© 2015 Universities Federation for Animal Welfare
The Old School, Brewhouse Hill, Wheathampstead,
Hertfordshire AL4 8AN, UK
www.ufaw.org.uk

Animal Welfare 2015, 24: 101-111
ISSN 0962-7286
doi: 10.7120/09627286.24.1.101

The risk factors affecting the development of vent pecking and cannibalism in free-range and organic laying hens

SL Lambton*†, TG Knowles†, C Yorke‡ and CJ Nicol†

† School of Veterinary Sciences, University of Bristol, Langford House, Langford, Bristol BS40 5DU, UK
‡ Stonegate Farmers, The Old Sidings, Lacock, Chippenham, Wiltshire, UK
* Contact for correspondence and requests for reprints: sarah.lambton@bristol.ac.uk

Abstract

Injurious pecking remains one of the biggest animal welfare and economic challenges for free-range egg producers. This prospective epidemiological study investigated the development of vent pecking (VP) and cannibalism on 62 free-range and organic UK farms (119 flocks). Flocks were visited at 25 (± 5) and 40 (± 5) weeks of age. Rates of VP were recorded and farmers were asked whether they had observed cannibalism in their flocks. Environmental and management data were collected for each flock. Risk factors associated with these behaviours were modelled using MLwiN. VP was observed in 19.5 and 29.9% of flocks, at mean rates of 0.35 and 0.21 bouts per bird per h, at 25 and 40 weeks, respectively. Cannibalism was reported at 22.6% of visits. The odds of flocks showing VP or cannibalism increased with rate of severe feather pecking (SFP). VP was more likely to be observed in laying houses with more and/or longer pop holes and where feed was scattered on the floor. Providing more aerial perch length, or perches > 0.5 m in height, was associated with increased risk of VP. When SFP was excluded from the model, likelihood of VP was higher in flocks fed pelleted feed. All of these may provide a useful basis from which to derive management strategies to reduce the risk of VP and thus improve the welfare of laying hens. However, it is important to remember that this study does not elucidate the causal relationships between these variables, and further work is needed to understand the mechanism behind these associations.

Keywords: *animal welfare, cannibalism, free range, laying hens, risk factors, vent pecking*

Introduction

Vent pecking (VP) is defined as a peck to the skin and underlying tissue surrounding the vent of a conspecific, while cannibalism is defined as pecking at the skin and tissue of a conspecific, but not including pecking to the vent area (Savory 1995). Both present persistent problems for the laying hen industry. They are associated with an economic cost, through increased mortality (Koene 1997; Yngvesson *et al* 2004), and a welfare cost, since they are painful for the victims. These behaviours are more difficult to manage in loose-housing systems and with the ban on conventional cages, which came into force in January 2012, loose-housing systems are becoming more common in the UK: 43.9% of eggs produced in the UK came from free-range systems in 2013 (Defra 2014), compared with 37.1% in 2009 (Lambton *et al* 2013). In 2013, a further 2.3 and 3.3% of eggs were produced in organic and barn systems, respectively. Historically, the VP and cannibalism have been managed by beak trimming; however, the UK Government has scheduled a ban on this practice in 2016, to be reviewed in 2015 (Defra 2010). Consequently, it is more important than ever that we understand the causes of VP and cannibalism, so as to better manage the problem.

In comparison with feather pecking (FP; eg Nicol *et al* 2013; Rodenburg *et al* 2013), defined as pecking and pulling at the feathers of a conspecific, risk factors for VP and cannibalism remain relatively under-investigated. VP and cannibalism have been associated with FP (Cloutier *et al* 2000; McAdie & Keeling 2000; Pötzsch *et al* 2001) and much of the information we have regarding VP and cannibalism comes from observations of cannibalistic attacks, during studies of FP. Many of the risk factors identified for VP and cannibalism are also risk factors for the development of FP, thus it becomes difficult to distinguish whether these factors cause increased levels of cannibalism in their own right, or as a result of their association with FP. For example, associations have been described between cannibalism and foraging behaviour and/or litter availability. Huber-Eicher and Wechsler (1998) found that both FP and bloody injuries caused by FP were more common where chicks were provided with shredded straw as opposed to long straw or polystyrene blocks, both of which promoted foraging behaviour. Similarly, Johnsen *et al* (1998) found that hens reared on wire (compared to sand and straw) performed more FP, had more plumage damage, and higher mortality rates, mainly due to cannibalism. Chicks reared with a broody hen showed more ground pecking, less FP and lower mortality due to cannibalism (Riber *et al* 2007). However, we do not know whether these treatments directly increased the risk of cannibalism, or if they increased FP, which led to an increased risk of cannibalism.

Cannibalism has also been associated with group or flock size, although the majority of this evidence again comes from studies of FP. In a study of FP, plumage condition was worse and injuries to skin on any part of the body were more common in larger groups (120 compared with 15, 30 and 60) of birds (Bilčík & Keeling 1999). FP and cannibalism were also more common in larger groups of caged laying hens (Allen & Perry 1975). Finally, Koene (1997) examined cannibalism explicitly (although he did not differentiate between forms of cannibalism) and found that mortality due to cannibalism increased with flock size in free-range flocks.

Diet has been linked with cannibalism. Low protein diets have been associated with increased FP and higher rates of mortality due to cannibalism (Schaible *et al* 1947; Ambrosen & Petersen 1997; Elwinger *et al* 2002), and some laying hens are motivated to consume blood (Yngvesson & Keeling 1998; Cloutier *et al* 2000). Feeding diets high in insoluble fibre has also been associated with decreased rates of mortality due to cannibalism (Bearse *et al* 1939; Karlsson *et al* 1997; Hartini *et al* 2002), and Steenfeldt *et al* (2007) found that high fibre diets were associated with lower rates of severe feather pecking (SFP), improved plumage and lower rates of mortality. Again, there is some difficulty in these studies in separating the causes of FP and the causes of cannibalism. Furthermore, where cannibalism is explicitly investigated studies simply record mortality due to cannibalism. Such a measure may under-report low levels of these behaviours.

