Applied Animal Behaviour Science 123 (2010) 32–42

Contents lists available at ScienceDirect

Applied Animal Behaviour Science

journal homepage: www.elsevier.com/locate/applanim

The risk factors affecting the development of gentle and severe feather pecking in loose housed laying hens

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ARTICLE INFO

Article history:
Accepted 17 December 2009

Keywords:
Feather pecking
Laying hens
Loose housing
Welfare

ABSTRACT

Injurious pecking remains one of the biggest problems challenging free range egg producers, with both economic implications for the farmer and welfare implications for the birds. The most widespread form of injurious pecking is feather pecking, the most damaging form of which is severe feather pecking (SFP) which has, as yet unclear, links with gentle feather pecking (GFP). The current prospective epidemiological study investigates the development of GFP and SFP on 61 free range and organic UK farms (111 flocks). Flocks were visited at 25 (20–30) and 40 (35–45) weeks, when rates of GFP and SFP respectively and levels of feather damage were recorded. Environmental and management data were collected for each flock. Factors affecting the development of these behaviours were modelled using the multilevel modelling program, MLwiN (Rasbash et al., 2004).

GFP was observed in 89.2% and 73% of flocks at 25 and 40 weeks, respectively, at a mean rate of 0.65 bouts/bird/h. GFP rates decreased with increased percentage range use (coeff.: -0.001 ± 0.0006, $p = 0.025$) and temperature inside the laying house (coeff.: -0.005 ± 0.001, $p = 0.001$). GFP was higher in flocks with soil or grass litter ($\chi^2 = 13.16$, df = 4, $p = 0.012$), flocks which had no perch access (0.010 ± 0.001 vs. 0.007 ± 0.002 bouts/bird/min, $p = 0.047$) and flocks which were beak trimmed compared to those non-beak trimmed or retrospectively beak trimmed (0.013 ± 0.002 vs. 0.003 ± 0.001 and 0.002 ± 0.001, $p = 0.007$). SFP was observed in 68.5% and 85.6% of flocks at the 1st and 2nd visits, respectively, at a mean rate of 1.22 bouts/bird/h. SFP rates decreased with range use (coeff.: -0.001 ± 0.0003, $p = 0.003$). Mean rates were highest in non-beak trimmed compared to beak trimmed flocks (0.032 ± 0.003 vs. 0.017 ± 0.003 bouts/bird/min, $p = 0.028$), flocks observed to be feather pecking when they arrived on farm compared to those that were not (0.062 ± 0.018 vs. 0.019 ± 0.002 bouts/bird/min, $p = 0.001$), and flocks fed pelleted compared to those fed mashed food (0.042 ± 0.002 vs. 0.016 ± 0.002 bouts/bird/min, $p = 0.005$). Plumage damage was lower in beak trimmed compared to non-beak trimmed flocks (plumage score 1.00 ± 0.0001 vs. 1.15 ± 0.068, $p = 0.040$), and flocks which were fed mashed feed, and showed a quadratic relationship with severe feather pecking ($p = 0.003$) which was positive over the observed ranges of the behaviours. In commercial situations, feeding mashed feed and increasing range use may reduce severe feather pecking and therefore feather damage.

1. Introduction

Feather pecking occurs in all domestic laying hen housing systems, but presents a particular problem in loose housing systems, where pecking birds have access to large numbers of potential victims (Keeling, 1995) and

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doi:10.1016/j.applanim.2009.12.010

perpetrators cannot be easily identified. Feather pecking is associated with increased feed consumption (Leeson and Morrison, 1978; Herremans et al., 1989), reduced egg production (El-Lethey et al., 2000; Huber-Eicher and Sebo, 2001a), outbreaks of cannibalism (Allen and Perry, 1975; Cloutier et al., 2000; McAdie and Keeling, 2000; Pötzsch et al., 2001) and increased flock mortality (Koene, 1997; Yngvesson et al., 2004). The removal of feathers is painful for the recipient bird (Gentle and Hunter, 1991), and performance of the behaviour may be indicative of unfulfilled behavioural needs in pecking birds (Duncan and Hughes, 1972; Bubier, 1996; Weeks and Nicol, 2006).

Feather pecking is traditionally controlled either by beak trimming, or by using reduced lighting in the laying house. However, beak trimming causes both acute and chronic pains (Gentle and McKeegan, 2007; Kuenzel, 2007; Jongman et al., 2008), while low lighting can result in abnormal eye development (Prescott et al., 2003). In the UK, organic certification bodies discourage use of beak trimming and FAWC (2009) have advised that every effort should be made to end routine beak trimming of laying hens as soon as possible. Despite this advice FAWC (2009) also recognise that no ban on beak trimming should be introduced until it can be reliably demonstrated that the risks of injurious pecking in non-trimmed commercial flocks can be managed at an acceptable level. The aim of this study was to contribute to this goal by examining the role of the environmental factors associated with the development of feather pecking in commercial conditions.

Many valuable small-scale experimental studies have examined the motivational basis of feather pecking behaviour and have suggested possible means of diminishing it, but their conclusions cannot always be extrapolated to farm situations, as they generally use small numbers of birds, under conditions that differ from those experienced on commercial farms, and they cannot predict the effect of altering one risk factor in the context of others present on farm. Studies on commercial units can examine interactions between complex risk factors. However, only a few such studies have been conducted in loose housing systems (Kjaer and Sorensen, 2002; Nicol et al., 2006; Zimmerman et al., 2006).

Cross-sectional epidemiological studies of commercial flocks have identified important risk factors. Access to litter at an early age in commercial perchery and aviary systems (Gunnarsson et al., 1999) and good use of the outdoor range, younger birds at purchase and cockerel presence (Bestman and Wagenaar, 2003) were associated with reduced plumage damage. Feather pecking was more likely to be observed in flocks with poor range use, frequent diet changes, the use of bell drinkers or litter restriction (Green et al., 2000; Nicol et al., 2003).

