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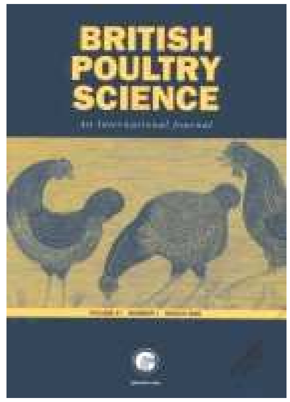

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Journal:	*British Poultry Science*
Manuscript ID:	CBPS-2009-342.R1
Manuscript Type:	Original Manuscript
Date Submitted by the Author:	14-Feb-2010
Complete List of Authors:	Drake, Kelly; Oxford University, Zoology Donnelly, Christl; Imperial College London, M.R.C. Centre for Outbreak Analysis and ModellingDepartment of Infectious Disease Epidemiology Dawkins, Marian; Oxford University, Zoology
Keywords:	Feather pecking, Feathers, Welfare

Note to P. Lewis. A few general formatting points. Some phrases in bold, some et al.s not in italics. The first para of “Statisitical analysis” contains several ‘levels’ – I try to encourage authors to avoid the word – it’s lazy and sometimes ambiguous – wherever possible it should be replaced by the actual measure – concentration, intensity, number etc and sometimes it can even be deleted altogether. Think about its use here. Some probability symbols are lower-case Roman. Ampersands in some text references.

Influence of rearing and lay risk factors on propensity for feather damage in laying hens

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Short title: Feather damage in laying hens

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Accepted for publication 10 July 2010

Abstract.

1. Feather pecking is one of the major problems facing the egg industry in non-cage systems and is set to become even more of an issue with the European Union ban on the keeping of laying hens in barren battery cages which comes into force in 2012 and **a** UK ban on beak-trimming in 2011. Reducing feather pecking without resorting to beak treatment is an important goal for the poultry industry.
2. We report here a longitudinal study that included over 335 500 birds from 22 free range and organic laying farms. Accelerated failure time models and proportional hazards models were used to examine the effects of a wide range of factors (management, environment and bird) on development of substantial feather damage in lay. Particular emphasis was placed on risk factors during rear and on practices that could feasibly be changed or implemented.
3. The age at which a flock exhibits substantial feather damage could be predicted both by factors in the environment and by early symptoms in the birds themselves. Factors that were associated with earlier onset of severe feather damage included the presence **of** chain feeders, raised levels of carbon dioxide and ammonia, higher sound and light levels, particularly in younger birds. Increased feather damage (even very slight) in birds **at** 17-20 weeks of age was also highly predictive of the time of onset of severe feather damage during lay. Increased feed intake also indicated that a flock was at risk of early severe feather damage.
4. Birds that stayed on the same farm for rearing and lay showed later onset of serious feather damage than those that experienced a change in farm from rearing to lay. However, an increased number of changes between rearing and

lay (feeder type, drinker type, light intensity etc) was not associated with earlier onset of serious feather damage. Further research needs to be done on the role of the transition from rearing to lay as a risk factor for FP in lay.

INTRODUCTION

A major welfare problem in the commercial egg production industry is that of injurious feather pecking (FP) in laying hens **(Savory, 1995;** Green et al., 2000; **Bright, 2009; Bestman et al., 2009).** Injurious FP leads to increased feed consumption due to heat loss (Tauson and Svensson, 1980), a reduction in egg production (El-Lethey et al., 2000), pain and suffering of the injured birds (Gentle and Hunter, 1991) and increased bird mortality, including cannibalism (Huber-Eicher and Sebo, 2001).

In 2012, barren cages will be banned in the European Union in line with Directive 1999/74/EU. This will increase the number of birds kept in **non-cage** laying systems (barn, colony, free range and organic), which in turn will increase the numbers of birds at risk of injurious FP and cannibalism (Blokhuis et al., 2007; Fossum et al, 2009). Beak treatments that blunt the beak and so reduce the impact of pecking either by infra-red or hot blade (Dennis et al., 2009) remain the main methods of controlling FP, but raise welfare issues in their own right (Gentle et al., 1990; Hughes and Gentle, 1995). **Furthermore, beak treatments of all types will be banned in the UK from 2011.** There is therefore an urgent need to find ways of controlling FP without resorting to beak treatment.