All the studies mentioned above examined cannibalism generally; however, it may be important to distinguish between the two forms defined above. Studies have found that VP in particular can occur independently of FP (Gunnarsson *et al* 1999). It has been suggested that exposure of the cloacal mucosa during egg laying appears to act as a stimulus for VP (Kawai *et al* 1987; Savory 1995), but has not been associated with other forms of injurious pecking. However, very few studies have directly investigated risk factors affecting VP. Gunnarsson *et al* (1999) recorded the presence or absence of mortality due to cloacal cannibalism at flock level and found that birds were more likely to have died as a result of cloacal cannibalism where flocks were provided with perches before four weeks of age. Nicol *et al* (1999) measured rates of VP in perchery systems, but rates observed were very low, and all birds were beak trimmed. Perhaps the most comprehensive study has been that of Pötzsch *et al* (2001), which recorded presence or absence of VP at flock level, based on farmer observations, in free-range, barn and perchery systems, and found that risk of VP was increased by use of lighting in nest boxes, use of bell drinkers, more than three diet changes during the laying period, and onset of lay before 20 weeks of age.

No study has examined the prevalence of, or risk factors associated with, VP and cannibalism on organic farms. Organic diets rely on plant protein sources and cannot be supplemented with synthetic amino acids. There is some anecdotal evidence that feeding entirely vegetable protein results in increased risk of injurious pecking, although experimental evidence is equivocal (Van Krimpen *et al* 2005). In an experiment using broiler chickens, Eriksson *et al* (2010) found that birds fed diets with a low crude protein content were more likely to show cannibalism than birds fed the same diet supplemented with amino acids. Organic farms are also discouraged from beak trimming, so injurious pecking might be expected to be more damaging.

The aim of this study was to investigate VP and cannibalism in free-range, barn and organic flocks of laying hens. We draw a clear distinction between VP and cannibalism directed at the other parts of the body, allowing us to examine the risk factors associated with each behaviour. For VP we use our own observations of the behaviour, rather than relying solely on farmer observations or mortality records. This allows more detailed examination of the risk factors associated with VP, since we record the behaviour even where it occurs at low levels, before damage results in death or becomes noticeable by the farmer. We also investigate the relationship between both forms of cannibalistic pecking and FP; modelling VP with FP as a risk factor, and then examining what happens when FP is excluded from the modelling process. The risk factors influencing FP in these same flocks were described in Lambton *et al* (2010).

Materials and 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, UK, who at that time produced barn, free-range and organic eggs. The sample constituted all farms to which we had access within the company, and all birds involved in the study were Columbian Blacktails, a crossbreed 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 1,100 and 24,480 birds (mean: 8,822), according to Stonegate records. 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 per m^2. Pullets received commercial standard or organic commercial rations as per European Council Regulation (EEC) No 2092/91. Beak trimming took place during rearing (within the first week of life) in 53.8% of flocks, and a further 12.6% were, retrospectively, beak trimmed as adults, as a consequence of injurious pecking observed on-farm.

Birds were transferred to laying farms at a mean age of 16 (range: 13.5–19) weeks, and brought into lay at approximately 20 weeks of age, continuing to approximately 70 weeks of age. Mean laying flock size was 2,947 (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, as more than one flock passed

https://doi.org/10.7120/09627286.24.1.101 Published online by Cambridge University Press

through them during the 18 months of the study. Therefore, a total of 119 flocks were included, from 108 laying houses, on 62 farms. Numbers of flocks per farm ranged from one to four. Overall, 42.0% of flocks were free-range, 55.5% were organic, and 2.5% were barn flocks. Whilst organic standard in the UK do not permit birds to be beak trimmed, some organic farmers may receive a derogation which allows them to beak trim birds where they have a history of IP in previous flocks. Thus, some organic flocks were beak trimmed.

Each flock was visited between 20 and 30 weeks of age to collect information on environment and farm management, bird behaviour and plumage condition. A second visit to each flock was carried out between 35 and 45 weeks, during which behaviour and plumage data were collected again, since Bright *et al* (2006) found that most flocks which exhibited injurious pecking at any age, did so by the age of 40 weeks.

Environmental and farm management variables

A description of all data collected can be found in Lambton *et al* (2010). Data were gathered through a combination of behavioural observations and farmer interviews. Laying houses were split into 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. The weather was recorded in three categories: sun — sunny, average or cloudy; rain — dry, average or wet; wind — still, average or windy. Temperatures inside and outside the house were measured to the nearest °C, using the thermometer provided inside each laying house for the former, and an in-car thermometer for the latter (the same in-car thermometer was used for all visits). Light levels inside the house were recorded using a HOBO U12 Data Logger (Onset, Mass, USA); six readings were taken 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 estimated by making an approximate count of birds in the litter area and dividing by the total number of birds in the flock. Litter friability was estimated by recording the percentage of the litter that was capped (flattened and compacted) on both the left and right. Litter samples were collected and moisture content measured later in the laboratory 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. The 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 an approximate count of the birds visible on the range and dividing by the total number of birds in the flock.

Observations

VP, gentle feather pecking (GFP) and SFP were recorded during behavioural observations on each of the two visits. Visits took place throughout the year, and observations were carried out between 1000 and 1400h. GFP was defined as gentle pecking directed at the tips of the feather of a conspecific, while SFP was pecking and pulling at the feathers of a conspecific, often causing the recipient bird to react and move away (Lambton *et al* 2010). A representative area of approximately 2 m^2 was selected in each of the house areas, not including any large obstacles which would obscure the observer's view, not overlapping with any other house area, and at a position at least 2 m from the house entrance. The observer stood at least 1 m away from the selected area, and waited for 2 min before beginning the observation. The same observer carried out all observations, but periodically her classifications were compared with a second accompanying person to ensure standardisation. A 2-min period of acclimatisation allowed the birds to settle and they remained undisturbed unless the observer moved. The selected area was observed continuously 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 VP, 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. For each house area, rates of VP, GFP and SFP were calculated as number of bouts per bird per h.

As rates of cannibalistic pecking, other than VP, were too low to measure meaningfully during our behavioural observations, farmers were asked whether they had noted cannibalism in their current flock. When interviewing farmers the interviewer explained the distinction between VP and cannibalism, as defined above.

Statistical analysis

All behavioural data from each of the house areas were averaged to provide a mean for each flock at each visit. As VP was rare during behavioural observations it was initially analysed as a binary outcome, ie presence or absence in a flock. Analyses were carried out using MLwiN (Rasbash *et al* 2004) and Stata 12.0 (Statacorp, Statacorp LP, TX, USA) to produce multi-level models which reflected the hierarchies inherent in the data.