In cross-sectional studies the causal factor in any significant associations is uncertain, as is the timing or development of the feather pecking problem. For this reason prospective studies are advantageous, but they are expensive and time-consuming to conduct. Two prospective studies have been published: Huber-Eicher and Sebo (2001b) found that rates of both gentle and severe feather pecking increased from weeks 5 to 14, and then decreased by 20 weeks of age. A positive correlation between feather pecking rates at 14 and 20 weeks suggested that feather pecking at lay was affected by feather pecking during rearing. Oden et al. (2002) found that the rate of severe feather pecking was higher at 55 weeks in perch system than an aviary system. Feather pecking was most frequent on the litter in both systems, although feather pecks in front of the nests were more common in the perch systems. Brown hybrids feather pecked more than white ones.

Despite growing interest in using epidemiological techniques to investigate feather pecking, there are still some substantial gaps. Just three of the seven studies on commercial flocks, examined free range flocks, although the numbers of birds housed in free range systems is increasing. Furthermore, only three of the studies (on indoor systems) recorded behaviour directly. A further two recorded plumage damage, which provides information only on severe feather pecking, while the remaining two relied on farmer observations (which are subjective and inconsistent). Both of these methods could underestimate the problem, since feather damage may not be visible at low rates of feather pecking. Only two studies examined the development of feather pecking over time, and none recorded the behaviour of non-beak trimmed birds. Anticipating a possible ban on beak trimming, inclusion of non-beak trimmed flocks in feather pecking studies is vital.

The aim of our prospective epidemiological study was to fill these gaps. We studied free range, organic and barn systems were studied. Free range standards are defined by the DEFRA code of recommendations for the welfare of laying hens, while organic standards for laying hens are defined by European Council Regulation (EEC) No. 2092/91. The sample population comprised both beak trimmed and non-beak trimmed flocks, which were studied to determine the factors associated with both gentle and severe feather pecking over a period of 18 months.

2. Methods

Data were collected from 62 farms in the UK between November 2004 and January 2007. All farms were either owned or contracted by Stonegate Farms Ltd., who at that time produced barn, free range and organic eggs. The sample comprised all farms to which we had access within the company, and all birds involved in the study were Columbian Blacktails, a cross-breed between Rhode Island Red males and Sussex female hens. Birds were all reared in loose, deep litter, either sawdust and/or straw, systems. During the rearing period perches were provided at the discretion of the farmer, although this information was not available to us as our observation of flocks did not begin until the laying period, and rearing flock size varied between 1100 and 24,480 (mean: 8822), according to the records kept by Stonegate. We did not have access to information regarding stocking density during rearing, however it varied between rearing farms and ages, and did not exceed 30 kg/m^2. Pullets received commercial standard or organic commercial rations as per European Council Regulation (EEC) No. 2092/91, and 53.8% of flocks were beak trimmed during rear (within the first week of life) and a further 12.6% were retrospectively beak trimmed as a consequence of injurious pecking observed on farm. The majority of beak trimming was by hot blade, but detailed information was unavailable.

Birds were transferred to laying farms at a mean age of 16 (range: 13.5–19) weeks, and were brought into lay at approximately 20 weeks of age, continuing to approximately 70 weeks of age. Mean laying flock size was 2947 (range: 540–19,500) birds. Most farms had more than one laying house and, throughout the course of the study, some houses were included twice, because more than one flock passed through them during the 18 months of the study. Therefore a total of 119 flocks were included, from 107 laying houses, on the 62 farms. Numbers of flocks per farm ranged from one to four (mean 1.82 flocks/farm). Overall 42.0% of flocks were free range, a further 55.5% were organic, and 2.5% were barn flocks. Each flock was visited twice, once between 20 and 30 weeks of age, and once between 35 and 45 weeks of age, to collect information on environment and farm management, bird behaviour and plumage condition. The final visit was carried out between 35 and 45 weeks since Bright et al. (2006) found that most flocks which exhibited injurious pecking did so by the age of 40 weeks.

2.1. Environmental and farm management variables

Data were gathered through a combination of behavioural observations and farmer interviews. Laying houses were split into up to five distinct House Areas: slats, litter, nest boxes, perches and verandas (roofed areas attached to the laying house without walls). Not all houses had all areas. A summary of the environmental and management information collected during lay is provided in Table 1. The weather was recorded in three categories: sun—sunny, average or cloudy; rain—dry, average or wet; wind—still, average or windy. Inside temperatures were measured to the nearest °C, using in-house thermometers, and outside temperatures using one in-car thermometer. Light levels inside the house were recorded using a HOBO U12 Data Logger, and taking six readings in each of the House Areas at chicken head-height. Three readings were taken on the left, and three on the right of the house, relative to the point of entry, at equal distances along the length of the house. Litter type was recorded and the percentage of hens on litter at the time of the visit was estimated by counting birds in the litter area. Litter friability was estimated by recording the percentage of the litter that was capped

Table 1
A summary of the environmental and management information collected on farm visits carried out when birds were 25 and 40 weeks of age.