Despite the much greater understanding of the factors predisposing hens to feather peck that has been gained from research over the past 25 years, prevention is still not possible (Rodenburg et al., 2004; Dixon, 2008). The problem is multi-factorial and stems from interactions between the bird, the environment and management variables in ways that are not yet understood (Rodenburg et al., 2008a). Environmental factors experienced by birds during rearing have been identified as particularly important to the development of later FP in adult flocks (**Johnsen et al.,**

1998; Gunnarsson et al., 1999; van der Wee**r**d, 2006, Staack et al, 2007; Riber et al, 2007; Rodenb**u**rg, et al., 2008b) but it is not clear whether particular factors are critical or whether it is **the** change between rearing and lay factors that **is** most important. However, even if it is not currently possible to prevent FP altogether, it would greatly help producers if they were able to predict outbreaks of FP before they occur or at least detect them at the onset. This would allow action to be taken before the welfare and production of the birds was adversely affected and to concentrate such measures on high risk flocks.

The aim of this longitudinal study was to identify factors (bird, management and environment) in the early environments of laying hens in commercial non-cage systems that predict which flocks are at the greatest risk of developing FP later in lay. Commercial flocks were followed from rear throughout the laying period until clearance and we **collected data on a variety of factors about the birds themselves (strain, feather cover, feed intake) as well as the environments they were in.** We looked for signs in young flocks that might indicate they were at high risk of developing FP later in life and also at factors in the rearing and laying environments that might be associated with severe feather damage. We examined both the role of particular factors in the rearing environment that might predispose **an** adult flock to feather damage and also the role of changes between the rearing and the laying environment that might constitute a particularly high risk.

MATERIALS AND METHODS

Approximately 335 000 commercially reared laying hens were followed from 12 rearing farms on to 19 laying farms between February 2006 and August 2008. The laying farms consisted of 44 houses, the majority of which were internally sub-divided into colonies (birds physically separated by a barrier but within the same house). This gave a total of 84 colonies, where a colony could be either a whole house (no internal barriers between flocks) or a single undivided house. A single colony could contain between 780-4000 birds. As colonies within a house were not fully independent, data were analysed statistically with house (n=44) as the independent unit.

The study included three different types of laying systems: barn (2 houses/10 colonies), organic free-range (19 houses/19 colonies) and free-range systems (42 houses/55 colonies). Flocks were comprised of 5 laying bird **hybrids**: Hyline, Lohmann (Brown and Traditional), Shaver, **Bovans** Goldline, **Columbian** Black Tail and a mix of Hyline and Goldline. Birds from 18 out of the 19 farms were beak-treated at 5-7 d old. One farm which did not beak-treat initially, had to beak treat two colonies at 30 weeks of age. Another farm had to repeat the beak-treatment for 4 colonies at 35 weeks of age. The methods used for beak treatment were; infra-red (4 houses) and traditional hot-blade (40 houses). Each house was visited on at least 4 occasions; towards the end of rear (<17 weeks), after transfer to the lay house (~18–22 weeks), peak-lay (~23–30 weeks) and close to clearance (~50 wks). Additional visits were made to some farms to establish a more thorough database of events**. Due to insufficient numbers in the barn systems and houses using infra-red beak treatments, we were unable to meaningfully compare the impact of these** variables on propensity for feather damage.

Feather damage

Feather damage scores were recorded during each visit for each colony both inside the house and from birds on the corresponding range outside the house by visual inspection using the method described by Bright et al. (2006); 100 birds were visually assessed for feather damage (Table 1) from each colony and 100 from each range outside the house. A random number grid map was used to select the birds. Five different body regions on the bird were selected (neck, back, rump, tail and wing) and scored on a best (0) to worst (4) scale (Table 1). Feather damage scores were collected during each visit and averaged to give a mean feather damage score for each body region and an average total (that is,. summed) feather score for each colony. We considered mean feather damage greater than or equal to the threshold of 3.8 (at any age) to be substantial feather damage in an attempt to ‘predict’ whether a flock was at risk of becoming a ‘feather pecking flock’.

