MINISTRY OF AGRICULTURE, FISHERIES AND FOOD **CSG 15**

Research and Development

Final Project Report

(Not to be used for LINK projects)

Project title	The development of a predictive model of damaging pecking in laying hens
MAFF project code	**AW0214**
Contractor organisation and location	Dr Laura Green/Dr Christine Nicol, Mr L. Wilkins Department of Clinical Veterinary Science University of Bristol Langford House Bristol BS40 5DU
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Executive summary (maximum 2 sides A4)

To date, most research on feather-pecking has involved either small-scale experimental trials, or observations of experimental flocks housed in research establishments. The aim of our study was to take an observational approach to identify and quantify management and disease associations with feather-pecking and vent pecking in adult laying birds in commercial alternative systems in the United Kingdom.

The methods we employed were:
A cross sectional study using a postal questionnaire on 200 alternative system egg producers to identify possible risks for feather (FP) and vent pecking (VP) and to generate hypotheses for further study.
A case control study to refine these risk factors and test them in a more rigorous setting. One hundred flocks, 50 with feather pecking, 50 without, and matched on age were visited. Univariate statistics, logistic regression and survival analysis were used to analyse data from these studies.
From the results of the above study an intervention study was designed to test the effect of enhanced litter management.

Experimental work complemented the epidemiological studies. We conducted a first experiment to test the hypothesis that there is a critical period in chick development when pecking patterns are established.
A follow-up experimental study was conducted to establish the importance of substrate exposure at the age of 2 months.

The work was integrated by comparison with a qualitative survey of expert opinion of the risks factors that affect feather and vent pecking.

The results we obtained were:

1. Cross sectional study. 46% of farmers reported that FP was a regular occurrence in their flocks, 56% reported FP in the last flock depopulated. The following were associated with FP: fewer than 50% hens using the outdoor area, no loose litter left by the end of lay, water provided via bell drinkers, more than 3 diet changes during lay, house temperature<20 oC, light levels raised to inspect birds, use of lights in nest boxes, one person inspecting the flock. The following were associated with VP: less than 25% of the flock using outdoor area, more than 3 diet changes, use of hanging drinkers, birds came into lay at <20 weeks of age. FP and VP were positively correlated and shared some common risk factors. VP was associated with increased flock mortality. FP was associated with infections bursitis and bronchitis.

Case control study. Univariate analysis showed that FP was more likely when ISA Brown birds were used, and when access to litter was restricted when birds were young, or during morning periods to prevent floor eggs. The importance of good range use was confirmed as both univariate and multivariate analysis showed that poor use of the outdoor area was a significant risk factor for FP.

Intervention study. The effects of enhanced litter management were monitored on 4 farms, where flocks were subdivided into treatment and control groups. There were suggestions that enhanced litter management was beneficial in reducing FP but the practicalities of maintaining litter condition should not be underestimated.

The experimental studies showed that young birds are strongly influenced by their experience with particular types of litter substrate. This greatly affects their dustbathing behaviour, and to a lesser extent their foraging behaviour. Birds with inappropriate experience of litter during rearing were more likely to feather peck. In contrast, adult birds were much more flexible and tolerant in their use of novel litter substrates, and were less influenced by their prior experience.

The survey of expert opinion showed that experts primarily identified risk factors based on those reported in the published literature. The value of our work was in identifying novel risk factors that had not been considered by the experts.

The final model showed that it should be possible to delay the onset of VP by manipulation of the risk factors. All variables that were associated with VP in the logistic regression model had a significant effect on the time of onset of VP using Cox proportional hazard analysis. This was not the case for the FP models. This may indicate a consistent effect of these variables and therefore a robustness of the VP logistic and Cox regression models.

Scientific report (maximum 20 sides A4)

The aims of this programme were to develop a predictive model of damaging pecking in laying hens housed in alternative systems. This was achieved via a set of questionnaire-based and on-farm investigations to identify risk factors for feather pecking and vent pecking, by consulting expert opinion, and by conducting experimental investigations of the effects of substrate exposure during the rearing period. Once the predictive model was developed the effects of introducing enhanced litter management procedures on farms were evaluated in an intervention study. Here the work is reported under six main headings:

1. Cross sectional study of risk factors for feather pecking
2. Cross sectional study of risk factors for vent pecking
3. Case-control study of feather pecking
4. Experimental work on substrate exposure during rearing
5. On-farm intervention trial
6. Expert opinion and the predictive model.

1. Cross-Sectional Study of Risk factors for Feather Pecking

Introduction

To date, most research on feather-pecking has involved either small-scale experimental trials, or observations of experimental flocks housed in research establishments. However, two recent papers have examined feather-pecking in commercial flocks. Gunnarsson *et al.* (1999) found no significant associations between environmental variables and feather-pecking in 59 flocks from 21 Swedish farms. In contrast, Huber-Eicher and Audige (1999) found that high stocking density and no access to elevated perches were significantly associated with increased feather-pecking in 64 rearing units in Switzerland.

The aim of our study was to take an observational approach to identify and quantify management and disease associations with feather-pecking in adult laying birds in alternative systems in the United Kingdom.

Materials and Methods

A questionnaire for alternative systems was designed using epidemiological principles. In the questionnaire, the producer was asked to recall the most recently depopulated flock on the unit and to answer the questionnaire using information from that flock. The questionnaire was 14 pages long with 12 sections and 3 - 34 questions per section. The majority of questions were closed or semi-closed with an ‘other’ section. Eight open questions asked farmers to describe techniques they used to encourage hens to adopt appropriate behaviours e.g. to use nesting boxes. A summary of the questions asked is given below in Table 1.1.

TABLE 1: Questions asked in the cross-sectional study

- How many hens on farm
- How many flocks on farm
- Average mortality per flock (%)
- Occurrence of FP before lay*
- Occurrence of FP after lay*
- Percentage affected with FP during lay*
- Age FP started*
- Behaviours seen in FP flock*
- Body sites affected by FP*
- Percentage mortality from FP*
- Age at first death from FP*
- Control measures taken to prevent FP*
- Control measures taken to reduce FP*
- Is FP a normal occurrence*
- Source of hens for flock (purchased/reared on farm)
- Strain of bird
- Were birds beak trimmed – when
- Age when housed
- Stocking density at start of lay
- Stocking density at end of lay
- Age flock came into lay
- Age at peak production
- Age at depopulation
- Total food consumed
- Type of house
- Type of litter
- Floor covered with litter (%)
- Depth of litter at start of lay
- Age of flock when accessed litter
- Hours a day with access to litter
- Any new litter added
- Quality of litter added
- Grain or grit added to litter
- Presence of toys/objects in house
- Access to perches/raised floor
- Flock using perches/raised floor during day and night (%)
- Access to outdoor area
- Size of outdoor area
- Type of outdoor area
- Rotation of outdoor area
- Size of pop holes
- Number of pop holes used by flock
- Distance of outdoor area from hen house
- Age of flock when allowed outdoors
- Hours per day allowed outdoors
- Flock outdoors on sunny day (%)
- Flock outdoors on wet, windy day (%)
- Flock outdoors on calm, dull day (%)
- Use of all outdoor area available
- Feed provided outdoors
- Grain/grit scattered outdoors
- Fencing of outdoor areas
- Wings clipped
- Type of nesting boxes
- Type of nesting material
- New material added to nest boxes
- Entrance to nest boxes covered
- Route of access to nest boxes
- Measures to encourage use of next boxes
- Light in nest boxes (hours per day)
- Type of feed
- Source of feed
- Dietary supplements
- System to distribute feed
- Feeders partitioned
- Location of feeders in house
- Height above slats/perches
- Any feed scattered on floor
- Number of diet changes
- Any restriction in diet
- System to distribute water
- Location of drinkers
- Method of ventilation
- Type of ventilation
- Supplementary heat
- Type of light in house
- Site of light source
- Lighting programme
- Light intensity
- How light intensity changed during lay
- Why light intensity changed
- Hours of light at point of lay
- Hours of light at peak lay
- Hours of light at end of lay
- Speed of transition from light to dark and transition from dark to light
- Were lights turned up when inspected
- Method of egg collection
- Number of times collected per day
- Any egg eating
- Eggs laid on floor (%)
- Where were eggs laid on floor
- Number of inspections other than when eggs collected
- Inspections by one person or more
- Did flock have any disease conditions
- Mites, lice, worms, Newcastle disease, Marek's disease, bronchitis, egg peritonitis, egg bound
- Avian rhinotracheitis, other
- Did any other events occur

* Same questions also asked about vent pecking
FP Feather pecking

Access to egg producers came from companies involved in egg retailing. They either provided the names and addresses of clients after gaining their permission, or sent the questionnaire out themselves. Other names and addresses came from the Internet Yellow Pages. Questionnaires, a covering letter and a stamped return addressed envelope were sent out on 16/07/98. All questionnaires were stamped with a unique code. A reminder was sent to all farmers who had not replied to the first mailing on 06/08/98 and a final reminder was sent out on 10/09/98.

Data input and error checking
Data were entered into a database (Access, Microsoft inc.). Frequency distributions and histograms were used to check the data. Any obviously incorrect values were rechecked from the reply questionnaire and amendments made. Missing values were coded and the data were prepared for analysis in Genstat.

Data analysis
Frequency distributions and means, medians, standard deviations and quartiles were used to describe the data. All exposures were then compared with the outcome variable, feather-pecking after point of lay, using Yate's and Pearson adjusted, Chi squared tests, t tests and Mann Whitney tests as appropriate (Kirkwood, 1988). All exposure variables were also compared with each other using Chi squared, t test, Mann Whitney and regression techniques. Finally, a forward stepwise logistic regression model was developed. Initially all variables significantly associated with feather-pecking at 0.05 were tested in the model and those which had a likelihood ratio chi square significant at p 0.05 were left in the final model. A second model with only consistent management variables was then developed using the same selection criteria. Interactions were tested for all significant variables in the final model and the goodness of fit of each model was checked.