Environment	Date Weather during visit Humidity (inside the house) Temperature, inside and outside
Housing	Lighting: intensity, shafting light, lighting scheme, nest box lighting Enrichments: toys, perches (availability, length, height, use) Litter: type, quality, use. Sample collected, moisture content analysed Range: quality, boundary, use Popholes: number, size Feeder: type, management Drinker: type, management General: design, ventilation system, slat material
Diet	Feed supplier Number of diet changes throughout lay Feed form Feed sample collected
Arrival	Treatment at transfer Condition at transfer
Life history	Age of purchase Age brought into lay Age allowed on litter Age allowed range access Beak trimming: yes/no, age
Farm history	Had there been problems with injurious pecking in previous flocks?
Farmer observations	Had farmer observed feather pecking (either behaviour, or resulting damage)? Had farmer observed vent pecking (either behaviour, or resulting damage)? Had farmer observed other forms of cannibalism (either behaviour, or resulting damage)? Management strategies employed to deal with injurious pecking
Productivity	Egg production and weight Mortality
Flock information	Flock/colony size Stocking density
Rearer	Rearing flock size Type of rearing house Litter used at rear

(flattened and compacted) on both the left and right. Litter samples were collected and moisture content was measure in the lab by comparing wet and dry weights. The quality of the range was categorised as compacted, stony, loose or grassy in three range areas: immediately outside the house, 20 m from the house, and at the edge of the range. The percentage of range boundary delineated by hedges, as opposed to fencing, was recorded. Percentage of the range under bushes or trees was estimated by counting the shaded areas. The percentage of the flock using the range at the time of the visit was estimated by making a count of the birds visible on the range. On both visits farmers were also asked whether they had noted feather pecking in their current flock. This formed a binary response (yes/no) which we could compare to our own observations.

2.2. Behavioural observations

GFP and SFP were recorded during both the 20–30 and 35–45 week behavioural observations. GFP was defined as gentle pecking at the tips of feathers and SFP as pecking and pulling at feathers, often with removal of the feather, and the recipient bird squawking and moving away.

Behavioural observations were carried out by selecting an area of approximately 2 square metres in each of the House Areas. Sample areas were chosen to be representative of each of the House Areas, not including any large obstacles which would obscure the observer's view of the birds, not overlapping with any other House Area, and at a position at least 2 m from the house entrance. Upon selecting a sample area, the observer stood at least 1 m away from the area for 2 min before beginning the observation. The same observer did all observations, but was periodically compared to a second to ensure agreement in recognition of each behaviour. Authors observed that a 2 min period of acclimatisation allowed the birds to settle and they remained undisturbed unless the observer moved. The selected area was then continuously observed for 10 min, and the number of birds in the area was counted at the start and end of that period.

During an observation period every bout of GFP or SFP was recorded, where a bout was defined as a sequence of pecks not separated by any other behaviour or a gap of more than 5 s between pecks (e.g. Kjaer and Sorensen, 2002). For each House Area, rates of GFP and SFP were calculated as number of bouts per bird per minute.

2.3. Plumage damage

Plumage damage (PD) was recorded for a sample of 100 birds from each flock. Birds were not handled, in order to minimise disturbance, but we used the remote plumage damage estimation method of Bright et al. (2006) which accurately estimated feather scores collected by handling birds, at sample sizes of 100 birds (Bright et al., 2006). Therefore we recorded PD for 100 birds, comprising an equal number of birds from each of the sample areas used for behavioural observations. We used an adjusted five-point scale and each bird was recorded as having 0–20%, 21–40%, 41–60%, 61–80%, or 81–100% of its surface area affected by PD. In addition, the areas of the bird primarily affected were recorded as head, neck, back, tail, wings, keel or vent.

A PD score was created for each House Area by calculating the proportion of birds sampled that fell within each surface area category (0–20%, 21–40%, 41–60%, 61–80%, and 81–100%). This proportion was multiplied by a constant which increased with category. The lowest possible score was 1, when all birds sampled were in the 0–20% category, while the highest score possible was 5, with all birds in the 81–100% category. However, it was noted during the first 6 months of the study that there was little variation between flocks, with the majority falling into the 0–20% category. As a consequence, for later visits the 0–20% surface area category was subdivided into 0–5% and 6–20%, and scores were calculated with constants adjusted accordingly.

2.4. Analysis

All behavioural and PD data from each of the House Areas were averaged to provide a mean for each flock at each visit, for the main analysis. Rates of GFP and SFP were square root transformed to meet the assumptions necessary for parametric analyses. Thus four behavioural dependent variables were analysed: gentle feather pecking at 25 (GFP25) and at 40 weeks (GFP40) and severe feather pecking at 25 (SFP25) and 40 weeks (SFP40). Of the 119 flocks only 111 (on 61 farms) were visited twice, thus the remainder were excluded and the data paired between visits. Using Minitab 14.0, bivariate analyses were performed, examining the relationship between each of the dependent variables and each of the environmental and management variables collected. Variables whose effects were significant at $p < 0.2$ were further analysed by means of backward and forward regressions. Those variables which remained significant at $p < 0.05$ were subsequently retained and used for multilevel modelling. MLwiN (Rasbash et al., 2004) was used to create a two-level multilevel model, reflecting the hierarchical structure of the dataset, using flock within farm as levels. House was not included as a level in the hierarchy because only 10 houses contained more than one flock during the course of the study, and it did not significantly affect the model ($p > 0.05$). Models were created by including all variables remaining after backwards and forwards regressions initially, and removing non-significant terms until all were significant. All other variables were then included one by one. The most significant was retained and the process repeated until no more variables were significant. The significance of individual factors in a model was tested using Z-tests, while the significance of groups of factors in a model (or categorical variables with more than two categories) was tested by means of a χ^2-test on the deviance in loglikelihood between models with and without the factors.

As a consequence of the lack of variation in PD score at 25 weeks (PD25), this was analysed using binary logistic models. At the first visit only 13 flocks had a PD25 score exceeding 1. Thus all flocks with a score of 1 were classified as low PD, and the remainder as high PD. The factors affecting the risk of a flock being classified as high PD were modelled using multilevel binary models in MLwiN. The hierarchy comprised two levels, farm and flock as described above. Bivariate relationships with each of the explanatory variables were analysed first. Those significant at $p < 0.2$ were entered together and non-significant variables removed. All other variables were then included one by one. The most significant was retained and the process repeated until no more variables were significant. In addition, interactions between risk factors were analysed. Odds ratios, giving the odds of a flock showing high levels of PD, were calculated for categorical variables. PD score at 40 weeks (PD40) had more variation and therefore was analysed as a continuous variable as described above for the behaviour variables.