Binary VP data from both visits were combined and analysed in a repeated measures logistic model, with a three-level hierarchy (visit within flock within farm). House was not included as a level in the hierarchy, as only ten houses contained more than one flock during the course of the study, and it did not significantly affect the model ($P > 0.05$). All models included flock age and time of year. All potential explanatory variables were entered into the model individually and variables which had a significant association with VP (at $P < 0.1$) were recorded and used to make a final model. All significant variables were entered into the model together and the variable with the highest P-value removed and the model re-run. This process was repeated until only significant variables ($P < 0.05$) remained in the model. All other variables which had been significant

Table 1 Mean (± SEM) and range of age of onset of feather pecking, vent pecking, cannibalism and lay, according to farmer observations.

Age of onset of	Mean (± SEM)	Min–Max
Feather pecking	23.0 (± 0.85)	14–40
Vent pecking	20.9 (± 0.74)	16–30
Cannibalism	20.7 (± 0.92)	16–32
First lay	19.4 (± 0.16)	17–25

in the initial individual variable analyses were then re-inserted one-by-one, and significant variables ($P < 0.05$) were retained. Interactions in the models were examined where they made biological sense.

Since VP occurred in different flocks at different ages (ie VP was not observed during the second visit in all flocks where it had been observed during the first and *vice versa*), we considered it possible that VP at different ages was associated with different risk factors. Therefore, data were also separated into visits one and two (response variables VP25 and VP40, respectively) and, using the methods described above, separate logistic regression models were created for VP25 and VP40, to identify any associations which may have been masked in repeated measures analyses. In this case a two-level hierarchy (flock within farm) was used.

In a separate analysis, flocks where VP had been observed were extracted from the whole dataset and used to analyse factors associated with rates of VP expressed as bouts per bird per h. As we observed VP in relatively few flocks, this extracted dataset constituted a small sample of the whole. However, linear regression analyses were performed, again reflecting the hierarchical structure of the dataset (visits within flocks within farms). Rates of vent pecking were log-transformed. Due to the small sample size and missing values in many of the potential explanatory variables, no attempt was made to produce a full model from this dataset. Associations significant at $P < 0.01$ in a likelihood ratio test are presented; a lower critical P-value was used to mitigate against potential errors arising from multiplicity of P-values, due to the large number of explanatory variables involved. Categorical variables were excluded where categories contained too few data-points to be meaningfully analysed, and categories could not be combined to resolve this.

Presence or absence of cannibalism, according to farmer observations, was analysed as a binary outcome in a repeated measures multi-level logistic model, built as described above for VP.

Results

Of the 119 individual flocks in this data set, VP was observed at 25 weeks and/or 40 weeks in 46 (39.9%) flocks; of those, eleven flocks showed VP at both 25 and 40 weeks. Not all flocks were visited twice: 113 flocks were visited at 25 weeks and 117 flocks at 40 weeks; 111 flocks were visited at both ages. In total, VP was observed in 22 flocks (19.5%) at 25 weeks, and 35 flocks (29.9%) at 40 weeks. In the flocks where VP was observed, mean rate of VP was 0.35 and 0.20 bouts per bird per h at 25 and 40 weeks, respectively. The mean ages that VP and cannibalism and FP were first noted by the farmer, as well as the mean age that laying began, are shown in Table 1. Farmers reported having seen evidence of VP at some point during the laying period in 33 of 111 (29.7%) flocks (this question was not answered for the remaining eight flocks in the study).

Farmers reported whether or not their flock had shown cannibalism (excluding VP) on 221 visits; farmers answered 'yes' on 50 visits (to 29 flocks, 17 farms).

Logistic repeated measures model of VP

In the final model (Table 2), based on 201 visits to 110 flocks, on 60 farms (VP was observed during 51 of those visits), the odds of observing VP increased with age, rate of SFP and length of aerial perch space. The likelihood of observing VP decreased with time since morning lights-on. Likelihood of observing VP was greater in flocks where feed was scattered on the floor at any point during the laying period. As shown in Table 2, likelihood of observing VP also increased with the size of individual pop holes, and with the total length of pop holes in the house. The final model is presented without the pop-hole variables, since they were both missing a large number of data-points, and the predictions of the model based on a larger sample are more accurate. However, inclusion of these variables in the model did not affect the overall pattern of associations with VP.

As the analysis described above includes SFP, then any risk factors which are associated with both VP and SFP may be masked by the SFP variable. Since our analyses can only identify correlations we cannot be sure that SFP is a causal factor for VP; indeed the reverse may be true. Furthermore, since both behaviours were recorded during the same observation periods, it may not be possible that SFP as we observed it caused VP in the same observation periods. Therefore, to investigate all management factors associated with VP, either directly or indirectly, the data were re-modelled, without the inclusion of SFP. All models included time of year and age, although none were significantly associated with likelihood of VP in this model. In a model based on 207 observations, likelihood of observing VP was 2.59 times higher in flocks with some perches ≥ 50 cm high, compared with flocks with no perches or only perches < 50 cm high (CI: 1.09, 6.20; $\chi^2 = 4.60$, df = 1; $P = 0.032$). Likelihood of observing VP was also 5.25 times higher in flocks fed a pelleted feed compared with flocks fed mashed feed (CI: 1.89, 14.6; $\chi^2 = 10.1$, df = 1; $P = 0.002$). Likelihood of VP was also associated with an increase in the number of pop holes (OR: 2.91, CI: 1.15, 7.40, $\chi^2 = 5.05$, df = 1; $P = 0.032$), total length of pop holes (measured in metres) in the laying house (OR: 1.18, CI: 1.03, 1.34, $\chi^2 = 5.68$, df = 1; $P = 0.001$), and length of pop hole per bird (OR: 1.08, CI: 1.01, 1.13, $\chi^2 = 5.36$, df = 1; $P = 0.012$). However, all pop-hole variables decreased the number of observations on which the model was based (n = 196, 192 and 171, respectively) due to missing data; consequently they were not included in the final model.

https://doi.org/10.7120/09627286.24.1.101 Published online by Cambridge University Press

Table 2 Variables significantly associated with a change in the odds of observing vent pecking in a flock at either visit, analysed using a repeated measures logistic regression model.

Variable	OR	CI	χ^2 (df)	*P*-value
One week increase in age	1.05	1.00, 1.09	3.88 (1)	0.049
One bout per bird per hour increase in rate of SFP	2.52	1.80, 3.53	29.1 (1)	< 0.001
1 h increase in time since lights on in laying house	0.84	0.72, 0.98	5.09 (1)	0.024
1 m increase in length of aerial perch available	1.01	1.00, 1.02	10.2 (1)	0.001
Not spreading (n = 169) vs spreading (n = 32) feed on the floor	0.33	0.12, 0.88	4.94 (1)	0.026
1 m increase in individual pop hole length (n = 191)*	3.85	1.23, 12.9	5.33 (1)	0.021
1 m increase in total pop hole length in the laying house (n = 185)*	1.07	1.01, 1.13	5.26 (1)	0.022

* Variable not incorporated into the main model. These variables were missing a large number of data-points, thus making the model less robust. However, both were significantly associated with likelihood of observing VP when entered individually into the main model, and did not change the relationship between VP and any of the other variables.