Results

Response rate

A total of 637 questionnaires were sent out to alternative producers. The response rate to the first mailing was 29%, by 08/09/98 37% of farmers had replied and the final response rate on 19/11/98 was 51.5%, 328/637. This included 214 (66%) completed questionnaires and 114 (34%) phone calls and letters explaining why questionnaires had not been completed. Reasons for non-completion were that producers were farming their first flock, were no longer in egg production, lacked time or that feather-pecking was not a problem.

General information about the flocks

Of the 198 flocks, 26 were housed in a perchery or barn with no outdoor area and 172 in free-range units. Only 32.8% of flocks had no raised floor area. There were 30.8% respondents with three or more flocks on site. Flock size ranged from 800 to 23,000 (mean 6024). Birds came into lay at less than 20 weeks old in 44.3% of flocks. The median mortality in all flocks was 7.0% (inter-quartile range 5 - 9). The strains kept were 62.6% ISA, 13.6% Lohmann, 12.2% Hisex, 6.1% Hyline, 3,5% Shaver and 2.0% Columbian Blacktail. 96.4% of the flocks were beak trimmed as chicks and 2.1% after onset of lay.

Farmers with flocks with outdoor areas reported that 81.8% of 170 free-range units had more than five pop holes to the outdoor area. This area was less than five hectares for 52.1% flocks and more than 10 hectares in 12.9%. Farmers reported that more than half the birds used the outdoor area on a fine sunny day in 28.3% flocks and on a calm dull day in 56.3% flocks.

Inside, 72.6% houses had communal nest boxes and 14.4% farmers placed dim lights in the nesting boxes to encourage the birds to use them. The majority of flocks were fed using chain feeders 88.1%; 13.3% flocks did not have food available on all levels of the house. Farmers changed the diet during lay in 80.2% flocks and 56.1% did so on more than two occasions. Water was supplied to 81.5% flocks in bell drinkers. The ventilation system was natural in 42.3% houses and artificial in the rest, 57.4%: 80.4% used roof fans. 98.4% houses had artificial light. Farmers reported no loose litter by the end of lay in 55.3% flocks.

Feather-pecking

Overall, 46.6% farmers reported that feather-pecking was a normal occurrence in their flock. However, 56.6% farmers reported feather-pecking in the last depopulated flock (the subjects for this questionnaire). Farmers reported seeing bald patches (70%), blood on hens (12%), damaged feathers (64%), hens pulling out their own feathers (10%), pulling out other hens feathers (49%), pecking other hens feathers (58%) and eating feathers (17%) Farmers saw damage on the back (68%), neck (57%), tail (55%), vent (27%), head (23%), wings (10%) and breast (4%) of affected birds. The median proportion of birds affected was 30 (IQrange 10-75). The median age that feather-pecking started was 40 weeks (IQR 30-44) and the first deaths were reported at 45.3 weeks (IQR 35 - 57.5). Very few birds were reported to have died from feather-pecking, the IQR was 0 - 1%.

There were 69/184 (37.5%) farmers who said that they took measures to prevent feather-pecking. Measures taken included: dimming lights (19%), use of red lights (3%), spraying birds (4%), beak trimming (8%), low stocking density (3%) and litter enrichment (5%). Approximately 62% (67/109) of farmers tried to reduce feather-pecking if it occurred, by using dimmed lights (51%), red lights (9%), spraying the birds with water (5%), providing vitamins (4%), isolating birds (4%), beak trimming(1%) or providing salt (2%).

Univariate analysis of exposures with feather-pecking

The exposures reported were compared with the occurrence of feather-pecking after lay and are reported in Table 1.2 below:

TABLE 2: Management factors that were significantly associated with feather pecking (FP) after point of lay

Management factor		Yes/no	Number (%) of flocks with FP	Total number of flocks	P†
General	Three or more flocks on site	Yes	27 (42)	65	0·003
		No*	83 (64)	130	
	Flocks came into lay after 19 weeks	Yes	54 (50)	108	0·035
		No*	56 (65)	86	
	Flock housed in perchery	Yes	11 (35)	31	0·010
		No*	99 (60)	164	
	Loose litter at end of lay	Yes	38 (50)	76	0·017
		No*	64 (68)	94	
	Areas of hard compact litter	Yes*	60 (67)	89	0·039
		No	42 (52)	81	
	Access to raised floor area	Yes*	82 (63)	131	0·022
		No	29 (45)	64	
	Egg eating controlled by electric wire	Yes*	8 (89)	9	0·046
		No	98 (55)	178	
	Inspections always carried out by same person	Yes*	62 (63)	99	0·047
		No	45 (48)	93	
	Communal nesting boxes	Yes*	81 (62)	130	0·005
		No	19 (39)	49	
	Dim light used in nest boxes	Yes*	22 (79)	28	0·011
		No	88 (53)	167	
Ventilation and temperature	Natural ventilation	Yes	40 (48)	84	0·027
		No*	71 (63)	112	
	Roof fan used	Yes*	62 (69)	90	0·001
		No	49 (46)	106	
	Temperature of house >20°C	Yes	24 (41)	58	0·001
		No*	70 (69)	102	
Lighting	Artificial light used	Yes*	109 (57)	190	0·047
		No	0 (0)	3	
	Light intensity decreased during lay	Yes*	68 (81)	84	<0·001
		No	40 (37)	108	
	Light intensity changed because of pecking	Yes*	16 (89)	18	0·003
		No	92 (53)	174	
	Light intensity changed because of FP	Yes*	32 (86)	37	<0·001
		No	76 (49)	155	
	Light intensity changed to calm birds	Yes*	5 (100)	5	0·046
		No	103 (55)	187	
	Light intensity changed when birds 25 weeks old	Yes*	51 (89)	57	0·017
		No	17 (68)	25	
	Lights turned up when flock inspected	Yes*	24 (83)	29	0·002
		No	84 (52)	162	
Food and water	Chain system for feed	Yes*	104 (61)	171	0·006
		No	7 (30)	23	
	Feeders located on all levels	Yes	10 (38)	26	0·047
		No*	100 (59)	169	
	Diet changed during lay	Yes*	92 (61)	150	0·004
		No	13 (35)	37	
	Diet changed three or more times	Yes*	69 (66)	105	0·003
		No	36 (44)	82	
	Vitamins added to food	Yes*	18 (78)	23	0·022
		No	90 (53)	170	
	Oyster shell scattered on floor	Yes*	9 (100)	9	0·007
		No	102 (55)	187	
	Bell drinkers	Yes*	99 (62)	159	0·002
		No	12 (33)	36	
Management of the range	Outdoor area	= 10 ha	12 (57)	21	0·008
		5-10 ha*	43 (75)	57	
		– 5 ha	42 (49)	85	
	Flock had >5 pop holes	Yes*	89 (64)	139	0·009
		No	12 (39)	31	
	50% or more used outdoors on fine, sunny days	Yes	16 (34)	47	<0·001
		No*	85 (71)	119	
	20% or more used outdoors on wet, windy days	Yes	27 (47)	57	0·011
		No*	73 (68)	108	
	50% or more used outdoors on calm, dull days	Yes	47 (50)	94	0·002
		No*	54 (74)	73	
	Range fenced with chicken wire	Yes	25 (46)	54	0·017
		No*	78 (66)	119	
Disease problems	Mites	Yes*	79 (65)	122	<0·001
		No	28 (40)	70	
	Intestinal worms	Yes*	6 (100)	6	0·028
		No	103 (55)	188	
	Infectious bronchitis in flock	Yes*	32 (82)	39	<0·001
		No	76 (50)	151	
	Deaths from infectious bronchitis	Yes*	17 (85)	20	0·006
		No	89 (53)	169	
	Egg peritonitis in flock	Yes*	69 (78)	88	<0·001
		No	39 (37)	105	
	Deaths from egg peritonitis	Yes*	57 (79)	72	<0·001
		No	45 (40)	112	
	Egg-bound birds	Yes*	28 (70)	40	0·041
		No	79 (52)	152	
	At least one of the conditions above	Yes*	97 (89)	109	<0·001
		No	46 (54)	85	
	Smothering	Yes*	49 (64)	76	0·033
		No	53 (49)	109	
	Died from smothering	Yes*	53 (65)	82	0·032
		No	53 (49)	108	

* Factor associated with increased risk of FP, † Probability of an association with FP

Logistic regression analysis

When all the variables that reached the cut off criteria were tested in the logistic regression model, three remained significant. Feather-pecking was more likely when the flock had birds affected with egg peritonitis and infectious bronchitis and when less than 50% of the birds used the outdoor area on a sunny day. Both diseases were associated with many management risk factors that were also significantly associated with feather-pecking . A second model with constant management variables was developed (Table 1.3) in which the variables listed below increased the risk of feather-pecking. Less than 50% flock used the outdoor area on a fine and sunny day, the diet was changed three or more times during lay, inspections were done by one person, no loose litter left by the end of lay, the hen house was <20^{o}C, lights were turned up when the flock was inspected and bell drinkers were used. The second model had a greater reduction in deviance, indicating a better fit than the first model. There were no significant interactions among these variables.

Table 1.3. Logistic regression model of factors associated with feather-pecking when constant management variables were included in the model.

Variable	Deviance	Estimate	s.e.	Odds Ratio	Confidence Interval	LR $\chi 2$
>49% of flock used outdoor area on fine, sunny day	-8.9	-1.699	0.68	0.18	0.05 - 0.70	< 0.01
Diet changed 3 or more times during lay	-8.0	1.769	0.59	5.86	1.83 - 18.8	< 0.01
Inspections always carried out by same person	-5.8	1.591	0.58	4.91	1.57 - 15.4	0.016
Loose litter at the end of laying period	-6.8	-1.23	0.59	0.29	0.09 - 0.92	< 0.01
Hen house> 20°C	-6.0	-0.913	0.57	0.40	0.13 - 1.22	0.014
Lights turned up when flock inspected	-4.0	2.44	1.00	11.5	1.62 - 81.5	0.046
Bell drinkers used	-6.1	2.426	0.99	11.3	1.62 - 78.9	0.014
Dim light in nest boxes	-3.90	1.573	0.80	4.82	1.00 - 23.2	0.048

s.e. = Standard error

LR $\chi 2$ = likelihood ratio chi square value

Discussion

The final logistic regression analysis included only those management factors that were likely to have been present and consistent throughout the laying period. Diseases and management practices that may have occurred subsequent to pecking were omitted. For example, many farmers adopted the technique of dimming lights to reduce bird activity and so control feather-pecking. Our second model did not include this or other changes to light intensity made in response to feather-pecking.