In each case dependent variables from visit 2 were analysed with respect to management and environment variables at both visits, as well as behavioural variables at the first visit. However, SFP40 was never included in the model of GFP40 and vice versa, and likewise SFP25 was not included in the model of GFP25. It was assumed that feather pecking behaviours observed during the same visit could not affect each other, and the relationships between the two forms of feather pecking were analysed separately (Lambton et al., 2007). In addition, data from both visits were combined and a repeated measures analysis was performed, using a similar hierarchical model, with visit as a third level. This allowed us to examine the effect of age upon each of the behaviours, and whether the effects of any of the risk factors identified changed over time.

Each dependant variable was examined for an effect of House Area. Mean rates of behaviour were used for each House Area observed, and a repeated measures hierarchical model was used, as described above, with four or five observations (depending on the number of House Areas) for each flock at each visit. House Area was included as an explanatory variable.

3. Results

According to the farmers' reports 65% of flocks showed feather pecking at some point during the laying cycle. Our observations showed that 89.2% of flocks at the first visit, and 73% of flocks at the second visit showed GFP, while 68.5% at the first visit and 85.6% at the second visit showed SFP (i.e. had rates >0 bouts/bird/min). Mean rates of GFP and SFP and mean PD score are shown in Table 2. In a repeated measures hierarchical model examining the relationship between the farmers' observations and the behaviours and PD we observed that higher rates of severe feather pecking significantly increased the likelihood of a farmer observing feather pecking ($Z = 4.9$, $p < 0.001$), but there was no effect of GFP. Although higher PD scores significantly increased the likelihood of the farmer observing feather pecking in a bivariate correlation ($Z = 3.1$, $p = 0.002$), it became insignificant once severe feather pecking was added to the model.

Table 2
Mean rate (bouts/bird/h) and standard error of gentle and severe feather pecking, and mean plumage damage score (calculated as described in Section 2.3) and standard error for visits 1 and 2.

Behaviour	Visit 1		Visit 2	
	Mean	SEM	Mean	SEM
Gentle feather pecking	0.771	0.068	0.516	0.069
Severe feather pecking	1.15	0.160	1.32	0.140
Plumage damage	0.660	0.032	0.980	0.061

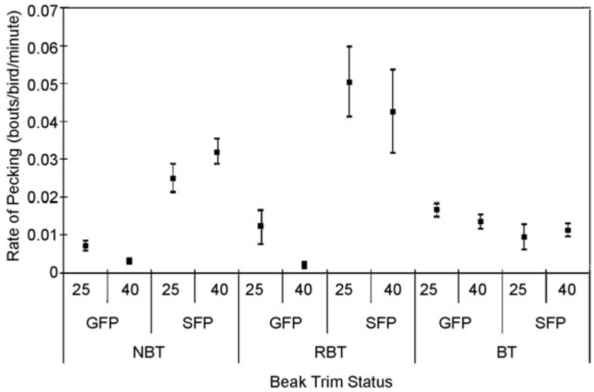

Fig. 1. Mean rates of gentle (GFP) and severe (SFP) feather pecking ± SEM at first (25 weeks) and second (40 weeks) visits according to beak trim status (non-beak trimmed: NBT; retrospectively beak trimmed: RBT; beak trimmed: BT). At 25 weeks $n = 38$ (NBT), $n = 12$ (RBT), $n = 61$ (BT), and at 40 weeks $n = 35$ (NBT), $n = 15$ (RBT), $n = 61$ (BT).

3.1. Gentle feather pecking

All response variables were significantly affected by beak trimming (Fig. 1). In the final model of GFP25, accounting for 19.6% of the variation in the data, only beak trim status was significant, with birds beak trimmed at rear showing the highest rates of gentle feather pecking ($Z = 4.88$, $p < 0.001$).

The final model of GFP40 (Table 3) accounted for 54.6% of the variation in the data (calculated as the difference between the variance of GFP40 before and after the addition of the explanatory variables to the model). The coefficient in this and all subsequent tables give the amount of change in average flock rate of gentle feather pecking for a unit change in each variable. Factors are not, and cannot be, arranged in order of importance. Positive parameter estimates mean that an increase in the value of a variable is associated with an increase in rate of feather pecking and negative parameter estimates, a decrease.[1] GFP rate increased with the average number of birds in the observation area, and decreased with the percentage of the flock ranging and the temperature inside the house. Rate of gentle feather pecking was higher in flocks with soil or grass as their litter, flocks with no perch access, and flocks which were beak trimmed. The effect of litter type should

[1] Parameter estimates may be used to calculate predicted values of the dependent variable. For example using the data from Table 3 if during a visit 3 birds were observed in each period (after centering), at a temperature of 21 °C, with 20% of the flock ranging, and in a house that uses a sawdust litter, perches and where the birds have been beak trimmed, the predicted rate of GFP would be calculated as follows: $\text{GFP} = 0.1797 + (3 \times 0.0037) + (21 \times (-0.0047)) + (20 \times (-0.0014)) + (21 - (21 \times 20 \times 0.000081) + 0.0040 + (-0.024) + 0.028 = 0.11$ bouts/bird/min.

Table 3
Risk factors affecting the rate of gentle feather pecking at 40 weeks of age. Variables suffixed by the number 25 were recorded during the 25-week visit, and those suffixed by 40 were recorded at the 40-week visit.