Table 3 Variables significantly associated with a change in the odds of observing vent pecking in a flock when visits at 25 and 40 weeks were analysed separately.

	Variable	OR	CI	χ^2 (df)	*P*-value
VP25	One bout per bird per hour increase in rate of SFP	4.01	1.58, 4.01	15.2 (1)	< 0.001
	Increase of one more pop hole in the laying house	49.8	1.38, 49.8	5.39 (1)	0.021
	Not spreading (n = 88) vs spreading (n = 16) feed on the floor	0.76	0.04, 0.76	5.39 (1)	0.020
VP40	One bout per bird per hour increase in rate of SFP	7.36	2.10, 7.36	18.4 (1)	< 0.001
	Providing perches ≥ 50 cm high (n = 45) vs no perches or perches < 50 cm high (n = 70)	21.1	1.69, 21.1	7.69 (1)	0.006
	1 ha increase in the size of the range	1.27	1.02, 1.27	5.71 (1)	0.017

It is notable that the perch height variable, which included two categories: no perches or only perches < 50 cm versus some perches ≥ 50 cm high, could be exchanged for length of aerial perch space in the model without SFP; likelihood of observing VP increased with length of perch space (OR: 1.01, CI: 1.00, 1.02, $\chi^2 = 6.29$, df = 1; $P = 0.012$). The perch height and perch length variables were strongly correlated: mean length of perch space in flocks with perches ≥ 50 cm was 63.6 m, compared to 12.9 m in flocks with no perches or perches < 50 cm. However, the perch length variable was missing a number of data-points and, in a model also including feed form, the sample size was reduced to 195 visits. A variable with three categories (no perches; perches < 50 cm; and perches ≥ 50 cm) was also examined, but was not significantly associated with VP.

Before the addition of other variables VP was 5.26 times more likely to have been observed in non-beak trimmed flocks ($P = 0.025$), although this variable did not remain significant in any models presented here. VP was examined in flocks of intact beaked birds (103 visits to 53 flocks on 27 farms; VP was observed during 34 of those visits). In a model (n = 95) which controlled for time of year and age (although neither were significant in the final model; $P < 0.05$) likelihood of observing VP was 3.00 times greater for every increase of one bout per bird per h in rate of SFP (CI: 1.42, 6.42; $\chi^2 = 7.98$, df = 1; $P = 0.005$), and 1.06 times greater for every 1% increase in proportion of the flock perching at night (CI: 1.00, 1.12; $\chi^2 = 3.88$, df = 1; $P = 0.049$). A second model was produced excluding SFP (n = 93): odds of observing VP were 1.60 times greater for every extra pop hole in the laying house (CI: 1.03, 2.48; $\chi^2 = 4.33$, df = 1; $P = 0.038$) and was 65.3 times higher in flocks fed a pelleted feed (CI: 1.70, 2,503.1; $\chi^2 = 5.04$, df = 1; $P = 0.025$).

Logistic regression analysis of VP25

The final model for VP25 (Table 3) was based on visits to 104 flocks (on 56 farms), in 20 of which we observed VP. Likelihood of observing VP increased with rate of SFP and number of pop holes. Odds of VP were also lower in flocks where feed was not spread on the floor. In addition, when added to the model above, VP was 1.02 times more likely for every 1 m increase in length of aerial perch space (n = 99; CI: 1.01, 1.03; $\chi^2 = 7.79$, df = 1; $P = 0.005$); however, this is presented separately due to the decreased sample size.

Logistic regression analysis of VP40

The final model for VP40 (Table 3) was based on one visit to each of 115 flocks (61 farms), during 35 of which VP was observed. Odds of VP increased with rate of SFP and range size. Odds of observing VP were also greater in flocks with perches ≥ 50 cm high. Note that VP at 40 weeks was not associated with VP at 25 weeks.

Table 4 Factors identified in repeated measures linear regression analysis as significantly associated with rate of vent pecking in a model corrected for time of year and age.

Variable		n	Coefficient	SEM	χ^2 (df)	*P*-value
Rate of SFP (bouts per bird per min)		57	7.75	2.59	8.93 (1)	0.003
Stocking density on range (birds m^{-2})		54	–4.16	1.53	7.39 (1)	0.007
Time of day (h since lights on)		53	–0.12	0.04	7.69 (1)	0.006
Local stocking density (in the observation area)		57	–0.06	0.01	22.6 (1)	< 0.001
Length of aerial perch available (m)		56	–0.005	0.002	9.44 (1)	0.002
Feed company	Company 1	15	0.52	0.25	13.3 (2)	0.001
	Company 2	27	0.83	0.23		
	Other	15	ref			
Provided with a pre-lay ration	Yes	10	–0.77	0.24	10.0 (1)	0.002
	No	47	ref			
Number of chain feeder runs	4–7 runs per day	13	–0.12	0.23	11.4 (2)	0.003
	8+ runs per day	10	–0.83	0.25		
	No chain feeder	34	ref			
Previous problem with feather pecking	No	18	0.54	0.21	6.77 (1)	0.009
	Yes	38	ref			

As in previous models, likelihood of VP showed a tendency to increase with number of pop holes (P = 0.051) and total length of pop holes in the laying house (P = 0.068), and with time of the observation relative to when the laying house lights were switched on (P = 0.077).

Linear regression analysis of VP

Flocks with rates of VP greater than zero (22 and 34 flocks at the first and second visits, respectively) were extracted from the main dataset and rates of VP were used to perform linear regression analysis to identify factors associated with rate of VP in flocks where VP was observed. Individual variables significant (P < 0.01) when entered into a model, which accounted for time of year and age, are presented in Table 4. Rate of VP increased with rate of SFP. Rate of VP decreased with: increases in stocking density on the range (calculated by dividing flock size by the total available range: birds per ha^2); time since lights in the house were switched on; number of birds in the observation area; and length of aerial perch space. Rates of VP were higher in: flocks provided with feed from feed company two (compared with 'other' feed companies); flocks that were not provided with a pre-lay ration during rearing; flocks where a chain feeder was not used, or where the chain feeder was run less than eight times per day (compared with flocks where the chain feeder was run ≥ 8 times per day); flocks on farms where there was no history of FP (in preceding flocks).