The model identified that when at least half the flock used the outdoor area on a bright and sunny day there was a fivefold decrease in the risk of feather-pecking. There was a high positive correlation between the proportion of the flock using the outdoor area on fine, wet and calm days so only one of these stayed in the final model; the finding can be taken as a general benefit of increased use of the outdoor area. If a large proportion of the flock go outdoors then stocking density, and possibly perceived flock size, within the house will be reduced. Experiments have shown that increasing stocking density, by increasing flock size within a given area, is associated with more feather-pecking (Nicol *et al.*, 1999). A recent epidemiological study in Switzerland also associated high stocking density with the occurrence of feather-pecking (Huber-Eicher and Audige, 1999).

The outdoor area may provide a greater variety of pecking opportunities than indoor housing and so encourage foraging and reduce feather-pecking. Another risk factor that was associated with increased feather-pecking was no loose litter indoors by the end of lay. Poor litter quality is likely to prevent both foraging and dustbathing, and has been shown experimentally to increase the feather-pecking tendency of individual birds (Kim-Madslien & Nicol, 1999). It is possible that the positive association between the use of bell-drinkers and feather-pecking was due to water spillage producing wet and compacted litter. Bell drinkers have another property: they are a clustered water supply, in comparison with nipple drinkers, which may create a focus for competition, another factor observed with feather-pecking experimentally (Lindberg and Nicol, 1996).

Changing the diet on three or more occasions increased the risk of feather-pecking. We do not know how the flock responded to these changes but neophobia could result in hungry birds, with a greater overall tendency to peck. Alternatively, birds might be attracted to novel feed, which would increase competition during feeding. Competition for feed is a known risk factor for feather-pecking in small groups of hens (Lindberg & Nicol, 1996). One way of reducing food demand, and consequently both hunger and competition for feed, is to raise the temperature of the house and the model showed that flocks kept at greater than 20^{o}C had a reduced risk of feather-pecking.

Feather-pecking was associated with just one person conducting flock inspections. Small units may have been more willing to report feather-pecking than larger producers, and single inspectors may observe the flock more closely and so identify feather-pecking at an earlier stage, or at a lower overall prevalence. Alternatively, there may genuinely be a higher rate of feather-pecking on smaller farms. Farmers with few flocks may have less experience or less contact with other producers and may not manage their flocks as effectively. In addition, birds familiar with only one inspector may be less able to cope with unpredictable events and so more likely to feather peck.

Two aspects of lighting management which were not changed by the farmer in response to feather-pecking were raising light levels to inspect birds and using dim lights in nesting boxes to encourage birds to lay eggs in the boxes. Changing light level may increase the general visibility or attractiveness of plumage as a pecking substrate, as well as affecting overall bird activity. Hens tend to perform severe feather pecks near nesting areas, in contrast to milder feather pecks which are observed in other locations (Nicol *et al.*, 1999). In addition, high light intensity affects mild and severe feather-pecking differentially, with birds reared at 30 lux showing reduced mild pecking but more than twice as much severe pecking as birds reared at 3 lux (Kjaer and Vestergaard, 1999). Together, these results suggest that it may be particularly important to avoid bright lighting, which may increase the attractiveness of plumage as a nesting material, around the nesting boxes.

In contrast to Gunnarsson *et al.* (1999) who reported no significant associations between management factors and feather-pecking in commercial flocks in Sweden, we found many highly significant associations. Because we were able to survey more than three times the number of flocks and measure many more variables, we were able to identify significant important risk factors for feather-pecking in commercial flocks.

2. Cross-Sectional Study of Risk factors for Vent Pecking

Introduction

Vent pecking (VP) is characterised by damage to the cloaca, and the surrounding skin and underlying tissue, by a conspecific. This can progress to evisceration and death. It is the most common cause of cannibalism in laying hens and is reported to occur at onset of lay. VP can cause high mortality in affected flocks (Allen and Perry, 1975; Savory, 1995) and is therefore one of the main constraints to the more common adoption of alternative systems (Jones and Hocking, 1999).

The reasons for the occurrence of VP remain largely unclear. The key stimulus seems to be the exposure of the cloacal mucosa immediately after laying, which attracts other birds to vent peck (Savory, 1995). In bigger groups of birds, VP is more likely to become a problem since more birds can detect and attack minor wounds or prolapses (Allen and Perry, 1975). Rearing conditions may be important since cannibalism may be prevented if chicks are reared with early access to perches. This is because they develop perching behaviour that allows them to escape from pecking flock-mates (Fröhlich, 1991). Apart from early access to perches, Gunnarsson et al. (1999) found no management or other variables associated with VP in 59 commercial flocks. Recent publications suggest that regular feather pecking may, after the onset of lay, lead to VP and cannibalism (Savory and Mann, 1997; Jones and Hocking, 1999).

The aim of this study was to investigate the frequency of VP and its associations with management and FP.

Materials and Methods

The data came from farmers who responded to the questionnaire described for the cross-sectional study of FP, and the detailed description of methods, general flock information and univariate data analysis can be found in the previous section.

Multivariate data analysis

Cluster analysis (Armitage and Berry, 1987) was used to test whether flocks were grouped by exposure types and thus whether some systems were more at risk of VP than others. Only exposure variables from the univariate analysis that were significant at p 0.05 and consistent throughout the laying period were tested in the cluster analysis. As a consequence, flock mortality, feather pecking, diseases in the flock and changes in management of light were excluded. Finally, backward stepwise logistic regression following standard procedures (Hosmer and Lemeshow, 1989) was performed (EGRET 2.0, Cytel inc.) on the variables significant at 0.05 in the univariate statistics. Variables with a reduction in the deviance significant at p 0.05 using the likelihood ratio chi square statistic were left in the final model. Interactions and goodness of fit were tested in the final logistic model. The ability to predict vent pecking were estimated by calculating the sensitivity and specificity of the final model.

Results

Vent-pecking

27.1% of farmers reported vent pecking as a regular occurrence in their flocks while 36.9% observed it in the last depopulated flock. Of these, 69.9% of farmers reported that they saw hens peck the vents of conspecifics, 31.4% saw hens eat the flesh of others, while 54.8% reported exposed skin around the vents, 41.1% damaged feathers and 71.2% blood around the vent.

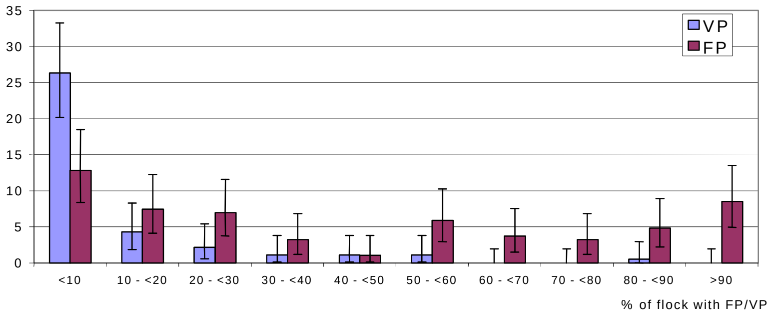
The median proportion of the flock affected with VP was 3.5% (IQR 1 - 10) and the mortality that farmers attributed to vent pecking was 1.3% (IQR 1 – 4). Vent pecking was first observed at a median age of 37.3 weeks ((IQR 29 – 49) and first deaths occurred at a median age of 45 weeks (IQR 31 – 55).

31.7% of farmers reported taking measures to reduce the risk of vent pecking. These measures included dim house light (17.6%), red house light (2.7%), beak trimming (7.7%) and spraying the birds with tar (0.5%). Once vent pecking had occurred in the flock, farmers controlled it with dim light (81.8%), red light (18.2%), spraying birds (13.0%), providing vitamins (3.7%), isolating birds (3.6%) and reducing egg size (3.6%).

Associations between vent-pecking and feather pecking

Both problems started at about 20 weeks (point of lay) and increased until the time of depopulation. A total of 56.1% flocks were affected with FP and 36.9% with VP. While 33.3% of flocks showed both problems at depopulation, 23.1% were affected only with FP and less than 5% of the flocks had VP alone. A positive correlation was found between the onset of VP and FP (Spearman rank correlation coefficient r = 0.69) as well as between the flock prevalence of VP and FP (r = 0.33). Significantly more flocks developed FP followed by VP (30/62). Only 13/62 flocks developed VP followed by FP. FP was observed approximately 8.3 weeks before VP (Figure 2.1). A late onset of FP was correlated with a low prevalence in the flock (r = -0.36) while no correlation was found between the start of VP and the flock prevalence.

Figure 2.1: Within flock prevalence of vent pecking and feather pecking and 95% confidence intervals



26.3% of all flocks and therefore the majority of all flocks affected with VP had a prevalence of less than 10% birds affected while the within flock prevalence of FP, on the other hand, was distributed more evenly between 0% and 100%.

Analysis of exposure variables with vent-pecking

The variables that were associated with an increased risk of vent pecking in univariate analyses are presented in Tables 2.2. Significantly more vent pecking was reported when the flock came into lay before 20 weeks of age, the flock was not housed in a perchery, not kept on wooden slats, if dim light or any other measure was used to encourage the use of nest boxes or if the stocking density at the end of lay was less than 12 hens/m^2. Start of lay was significantly correlated with the age of the birds at housing (Spearman rank correlation coefficient r = 0.25). Flocks that started laying before 20 weeks were housed at a median age of 16 weeks compared with 17 weeks for those beginning lay at a later age, therefore accounting for a similar length of housing. A temperature of above 20°C in the hen house was also associated with reduced VP .