Management and husbandry

The first visit was conducted at the rearing house (12 - 17 weeks of age). This visit gathered detailed information on general management, husbandry practices and the bird. **The following were recorded: season of rear and hatch month, size of farm (number of houses, numbers and ages of birds currently on farm, strain of bird, age of parent flock, flock size, stocking density, drinker type (bell, bell and nipple, nipple, nipple with cup), number of drinkers per house, feeder type (chain, chain and pan, pan), number of feeders per house, litter type (cut straw, newspaper, woodchip), lighting source/number (fluorescent, tungsten, daylight, redlight or combination, enrichments such as perches, bales etc.** Birds were transferred to the laying houses between 17 – 18 weeks. A record was kept of whether the laying houses were on the same or a different farm. The first visit to the laying farm (between 18 and 22 weeks of age) consisted of recording **the** management, husbandry practices, bird, environment and production variables **listed above and in addition recording details of the laying system (barn, free-range, organic), other species on farm, age at transfer, verandas (Y/N) % of house floor slatted or litter, range size, % range area covered by vegetation, vegetation type**

(no trees, artificial shelter, small growing trees, mature growing trees, mature trees with artificial shelter).

Environmental variables

Environmental variables were measured during each visit. Within each colony, **4 locations were chosen randomly using a grid map, two in the slatted area and two on litter.** Environmental measures were taken at all 4 **locations and the mean of these calculated for each colony**. The measures taken were: sound (dB) intensity (using a Sound level meter ST-8850, Farnell in One, Leeds, UK), lux (using a TES 1330A Digital Lux meter, York Survey Supply Centre, York, UK), litter pH and temperature (using a HI-991300 pH/Temperature meter, Hanna Instruments, Bedford, UK) and ammonia and carbon dioxide gas concentrations (5-100 ppm and 300-5000 ppm respectively) (using RAE gas detection tubes, RAE Systems Inc., California, USA and a Gastec GV-100S pump, Gastec Corporation, Japan) were recorded. All variables were recorded at bird height (~ 30 cm from ground).

Production variables

Weekly production records were collected by the producers and included percent of birds in lay, percent mortality and feed consumed (gram/hen/d). Production records that were not directly supplied varied from farm to farm, and not all farms collected the same information; however all recorded those listed above.

Statistical analysis

The independent unit for analysis was the house (n=44). The aim of the analysis was to identify which factors contributed to the risk of 'failure', that is a given flock yielding a mean feather damage score of ≥3.8. Although any arbitrary level of feather damage could be defined as 'failure', 3.8 represents a substantial level when feathers are severely damaged and/or areas of naked skin are visible (Table 1). This is the level of damage seen in approximately half of all flocks before 40 weeks of age, with some flocks reaching this level earlier and some never (Figure 2). The choice of this threshold gives the model better predictive power than by choosing a threshold that was always met or never met.

The aim of our analysis was to describe associations between the time at which a flock experiences failure (mean feather damage score of ≥3.8) and characteristics of the farm, house and flock. If every flock had been observed to fail (in other words there were no censored data), then regression would be an obvious choice for describing relationships between predictors and the time at which each flock experienced failure. In our study, however, many flocks were never observed to fail. Thus, our analyses needed to allow for censoring. We performed two parallel sets of such analyses, based on accelerated failure time models and Cox proportional hazards models, each indicating whether or not (and to what extent) the variable in question had a significant effect on 'failure' times of flocks. Accelerated failure time models (Wei, 1992) produce estimates of differences (in weeks) in the time to failure associated with different potential predictors (such as with or without transfer to a different farm between rear and lay) by regressing the logarithm of the survival time over the covariates, while allowing for censored data. In contrast, Cox proportional hazards models (Cox, 1972) produce estimates of relative hazards (risk of failure), under the assumption that the impact of a predictor is multiplicative. In other words, a factor that halves risk for a relatively low-risk flock will also halve risk for a relatively high-risk flock. The results of the two methods were highly consistent.

We report the results of the accelerated failure time models here because the results are in terms of absolute differences (in weeks) in times to failure and therefore have immediate biological meaning. The results are given as the estimated % reduction (or increase) in the age at which flocks showed a mean feather score of 3.8 or more, together with 95% confidence limits for the % reduction (or increase) and its associated *P*-value.