Logistic analysis of cannibalism

Flocks which were not beak trimmed during rearing were significantly more likely to show cannibalism (48 of the 50 flocks which showed cannibalism were not beak trimmed during rearing; OR: 89.03, CI: 10.11, 784.15, χ^2 = 16.36, df = 1; $P \leq 0.001$). However, beak trimming could not be included in the final model since only two flocks which showed cannibalism were beak trimmed. All other variables were interrogated for an association with cannibalism. Models included age to allow a thorough examination of the data from both visits, although it was not significantly associated with cannibalism in the final model. However, time of year was not included, since farmers may have been reporting cannibalism at any point during the life of their flock. This produced a model based on 202 visits (to 108 flocks, on 57 farms); cannibalism was reported by farmers in 50 of those visits. Likelihood of cannibalism increased with rates of SFP, number of flock inspections by the farmer per day, age at light increase and the provision of perches. Likelihood of cannibalism decreased as number of pop holes increased (Table 5).

Cannibalism was examined in flocks of intact beaked birds (101 visits to 52 flocks on 27 farms; the farm reported cannibalism on 48 of these visits). However, the reduced dataset made it impossible to produce full models and no variables were significantly associated with likelihood of cannibalism.

Discussion

Rates and prevalence of VP were lower than those of GFP and SFP (Lambton *et al* 2010), although the behaviour was prevalent, occurring in 39.9% of flocks at some point. It is notable that VP appears sporadic; of the flocks in which VP was observed at 25 weeks, only half showed VP during observations at 40 weeks, suggesting that a flock may 'recover' from this behaviour. It is generally thought that once FP starts in a flock it is hard to stop; however, these results suggest this may not be the case for VP. There was no evidence that different risk factors were associated with

https://doi.org/10.7120/09627286.24.1.101 Published online by Cambridge University Press

Table 5 Factors significantly affecting the likelihood of a flock showing cannibalism (other than vent pecking) from a repeated measures logistic regression analysis.

Variable	OR	CI	χ^2 (df)	*P*-value
One week increase in age	0.99	0.94, 1.04	0.22 (1)	0.642
One bout per bird per hour increase in rate of SFP	2.00	1.41, 2.83	15.1 (1)	< 0.001
One unit increase in number of pop holes	0.71	0.60, 0.84	16.6 (1)	< 0.001
Increase by one flock inspection per day	1.35	1.07, 1.71	6.51 (1)	0.011
One week increase in age at light increase	1.97	1.15, 3.38	6.10 (1)	0.014
Provision of perches (n = 95) vs no perches (n = 107)	7.67	2.08, 28.3	9.37 (1)	0.002

VP at different ages. We observed VP in a similar proportion of flocks to that reported by farmers; however, we did not observe VP in all flocks where farmers reported it, and farmers did not report VP in all flocks where we observed it. Consequently, it is likely that the real prevalence of VP is higher than our figures suggest. Farmers may only notice and/or recall VP if it leads to significant injury or death thus underestimating prevalence where VP occurs at low levels. Our observations may have picked up even low rates of VP, as we observed behaviour directly, but since VP is a relatively rare behaviour, and we only carried out two visits per flock, it is unlikely we would have observed it in all flocks where it occurred.

Prevalence of cannibalism was lower at 22.6%. There is a similar risk that cannibalism may be under-reported, since this figure is based on farmer observation, and is thus prone to underestimating prevalence where the problem occurs at a low level.

Mean age at which VP and cannibalism were first observed by farmers was 20.9 and 20.7 weeks, respectively. This was just after mean age at the start of lay (19.4 weeks). Pötzsch *et al* (2001) found that onset of lay before 20 weeks was a risk factor for VP, suggesting that smaller birds may be more prone to exposure of the cloacal mucosa during egg laying, which may in turn act as a stimulus for VP (Kawai *et al* 1987; Savory *et al* 1995). No such association has been previously found with other forms of cannibalism, and it may be the case that the physical stress of coming into lay increases the risk of any cannibalistic pecking. Notably, age of onset of VP and cannibalism was earlier than that for FP; however, since these ages are based on farmer observations, and it is likely that farmers identify FP only when it results in observable plumage damage, it may be that there is a delay between the onset of FP and farmers becoming aware of it. Despite this possible association with the onset of lay, VP was more likely to be observed during the second visit than the first.

VP was less likely to occur, and occurred at lower rates where it did occur, later in the birds' day (longer after the time at which lights had been switched on in the laying house). If, as above, VP is stimulated by egg laying then it would be expected to occur less frequently later in the day, since eggs are laid in the morning. Alternatively, it may simply be that birds are less active later in the day. In either case this may be important to note for future work.

Perch height and length were consistently associated with the likelihood of observing VP and rate of VP. From the repeated measures analysis, VP was more likely to be observed in flocks which had more aerial perch space, or in flocks provided with perches ≥ 50 cm high, when the data from the second visit were analysed separately. These two variables were strongly correlated, and were interchangeable in most models, which makes it difficult to understand the reason for this association. Previous studies have found perch availability to be protective against VP (Wechsler & Huber-Eicher 1998; Gunnarsson *et al* 1999; Bilčík & Keeling 2000). We also found previously that rates of SFP were lower in flocks with access to high perches (Lambton *et al* 2010). However, in most cases perches were provided at a number of different heights within the laying house (ie in a house which did provide perches ≥ 50 cm from the ground, there may also have been lower perches). Although we did not record the distance between all perches in a house, it may be that where more perch space is available, and perches are tiered in this fashion, perches are closer together to fit in the perch length. Therefore, perching birds are close together, with the head of one bird frequently at the height of the cloacal region of another. This may stimulate pecking to be directed at those areas; both Wechsler and Huber-Eicher (1998) and Bilčík and Keeling (2000) found that more pecking was directed toward the rump or vent area of a bird if it was on a perch, or when provided with low (45 cm) compared with high perches (70 cm).