Variable	Coefficient	SE (coeff.)	*p*-Value
Constant	0.1797	0.02680	<0.001
Average no. birds observed 40 (centred)[a]	0.003657	0.000826	<0.001
Temperature inside house 40	−0.004723	0.001410	0.001
Percentage of flock ranging 25	−0.001378	0.000616	0.025
Interaction: temp. × flock ranging	0.000081	0.000039	0.038
Litter type 40			
Sawdust (n = 33)	0.003973	0.01173	0.735
Woodchip (n = 15)	0.001370	0.01504	0.927
Soil (n = 3)	0.05808	0.02566	0.024
Combination (n = 26)	−0.00105	0.01222	0.932
Grass (n = 2)	0.1189	0.03097	0.001
Straw (n = 29)	Reference category		
Perch available[b]			
Yes (n = 93)	−0.02415	0.01216	0.047
No (n = 18)	Reference category		
Beak trimmed 40			
Yes (n = 61)	0.02817	0.01037	0.007
Retrospectively (n = 15)	0.006130	0.01449	0.672
No (n = 35)	Reference category		

[a] The average number of birds observed in the observation area during the behavioural observation periods at the same visit.
[b] Whether or not perches were provided in the laying house at any point during the laying period.

be interpreted with caution. Although it was highly significant (χ^2 = 18.03, df = 5, p = 0.003), the difference was largely due to the effects of the soil and grass substrate categories, which were found in only five flocks. GFP also occurred at higher rates around the nest boxes and on the slats (means bouts/bird/min were litter 0.009; nest boxes 0.012; perches 0.008; slats 0.011; veranda 0.016. χ^2 = 13.16, df = 4, p = 0.012) than in other House Areas. Although veranda had the highest mean rate this difference was not significant due to the high variation in rates in this Area. The same factors remained significant in a repeated measures analysis of GFP. In addition GFP was negatively correlated with age (Z = 4.68, p < 0.001).

3.2. Severe feather pecking

In the final model of SFP25, accounting for 49.8% of the variation in the data (Table 4), only beak trimming and feed company remained significant. Severe feather pecking was highest in retrospectively beak trimmed flocks, followed by non-beak trimmed flocks, and in flocks supplied with their feed by company H. The effect of feed company on rate of severe feather pecking, when all other variables remain constant, is shown in Fig. 2. There was a significant effect of feed grain size found in the first round of bivariate correlations, however, this variable was missing a large number of data points, and its effect was subsumed by that of feed company. Fig. 3 shows the breakdown of mash and pellets provided by each company. Seven out of ten companies supplied all of their feed as mash, with only company H supplying the majority of their feed as pellets.

In the final hierarchical model of SFP40 (Table 5), which accounted for 62.6% of the variation in the dataset, there was a quadratic relationship with severe feather pecking at the first visit, which was positive over the majority of the observed range (Fig. 4). Severe feather pecking decreased with percentage of flock ranging, was higher in flocks which had not been beak trimmed (see Fig. 1; mean bouts/bird/min NBT: 0.032 ± 0.003 vs. BT: 0.017 ± 0.003; the retrospective category was no longer significant), higher in flocks for which feed was spread on the floor (0.034 ± 0.005 vs. 0.020 ± 0.003 bouts/bird/min), higher in flocks which were feather pecking at transfer (0.062 ± 0.018 vs. 0.019 ± 0.002 bouts/bird/min), and higher in flocks fed a pelleted ration (0.042 ± 0.006 vs. 0.016 ± 0.002 bouts/bird/min).

When severe feather pecking data from both visits were combined and analysed with visit treated as a repeated measure, the same factors remained significant as in the models for SFP25 and SFP40, and the effects were in the same directions. Feed form was not significant, but feed

Table 4
Risk factors affecting the rate of severe feather pecking at 25 weeks. Variables suffixed by the number 25 were recorded during the 25-week visit, and those suffixed by 40 were recorded at the 40-week visit.

Variable	Coefficient	SE (coeff.)	*p*-Value
Constant	0.1139	0.05644	0.044
Beak trimmed 25			
Yes (n = 61)	−0.03555	0.01694	0.036
Retrospectively (n = 12)	0.05051	0.02445	0.039
No (n = 38)	Reference category		
Feed company			
A (n = 10)	−0.07586	0.02761	0.006
B (n = 2)	−0.07833	0.05590	0.161
C (n = 8)	−0.04252	0.02926	0.146
D (n = 3)	−0.000653	0.04187	0.988
E (n = 15)	−0.05590	0.02422	0.021
F (n = 8)	−0.01067	0.02915	0.071
G (n = 2)	0.05968	0.05644	0.290
H (n = 28)	0.07623	0.02161	0.000
I (n = 3)	−0.02992	0.04428	0.499
J (n = 32)	Reference category		

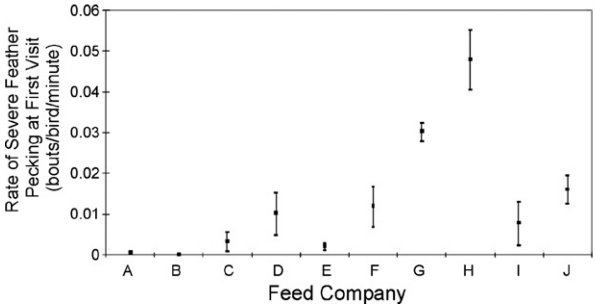

Fig. 2. Mean rates of gentle and severe feather pecking ± SEM at 25 weeks for each feed company (A–J).

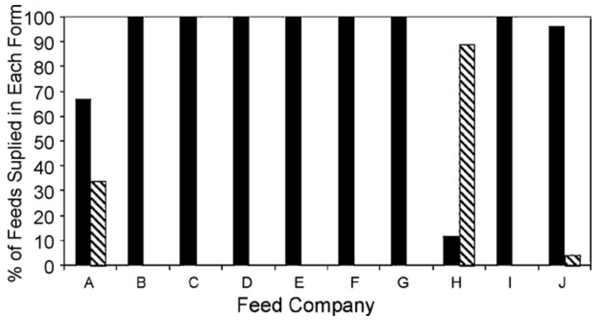

Fig. 3. Percentage of feeds supplied by each of the feed companies A–J as either mash or pellets, with solid bars representing mash, and hashed bars pellets.

