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The prevention and control of feather pecking: application to commercial systems

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Studies on the prevalence of feather pecking in different commercial laying hen systems and its welfare and economic impacts are reviewed in the following paper. Current methods for controlling feather pecking include beak-trimming and alterations to light regimes, but these methods have significant disadvantages from the perspective of bird welfare. A substantial body of research has now identified risk factors for feather pecking during both the rearing and laying periods. It is argued that these findings can be translated into optimised management practices that can prevent and control feather pecking whilst simultaneously conferring welfare benefits. The genetic basis of feather pecking is considered, and studies that suggest group selection techniques could produce birds with a reduced tendency to feather peck in commercial flocks are highlighted.

Keywords: laying hen; feather pecking; beak-trimming; light; risk factor; genetic selection

Introduction

A range of fundamental studies on the developmental and motivational systems that underpin different types of feather pecking (FP) (Rodenburg *et al.*, 2013) were recently reviewed. Attention is now turned to the manifestation of this behaviour in commercial practice, by describing how the prevalence of feather pecking is affected by age, housing system, and management practices as revealed by epidemiological studies. It has been

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shown that genetic selection and management strategies derived from a fundamental understanding of the basis of FP behaviour compare favourably with current practices of beak-trimming and light reduction as potential control methods.

When does FP develop in commercial systems?

Gentle feather pecking (GFP) is commonly observed during the rearing period (Huber-Eicher, 1999; Huber-Eicher and Sebo, 2001; Chow and Hogan, 2005) and can start from as early as one day after hatching (Riedstra and Groothuis, 2002). Plumage damage does not usually occur during the rearing period, since pecking is largely gentle and birds moult several times before lay (van Hierden *et al.*, 2002; van de Weerd and Elson, 2006). However, even low rates of FP (possibly exploratory GFP – see Rodenburg *et al.*, 2013) or slight plumage damage during rearing present a significant risk for later plumage damage during the laying period (Huber-Eicher and Sebo, 2001; Bestman *et al.*, 2009; Drake *et al.*, 2010), possibly due to misplaced feathers, which subsequently attract further pecking damage (McAdie and Keeling, 2000).

Vent pecking (VP) tends to start at the onset of lay (Pötzsch *et al.,* 2001). After this period, GFP tends to remain relatively stable or even declines with age, whereas SFP tends to increase throughout the laying period (Nicol *et al.*, 1999; Pötzsch *et al.,* 2001; Lambton *et al.*, 2010), but there can be considerable variation between flocks in the timing of plumage loss.

Prevalence of FP in different systems

Feather pecking is present in all housing systems, from conventional and furnished cages, to barn and free range systems (Gunnarsson *et al.,* 1999; Green *et al.,* 2000; Sherwin *et al.,* 2010). However, estimates of its prevalence depend on the recording method used:

FARMER AND RESEARCHER ESTIMATES OF PERCENTAGE OF FLOCKS SHOWING FEATHER PECKING

Many epidemiological studies use questionnaires or interviews with farmers to gather information on the prevalence of FP. Huber-Eicher (1999) found that a third of Swiss free-range farmers judged FP to be a sufficiently serious problem to take action. In the UK, 47% of free-range farmers said FP was a normal occurrence on their farm, with 57% noting it in their last flock (Green *et al.,* 2000). In a second UK survey, free-range farmers indicated that 65% of their flocks showed FP at some point during the laying cycle, but researcher observations of these same flocks found that, at 25 weeks GFP, occurred in 89% and SFP in 69% of flocks, and at 40 weeks GFP occurred in 73% and SFP in 86% of flocks (Lambton *et al.,* 2010). This suggests that farmers may, for a variety of reasons (lack of recognition, lack of systematic recording) underestimate the prevalence of FP. Thus, although useful, their reports should not provide the sole source of information in epidemiological studies. Other researchers report 62% of flocks affected by FP (Gunnarsson *et al.*, 1999). Using direct observations Gilani (2012) found GFP in 94% of flocks and SFP in 65% of flocks at 35 weeks. However, if these behaviours occur at low rates, or are exhibited by only a few birds within a flock, then widespread plumage damage or injury may not necessarily occur.