RESULTS

Descriptive results of feather pecking

Figure 1 shows initial bird numbers on transfer into the lay houses (n=44), final bird number at depletion (mark on bar) and houses which ones develop**ed** FP prior to 40 weeks of age (asterisk). There was large variability of number of houses on farms and numbers of birds housed across, and within farms.

Feather scores

Figure 2 shows the incidence of feather damage in flocks of different ages for all colonies (n=84) observed in the study. Feather damage increase**d** with age and **was** cumulative but 23% of houses never reach**ed** the FP threshold of 3.8. Within houses, 16 out of 84 colonies (19%) reached the threshold of ≥3.8 by 40 weeks of age, 29 colonies (35%) by 41-50 weeks of age and by 60 weeks of age, 49 colonies (59%) had reached the feather damage threshold.

Table **2** shows that the feather damage score at a given age predict**ed** the time in the future when a flock **would** reach the FP threshold. (A unit = an increase of 1.0 in the average total feather score as defined in Table 1). Particularly notable is the fact that predictions **could** be made even by observing young birds less than 20 week of age, where there **was** relatively little feather damage (Figure 2). The feather damage scores for birds 17-20 weeks ranged between 0.03-1.18. Nevertheless, the feather damage score measured at this time **were** highly predictive of the age at which a house would later cross the threshold feather score of ≥3.8 (**Table 2).**

Management and husbandry

The effect of various management systems and husbandry practices are shown in Table **3**. Chain feeders were significantly associated with earlier failure times than pan feeders. **Low** feeders (those on the ground) **were associated with earlier onset of FP than High (**raised above the ground). Pan feeders were always raised above ground level.

Production

Neither % mortality in the flock nor the % of birds in lay was predictive of when that flock would reach a FS of ≥3.8 (for mortality p>0.1 at all ages; for % birds in lay p>0.5 at all ages). However, the mean amount of feed eaten **(g/day per individual)** was significantly predictive, at least when birds were less than 17 weeks and between 20 and 24 weeks of age, indicating that the more feed that was eaten, the earlier failure time occurred (**Table 4).**

Environmental variables

The levels of **the** environmental variables **recorded** (carbon dioxide (CO_2), ammonia (NH_3), light (lux), noise (dB), litter pH and temperature (^{0}C) are shown in **Table 5**.

In laying houses, higher CO_2 levels were associated with earlier onset of FP: between 24 and 30 weeks of age, each 200 ppm increase in CO_2 was associated with a 14.8% reduction in time to failure (95% confidence interval -19.7% - - 9.5%; p=0.0001). Higher ammonia levels were also associated with earlier onset of FP: every 15 ppm increase in NH_3 recorded between the ages of 15 and 17 weeks was associated with a 10.1% reduction in time to failure (CI -16.2%- -

3.5%; p=0.003); between the ages of 24 and 30 weeks, it was associated with a 12.9% reduction in time to failure (CI: -18.7% - -6.8%; p=0.0001).

Light was another risk factor, particularly if light levels were high in young birds. Higher light levels in birds of 17-20 weeks were associated with an earlier onset of FP: each 100 lux increase was associated with a 12.2% reduction in time to failure (C.I.: -18.9%- -3.9%; p=0.0034). The final factor we found to be associated with earlier onset of FP was sound level. Between 15 and 17 weeks, each 10 dB increase in sound was associated with 25.5% reduction in time to failure (C.I.= -39.6% - -8.2%; p=0.0056) and between 17-20 weeks, with a 7.9% reduction in time to failure (C.I.= -13.5% - -2.0%; p=0.0099). No significant differences were found at any age category for either litter pH (p>0.3) or for temperature (p>0.05) measured during the visit.

Environmental factors during rearing

Factors in rearing that influenced FP later in lay are shown in **Table 6**. The type of feeders and drinkers had a significant effect on age at which FP developed**. FP** developed earlier in flocks that came from rearing houses with chain feeders than from those with pan feeders or a combination of feeder types. FP developed earlier in laying flocks that had been reared in houses with a bell and nipple drinker system than those with nipples only, or nipple/cup systems.

