviors occur during the nest exploration and pre-laying

behavior (Wood-Gush and Murphy, 1970; Freire et al., 1996; Struelens et al., 2008; Hunniford et al., 2014; Ringgenberg et al., 2014). A platform generally provides more space for hens to walk in front of the nest compared to a perch, and therefore creates less disturbance or competition in front of the nest when the hens need to choose a nest for egg laying.

Several dietary factors are known to influence feather pecking behavior such as energy levels, minerals, crude protein, and fiber levels (Rodenburg et al., 2013). Switching to a new diet can change food palatability, resulting in increased or decreased food intake and perhaps in increased food competition. We found that more frequent dietary changes during the laying period was associated with decreased feather damage of the neck but made no difference to other body areas. These results are not in line with previous studies which showed that 3 or more changes of diet during the laying period increases the risk of feather pecking (Green et al., 2000; Pöttsch et al., 2001).

We cannot clarify the difference in neck plumage scores between row-type and portal-type aviaries. A possible confounding factor for the better neck feather score in row-type aviaries was system flooring, as no portal-type aviaries with plastic-slatted flooring system were included in this study. However, system flooring was not associated directly with neck feather score.

The higher laying rate found in the Lohmann Brown Classic hybrid compared to ISA Brown hens is in accordance with the production sheets provided by the respective breeders. This study found a better wing plumage score for the ISA Brown hens compared to the Lohmann Brown hens, whereas Nicol et al. (2003) found that flocks with ISA Browns were more likely to exhibit feather pecking. Our study was not able to investigate differences between white or brown hybrids because only 3 flocks contained white hybrids (all Dekalb White).

In conclusion, feather pecking and flock mortality remain common problems in aviary systems. Although the relationships between laying hen welfare, performance, and mortality and environment are very complex and multifactorial (Appleby and Hughes, 1991), we identified several aviary housing characteristics as risk factors for feather pecking and feather damage, variability in production rate, and mortality. In particular, wire mesh flooring should be the preferred aviary flooring material as it can have both animal welfare and economic advantages as compared to plastic flooring. Investigation of the underlying cause(s) of this flooring effect, and the possible effects of hygiene, disinfection, and red mite control of the aviary system could further explain its impact on plumage condition, production, and mortality. Providing a free-range area, adding platforms in front of the laying nests, and selection of hen hybrid can also be ef-

fective in reducing the welfare problems of laying hens.

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