Table 5
Risk factors affecting the rate of severe feather pecking at 40 weeks. Variables suffixed by the number 25 were recorded during the 25-week visit, and those suffixed by 40 were recorded at the 40-week visit.

Variable	Coefficient	SE (coeff.)	p-Value
Constant	0.1298	0.01836	<0.001
SFP25	2.435	0.5091	<0.001
SFP^{2}25[a]	−17.40	4.174	<0.001
Percentage of flock ranging 40	−0.000988	0.000330	0.003
Beak trimmed 40			
No (n = 35)	0.03058	0.01393	0.028
Yes (n = 76)	Reference category		
Feed spread on floor[b]			
No (n = 17)	−0.04638	0.01472	0.002
Yes (n = 90)	Reference category		
Feather pecking at transfer[c]			
Yes (n = 8)	0.07144	0.02160	0.001
No (n = 103)	Reference category		
Feed form 40			
Pellets (n = 27)	0.03884	0.01383	0.005
Mash (n = 80)	Reference category		

[a] This is a squared term representing the significance of a quadratic (curved) relationship between SFP at 25 and 40 weeks.
[b] Whether or not the farmer spread feed on the floor of the laying house at any point during the laying period.
[c] Whether or not the farmer observed any evidence of feather pecking when the hens were first transferred to the laying house.

company was, in the same pattern as illustrated for SFP25. In addition rate of severe feather pecking was positively correlated with age (Z = 2.96, p = 0.003). No other behaviours were significant in the final model.

SFP was significantly affected by House Area (χ^2 = 45.96, df = 4, p = 0.007), with rates being highest on the litter and followed by the slats.

3.3. Plumage damage

A binary model was produced of PD25 (Table 6). Those flocks showing more PD were older and had higher rates of severe feather pecking. Non-beak trimmed flocks were more likely to show high PD (odds ratio: 10.3) as were those flocks kept up on the slats of the laying house during nest box training (odds ratio: 24.3). Feed form was also significant (p = 0.011) with flocks fed pelleted feed being over 550 times more likely to show high levels of PD, however, it could not be included in the final model, since there were a large number of missing data points.

The final model of PD at the second visit accounted for 67.2% of the variation in the data. Relationships were found with SFP at first and second visits, and PD at first visit (Table 7). All relationships were quadratic curves, and were positive over the observed ranges of the variables. PD increased steadily with both SFP25 above a level of 0.08 bouts/bird/min and with SFP40 until it reached a level of 0.06 bouts/bird/min, where the relationship

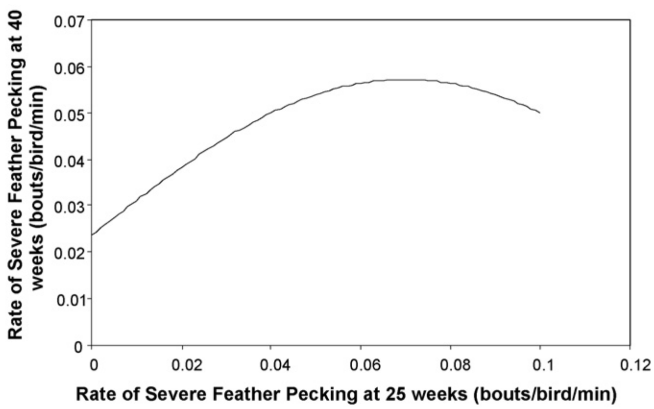

Fig. 4. Rate of severe feather pecking at 40 as predicted by the observed range of rates of severe feather pecking at 25 weeks, when all other variables remain constant.

Table 6
Risk factors affecting the level of plumage damage at 25 weeks. Variables suffixed by the number 25 were recorded during the 25-week visit, and those suffixed by 40 were recorded at the 40-week visit.

Variable	Coefficient	SE (coeff.)	p-Value
Constant	−6.826	1.808	<0.001
Flock age 25 (centred)	0.3652	0.1265	0.004
Rate of severe feather pecking 25	29.1662	14.50	0.044
Beak trimmed			
No ($n = 38$)	2.330	1.137	0.040
Yes ($n = 73$)[a]	Reference category		
Birds kept on slats during training[b]			
Yes ($n = 57$)	3.191	1.465	0.029
No ($n = 52$)	Reference category		

[a] The effect of retrospective beak trimming was not significantly different from that of beak trimming early in life, thus it a more parsimonious model was produced by concatenating the two categories.
[b] Whether or not birds were restricted to the slatted area of their laying house during nest box training, immediately after arrival on the laying farm (i.e. without access to litter or the range).

Table 7
Fisk factors correlated with the level of plumage damage at 40 weeks. Variables suffixed by the number 25 were recorded during the 25-week visit, and those suffixed by 40 were recorded at the 40-week visit.

Variable	Coefficient	SE (coeff.)	p-Value
Constant	−1.465	0.1509	<0.001
SFP25	−4.838	3.353	0.149
SFP[2 a] 25	78.16	27.36	0.004
PD25	1.325	0.2677	<0.001
PD[2 a] 25	−0.2825	0.07558	<0.001
SFP 40	14.40	3.166	<0.001
SFP[2 a] 40	−78.25	18.94	<0.001
Temperature inside 40	0.01480	0.006462	0.011

[a] A squared term, showing the significance of a quadratic (curved) relationship with plumage damage at 40 weeks.

plateaued. PD40 increased steadily with PD25 over the observed range of PD25. There was also a positive correlation with temperature inside the house.

Plumage damage data from both visits were combined and analysed as a binary variable, with visit treated as a repeated measure. Results from this analysis supported those described in the individual analyses of PD at 25 and 40 weeks. Additionally, flocks fed pelleted rations were 4.3 times more likely to have high levels of PD compared with those fed mashed rations ($p = 0.012$), although the effect of feed form decreased as rate of severe feather pecking increased.