PLUMAGE DAMAGE

Although plumage damage is an imperfect proxy measure of FP, it is often easier to assess than the behaviour itself. In some circumstances there is good correlation between measures of SFP and the extent of plumage damage (Bilcik and Keeling, 1999; Lambton *et al.,* 2013) but plumage damage can occur due to abrasion, or from aggression (Bilcik and Keeling, 1999). A high intensity of FP can result in the rapid denudation of most hens and, due to this 'ceiling' effect, further FP cannot be documented by plumage scores (Kjaer, 2000). Bestman and Wagenaar (2003) found little or no plumage damage at 50 weeks in 29% of non-trimmed organic flocks, moderate damage in 19%, and severe damage in 52% of flocks. Gunnarsson *et al.* (1999) assessed 59 flocks on 21 farms in Sweden and reported a median 62% of birds within a flock with plumage damage on their backs. Since abrasion rarely occurs in this body area, this could be ascribed to FP.

The severity of plumage damage in different body regions can be scored using methods which involve handling birds (Bilcik and Keeling, 1999; Kjaer and Vestergaard, 1999; Tauson, 2005) or ones that rely on visual inspection from a distance (Bestman and Wagenaar, 2003). Strong correlations exist between these different methods (Bright *et al.,* 2006). After scoring plumage damage on different body areas of individual hens, Bright (2009) and Drake *et al.* (2010) found that 39% and 19% of flocks respectively reached a threshold level of plumage damage by the age of 40 weeks. The threshold level was a mean flock score of 3.8 (Drake) or 4.0 (Bright) based on scoring individual birds on a five point scale assessing five body regions (Bright *et al.,* 2006).

PERCENTAGE OF BIRDS PER FLOCK PERFORMING FP – DIRECT BEHAVIOUR

If individual pecks, or bouts of pecking, are recorded directly, then the percentage of birds within a flock engaging in this behaviour can be closely estimated. Kjaer and Sorensen (1997) found that 94%, 48% and 52% of birds housed in experimental pens performed FP when all forms of FP were summed at six, 38 and 69 weeks of age. This was a much higher estimate than that provided for 51 commercial flocks by Oden *et al.* (2002) who found 27% of birds performed GFP and 11.5% performed SFP. Rodenburg *et al.* (2004) studied 630 birds housed in experimental pens and found that, whilst most showed GFP at six weeks of age, only 2% showed SFP. At 30 weeks of age SFP was observed in 15% of the birds. No evidence was found that GFP developed into SFP, although correlations were found between GFP and SFP at the same age (severe peckers would also show GFP).

RATE OF FP – INDIVIDUAL BIRDS

The Laywel project (www.laywel.eu deliverable 4.2; Blokhuis *et al.,* 2007) summarised studies that reported highly variable rates of FP between birds (from 0.5 pecks/bird/hour to over 30 pecks/bird/hour), with great variation between hybrids. Likewise, others have reported rates varying between 0.8 and 10.3 pecks/bird/hour for white hybrids and 16.8 to 30.2 for brown hybrids (Kjaer, 2000; Oden *et al.,* 2002). Sherwin *et al.* (2010) reported higher rates of GFP in free-range systems (23 pecks/bird/hour) than indoor barns (9.6 pecks/bird/hour) furnished cages (3.6 pecks/bird/h) or conventional cages (0.6 pecks/bird/h). Nicol *et al.* (1999) reported GFP at 3.3 pecks/bird/hour, SFP at 1.15 pecks/bird/hour and vent pecking at 0.3 pecks/bird/hour in birds aged 30 weeks in an indoor non-cage system. More recently, Zimmerman *et al.* (2006) reported lower rates of FP (mostly GFP) for brown hybrids housed in single-tier aviaries with average rates varying between 0.1 and 0.5 pecks/bird/hour. Lambton *et al.* (2010) recorded bouts of pecking rather than individual pecks in free-range flocks, and reported GFP at 0.65 bouts/hen/hour and SFP at 1.22 bouts/bird/hour.