Changing or decreasing light intensity over the laying period, as well as inspecting the flock by turning lights on was associated with vent pecking. Feeders located on wire mesh, three or more diet changes during lay, hanging drinkers or drinkers located on plastic slats were associated with increased VP. More vent pecking was reported if less than 25% of the flock used the outdoor area on fine, sunny day, if the outdoor area was partly covered with wire mesh, not covered with wooden slats or if it was not fenced with chicken wire. Finally, VP was associated with the occurrence of and deaths from infectious bronchitis and egg peritonitis in the flock, deaths from intestinal worms, the occurrence of feather pecking and an average flock mortality of greater than 7%.

Table 2.2 describes the exposure (column 1), whether it was present or not ([column 2], [* = exposure with increased risk]) by the number and proportion of flocks that had vent pecking (column 3). The total number of flocks with and without each exposure is listed in column 4 (The maximum number of flocks in the analysis is 198. However, farmers did not answer every question.). The probability of an association with feather pecking is listed in column 5 (Fisher exact test whenever one or more cells in the table had expected values of less than five).

Table 2.2 : Associations between vent-pecking and management variables

Associations between VP and management	Yes/No	VP	Total	P
Flock came into lay before 20 weeks	Yes*	41 (48%)	86	0.009
	No	31 (28%)	109	
Flock housed in perchery	Yes	6 (19%)	32	0.037
	No*	66 (40%)	165	
Flock housed on wooden slats	Yes	22 (27%)	81	0.033
	No*	50 (43%)	116	
Stocking density at the end of lay less 12 hens/m2	Yes*	50 (42%)	120	0.007
	No	4 (13%)	30	
Measures taken to encourage the use of nest boxes	Yes*	43 (45%)	95	0.031
	No	30 (29%)	102	
Dim light used to encourage the use of nest boxes	Yes*	19 (68%)	28	0.001
	No	54 (32%)	169	
Temperature of house >20°C	Yes	15 (25%)	59	0.021
	No*	46 (45%)	102	

Associations between VP and light management	Yes/No	VP	Total	P
Light intensity changed at any time during lay	Yes*	55 (59%)	94	<0.001
	No	17 (17%)	100	
Light intensity decreased during lay	Yes*	53 (62%)	85	<0.001
	No	19 (17%)	109	
Light intensity changed because of feather-pecking	Yes*	26 (70%)	37	<0.001
	No	46 (29%)	157	
Light intensity changed because of vent-pecking	Yes*	9 (90%)	10	0.001
	No	63 (34%)	184	
Light intensity changed at over 35 weeks age	Yes*	25 (81%)	31	0.026
	No	28 (54%)	52	
Lights turned up when flock inspected	Yes*	19 (63%)	30	0.003
	No	53 (32%)	163	

Associations between VP and food and water	Yes/No	VP	Total	P
Feeders located on wire mesh	Yes*	34 (47%)	73	0.049
	No	39 (31%)	124	
Diet changed during lay	Yes*	65 (43%)	151	0.002
	No	5 (13%)	37	
Diet changed 3 or more times	Yes*	50 (48%)	105	0.002
	No	20 (24%)	83	
Drinkers located on plastic slats	Yes*	9 (69%)	13	0.028
	No	64 (35%)	185	
Drinkers were hanging	Yes*	47 (46%)	103	0.012
	No	26 (27%)	95	

Associations between VP and range management		VP	Total	P
25% or more used outdoors on fine, sunny day	Yes	21 (26%)	80	0.002
	No*	44 (51%)	86	
Outdoor area partly covered with wire mesh	Yes*	31 (51%)	61	0.035
	No	24 (32%)	76	
Outdoor area partly covered with wooden slats	Yes	17 (29%)	59	0.029
	No*	38 (49%)	78	
Range fenced with chicken wire	Yes	12 (22%)	54	0.008
	No*	53 (45%)	119	

Associations between VP and disease		VP	Total	P
Average flock mortality greater than 7%	Yes*	40 (49%)	82	0.011
	No	31 (30%)	105	
Presence of feather pecking	Yes*	66 (59%)	111	<0.001
	No	7 (8%)	87	
Deaths from intestinal worms	Yes*	6 (100%)	6	0.005
	No	67 (35%)	190	
Presence of Infectious Bronchitis	Yes*	25 (64%)	39	<0.001
	No	47 (33%)	153	
Deaths from infectious bronchitis	Yes*	13 (65%)	20	0.005
	No	57 (27%)	171	
Presence of egg peritonitis	Yes*	48 (54%)	89	<0.001
	No	25 (24%)	106	
Deaths from egg peritonitis	Yes*	38 (52%)	73	<0.001
	No	30 (27%)	113	

In the cluster analysis, two clusters, each with two sub-clusters, were identified. One cluster was typical for perching systems, but no other management systems could be distinguished. The prevalence of VP between the clusters and the overall average did not differ, indicating that VP was not associated with certain management systems.

In the final logistic model, four variables significantly increased the risk of VP, these were: the flock came into lay before 20 weeks, the use of hanging drinkers, three or more diet changes during lay and dim light to encourage nest box use (Table 2.3).

Table 2.3: Logistic regression model of constant management factors associated with vent-pecking

Variable	Deviance	Coefficient	s.e.	Odds Ratio	Confidence Interval	LR χ^2
Intercept term	260.7					
Dim light used to encourage the use of nest boxes	246.9	1.52	0.47	4.59	1.83-11.52	0.001
Diet changed 3 or more times	226.5	0.86	0.35	2.36	1.20- 4.67	0.013
Flock came into lay at 20 weeks	217.6	-0.93	0.34	0.40	0.20- 0.77	0.007
Drinkers were hanging	211.3	0.84	0.34	2.32	1.19- 4.53	0.013

s.e. = Standard error

LR χ^2 = likelihood ratio chi square value

The regression model had a specificity of 82.4% (61/74) and a sensitivity of 60% (27/45). The fitted model therefore predicted 82.4% of VP-free flocks and 60% of those that reported VP. There were no significant interactions in the model. The model goodness of fit of the model was acceptable.

Discussion

Four exposures were significantly associated with VP in the logistic regression model of which three were common associations with both VP and FP (Green et al, 2000): lighting of the nest boxes, more than two diet changes and the use of hanging bell drinkers. The strongest association with VP was the use of light to encourage the use of nest boxes in comparison with no nest box lighting. Low light intensity in the hen house is frequently used to control VP and FP, and illuminated nest boxes are generally screened with curtains, so there may be a sharp gradient between the light levels outside and inside the nests. The change in light intensity experienced on entering an illuminated communal nest box may increase the visual attractiveness of the cloacal mucosa of a hen that has just laid an egg. As the risk of FP also increased when house light levels were raised during flock inspections, changes in light intensity should be managed with great care. A new diet can result in decreased intake or in increased competition for food, both might lead to stress or frustration which are reported risk factors for VP and FP (Duncan and Wood-Gush, 1971; Lindberg and Nicol, 1994). A new diet might also cause diarrhoea, leading to an inflamed and reddened vent and soiled surrounding, attracting pecking from flock-mates. Furthermore, diet change can be used to produce bigger eggs. Increased egg size might result in a clearer exposure of the cloacal mucosa or more mucosal injuries related to laying. Flocks with hanging bell drinkers were 5.5 times more at risk of VP and 11.3 times of FP than flocks provided with water via other systems.

Flocks that started laying before 20 weeks of age had approximately 4 times the risk of VP compared with flocks where onset of lay occurred after 20 weeks. Early sexual maturity is a result of the competitive pressure to maximise egg production per unit time (Jones and Hocking, 1999) and may be associated with stress (Craig et al. 1975). Early laying birds may be smaller at the start of lay and therefore have a smaller body size:egg ratio. This could increase the risk of damage to the cloacal mucosa. Flocks that began laying before 20 weeks were housed one week earlier compared with later laying flocks and therefore spent a comparable time in the hen house before lay to those with a later onset of lay.

Comparing the results of this study and the FP findings from the same flocks, more flocks showed FP (56.1%) than VP (36.9%) and the frequency of FP in affected flocks was higher (30%) than for VP (3.5%). This finding corresponds with Nicol et al. (1999) and Carmichael et al. (1999) who also found a low incidence of VP. However, out of a 3.5% prevalence in flocks in this investigation, about one third (1.3%) were reported dying while the FP-mortality was less than 1% in those flocks affected. FP generally occurred before VP supporting the theory that VP might develop from FP (Savory and Mann, 1997; Jones and Hocking, 1999). Most farmers were very much aware of the potential danger of VP in their flocks. Although the prevalence of VP was lower than FP, about the same proportion of farmers carried out preventive measures against VP and FP (31.7% and 37,5% respectively) and control measures once it had occurred (75.7% and 61.5% respectively).

The occurrence of disease was positively associated with VP and FP in the univariate analysis. However, it is not clear whether this association was causal or whether FP and VP were a response to disease.

The aim of the cluster analysis was to identify possible associations between management systems and VP. Although different management practices were used in alternative systems for laying hens, no overall farm management system could be identified through cluster analysis that was related to VP. VP therefore seems associated with detailed management measures rather than overall management systems.

This study relied on the farmers' information and their judgement of FP and VP. Different perceptions of pecking, different levels of experience and a possible tendency to hide welfare problems might have contributed to inaccuracies. However, it is clear from the results that feather and vent pecking were associated with different risk factors indicating that farmers were differentiating the two sorts of pecking behaviour. Cross sectional studies cannot demonstrate causality. Nevertheless, a large and important range of associations between VP and FP and environmental factors under commercial conditions were identified.

3. A Case -Control Study of Feather Pecking

Introduction

The use of epidemiological analysis to establish associations between management procedures, feather pecking and vent pecking in commercial flocks proved to be an important and valuable approach. However, it was felt necessary to undertake a case control study for three reasons. First, because by actually visiting farms and obtaining objective information we could assess more closely whether the responses to the previous questionnaires had been accurate or misleading. Second, because by actually visiting farms we could obtain more detailed information about house design, bird condition and bird behaviour than farmers would be able to provide for us. Third because a case control study would allow us to make inferences about the causality of risk factors. The case-control study focussed on feather pecking in free-range flocks, the area where we had obtained the most useful information in the cross-sectional studies.