Another factor which appeared consistently in these analyses was the length and number of pop holes in the laying house. These are hatches at ground level in the walls of chicken houses which are opened to allow access to the range for birds. Although these variables were missing large numbers of data-points and were thus difficult to incorporate into full models, they were consistently associated with likelihood of VP when entered individually into models. Furthermore, from the repeated measures analysis, the likelihood of observing VP increased with both individual pop-hole length and total pop-hole length in the house when included in the final model. Likelihood of observing VP at the first visit also increased with the number of pop holes in the laying shed. The explanation for this relationship is not clear; one might have thought that larger pop holes would lead to increased range use, which in turn has been associated with a reduction in risk of SFP (Green *et al* 2000; Bestman & Wagenaar 2003). However, it may be that more and larger pop holes increase light intensity and patches of bright sunlight in the house. An effect of light intensity has previously been observed: Kjaer and Vestergaard (1999) found that rate of SFP at 28 weeks of age was 2–3 times higher in birds housed at 30 lux compared with those housed at 3 lux, and plumage was better in those birds housed at 3 lux. Furthermore, bright light is widely regarded by the industry to act as a risk factor for injurious pecking (eg Nicol *et al* 2013). Although we found no association between light intensity and VP in this study, we measured average light intensity for the whole house and did not specifically record light levels in front of the pop holes.

Alternatively, larger pop holes may be associated with decreased litter quality. If the pop holes allow rain or wind to enter the laying house, the litter may become wet. Although we found no association between VP and litter quality in this study, others have found that improved litter availability reduced injuries and/or mortality from cannibalism (Huber-Eicher & Wechsler 1998; Johnsen *et al* 1998). Furthermore, litter quality has been strongly associated with the development of FP, as reviewed by Rodenburg *et al* (2013). Additionally, larger pop holes may simply make environmental conditions inside the laying house more variable. Variable environmental conditions in the rearing house have been associated with an increased risk of IP later in life (Gilani 2012).

VP was more likely to be observed in flocks where feed was spread or scattered on the floor at some point during the laying period. Again, this result is unexpected. Blokhuis and van der Haar (1989) increased foraging behaviour by spreading feed on the floor during the rearing period, which in turn decreased both FP and plumage damage. However, in an analysis of FP within the same flocks as presented here, Lambton *et al* (2010) found that rates of SFP were also higher in flocks where feed was spread on the floor. It is possible that spreading feed on the litter during the laying period may not have the same effect as that found by Blokhuis and van der Haar during the rearing period. Often this feed scattering/spreading is carried out only early in the laying period, when the hens first arrive in the laying house. Beginning this practice and then stopping could increase frustration. It is also possible that farmers began spreading feed *in response* to an outbreak of VP. Particularly where variables can change throughout the life of a flock, this type of epidemiological analysis cannot make definitive statements about cause and effect.

In all logistic regression analyses higher rates of SFP were consistently associated with an increased likelihood of VP and cannibalism. Again, this supports previous studies (Cloutier *et al* 2000; McAdie & Keeling 2000; Pötzsch *et al* 2001), which have suggested that damage to the plumage and skin caused by SFP may act as a stimulus for VP and cannibalism. However, it is important to remember that our analyses can only identify an association; we cannot infer that SFP causes VP. Indeed, since farmers see VP before FP, according to the figures given for age of onset of these behaviours, it is possible that the relationship is the other way around, or simply that the two behaviours share risk factors. By including SFP in the model for VP the risk factors identified should be those that are associated with VP by some mechanism other than their effect on SFP; in this case such factors would be perch length/availability, pop-hole number/size and feed scattering.

However, including SFP in the analysis may also mask risk factors for VP. Since we are unsure of the causal relationship between SFP and VP, it was important to carry out the modelling process without SFP, in order to identify risk factors which may have been masked in this way. For example, using the same dataset, Lambton *et al* (2010) found that rates of SFP decreased as more of the flock ranged, and rates were higher when: flocks were non-beak trimmed; feed had been spread on the floor; FP was recorded at transfer to the laying house; and pelleted feed was used. When repeated measures analysis of all VP data were carried out excluding SFP from the explanatory variables, the risk factors identified were largely the same. The only new risk factor identified was an increased risk of VP in flocks fed a pelleted feed. This is in line with the results of previous analyses mentioned above (Lambton *et al* 2010) and highlights the potential role of this risk factor in the development of VP as well as SFP, although it is unclear whether this is a shared risk factor for both behaviours, or whether it causes one behaviour, which in turn leads to the other.

Notably, there was no difference observed between standard free range, barn or organic farms. Furthermore, there was no association with beak trimming in any of the final models of VP, although VP was significantly less likely to be observed in beak-trimmed flocks when this was the only explanatory variables (except for time of year and age) in the model. Flocks beak trimmed at rearing were significantly less likely to show cannibalism. Interestingly, this suggests that, for VP at least, other risk factors are more important than beak trimming in reducing the likelihood of VP. When risk factors for VP were examined in flocks with intact beaks, no new risk factors were identified; the same associations with SFP, number of pop holes and pelleted versus mashed feed were apparent. Likelihood of observing VP increased with percentage of the flock perching at night, and it is likely that this reflects the perch space variables previously mentioned, since a higher proportion of the flock is likely to perch at night if there is more perch space.

When linear regression analysis was performed on a subset of the data containing only flocks where VP was observed during our visit to the farm, some of the same risk factors were identified: rate of VP increased with rate of SFP and decreased with time since house lights were switched on. There was a negative correlation between length of perch space and rate of VP, in contrast to the associations discussed above, but more closely matching the findings of previous studies (Wechsler & Huber-Eicher 1998; Gunnarsson *et al* 1999; Bilčík & Keeling 2000). Possibly, perches are a risk for the initiation of VP but also provide

https://doi.org/10.7120/09627286.24.1.101 Published online by Cambridge University Press

opportunities for escape once VP has started. Rate of VP varied with feed company: Feed Company 2 was associated with the highest rates of VP. Diet composition has been linked with cannibalism, in particular protein and fibre content (eg Elwinger *et al* 2002; Steenfeldt *et al* 2007). However, a similar relationship was noted by Lambton *et al* (2010); in that analysis the same feed company was associated with the highest rates of SFP, and also provided most of its feed in pelleted form. Feeding a pelleted ration was associated with an increased risk of VP, as discussed above, and has previously been associated with reduced FP (eg Savory *et al* 1999; Aerni *et al* 2000; El-Lethey *et al* 2000). Flocks where chain feeders were run eight or more times per day had lower rates of VP than those flocks where chain feeders were run seven times or less, or where there were no chain feeders. It may be that where chain feeders were run less frequently there were periods of time where food was not available, thus there may be less opportunity or stimulation for the birds to perform foraging behaviours (Blokhuis & van der Haar 1989; Wechsler & Huber-Eicher 1998). Rate of VP decreased as stocking density on the range increased. It is possible that smaller ranges may be better managed, and thus more attractive, increasing range use. Flocks provided with a pre-lay ration also had lower rates of VP; these flocks may be better physically prepared for the start of lay, thereby reducing the stimulation for VP at that time. It should be noted that this analysis is performed on a very small subset of the data, including just 57 data-points, which makes the models far less robust, and as such they should be interpreted with caution.