Economic consequences

There is a complex relationship between FP, other forms of injurious pecking, and cannibalism which makes estimating the economic consequences of FP behaviour complicated. Birds with poor plumage cover have less thermal insulation, and, in cooler environments, they lose more body heat. Reduced plumage cover is thus linked with lower food conversion ratio or feed efficiency and bald chickens need up to 40% more feed to maintain body temperature (Blokhuis *et al.*, 2007) and the birds are less efficient at converting energy from feed into egg mass. Additionally, due to stress from being pecked, so-called 'pariah birds' may be less likely to access feeders and drinkers.

Feather pecking during the rearing period is not associated with increased mortality (Huber-Eicher, 1999). However, FP in adults is associated with significantly increased mortality (Johnsen *et al.,* 1998; Green *et al.,* 2000). At both an individual (Fossum *et al.,* 2009) and flock (Green *et al.,* 2000) level there is an association between FP and an increased risk of diseases such as egg peritonitis and infectious bronchitis.

Sometimes SFP can lead to cannibalistic pecking directed at live birds, although such behaviour can be directed towards the carcasses of birds that may have died from unrelated causes. In caged birds, mortality due to cannibalism has been reported at 14.1% (Tablante *et al.,* 2000), and 3.5% (Sherwin *et al.,* 2010). In furnished cages, although overall mortality is generally very low, the proportion due to cannibalism can be high, at varying reported levels of 5.0% (Fossum *et al.,* 2009), 8.67% (Sherwin *et al.,* 2010) and 65.5% of the overall mortality (Weitzenbürger *et al.,* 2005). In non-cage systems mortality rates can be much higher than in cages, not infrequently occurring at rates of over 15 or even 20% (Blokhuis *et al.*, 2005; Blokhuis *et al.,* 2007; Rodenburg *et al.*, 2012). In these systems FP and cannibalism are described as one of the 'dominating' (Abrahamsson *et al.,* 1998) or main causes (Rodenburg *et al.,* 2008) of flock mortality. In an analysis of dead birds submitted for post-mortem examination in Sweden, the proportion of mortality ascribed to cannibalism was 18.6% from indoor non-cage systems and 26.1% from free-range (Fossum *et al.,* 2009). In the UK, Sherwin *et al.* (2010) reported similar a similar proportion of 26% for indoor barn systems, although they found a lower proportion of 6% for free-range systems.

Methods of control – beak trimming

Beak trimming conducted either by infra-red (IR) or hot blade (HB) (Dennis *et al.,* 2009) remains the main method of controlling FP. In adult birds, beak-trimming is associated with reduced plumage damage (Staack *et al.,* 2007; Lambton *et al.,* 2013) , thought to be because the birds perform less SFP (though more GFP) (Gilani, 2012; Lambton *et al.,* 2013). However FP and plumage damage can still be observed at high levels in beak-trimmed flocks (Green *et al.*, 2000; Lambton *et al.,* 2013), although the effects of beak-trimming on younger birds are less clear. Staack *et al.* (2007) found increased plumage damage in pullets that had been beak-trimmed compared with pullets with intact beaks on 50 rearing farms in Germany and Austria.

Thus, the effectiveness of beak trimming as a control method is not absolute, and it additionally raises welfare issues in its own right. HB trimming causes pain and changes in beak sensitivity and function (Freire *et al.,* 2008; Jongman *et al.,* 2008; Freire *et al.,* 2011). IR trimming has been proposed as a more precise and effective method (Dennis *et al.,* 2009), but there is disagreement about whether it is more humane (Gentle and McKeegan, 2007; Marchant-Forde *et al.,* 2008; Dennis *et al.,* 2009). Beak blunting is a possible alternative method of reducing the damage that birds may inflict if they feather peck, although its effects on plumage condition and mortality are relatively minor (Fiks-van Niekerk and Elson 2004; van de Weerd and Elson, 2006).

Most member states of the EU permit beak trimming before 10 days of age (FAWC, 2007), but organic certification bodies prohibit the use of routine beak trimming, and a number of member states are currently considering whether the practice of beak-trimming should be banned completely (Van Horne and Achterbosch, 2008). Furthermore, in some EU countries such as Austria, there is an increasing demand for eggs from hens with intact beaks. Clearly, there is a need to find improved methods of preventing FP.