Method

One hundred flocks were included in the study, fifty case flocks where birds had recently started feather pecking and fifty matched control flocks where birds of the same age had *not* started feather pecking. Pairs of case and control flocks, matched for age with no more than 6 weeks age difference at the time of survey, were visited within 2 weeks of each other. A case flock was identified as one where more than 2% of the flock had feather damage. It was not always possible to classify flocks as case or control until the visit had been carried out. For some larger flocks where hens were housed in 2 or more separate colonies, the individual colonies were used as the 'flock', but only if the colonies were completed segregated with no mixing or contact between colonies. Occasionally a case 'flock' and control 'flock' were identified under the same roof because feather pecking was occurring in one colony but not in another.

Each visit comprised a detailed interview with the flock manager, covering 241 aspects of management practice within 13 general sections covering flock details (age, breed, housing age, flock size), Flock health (mortality rate, disease challenges, treatments), egg production (peak production % rates, current % production rates), housing system, housing management, nest box details, range area details, lighting system, ventilation system, feed and diet management, water supply, feather pecking and vent pecking. This was followed by a 2 hour inspection of the house and the flock between 11.00 and 13.00h during which the birds were plumage scored, and the percentage of the flock using the outside range was recorded. In addition, recordings of temperature and relative humidity were recorded using a Vaisala HM 34C Humidity and Temperature meter on the same area of the staging and litter areas within each house. Airflow was recorded using a TA 400 anenometer, and light intensity using an RS 180-7133 light meter. Measurements were also taken of floor type and condition, nest-box, perch, feeder and drinker design, type and location and size and condition of the outdoor range area. Simple behavioural tests were conducted including a novel object test, and a general description of bird noise and activity.

Results

A total of 112 flocks were surveyed of which 50 were control flocks and 62 were case flocks. It was not possible to find suitable matched control flocks for 12 of the case flocks so these have been omitted from the analysis. The 100 case and control flocks used in the analysis came from 70 free-range egg-producing units in the UK. The mean age of the case flocks was 41.7 (se 1.255) with a minimum age of 29 weeks and a maximum of 68 weeks. For the control flocks the mean age was 40.6 (se 1.336) with a minimum age of 23 weeks and a maximum of 74 weeks. The average flock size was 4999.4 (se 257.5) and all the flocks surveyed were beak trimmed.

Initial univariate analyses using paired t-test, Wilcoxon matched pairs signed rank test or McNemar test, as appropriate, revealed important risk factors associated with feather pecking. Of the 241 questions, 26 were associated with a significant difference between case and control flocks. These are shown below. Case flocks were more likely to comprise IsaBrown than Lohmann hens, were more likely to be restricted from litter areas to prevent floor eggs, were less likely to use the outside range, and had more closely spaced feed lines.

Table 3.1

Risk factors associated with feather pecking	**p-value**
ISA Browns (Lohmann protective)	0.012
Younger age at housing	0.05
Stress reported as main cause of mortality	0.008
Higher % production rate at time of survey	0.05
Use of electric wire to prevent floor eggs	0.032
Restricted litter access to prevent floor eggs	0.007
Litter access restricted in mornings	0.058
Fewer hens using range when warm and sunny	0.011
Fewer hens using range when wet and windy	0.038
Fewer hens using range when calm and dull	0.005
More stages of light increase in mornings	0.021
Light intensity reduced because of F.P.	0.019
Using Crediton Millings Feeds (Bibby feeds protective)	0.026
Use of multi-vitamin supplement in water	0.029
Lower temperature on staging at survey	0.007
Less distance between feed lines	0.050
Use of wire staging (plastic staging protective)	0.057
Litter area on 2 sides	0.04
Higher noise level score on litter	0.006
Hens more 'flighty' in litter area	<0.0001
Higher noise level score on staging	0.002
Hens more 'flighty' on staging	<0.0001
Low % of hens using range at survey	0.0003

When these risk factors were tested in a conditional logistic regression model one factor remained significant. When more than 50% of birds used the outdoor area there was a significant reduction in feather pecking, an odds ratio of 0.12 (95% confidence intervals 0.03 - 0.51). That is a reduction of 8.3 fold (CI 1.96 - 33.3).

Table 3.2 Final conditional logistic regression model of use of the range and its association with feather pecking. (Number of valid Observations: 100).

Terms	Coefficient	Std.Error	p-value (Wald-test)	Odds Ratio	Lower 95% C.I	Upper 95% C.I
>20% of the flock out on a sunny day	-2.1401	0.7475	0.0042	0.1176	0.0272	0.5092

Deviance 55.762, Likelihood ratio test, 13.5528 < 0.001

Conclusions
The study revealed a cluster of factors that differentiated between case and control flocks and which related to management practices that restricted bird access to litter or the outdoor range. These included restricting access to litter when birds were young, restricting access to litter each morning to avoid floor eggs and a low percentage of the flock using the outside range, confirming findings from the cross-sectional survey. Previous surveys have not been able to identify causality in interpreting many associations between management practice and feather pecking. This study identified case flocks at the time that feather pecking started, suggesting that many of the management practices identified are causal in stimulating new outbreaks of feather pecking. The behaviour of the birds in the case flocks was also notably different from the control flocks, with higher noise and activity levels. The multivariate analysis highlighted once again that use of the range was highly significant in reducing feather pecking in the flock.

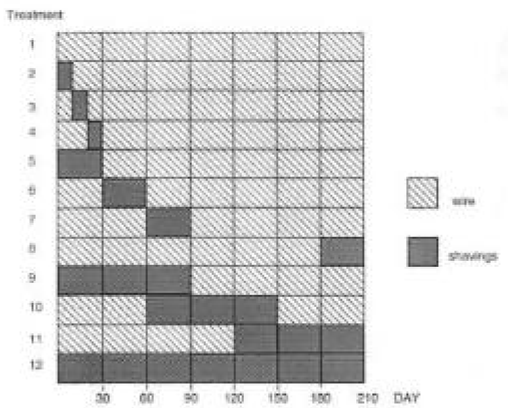
4. Experimental work on substrate exposure during rearing

4.1 Introduction
The inability to access a substrate appropriate for foraging or dustbathing behaviour is associated with a high risk of feather pecking in laying hens. There is generally a high prevalence of feather pecking in hens kept on wire or slats (Hughes and Duncan, 1972; Blokhuis and Arkes, 1984; Aerni et al., 2000). Substrates that are particularly favoured for foraging or dustbathing reduce the risk of feather pecking (Savory and Mann, 1999), while high stocking densities, which may reduce litter quality and access, are associated with an increased prevalence of feather pecking (Nicol et al. 1999). Epidemiological studies also show that high stocking density and compacted litter are significant risk factors for feather pecking in growing birds (Huber-Eicher and Audige, 1999) and adult laying hens (Green et al., 2000). These findings can be explained by the general hypothesis that birds redirect their pecking behaviour towards feathers when a more appropriate substrate is absent or inaccessible. It has therefore been suggested that the best strategy to prevent feather pecking is to provide an adequate substrate throughout life, from the start of the rearing period onwards (Blokhuis and Wiepkema, 1998). But even when this is done there is no guarantee that feather pecking will not arise, particularly as birds come into lay and are transferred from rearing to laying accommodation. An increased incidence of feather pecking is often noted at point of lay (Hughes and Duncan, 1972; Norgaard-Nielsen et al., 1993). Apart from hormonal effects, birds at this age often encounter a *change* in substrate. If preferences for particular substrate types have developed during the rearing phase then a change of substrate could precipitate feather pecking. This raises the question of how and when birds develop their perceptions about substrate suitability. The involvement of both foraging and dustbathing in the development of feather pecking suggests a need to establish how and when chickens develop their perceptions of appropriate foraging and dustbathing substrates.

4.2 Experiment 1
The aim of this study was to establish the importance of substrate experience on adult feather pecking, foraging and dustbathing. A wood-shavings substrate was chosen as it is utilised, but not highly preferred, as a foraging and a dustbathing material. This was to avoid very strong preferences masking potentially subtle effects of age at exposure in later tests of relative substrate preference. Birds were given access to shavings at different ages (to examine possible ‘sensitive periods’ of preference formation) and for different durations (to examine effects of familiarity). This exposure phase lasted from Day 1 to Day 210, and feather pecking behaviour was assessed at the end of the exposure phase. Starting on Day 211 (30 weeks of age) all birds were given a 10 day test where they received shavings or straw on alternate days and their foraging and dustbathing behaviour was examined.

Materials and Methods- Exposure Phase
144 chicks were paired at 1 day of age, and each pair randomly allocated to one of 12 exposure treatments. Each pair was housed in the same pen for both exposure and test phases. Pens were 0.5m wide, 1.0m deep, with a height of 0.6m at the front and 0.9m at the back. The wire mesh floor of each pen was flat but the wire roof sloped to accommodate a raised nesting area and perch towards the rear of each pen. Pens were 0.4m above ground to allow droppings to fall and for ease of access. The gauge of the wire mesh was adjusted as the birds aged to provide maximum support to their feet. Where a treatment required that the birds should receive shavings, the wire mesh floors were removed and replaced with solid wooden floors covered with shavings to a depth of approximately 2cm.
There were 12 pens, representing each of the 12 treatments, in each of 6 identical rooms. The positions of the treatments were randomised within rooms. Fluorescent tubes provided an average light intensity of between 112 and 154lx, and the average room temperature for the adult birds was 18^{o}C.
Treatments provided a range of exposures to shavings at different ages and for different durations. The treatments varied in key aspects including the age at which birds received shavings, the duration for which they were exposed to shavings, and the time from their last exposure to shavings to their preference tests. T1 and T12 were the controls for no exposure and complete exposure to shavings, respectively. The choice of treatments was biased towards an assessment of the enduring effects of early exposure to shavings, although T8 was included as an important control for the effects of late exposure. The pattern of substrate exposure for each treatment is shown in Figure 4.1.
Plumage was scored once a week during the last four weeks of the exposure phase. Two 30 minutes video recordings were made of all 72 pairs once between Days 5 and 7, and once between Days 15 and 17 to check that young birds were using the shavings substrate.