Finally, a repeated measures analysis of the factors associated with the likelihood of farmers reporting cannibalism in their flocks was carried out. As for VP, cannibalism was more likely to be reported in flocks with higher rates of SFP and in flocks with perches compared with flocks without perches. Likelihood of farmers reporting cannibalism increased with the number of flock inspections each day. Since these data are based on farmer reports of cannibalism then it may simply be that farmers who inspect their flocks more often were more likely to see cannibalism. Likelihood of farmers reporting cannibalism decreased as number of pop holes increased — the opposite relationship to that seen above with VP. The reason for this association is not clear and the analysis of cannibalism should be interpreted with caution since it is a relatively infrequent behaviour, and relies entirely on farmer observations.

Animal welfare implications

The data collected for this study indicate that VP and cannibalism are continuing problems for free-range and organic farms in the UK, potentially affecting large numbers of birds. This is supported by evidence from other, more recently collected data (Lambton *et al* 2013). By identifying several risk factors associated with VP and cannibalism in commercial free-range and organic flocks, this study contributes valuable insight to the ongoing effort to find practical management strategies that can be used on-farm to protect against these behaviours.

Conclusion

This study has identified a number of risk factors associated with the likelihood of VP and cannibalism in free-range and organic flocks of laying hens. There was a clear association between SFP and both of these behaviours, although it is not clear what the causal relationship is between them. Providing smaller pop holes and taking care to design perch space in such a way that perching birds are never at head height for non-perching birds may have protective effects against VP. Clearly, feeding mashed feed may have a protective effect against both SFP and VP, although it is not clear whether this is a direct association with VP, or whether it occurs via the association between feed form and SFP. This study used occurrences and rates of VP observed by researchers, rather than relying on farmer observations, and distinguished between different types of cannibalism; as such it is the first to investigate VP, in particular with this level of detail.

Acknowledgements

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

References

Aerni V, El-Lethey H and Wechsler B 2000 Effect of foraging material and food form on feather pecking in laying hens. *British Poultry Science 41*: 16-21. http://dx.doi.org/10.1080/00071660086349

Allen J and Perry GC 1975 Feather pecking and cannibalism in a caged layer flock. *British Poultry Science 16*: 441-451. http://dx.doi.org/10.1080/00071667508416212

Ambrosen T and Petersen VE 1997 The influence of protein level in the diet on cannibalism and quality of plumage of layers. *Poultry Science 76*: 559-563. http://dx.doi.org/10.1093/ps/76.4.559

Bearse GE, Miller VL and McClary CF 1939 The cannibalism preventing properties of the fibre fraction of oat hulls. *Poultry Science 18*: 210-214

Bestman MWP and Wagenaar JP 2003 Farm level factors associated with feather pecking in organic laying hens. *Livestock Production Science 80*: 133-140. http://dx.doi.org/10.1016/S0301-6226(02)00314-7

Bilčík B and Keeling LJ 1999 Changes in feather condition in relation to feather pecking and aggressive behaviour in laying hens. *British Poultry Science 40*: 444-451. http://dx.doi.org/10.1080/00071669987188

Bilčík B and Keeling LJ 2000 Relationship between feather pecking and ground pecking in laying hens and the effect of group size. *Applied Animal Behaviour Science 68*: 55-66. http://dx.doi.org/10.1016/S0168-1591(00)00089-7

Blokhuis HJ and van der Haar JW 1989 Effects of floor type during rearing and of beak trimming on ground pecking and feather pecking in laying hens. *Applied Animal Behaviour Science 22*: 359-369. http://dx.doi.org/10.1016/0168-1591(89)90030-0

Bright A, Jones TA and Dawkins MS 2006 A non-intrusive method of assessing plumage condition in commercial flocks of laying hens. *Animal Welfare 15*: 113-118

Cloutier S, Newberry RC, Forster CT and Girsberger KM 2000 Does pecking at inanimate stimuli predict cannibalistic behaviour in domestic fowl? *Applied Animal Behaviour Science 66*: 119-133. http://dx.doi.org/10.1016/S0168-1591(99)00068-4

Defra 2010 *Ministerial Statement.* http://www.publications.parliament.uk/pa/cm201011/cmhansrd/cm101108/wmstext/101108m0001.htm#1011083000067

Defra 2014 *United Kingdom Egg Statistics.* https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/277409/eggs-statsnotice-06feb14.pdf

El-Lethey H, Aerni V, Jungi TW and Wechsler B 2000 Stress and feather pecking in laying hens in relation to housing conditions. *British Poultry Science 41*: 22-28. http://dx.doi.org /10.1080/00071660086358

Elwinger K, Tauson R, Tufvesson M and Hartmann C 2002 Feeding of layers kept in an organic feed environment. *Proceedings of the 11th European Poultry Conference.* 6-10 September 2002, Bremen, Germany

Eriksson M, Waldenstedt L, Elwinger K, Engstrom B and Fossum O 2010 Behaviour, production and health of organically reared fast-growing broilers fed low crude protein diets including different amino acid contents at start. *Acta Agriculturae Scandinavica Section A, Animal Science 60*: 112-124. http://dx.doi.org/10.1080/09064702.2010.502243

Gilani A-M 2012 *Investigation of rearing environment and its association with feather pecking in free range pullets.* PhD Thesis, University of Bristol, UK

Green LE, Lewis K, Kimpton A and Nicol CJ 2000 Cross-sectional study of the prevalence of feather pecking in laying hens in alternative systems and its associations with management and disease. *Veterinary Record 147*: 233-238. http://dx.doi.org/10.1136 /vr.147.9.233

Gunnarsson S, Keeling LJ and Svedberg J 1999 Effect of rearing factors on the prevalence of floor eggs, cloacal cannibalism and feather pecking in commercial flocks of loose housed laying hens. *British Poultry Science 40*: 12-18. http://dx.doi.org /10.1080/00071669987773

Hartini S, Choct M, Hinch G, Kocher A and Nolan JV 2002 Effects of light intensity during rearing and beak trimming and dietary fiber sources on mortality, egg production, and performance of ISA brown laying hens. *Journal of Applied Poultry Research 11*: 104-110. http://dx.doi.org/10.1093/japr/11.1.104