Changes from rearing to laying environment

Table 7 shows the effects of changes from the rearing environment to the laying environment. Where the feeder system did not change from rear to lay, FP was found to start sooner than when the feeder system changed between farms (**Table 7**). However, it should be noted that the only recorded instances of where the feeder system was the same in rear and in lay were those in which there was a chain feeder in both. Chain feeders appear to be a risk factor in themselves (Table 6). An earlier start to FP occurred earlier in lay with birds that were moved to a different farm (**Table 7**).

To obtain an idea of whether FP was affected by the number of changes between rearing and lay, we added together the effects of **all recorded changes** (veranda, perches, feeder type, drinker type, lighting, transfer to a different lay farm). This is shown as 'sum' in the bottom row of **Table 7** and was not associated with an earlier risk of feather damage.

Birds hatched as chicks in July-March showed a delay in reaching the feather score of $\geq$3.8 of 17.2% compared to birds hatched in April, May or June (2.9-33.5%, p =0.0169) indicating FP started earlier for those hatched April-June.

DISCUSSION

Our results show that the age at which a flock exhibits substantial feather damage can be predicted both by factors in the environment and by early symptoms in the birds themselves. Environmental actors that were associated with earlier onset of severe feather damage included the presence of chain feeders, raised levels of carbon dioxide and ammonia, higher sound and light levels, particularly in younger birds.

Our results also show that it is possible to predict which flocks are at greatest risk of feather pecking before serious feather damage is apparent. Even in young birds (under 20 weeks of age), when very little feather damage is seen in any flocks, slight differences in feather score are predictive of the level of feather damage at later ages (**Table 2**). In other words, even slightly raised feather scores in young birds are associated with earlier onset of serious feather damage, supporting similar studies by **Bright (2009) and Bestman et al. (2009). This means that just by looking at a**

young laying flock, it may be possible to predict how likely they are to develop serious feather damage.

Another factor that is suggestive of future problems is feed intake. Flocks that show**ed** early signs of increased daily feed intake **were** also likely to show earlier severe feather damage **(Table 4).** However, this was only shown to be significant between 20 -24 weeks of age. This is of interest as it is known that birds increase their feed consumption due to heat loss, if, severely feather pecked (Tauson and Svensson, 1980). **Therefore, the first signs of an increase** in food consumption may indicate a measure in which to 'predict' a problem before it becomes an issue of welfare or productivity.

While our results are consistent with the previous studies that have emphasized the factors in the rearing environment that influence feather pecking in later life (Blokhuis & van den Haar, 1989, 1992; Norgaard-Nielsen et al., 1993; Johnsen et al, 1998; Newberry et al,, 2007), we have here attempted to separate the influence of factors in the rearing environment *per se* from the influence of *changes* between rearing and laying environments. For example, factors such as light levels in rearing might appear to have little effect on likelihood of feather damage in lay (Kjaer & Sorenson 2002), but a change in light level as the birds were moved from rear to lay might have a much bigger effect. We therefore asked separate questions about the factors in rearing that were associated with later feather pecking and about whether or not birds had experienced a change in those factors as they were moved from rearing to laying houses.

The accelerated failure time models used in this study point to a number of factors in rearing that are associated with earlier onset of serious feather damage.

Factors associated with such **a** risk include feeder type and position, with chain feeders associated with earlier failure (**Table 6**). It is not clear why chain feeders appear to pose a risk.**. Freire et al. (1999) found that, in modified cages, increased feather pecking was associated with lower feed troughs (6 cm above ground) compared to 28 cm.. They suggested that this was because hens stepped on each other, leading to feather damage and subsequent FP. The possibilities that low feeders may hamper movement of an attacked bird, lead to feather damage or that they are associated with more restricted feeding would be well worth further investigation**. Although our data are suggestive rather than conclusive, a lack of a veranda for young birds during rearing may also be associated with earlier risk of feather pecking. (The value of providing verandas for young birds could usefully be explored). Among environmental factors, poor air quality (levels of CO_2 and ammonia) and higher light levels predispose flocks to develop feather pecking at an earlier age (**Table 6**).