Figure 4.1: Plan showing when birds in each of the 12 treatments received shavings litter during the 210 days of the exposure phase. Birds in T1 never received litter. Birds in T12 had continuous litter.



A further two 30 minutes video recordings were made of all pairs once they were in full lay. Each pair was filmed once between Days 185 and 187, and once between Days 207 to 209. For each bird, the frequency of 17 different behaviours were recorded and then averages for the 2 birds within each cage were calculated and used as independent units for analysis. Pecking behaviours were categorised as aggressive pecks, mild feather pecks, feather pecks, vent pecks, beak pecks, floor pecks (foraging directed at either the shavings or the wire floor), and object pecks to any other inanimate part of the pen. Data were transformed with a square root transformation. Repeated measures analysis of variance, with day as the repeated measure, was used to compare birds from T8, T11 and T12, housed on shavings at the time of both recordings (Shavings Group), with birds from all other treatments, housed on wire at the time of both recordings (Wire Group) to examine effects of current substrate. Further analysis was then performed separately for birds housed on wire and birds housed on shavings to examine effects of previous substrate exposure.

Materials and Methods – Test Phase
During the 10 day test phase, each pair of birds was provided with shavings from 0900 on one day until 0900 the next day, when chopped straw was substituted. Three pairs from each treatment received shavings on Test day 1 followed by chopped straw on Test day 2, and so on for the 10 day period. The other three pairs from each treatment received the substrates in the reverse order. A video recording of each pair of birds was made from 0930 until the house lights went out at 22.30. Unfortunately, birds from treatment 6 were not included in the test phase due to the mortality of 3 birds. The use of the substrate for foraging and dustbathing on Test Days 1 and 2 was assessed by recording bird activity once every 10 minutes during the daylight period. The total number of scans in which individual birds were observed foraging in the shavings or straw, feeding, dustbathing, pecking, sitting on the perch, or sitting in the nest box was recorded for each bird. The data for each pair were then averaged and transformed prior to analysis. A three factor analysis of variance was performed with exposure treatment (11 treatment levels) substrate (shavings or straw) and order (whether shavings had been given on Test Day 1 or test Day 2) as the main factors. Post-hoc comparisons were made between treatment levels using Fisher’s LSD test.

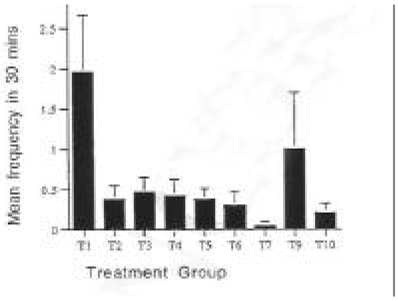
Dustbathing behaviour was then examined in more detail over the full ten day testing period, to assess whether treatment effects reflected transient 'rebound' behaviour, or a more stable substrate preference.

Results- Exposure Phase

Young birds observed between Days 5 and 7, and between Days 15 and 17, accepted shavings for dustbathing. Birds provided with shavings initiated an average of 0.50 dustbathing bouts per pair per hour in comparison with birds housed on wire, which initiated an average of 0.16 'sham' dustbathing bouts per pair per hour.

At the end of exposure phase birds from the Wire Group performed more feed pecks overall than birds from the Shavings Group. Birds from the Wire Group lay down and stood more frequently but performed substantially fewer floor pecks than birds from the Shavings Group. In contrast, birds from the Wire Group performed more feather pecks than birds from the Shavings Group. Within the Wire Group there was a significant difference between treatments, revealing effects of rearing history ($F=2.47$; $p<0.05$). In particular, significantly more feather pecking was initiated by birds in T1 that had never had shavings than by birds in any other treatment ($p<0.005$ in all post-hoc comparisons with T2, T3, T4, T5, T6 and T10; $p = 0.08$ in comparisons between T1 and T9) (Figure 4.2).

Figure 4.2: Frequency of feather pecking by birds housed on wire floors. Data show the mean of six cages per treatment.

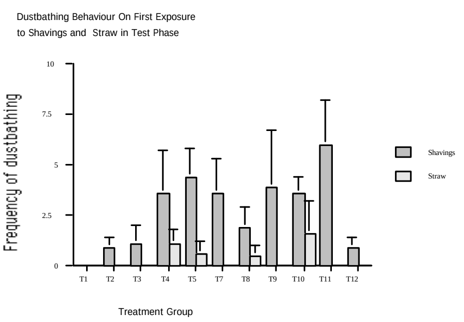


Results – Test Days 1 and 2.

There were no significant effects of any of the main factors, (exposure, current substrate, or order) and no significant interactions for feeding, perching or nesting behaviour.

Dustbathing behaviour was affected profoundly both by substrate type ($F=39.9$, $p<0.001$) and by the birds' previous exposure experience ($F=2.41$, $p=0.01$). Dustbathing on straw was rare. Post-hoc analysis showed that birds from T1 that had never previously experienced shavings performed significantly less dustbathing than birds from treatments 4,5,7,10 and 11. Birds from treatments 2 and 3 that had experienced shavings only between Day 1 and Day 10, or between Day 10 and Day 20 of age also performed significantly less dustbathing than birds from treatments 4,5, and 10. Birds from treatment 12 that had always been housed on shavings also performed significantly less dustbathing than birds from treatments 4,5 and 10 (Fig. 4.3).

Figure 4.3



A descriptive model of dustbathing on shavings was then developed using step-wise regression analysis. The average number of scans on which pairs were observed to dustbathe was entered as the dependent variable. Four independent variables, which varied between treatments, were felt to be potentially important:

1. Total duration of previous exposure to shavings: if substrate preferences are based on simple familiarity then birds with a long total duration of previous exposure should perform more dustbathing.
2. Time since last exposure to shavings and first test day: if motivation to dustbathe increases during periods of litter deprivation then birds that have had a long period without shavings should perform more dustbathing.
3. Age at time of exposure to shavings: if there are 'sensitive' periods during which birds are more likely to form stable substrate preferences then birds which are exposed to shavings during these periods should perform more dustbathing. This effect was explored by calculating weighting factors centred on different possible 'sensitive' periods. Thus, if a given day was hypothesised as a possible

peak in sensitivity, all birds that had shavings at this age were given a score of 1.0. A log linear decrease either side of this day was then proposed.
4. The number of changes of substrate experienced during the exposure phase: this varied from zero to two and might influence general fear or exploratory responses.

The stepwise regression showed that age at time of exposure, with a weighting factor centred on Day 60, was the only significant explanatory variable (p=0.02). Selecting other days as the possible peak in sensitivity resulted in a reduced fit.

Results -Test Days 1-10
Each pair of hens received five 24-hour exposures to shavings and there was little change in their behaviour with increasing exposure. Birds from treatments such as T5 and T9, that performed dustbathing at a high frequency on their first re-exposure to shavings maintained a high duration of dustbathing over the entire test period.

Discussion
The current substrate of the adult hens was the most important determinant of their behaviour. Significantly more floor pecking and significantly less feather pecking was performed by birds that had shavings litter at the end of the exposure period, than by birds that were housed on wire at the end of the exposure period. Even birds that did not receive shavings until day 180 pecked at the shavings and performed virtually no feather pecking at the end of the exposure phase. Thus birds are adaptable and able to accept substrates not experienced during early development. Petherick et al. (1995) showed that 12 week old, wire-reared birds accepted peat for dustbathing if it was placed below the cage floor, but that high levels of fear inhibited dustbathing if the peat was placed within the cage. However, their birds were given only 1 hour to adapt to the new substrate. Our birds rapidly adapted to shavings, such that floor pecking was increased and feather pecking reduced 4 days after birds were first given shavings during the exposure phase. Conversely, the sudden removal of shavings during the exposure phase resulted in an immediate drop in floor pecking and an increase in feather pecking in some treatment groups, particularly those where the birds were older at the time of substrate change. Another sign of rapid adjustment was that birds immediately accepted straw as foraging substrate during the test phase.
Prior substrate exposure was, however, also very important. Birds that had received shavings, even for only 10 days at an early age (T2, T3, T4), were significantly less likely to feather peck when housed on wire at the end of the exposure phase, than birds that had never received shavings (T1). This supports the view that early substrate experience may be important to prevent feather pecking. However, feather pecking was also low in birds that were not exposed to shavings until Day 30 or Day 60 (T6, T7, T10). This suggests that pecking preferences are not irrevocably fixed during an early sensitive period but can be revised in the presence of a more suitable substrate (Sanotra et al., 1995). The reduction of feather pecking behaviour obtained in response to shavings was maintained, even when the shavings were again removed.
Young chicks imprint on dustbathing substrates (Vestergaard and Lisborg, 1993) but this did not fully explain the dustbathing behaviour of adult birds. Birds that used shavings for dustbathing during days 1 to 10, or 10 to 20, of age, did not accept shavings as a suitable substrate for dustbathing when they were adult. The only experiential factor that was significantly associated with an increased acceptance of shavings for dustbathing behaviour was a *later* age at exposure. Birds from treatments that were given shavings for periods that included Day 60 performed more adult dustbathing than birds given shavings before or after Day 60. We cannot conclude that there is anything especially significant about day 60 but we suggest that although early substrate imprinting may guide juvenile behaviour, adult dustbathing behaviour is guided by preferences acquired after the first month of life.

4.3 Experiment 2
The aim of this experiment was to examine the importance of period around day 60 in influencing pecking and dustbathing activity, whilst providing counterbalanced exposure to straw and substrate during the exposure phase.