Methods of control – light regime

Farmers frequently try to control FP by reducing the light intensity in the laying house, or by using light of specific wavelengths such as red, blue or ultraviolet (Mohammed *et al.,* 2010). The intention is to diminish the birds' perception of colours and the details and reflectivity of their flock mates' plumage (Bright, 2007) as well as to reduce overall activity levels. Excessive light has been identified as one factor initiating FP (Kjaer and Vestergaard, 1999; Drake *et al.*, 2010; Mohammed *et al.*, 2010), while low light intensities reduce SFP (Tauson, 2005).

As with beak trimming, there are disadvantages to this method of control, in relation to eye anatomy and function (Prescott *et al.,* 2003). The axial length of the eye normally increases in daylight whilst choroidal thickness increases at night, so low light intensity during the day causes disproportionate development (Nickla *et al.*, 2001). Additionally, the ability to focus is influenced by light input (Prescott *et al.,* 2003). Other consequences of low light intensity are a reduced latency for birds to move between perches (Taylor *et al.*, 2003) and stereotyped GFP, which may result if impaired vision increases the tendency for exploratory pecking (Kjaer and Vestergaard, 1999; Sedlackova *et al.,* 2004).

The provision of red light is often applied to control FP (Mohammed *et al.*, 2010) as it reduces the detection of blood and naked skin. Red light should not be used as a general preventive measure, as photoreceptor sensitivity in the retina can be affected by the lack of other wavelengths penetrating the eye (Prescott *et al.,* 2003; Lind and Kelber, 2009). Housing under UV-deficient conditions can negatively affect basal corticosterone levels and exploration (Maddocks *et al.*, 2001) and a lack of UV light might encourage FP (Prescott *et al.,* 2003). However, evidence for this is mixed. Bestman *et al.* (2009) and Drake *et al.* (2010) found that daylight (with UV) provision during rearing increased the risk of FP during lay. In contrast, Yngvesson *et al.* (2011) found reduced feather damage and cannibalism in flocks with access to daylight through windows compared with flocks housed without windows. The type of light and intensity should be chosen based on age to diminish the negative effects on eye development. Light type can be used as curative measure while light intensity can be used as preventive measure on the basis of age of the birds.

Dark brooders

Under commercial conditions, young chicks are usually kept warm using brooders or whole house heaters. Under these conditions, they experience periods of continuous light for up to 24 hours in the first week of their life. A consequence of continuous light is that active chicks disturb inactive chicks. Crucially it also appears that FP is mainly directed towards inactive chicks by active ones (Riber and Forkman, 2007). Under natural conditions, chicks rest frequently in the dark under the feathers of their mother. The provision of dark brooders, where chicks can enter a heated area through a fringed perimeter, has resulted in greatly reduced FP in small scale experiments (Jensen *et al.,* 2006). Recently, the use of dark brooders on two commercial rearing farms was examined. Each farm contributed two identical but separate houses (dark brooder versus regular brooder) and 10 flocks in total were examined. Dark brooders were present for 16 weeks on the first farm and for eight weeks on the second. On average, across observations taken from one to 35 weeks, flocks with access to dark brooders exhibited significantly less SFP than control flocks, and had significantly better feather cover (Gilani *et al.,* 2012).

Genetics and selection programmes

Whereas beak-trimming and light manipulations are both commonly used in an attempt to reduce FP, other potential methods have not been so readily implemented. A promising alternative route is to select birds with a reduced tendency to peck or be pecked. Considerable differences in FP and feather damage exist between different commercial hybrids, and more specifically between white and brown egg layers (*e.g.* Oden *et al.,* 2002). Even different colour variants of the same strain differ in both pecking behaviour and the attractiveness of their plumage as a pecking substrate (Bright, 2007). Keeling *et al.* (2004) found pigmented birds (white with brown pigmentation) to be significantly more vulnerable to feather-pecking than white birds, probably due to the fact that the combination of white and brown feathers offers a clear contrast which is attractive to peck at. Uitdehaag *et al.* (2008) compared feather damage in six purebred White Leghorn (WL) lines and six Rhode Island Red (RIR) lines in cage housing. They found higher levels of fearfulness and feather damage in the WL lines. If RIR birds were mixed with WL birds, the RIR birds became more fearful and developed FP, mainly directed at the WL birds (Uitdehaag *et al.*, 2009). These results from cage experiments, however, may not be comparable to results from commercial non-cage flocks. When housed in an aviary system, RIR birds showed more FP and feather damage than WL birds (Kjaer, 2000).