Huber-Eicher B and Wechsler B 1998 The effect of quality and availability of foraging materials on feather pecking in laying hen chicks. *Animal Behaviour 55*: 861-873. http://dx.doi.org/10.1 006/anbe.1997.0715

Johnsen PF, Vestergaard KS and Norgaard-Nielsen G 1998 Influence of early rearing conditions on the development of feather pecking and cannibalism in domestic fowl. *Applied Animal Behaviour Science 60*: 25-41. http://dx.doi.org/10.1016/S0168-1591(98)00149-X

Karlsson A, Tauson R, and Abrahamsson P 1997 Feather pecking and cannibalism in non beak trimmed layers subjected to salt deficiency - effects of diet, hybrid and housing system. In: Koene P and Blokhuis H (eds) *Proceedings of the 5th European Symposium on Poultry Welfare.* 5-10 June 1997, Wageningen, The Netherlands

Kawai M, Umeda I, Sakurai S and Makashima Y 1987 Observations on cannibalism induced by prolapse and its incidence in two commercial layer strains. *Japanese Poultry Science 24*: 316-319. http://dx.doi.org/10.2141/jpsa.24.316

Kjaer JB and Vestergaard KS 1999 Development of feather pecking in relation to light intensity. *Applied Animal Behaviour Science 62*: 243-254. http://dx.doi.org/10.1016/S0168-1591(98)00217-2

Koene P 1997 Cannibalism in extensive poultry keeping in the Netherlands: an inventory. In: Koene P and Blokhuis H (eds) *Proceedings of the 5th European Symposium on Poultry Welfare.* 5-10 June 1997, Wageningen, The Netherlands

Lambton SL, Knowles TG, Yorke C and Nicol CJ 2010 The risk factors affecting the development of gentle and severe feather pecking in loose housed laying hens. *Applied Animal Behaviour Science 123*: 32-42. http://dx.doi.org/10.1016/j.applanim.2009.12.010

Lambton SL, Nicol CJ, Friel M, Main DCJ, McKinstry JL, Sherwin CM, Walton J and Weeks CA 2013 A bespoke management package can reduce levels of injurious pecking in loose-housed laying hen flocks. *Veterinary Record 172*: 423-430. http://dx.doi.org/10.1136/vr.101067

McAdie TM and Keeling LJ 2000 Effect of manipulating feathers of laying hens on the incidence of feather pecking and cannibalism. *Applied Animal Behaviour Science 68*: 215-229. http://dx.doi.org/10.1016/S0168-1591(00)00107-6

Nicol CJ, Bestman M, Gilani A-M, de Haas EN, de Jong IC, Lambton SL, Wagenaar JP, Weeks CA and Rodenburg TB 2013 The prevention and control of feather pecking: application to commercial systems. *World's Poultry Science Journal 69*: 775-788. http://dx.doi.org/10.1017/S0043933913000809

Nicol CJ, Gregory NG, Knowles TG, Parkman ID and Wilkins LJ 1999 Differential effects of increased stocking density, mediated by increased flock size, on feather pecking and aggression in laying hens. *Applied Animal Behaviour Science 65*: 137-152. http://dx.doi.org/10.1016/S0168-1591(99)00057-X

Pötzsch CJ, Lewis K, Nicol CJ and Green LE 2001 A cross-sectional study of the prevalence of vent pecking in laying hens in alternative systems and its associations with feather pecking, management and disease. *Applied Animal Behaviour Science 74*: 259-272. http://dx.doi.org/10.1016/S0168-1591(01)00167-8

Rasbash J, Steele F, Browne W and Prosser B 2004 *A User's Guide to MLwiN.* Centre for Multilevel Modelling, University of Bristol: UK

Riber AB, Wichman A, Braastad BO and Forkman B 2007 Effects of broody hens on perch use, ground pecking, feather pecking and cannibalism in domestic fowl (*Gallus gallus domesticus*). *Applied Animal Behaviour Science 106*: 39-51. http://dx.doi.org/10.1016/j.applanim.2006.07.012

Rodenburg TB, van Krimpen MM, de Jong IC, de Haas EN, Kops MS, Riedstra BJ, Nordquist RE, Wagenaar JP, Bestman M and Nicol CJ 2013 The prevention and control of feather pecking in laying hens: identifying the underlying principles. *World's Poultry Science Journal 69*: 361-374. http://dx.doi.org/10.1017/S0043933913000354

Savory CJ 1995 Feather pecking and cannibalism. *Worlds Poultry Science Journal 51*: 215-219. http://dx.doi.org/10.1079/WPS19950016

Savory CJ, Mann JS and Macleod MG 1999 Incidence of pecking damage in growing bantams in relation to food form, group size, stocking density, dietary tryptophan concentration and dietary protein source. *British Poultry Science 40*: 579-584. http://dx.doi.org/10.1080/00071669986936

Schaible PJ, Davidson JA and Bandemer SL 1947 Cannibalism and feather pecking in chicks as influenced by certain changes in specific ration. *Poultry Science 26*: 651-656.http://dx.doi.org/10.3382/ps.0260651

Steenfeldt S, Kjaer JB and Engberg RM 2007 Effect of feeding silages or carrots as supplements to laying hens on production performance, nutrient digestibility, gut structure, gut microflora and feather pecking behaviour. *British Poultry Science 48*: 454-468. http://dx.doi.org/10.1080/00071660701473857

https://doi.org/10.7120/09627286.24.1.101 Published online by Cambridge University Press

Van Krimpen MM, Kwakkel RP, Reuvekamp BFJ, Van der Peet-Schwering CMC, Den Hartog LA and Verstegen MWA 2005 Impact of feeding management on feather pecking in laying hens. *Worlds Poultry Science Journal 61*: 663-685. http://dx.doi.org/10.1079/WPS200478

Wechsler B and Huber-Eicher B 1998 The effect of foraging material and perch height on feather pecking and feather damage in laying hens. *Applied Animal Behaviour Science 58*: 131-141. http://dx.doi.org/10.1016/S0168-1591(97)00137-8

Yngvesson J and Keeling LJ 1998 Are cannibalistic laying hens more attracted to blood in a test situation than other hens? *Proceedings of the 32nd Congress of the ISAE*. 21-25 July 1998, Clermont-Ferrand, France

Yngvesson J, Keeling LJ and Newberry RC 2004 Individual production differences do not explain cannibalistic behaviour in laying hens. *British Poultry Science 45*: 453-462. http://dx.doi.org/10.1080/00071660412331286163