There was a relationship between SFP at 40 weeks and the part of the body affected by PD. Flocks with the highest levels of SFP had birds with more tail damage or multiple areas damaged ($\chi^2 = 15.2$, df = 4, $p = 0.004$). This was not the case for any other behaviour.

4. Discussion

This study shows that feather pecking remains a widespread problem for free range and organic laying hen farms. Farmers reported feather pecking at some point prior to the last visit in 65% of flocks, and we observed gentle feather pecking on 89.2% of farms, and severe feather pecking on 85.6% of farms. This suggests that feather pecking is under-reported by farmers, probably because it is not identified when it occurs at low rates. Surprisingly farmers' detection of feather pecking appeared to be more closely related to our observations of SFP than those of PD, suggesting that farmers do detect the behaviour as well as resultant damage. Prevalence of feather pecking observed in this study is much higher than that observed in previous epidemiological studies, with figures ranging from 57 to 71% (Green et al., 2000; Bestman and Wagenaar, 2003). This is likely because our behavioural observations identify feather pecking even when it occurs at low rates, in contrast to both measures of PD and surveys based on farmer observations, and this underlines the importance of carrying out detailed behavioural observations.

We must be cautious when inferring causation from the observed correlations; it is possible that feather pecking may be the cause rather than the effect of some relationships. For example SFP was negatively correlated with production rate and positively with mortality. Such effects of SFP have been observed previously (Huber-Eicher and Sebo, 2001a; El-Lethey et al., 2000; Yngvesson et al., 2004). Thus such factors were excluded from analysis in the final model on this basis, where it made biological sense; however, a number of risk factors were identified, which could provide useful guidance for farmers in commercial situations.

4.1. Beak trimming

The only factor that affected all responses was beak trimming. As expected, beak trimming at rear was associated with reductions in both SFP and PD, in agreement with previous authors (Craig and Lee, 1990; Lee and Craig, 1991; Damme, 1999; Hartini et al., 2002; Staack et al., 2007). However, retrospectively beak trimmed flocks had higher rates of severe feather pecking. It is likely that the flocks with the highest rates of severe feather pecking were beak trimmed as a consequence, thus explaining the initial association. Interestingly, rates of SFP remained high in those flocks at the second visit, despite PD levels falling. It seems that while retrospective beak trimming may ameliorate the effects of severe feather pecking, it does not necessarily reduce the behaviour as in the case of trimming early in life.

Conversely beak trimming was associated with increased rates of GFP. Beak trimming might make more general exploratory behaviour painful (Blokhuis and van der Haar, 1989; Duncan et al., 1989; Gentle et al., 1990, 1997), and GFP could develop as a stereotypic response to this deficiency.

4.2. Range use

The only factor which affected both gentle and severe feather pecking similarly was range use. As range use increased, rates of both forms of feather pecking at 40 weeks of age decreased. The protective effect of increased ranging at 25 weeks on GFP was significant in an interaction with temperature; the effect of range use decreasing as temperature increased, although, the overall correlation always remained negative. More significant was the negative correlation between SFP and range use at 40 weeks. This was in line with the results of previous work (Bilčík and Keeling, 2000; Green et al., 2000; Bestman and Wagenaar, 2003). It is likely that the range provides increased opportunities for rewarding exploratory and foraging behaviour, thereby reducing the motivation to feather peck (Blokhuis, 1986; Huber-Eicher and Wechsler, 1998; Chow and Hogan, 2005). Decreased range use will also increase local stocking density inside the house.

4.3. Additional risk factors for gentle feather pecking

At 40 weeks, GFP rate was lower if birds had access to perches, likely because providing perches removes potential victims from the immediate environs of the pecking bird (Huber-Eicher and Audigé, 1999). Lower rates of GFP were also observed in flocks provided with straw, even in comparison with those provided with sawdust. Straw tends to give a deeper covering than sawdust, thus it may be a better foraging or exploratory stimulus. Soil and grass (provided as litter substrates inside the house) are also relatively wet substrates and, although infrequently used, they were associated with the highest levels of GFP.

GFP was also positively correlated with number of birds in the observation area. Since rates of behaviour were calculated per bird they should not increase simply because there are more birds in the area to peck. Instead number of birds in the observation area may act as a measure of local stocking density, since all areas were approximately the same size. Stocking density has been associated with increased rates of feather pecking (Hansen and Braastad, 1994; Bilčík and Keeling, 1999, 2000). Additionally, higher numbers of birds in the observation area may reflect a lower range use (the effect of which is discussed above); these two factors were negatively correlated. Furthermore, higher rates of GFP occurred around nest boxes and on slatted areas, possibly because there are likely to be fewer exploratory stimuli in these areas. Since the majority of the behavioural observations (i.e. those in nest box, perch and slat House Areas) were carried out on the slats, if more birds were on the slats the average number of birds in the observation area throughout the house may be biased towards this. If GFP occurs more on the slats, the correlation between this and the number of birds in the observation area could have occurred as an artefact of this bias.

4.4. Additional risk factors for severe feather pecking

Aside from beak trimming and range use the recurring theme in the analysis of severe feather pecking was the influence of diet and foraging behaviour. SFP was significantly affected by feed company at 25 weeks, and feed form at 40 weeks. Lower rates of SFP were observed in flocks fed mashed rather than pelleted feed at 40 weeks. It is likely that feed form may in part have been responsible for the differences between the companies at 25 weeks, since those companies associated with the highest rates of SFP, were also those that provided the majority of their feed as pellets. As explained in Section 3.2 the variable 'feed form' at 25 weeks was missing a large amount of data and became insignificant with the addition of feed form. This effect of feed form has frequently been observed experimentally (Lindberg and Nicol, 1994; Savory et al., 1999; Aerni et al., 2000; El-Lethey et al., 2000), with authors suggesting that the increase in foraging behaviour resulting from feeding a mashed ration (Savory et al., 1999) has a protective effect against severe feather pecking. However, it should be noted that a large amount of variation between mean rates of severe feather pecking associated with each company remained in the data, which could not be explained by feed form alone. Therefore, there may be other effects of diets which vary between feed companies, for example deficiencies in fibre or protein content (Elwinger et al., 2002; Hetland et al., 2003; Steenfeldt et al., 2007) which have previously been associated with severe feather pecking and PD.