Method
92 chicks were paired at 1 day of age, and each pair randomly allocated to one of 9 exposure treatments using the same pens and procedures as Experiment 1. The treatments are listed below:

Treatment and test day	Day 0-40	Day 40-80	Day 80-120
T1 tested Day 41 and 42	straw		
T2 tested Day 41 and 42	shavings		
T3 tested Day 81 and 82	straw	shavings	
T4 tested Day 81 and 82	shavings	straw	
T5 tested Day 121 & 122	straw	straw	shavings
T6 tested Day 121 & 122	straw	shavings	straw
T7 tested Day 121 & 122	shavings	straw	straw
T8 tested Day 121 & 122	straw	straw	straw
T9 tested Day 121 & 122	shavings	shavings	shavings

During the two test days, 3 pairs from each treatment received shavings on Test day 1 followed by chopped straw on Test day 2. The other three pairs from each treatment received the substrates in the reverse order. A video recording of each pair of birds was made from 09.30 until the house lights went out at 22.30.

Results
Birds tested at 40 and 80 days of age behaved similarly, and very differently from birds tested at 120 days of age. The younger birds performed more feed pecking, and less resting, walking and floor pecking. Older birds were more likely to peck at shavings than straw, and this was not influenced by their rearing experience. Surprisingly, the older birds were more likely to dustbathe on straw than shavings, and this tendency was also not influenced by rearing experience. In contrast, the younger birds were strongly influenced by their rearing environment. Birds from T2 and T4 that received shavings at an early age dustbathed at a higher rate than any other birds, and this was almost exclusively on shavings. Birds from T7 and T9 that also received shavings at an early age, but were tested when older, showed no such preference for dustbathing on shavings. Feather pecking occurred at an incidence that was too low for statistical analysis.

Discussion
These results support the view that substrate imprinting guides juvenile but not adult bird behaviour. Adults appear to accept both straw and shavings substrates for foraging and dustbathing behaviour. No evidence was found of any particular age at which early preferences are revised. Rather, the results suggest that a general tolerance for novel substrates develops by 120 days, the time at which birds are usually moved from rearing to laying accomodation. As feather pecking is likely to develop when birds find other substrates unacceptable or impossible to access, these results suggest that providing an acceptable substrate during the early rearing period will be particularly important to avoid the early onset of feather pecking. However, for adult birds the effects of rearing are not likely to persist, and the provision of any loose substrate is likely to be protective against feather pecking.

5. On Farm Intervention Trial

Aim
The aim of this part of the study was to use one of the risk factors associated with feather pecking in our previous studies and intervene on commercial farms to pilot test the effect of a prevalence reduction study. The management change had to be one that farmers would adopt in a commercial situation and one that we had enough evidence to know how to change. The risk factor with greatest strength of association from the observational studies was use of the outdoor area. However, when we considered management changes to encourage birds to use the outdoor area we considered that we did not have enough knowledge to understand why some flocks use the range and others don't. We also met with some resistance from farmers when we discussed this management change, indicating that it would not be adopted readily in a commercial situation.
However, evidence from both our epidemiological studies and the experimental work pointed to the importance of access to a good quality litter substrate was also a factor that reduced the risk of feather pecking. From visits during the case-control study it was clear that the litter area in many establishments became damp and compacted with time, reducing its value as an area where birds can forage, scratch and dustbathe. The aim of this part of the study was to determine the practicality of adopting enhanced litter management routines, and to determine whether enhanced litter condition would delay the onset of, or reduce the severity of feather pecking within commercial flocks.

Method
Four commercial free-range laying hen units were used. Each flock was divided into 2 equal and separate sub-flocks, one acting act as the control and the other as the treatment. In the treatment sub-flocks the litter substrate was managed to maintain a loose and friable litter substrate, and enriched by the addition of straw or chopped straw. The control litter area received the routine management provided by the farm. Each litter area was divided into 3 notional areas (bottom, middle and top) of equal size. The 3 areas on one side corresponded to the same 3 areas on the other side. These areas were then used for observations of hen behaviour and for recording the condition of the litter substrate. Descriptive comparisons between treatment and control sub-flocks from the same farms were made.
Observations of behaviour, litter condition and feather scores were taken once a week for each of the flocks. 30 hens from each sub-flock (approximately 10 from each area of the litter) were feather scored for plumage condition on a 4-point scale, and litter condition was scored on a 5-point scale. The average depth of the litter was also recorded at each location. Levels of ammonia were recorded at each area on the litter using Drager Tube Measurement. A standard measuring range was used of 5 - 70 PPM. Observations of hen behaviour were recorded at each of the 3 areas of the litter in both the test and control colonies. For dustbathing and feather pecking an observation period of 1 minute was allowed for each behaviour. For ground pecking and preening an observation period of 30 seconds was allowed for each behaviour.

Litter maintenance & enrichment

Enhanced management and enrichment of the litter areas was conducted after the observations and measurements had been taken. The control sub-flocks were walked through whenever anything was done to the treatment sub-flocks to ensure that both the test and control colonies experienced the same amount of 'human contact'.

Flock 1: Base substrate of sand. The treatment litter area was enriched by the addition of 4 intact bales of straw at week 24, and was also raked over in places where the sand became hard and compact.

Flock 2: Base substrate of bark chippings. The treatment litter area was enriched by the addition of chopped straw 3 times a week starting at week 25. Where necessary the compact litter areas were broken up and raked over.

Flock 3: Base substrate of limestone. The treatment area was initially managed by regular raking. No additional enrichment was added at the request of the flock manager.

Flock 4:The treatment litter area was enriched by the addition of chopped straw 3 times a week starting at week 29. Where necessary compacted litter areas were broken up and raked over.

Results

Flock 1

At 22 weeks of age (visit 2) the sand in the control litter area was wet and compact while the sand in the treatment area remained dry and friable. Dust-bathing and ground pecking were more frequent in the treatment sub-flock and these birds were more docile and inquisitive than control birds. However, there were no significant differences in plumage condition. The hens were very interested in the straw bales and there was a lot of pecking activity directed towards the bales but there was a steep increase in the number of floor eggs laid on and around the straw bales. Feather pecking was observed in both colonies from 22 weeks of age.

Flock 2

The bark substrate remained in good condition in both treatment and control sub-flocks and there were no significant differences in bird behaviour or plumage condition.

Flock 3

The only management of the litter that could be carried out was to break up compact areas that developed in the treatment sub-flock. Unfortunately poor fencing and the removal of nest boxes resulted in considerable mixing of birds between sub-flocks, so it was difficult to draw conclusions about the effects of additional management.

Flock 4.

The sand in the control area quickly became very wet and compact. In contrast the sand in the treatment area remained loose and friable throughout. Chopped straw was scattered on the treatment area 3 times a week from week 29. Until week 29 birds were confined to their staging. Even after 29 weeks birds were confined on the staging until 14.00h each day, and thus had access to the litter areas for just a few hours a day.

The control birds were extremely anxious and flighty, constantly surging up and down the litter areas in waves of panic. The treatment birds were generally less reactive and much dust-bathing and ground pecking behaviour was observed. The plumage condition of the hens in both treatments started to deteriorate at about week 25, but damage progressed faster and affected more control birds than treatment birds. At the final visit, week 38, the hens were looking very poor. At least 75% of the control birds had extensive baldness and much feather pecking was observed. The carcasses of 2 cannibalised hens were found on the litter area. The plumage of the treatment hens had also deteriorated quite significantly but the baldness was not quite as extensive.

6. Predictive models using survival analysis and comparisons with expert opinion.

Use of survival analysis to predict the occurrence of feather and vent pecking.

The data for this study came from the postal questionnaire that requested details about the last flock depopulated on their farm. Survival analysis was employed to estimate the effect of the significant variables obtained from the logistic regression models with age at development of abnormal pecking defined as the failure time. The variables were tested using a Cox proportional hazards regression analysis (Collett, 1994) using a likelihood ratio chi square significance level of p 0.05. Interactions were tested in the two final regression models. The significant variables in the Cox proportional hazards models were then assessed by Kaplan-Meier survival function plots.

Results

These variables were then tested in Cox proportional hazards models for FP and for VP. The following variables remained significant for FP (hazard ratio): >49% of flock used an outdoor area on a fine, sunny day (0.38); inspections were always carried out by the same person (1.6) and lights were turned up when the flock was inspected (1.69) (Table 6.1).

Table 6.1. Cox proportional hazards regression model of constant management factors associated with FP

Variable	Deviance	Coefficient	s.e.	Hazard Ratio	Confidence Interval	LRS χ^2
>49% of flock used outdoor area on fine, sunny day	858.4	-0.96	0.29	0.38	0.21-0.67	<0.001
Inspections always carried out by same person	858.2	0.46	0.21	1.60	1.06-2.42	0.023
Lights turned up when flock inspected	849.3	0.52	0.24	1.69	1.03-2.75	0.046

s.e. = Standard error
LRS χ^2= Likelihood ratio statistic chi square value

All four variables that were tested in the VP-Cox proportional model remained significant (hazards ratio): dim light used to encourage the use of nest boxes (2.82); flock came into lay before 20 weeks (0.53); the use of hanging drinkers (2.2) and three or more diet changes during lay (1.72) (Table 6.2).

Table 6.2. Cox proportional hazards regression model of constant management factors associated with VP

Variable	Deviance	Coefficient	s.e.	Hazard Ratio	Confidence Interval	LRS χ^2
Dim lighting used to encourage the use of nest boxes	691.6	1.03	0.28	2.82	1.62-4.93	0.001
Flock came into lay at 20 weeks	671.1	-0.63	0.26	0.53	0.32-0.89	0.002
Drinkers were hanging	661.9	0.78	0.26	2.20	1.31-3.69	0.003
Diet changed 3 or more times	623.1	0.53	0.27	1.72	1.00-2.96	0.045

s.e. = Standard error
LRS χ^2= Likelihood ratio statistic chi square value

There were no interactions among the significant variables in the final logistic model or in the Cox proportional hazards model.
The effects of the variables on the survival functions were plotted using Kaplan-Meier survival curves. The survival ratio for all flocks at depopulation was 0.4 for FP and 0.62 for VP (Fig. 6.1 and 6.2 respectively).