In addition, increased sound levels within a house (up to 20 weeks of age) were associated with an early propensity to feather peck. However, as in a study by Bright (2008), it is not clear whether the observed effects were due to noise made by the birds themselves (birds that vocalise a lot have a tendency to FP) or due to environmental noise increasing the tendency to FP. Either way, the role of sound deserves more attention in future (Bright, 2008). It could either be a useful indicator that a given flock is 'at risk' of developing FP or a pointer to the relatively easy intervention of reducing noise levels to reduce risk of FP**.**

We then examined the effects of *change* between rear and lay. One factor that seemed to be of considerable importance **was** whether birds **moved** farms between rear and lay. Although the numbers reported here are small, there is a strong suggestion that staying on the same farm may postpone the risk of feather pecking in lay **(Table 7).** This might be because birds staying on the same farm do not experience a long journey or it could be that where rearing and laying houses are on the same farm, they are more likely to provide more similar conditions than if they are on different farms. We attempted to test the idea that 'amount of change' in environmental conditions was important by looking at the effects of **the number of changes** between rear and lay. We failed to detect any additive effect of the **number of changes (Table 9).** Nevertheless, we suggest that further studies of the transition between rearing and laying environments could be very valuable. Keeping birds on the same farm throughout their lives is not usually possible, but **more** attention to the differences they experience as they move from rear to lay might suggest ways of reduc**ing** the chances of severe feather damage later on.

In conclusion, it is possible to predict which flocks are at risk of FP before serious feather damage has occurred later in lay. Given the multifactorial nature of FP and the difficulties of eliminating it altogether, the ability to identify 'at risk' flocks could still be of value to producers since it could enable them to target **preventive** action specifically on the flocks most at risk. Future research aimed at reducing the risk of feather pecking could profitably concentrate on the role of feeder layout, air quality, and light and sound levels, as well as the role of changes between rearing and laying environments.

Acknowledgements

We thank DEFRA for funding this research (Contract no. AW 1134), and also thank Noble Foods Ltd, Stonegate and farmers for providing facilities which we were permitted to visit.

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Captions to figures.

Figure 1**.** Initial bird numbers on transfer to the lay house and incidence of FP in the study houses. Each bar represents one house and points on each bar represent the final bird number at clearance. Houses on the same farm are grouped by dotted lines. Columns with an asterisk represent flocks that went on to develop FP (mean feather score of ≥ 3.8) prior to 40 weeks of age.

Figure 2. Average feather damage score by age category for each house. The solid black horizontal line represents the level of feather damage regarded as 'failure' –a mean flock feather score of 3.8 or greater. Grey lines represent houses that fail before 40 weeks of age.

Tables

Table 1. Feather damage score

Score	Description of body
0	Well feathered body parts with no or little damage
1	Slight damage to any area of the body with feathers ruffled, body completely/almost completely covered
2	Severe damage to feathers, but localised naked area (<$5cm^2$)
3	Severe damage to feathers, and large naked areas (>$5cm^2$)
4	Severe damage to feathers, >$5cm^2$ naked area and haemorrhage or broken skin

Table 2. Feather damage scores (FS) in birds of different ages as predictors of the future time at which a house would reach a mean feather score of 3.8 or more.

Age in weeks	Estimated effect	95% confidence interval		p-value	Comments
15-17	30.3%	-54.3%	271.7%	0.62	
17-20	-38.2%	-55.9%	-13.5%	**0.005**	Each 1 unit increase in FS associated with 38.2% reduction in time to failure
20-24	-16.2%	-47.3%	33.1%	0.45	
24-30	-15.0%	-25.6%	-2.9%	**0.017**	Each 1 unit increase in FS associated with 15.9% reduction in time to failure
30-40	-9.6%	-16.1%	-2.7%	**0.007**	Each 1 unit increase in FS associated with 9.6% reduction in time to failure

Table 3. Management systems and husbandry practices as predictors of the time at which a house would reach a mean feather score of 3.8 or more.

	Estimated effect	95% Confidence	interval	p-value	Comments
Organic * (Y/N)	**-6.6%**	**-18.9%**	**7.4%**	**0.34**	
Veranda (Y/N)	-7.6%	-19.4%	6.0%	0.26	
Perch (Y/N)	-7.1%	-19.2%	6.7%	0.30	
Feeder ** (Chain/pan)	-19.7%	-31.9%	-5.3%	**0.009**	Houses with chain feeders failed 19.7% sooner than pan
Feeder ht (H/L)	21.1%	5.9%	38.4%	**0.005**	Houses with high feeders failed 21.1% later than low

*This analysis compared free-range with organic and omitted barn systems

**This analysis omitted houses that had both chain and pan (n=3).

Table 4. Daily feed intake (grams/hen/day) at different ages as a predictor of the time at which a house would reach a mean feather score of 3.8 or more.