Rates of SFP were also significantly higher in flocks for which feed was spread on the floor. This practice was usually carried out during the first week or so after transfer to the laying house to encourage use of litter areas. Furthermore, rates of severe feather pecking were higher in the litter areas than in other House Areas. This difference between House Areas is somewhat surprising; we would expect litter use and foraging behaviour to be associated with reduced severe feather pecking. However, if increasing litter use stimulates foraging behaviour, without being sufficiently rewarding where litter quality is poor, then frustrated foraging behaviour could be redirected as severe feather pecking. Birds from a high feather pecking line do not peck at operant stimuli as frequently as those from a low feather pecking line when frustrated (Rodenburg et al., 2002, 2004). Therefore birds which are predisposed to feather peck may redirect pecks towards feathers rather than litter when frustrated. Lindberg and Nicol (1994) found that use of operant feeders, which increased the amount of pecking that had to be performed in order to receive a food reward, was associated with higher rates of feather pecking, when compared to feeding *ad libitum*. Encouraging birds to use the litter could also reduce the time spent at the feeders, where foraging behaviour will be more rewarding.

Finally, SFP40 was significantly higher in those flocks for which feather pecking had been noted by the farmer when they arrived on farm. It was also positively correlated with SFP25. It is clear therefore that experiences during rearing have a lasting effect on the birds' behaviour, at least until 40 weeks of age, and that flocks which develop high rates of SFP early in lay or as pullets maintain high rates, since the rate of SFP increased with age. It is therefore important to understand the conditions at during rearing and early lay that affect the development of severe feather pecking.

4.5. Plumage damage

It should be noted that since PD was only recorded inside laying houses we cannot draw conclusions about ranging birds. Furthermore, birds with the worst PD tended to be observed more often inside the house than outside; thus recorded PD may be artificially high. Severe feather pecking was consistently associated with PD in all analyses. Additionally severe feather pecking was associated with damage to multiple or tail areas. PD score increased with age, and if flocks were fed on pelleted rations, paralleling the effect observed of these factors on severe feather pecking.

All of these relationships between PD at 40 weeks and severe feather pecking and earlier PD are quadratic, but positive over the observed ranges for rates of severe feather pecking. Predicted values of PD at 40 weeks increased exponentially if SFP at 20–30 weeks was greater than 0.08 bouts/bird/min. SFP25 at lower rates had no observable effect on PD. In support of this, at 25 weeks of age, the body area predominantly affected by PD was not related to feather pecking. It is likely since there was very little PD at 20–30 weeks, any effect of SFP at this age would have been obscured by other factors such as stress from the onset of lay, or abrasion during transport. This may partly explain the high prevalence of feather pecking observed in this study, compared both with our farmers' observations, and previous studies which have relied on plumage scores and/or farmer observation, and highlights the importance of including behavioural observations in any study of feather pecking, particularly early in lay. Increased PD at 35–45 weeks occurred in association with increasing rates of SFP at 35–45 weeks, up to a rate of 0.06 bouts/bird/min of severe feather pecking, and plateaued above that level, perhaps as a result of farmers responding to the problem by beak trimming or reducing light intensity. Alternatively, PD might become so extensive that it reaches a maximum recordable value. It should be noted, however, that models of predicted relationships become less reliable at extreme values: there are fewer data points, so relationships become more difficult to model accurately, and consequently should not be over-interpreted.

Finally PD was positively correlated with temperature inside the laying house, contrary to results reported by Green et al. (2000). Possibly, if the laying house is consistently hot birds become more stressed, and thus perform more feather pecking, or lose plumage for other metabolic reasons e.g. moult. Alternatively, birds with PD lose body heat more easily (Leeson and Morrison, 1978; Herremans et al., 1989), therefore in a house with a lot of plumage damaged birds the ambient temperature might increase.

5. Conclusion

This study identifies a number of factors which could potentially be used to combat feather pecking in commercial situations. It highlights the importance of including behavioural observations in order to obtain an accurate measure of the behaviours. Gentle and severe feather pecking were largely affected by different risk factors or were affected differently by the same risk factors, an exception being that a lower % of birds using the range increased the risk of both GFP and SFP. Gentle and severe feather pecking were also consistently negatively correlated, and occurred independently more often than would be expected if they were different intensities of the same behaviour (Lambton et al., 2007). Since gentle feather pecking does not appear to be related to plumage damage or to farmer identification of feather pecking, then those studies which have relied on these measures in the past have very likely been measuring the consequences of severe feather pecking. Although severe feather pecking has the greatest economic and welfare consequences, gentle feather pecking too may have welfare implications, with the possibility that birds' behavioural needs are not being fulfilled, resulting in the development of abnormal behaviours. Greatest weight should perhaps be given to interventions, such as methods of increasing range use, which could reduce the frequency of both GFP and SFP. However, to reduce plumage damage we must reduce severe feather pecking. Increasing rewarding foraging opportunities may be important in reducing severe feather pecking, both through use of mashed feeds and provision of real foraging opportunities on the litter. It is also clear that there is an effect of rearing conditions, and early lay, which continues into later life, and as such it is important to study those factors during rearing which precipitate later feather pecking.

Acknowledgements

The authors would like to thank Stonegate Farms Ltd. for funding this project and also Prof. Bill Browne for invaluable statistical advice.

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