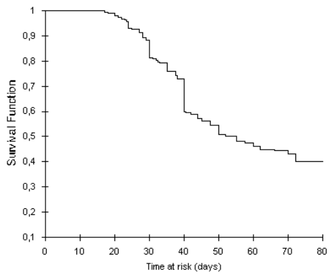


Fig. 6.1. Kaplan-Meier survival function for FP for all flocks

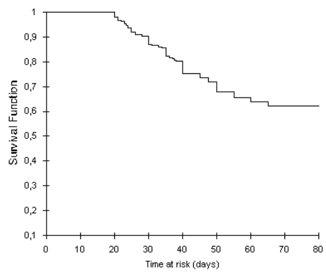


Fig. 6.2. Kaplan-Meier survival function for VP for all flocks

Both curves continuously drop from the beginning of the laying period (circa 20 weeks) to end of lay at approximately 72 weeks. Figures 3 and 4 show the Kaplan-Meier survival functions for FP and VP after stratification with the factors significant in the Cox regression models. When all three significant factors were applied to reduce the risk of developing FP, the survival ratio for FP increased to 0.89 from 40 weeks (group 1). When tested as three hazards, the survival ratio was 0.18 from week 42 (group 2).

The optimum combination of variables to reduce VP was: dark nest boxes, less than two diet changes during the laying period, no hanging bell drinkers, flocks came into lay at 20 weeks or later. This combination gave a value of 0.83 survival ratio from week 50 whilst, when presented as hazards, the survival ratio was 0.33 from the 30th week of age.

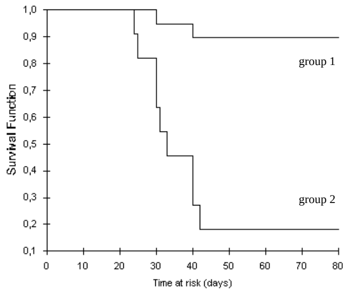


Fig. 6.3. Kaplan-Meier survival functions for FP for flocks stratified by management variables: group 1: 50% or more of the flock used the outdoor area on a fine, sunny day; flock inspections were not carried out by same person; lights were not turned up when the flock was inspected; group 2: less than 50% of the flock used the outdoor area on a fine, sunny day; flock inspections were always carried out by same person; lights were turned up when the flock was inspected.

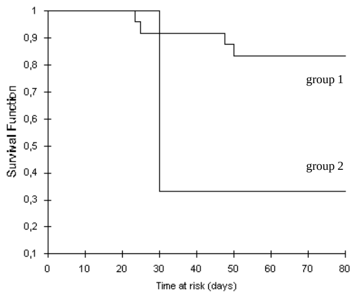


Fig. 6.4. Kaplan-Meier survival functions for VP for flocks stratified by management variables: group 1: dark nest boxes, less than two diet changes during the laying period, no hanging bell drinkers, flocks came into lay at 20 weeks or later; group 2: nest boxes were lit, more than two diet changes during the laying period, use of hanging bell drinkers, flocks came into lay before 20 weeks

Discussion

The presence of loose litter at the end of lay reduced FP in the logistic regression model but interestingly was not significant in the Cox proportional hazard model. Loose litter allows foraging, this has frequently been reported to reduce behavioural abnormalities in experimental studies on growing birds. This study showed that the use of the Cox proportional hazard model was of additional benefit to the results of the logistic regression models. All variables that were associated with VP in the logistic regression model had a significant effect on the time of onset of VP. This was not the case for the FP models. This may indicate a consistent effect of these variables and therefore a robustness of the VP logistic and Cox regression models. Only 3% of VP cases occurred in flocks without FP, so it may be that the FP models are confounded by the impact of VP. Bugnard et al. (1994) found the same risk factors in a logistic and a Cox proportional regression for one data set, all factors from the logistic model remained in the Cox model.

Expert opinion

A group of experts from Bristol vet. school and the poultry industry were asked to complete a questionnaire on their opinion of factors that influenced the occurrence of feather and vent pecking. The exposures were listed and respondents were asked to rank from 1 - 5 their relationship with feather and vent pecking. The codes used were 1-much less likely, 2-less likely, 3 - no effect, 4-more likely and 5-much more likely. Respondents were asked to leave a blank when they felt unable to comment on an exposure. These results were summarised using weighted averages.

Results

	Statements	Feather pecking	difference. of 0.5	difference of 1	Vent Pecking	difference of 0.5	difference of 1
	when there is blood on the birds	4.7	increased	increased	4.9	increased	increased
	when there are wounds on the birds	4.6	increased	increased	4.7	increased	increased
	when light intensity in the house is increased	4.3	increased	increased	4.5	increased	increased
	as group size increased (ignore stocking density	4.3	increased	increased	4.2	increased	increased
	as age of the birds increased	4.2	increased	increased	4.2	increased	increased
	as stocking density increased (ignore group size)	4.2	increased	increased	4.0	increased	
	when there is restricted food	4.1	increased	increased	4.2	increased	increased
	when birds are kept on wire	4.0	increased		3.8	increased	
	when birds sit on slats	3.8	increased		3.8	increased	
	when there is light in the nestboxes	3.8	increased		4.2	increased	increased
	as age at housing increased	3.7	increased		3.4		
	when the birds are ISA	3.7	increased		3.5		
	when the diet is changed more than 3 times during lay	3.5			3.6	increased	
	when bell drinkers are used	3.5			3.5		
	when the birds are Shaver	3.5			3.4		
	when the birds are Lohmann	3.4			3.4		
	when the temperature in the hen house is over 20 ºC (68 ºF)	3.1			3.2		
	when only 1 person handles the flock	2.9			2.9		
	as age of coming into lay increased	2.9			3.1		
	when the birds are Hyline	2.8			2.5		
	when birds are beak trimmed	2.4	decreased		2.3	decreased	
	when birds have access to wood shavings	2.4	decreased		2.6		
	when birds can access perches	2.4	decreased		2.8		
	when birds ground peck	2.2	decreased		2.7		
	when birds have access to polystyrene blocks	2.1	decreased		2.5		
	when birds can dustbathe	2.1	decreased		2.2	decreased	
	when birds have access to sand	2.1	decreased		2.6		
	when loose litter is available throughout lay	1.9	decreased	decreased	2.3	decreased	
	when birds use the outdoor area	1.8	decreased	decreased	2.0	decreased	
	when birds have access to straw	1.8	decreased	decreased	2.2	decreased	

There were 22 respondents to questions on feather pecking and 20 to questions on vent pecking. The factors that the experts considered increased and decreased the risk of feather and vent pecking by 0.5 and 1.0 of a point score are listed in Table 6.3. Differences of 0.5 and 1.0 score from score 3 increased and decreased the risk.

The experts identified the following factors to be associated with abnormal pecking that were also identified in our studies: Use of the range, access to loose litter, light in nest boxes, age of birds.

The experts did not identify the following factors that were detected in our study: diet change, use of bell drinkers, house temperature <20°C, one person handling the flock, age at lay.

The experts identified the following factors that we did not identify: beak trimming, use of certain substrates for dustbathing and foraging, age at housing, breed dispositions, restricted food, bright lights, group size, stocking density.

Many of these associations are results from experimental studies and are tighter exposures than can be detected on commercial farms. Some of the risk factors that were detected during this study correlate to these factors. E.g. Use of the range will decrease stocking density in the house, changing the diet may lead to restricted food access.

Conclusions

We consider that feather pecking and vent pecking are age related abnormal behaviours. We have developed predictive models to demonstrate that these behaviours can be prevented, or avoided until late in the laying period, when the risk factors identified are removed from a flock. Some of these risk factors can be acted upon immediately but others require further research before we can recommend that farmers change their management practices.

Our epidemiological work was concerned entirely with laying flocks and did not examine rearing accommodation. The experimental work conducted in parallel suggests that young birds react to the familiarity and detailed properties of substrates far more strongly than older birds. Epidemiological studies of younger birds should be conducted to examine the effects of rearing environment on the pre-laying onset of damaging pecking. In general, we found that older birds appeared to accept and use novel substrates for foraging, and to a more limited extent for dustbathing, regardless of their rearing environment. This is encouraging as it suggests that the provision of additional substrate (even if novel) should be protective against feather pecking at any age. The epidemiological work also provided strong evidence that access to a good quality foraging/dustbathing substrate is important to limit feather pecking in adult laying hens. However, farmers adopt many practices designed to restrict access to these substrates, often in an attempt to avoid lost eggs. This tension must be recognised. Birds should be encouraged to use nest sites using methods other than physical restricion (or light, see below), and alternative pecking opportunities should be provided if birds are to be confined to slatted areas when they are young, or at certain times of day. The practicalities of maintaining a good substrate should not be underestimated and many 'litter' areas comprise nothing more than a solid, damp area. Even in our intervention trial it proved difficult to make a real impact on litter quality. This is an area where a technological solution is probably required.

Free-range flocks potentially have the additional substrates of the outdoor area available to them. However, use of the range was low in many flocks, despite the fact that good use of the range had the strongest impact in preventing feather pecking in our studies. This result was consistent and robust and further understanding of the reasons behind this result (effects on stocking density, foraging behaviour, patterns of bird interactions) may also have implications for indoor systems. We need to understand these reasons and also farmer's attitudes towards encouraging birds to use the range. We received negative responses when we suggested this as a possible intervention.

Although feather pecking is an important and widespread welfare problem, vent pecking is perhaps more serious when it occurs. The predictive models for vent pecking indicated that lighted nesting boxes were a risk, possibly drawing attention to the cloacal region after lay. We would encourage farmers to consider removing these lights. The risks associated with early onset of lay were also important and require further investigation, focussing on possible cloacal damage of early egg laying by immature birds.

It was encouraging that our study confirmed the importance of many risk factors that have been suggested in the literature following experimental work, or identified by experts after years of practical experience. This suggests that the results we obtained were valid. But it was perhaps even more valuable that we were able to identify novel risk factors that have not been suggested before. Some of these, for example the use of hanging bell drinkers, were consistent across different analyses, and also significant in the magnitude of their effect. For each such risk factor we have proposed a set of possible hypotheses to explain why they might affect the incidence of damaging pecking. These hypotheses now require testing.

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