Age (weeks)	Estimated effect	95% Confidence	interval	p-value	Comments
15-17	-1.0%	-1.78%	0.0%	**0.041**	Based on very limited data
17-20	-2.6%	-11.7%	7.5%	0.60	
20-24	-13.4%	-23.7%	-1.8%	**0.025**	Each 20 g/h/d increase in feed associated with a 13.4% reduction in time to failure
24-30	-1.0%	-5.6%	3.9%	0.67	
30-40	-0.6%	-3.1%	2.0%	0.68	

Table 5. Levels of environmental variables measured.

	Mean (sd)	Range
Light (lux)	29.6 (65.4)	2.0 - 869.1
Sound (dB)	59.4 (12.7)	14.3 – 80.0
CO_2 (ppm)	586 (327)	43-2000
Ammonia (ppm)	21.9 (18.4)	0-100
Litter temp. (^{o}C)	17.5 (4.5)	5.7-27.9
Litter pH	7.13 (2.5)	1.14-13.62

Table 6. Factors in rear as predictors of time at which a house reached a mean feather score of 3.8 or more.

Reared with	Estimated effect	95% Confidence	interval	p-value	Comments
Chain feed	-26.8%	-41.6%	-8.2%	**0.0068**	Houses with chain feeders in rear failed 26.8% sooner than houses with both chain and pan in rear
Bell	-15.0%	-26.3%	-2.0%	**0.0255**	Houses with bell drinkers in rear failed 15% sooner than houses with nipple + cup drinkers in rear
Bell/nipple	-39.6%	-50.6%	-26.1%	**<0.0001**	Houses with both bell and nipple drinkers in rear failed 39.5% sooner than houses with nipple drinkers
Nipples +/-cups	-6.8%	-23.8%	14%	0.49	
Light type	29.8%	6.9%	57.8%	**0.0086**	Houses with fluorescent or natural light in rear failed 29.8% later than houses with tungsten light in rear

Table 7. Factors that changed between rear and lay as predictors of the time that a house reached a mean feathers score of 3.8 or more.

Change in	Estimated effect	95% Confidence	interval	p-value	Comments
Veranda in rear Y/N	9.4%	-4.5%	255.4%	0.19	
Perch Y/N	6.7%	-6.3%	21.7%	0.33	
Feeder type Y/N	-19.2%	-28.5%	-8.7%	**0.0006**	Houses which had the same feeder type in rear and lay failed 19.2% sooner than houses of birds which experienced a change in feeder type from rear to lay.
Drinker type Y/N	-10.1%	-22.3%	-4.1%	0.15	
Light type Y/N	10.1%	-5.1%	27.6%	0.20	
Farm Y/N	28.4%	6.1%	55.5%	**0.010**	Houses of birds reared on the same farm as lay failed 28.4% later than houses of birds reared on different farm.
Sum	-1.7%	-8.1%	5.2%	0.62	

Figure 1.

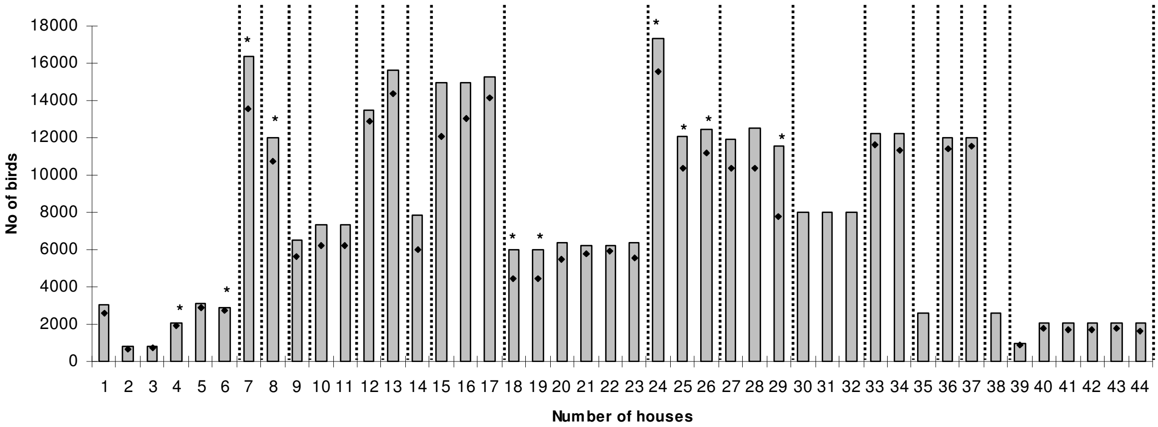
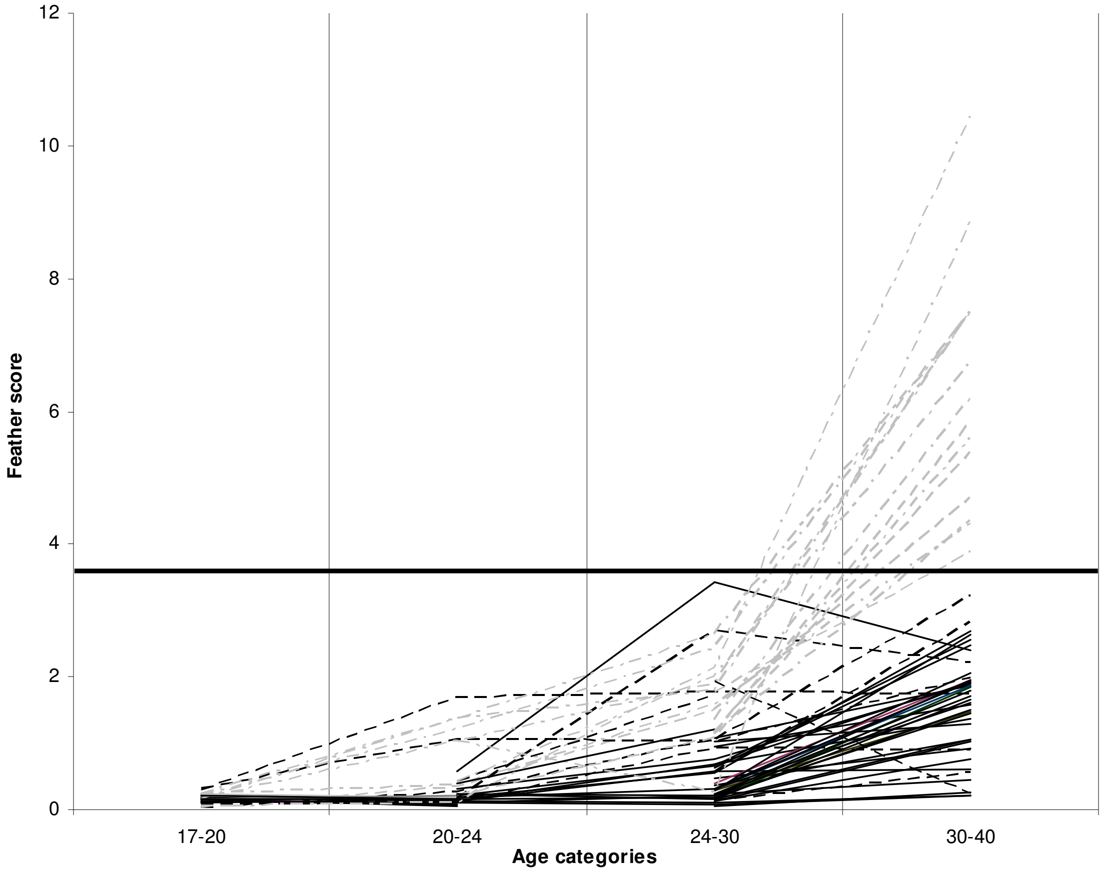

No of birds
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44
Number of houses

Figure 2.


12
10
8
6
4
2
0
Feather score
17-20
20-24
24-30
30-40
Age categories