To date, laying hen breeding companies have mainly focused on individual selection for egg laying performance. But selection against FP can have other beneficial effects, including reduced stress responses in social situations (Kjaer and Jorgensen, 2011). With an imminent future of large flocks of laying hens kept under NC systems, this may not result in birds with desirable traits: birds with high individual performance may also show high levels of FP and/or cannibalistic behaviour, lowering group performance (Rodenburg *et al.*, 2010). By using group selection techniques, it is possible to reduce mortality due to FP and cannibalism and improve overall group productivity (Muir, 1996). Based on Muir's results, Ellen *et al.* (2007) developed methods for a selection scheme in which information of the (individually housed) selection candidate was combined with information from its siblings housed in family groups. This method was used for a selection experiment on low mortality in group housing, with a 10% decrease in mortality in the first generation of selection (Rodenburg *et al.,* 2010). Further selection on low mortality resulted in birds that were less fearful and sensitive to stress, both as chicks (Rodenburg *et al.*, 2009b) and adult hens (Bolhuis *et al.*, 2009; Rodenburg *et al.*, 2009a). Further, in the latter two studies changes in the serotonergic system, which plays an important role in coping with fear and stress, were detected. This type of selection, where the focus is not only on individual performance but also on group performance, holds great promise for the future if breeding companies can be persuaded to adopt similar techniques.

Identification of risk factors

Risk factors for FP in commercial systems can be identified by taking an epidemiological approach that considers the influence of small and large-scale management factors and their interactions. Studying FP *in situ,* rather than instigating it experimentally and causing additional harm, has ethical advantages and practical value since FP outbreaks can be rare or unpredictable in experimental settings. Experimental studies provide a useful adjunct, where there is little on-farm variability in management practice or where cause and effect relationships require further investigation.

RISK FACTORS DURING THE REARING PHASE

Environmental and management factors experienced by birds during rearing have been identified as particularly important to the development of later FP in adult flocks housed in barn, free-range and organic systems (Johnsen *et al.,* 1998; van de Weerd and Elson, 2006, Riber *et al.,* 2007; Staack *et al.,* 2007; Rodenburg *et al.*, 2008, Bestman *et al.,* 2009; Lambton *et al.,* 2010; Gilani, 2012). Reducing stressors between rearing and laying units seems important, and both Bestman and Wagenaar (2003) and Drake *et al.* (2010) found that FP in adult flocks was lower if birds were reared on the same farm as they were kept during lay.

Given the importance of early access to substrate (Rodenburg *et al.,* 2013), practices such as grain scattering and the presence of litter during the first four weeks of life can be highly protective during the rearing period (Van de Weerd and Elson, 2006; Knierim *et al.*, 2008; Bestman *et al.*, 2009). Stocking density is important during this early period. Organic flocks that did not feather peck had an average of 21 birds/m^2 in the first four weeks of life, whereas flocks that showing FP had 34 birds/m^2 (Bestman *et al.,* 2009). Huber-Eicher and Audige, (1999) found that birds reared at a stocking density greater than10 birds/m^2 were more likely to develop FP. But, as stocking density, space allowance and group size are inter-related, further studies are needed to reveal their independent effects on commercial farms. In an experimental study Savory and Mann (1999) found the negative effects of higher stocking density on FP were more apparent in larger group sizes.

The availability of perches can decrease pecking as shown by Gunnarsson *et al.* (1999) who found that access to perches from not later than four weeks decreased cloacal cannibalism during the entire laying period, Huber-Eicher and Audige (1999) who found that perches reduced the risk of FP fourfold, and Knierim *et al.* (2008) who found a protective effect of perches on 23 organic rearing farms.

Two prospective studies have observed pullets during the rearing phase and followed their progress during transfer and subsequent housing in laying units. Drake *et al.* (2010) analysed the factors that resulted in laying flocks exceeding the threshold plumage damage level described earlier; these included the presence of chain feeders, bell drinkers, and fluorescent or natural light, as opposed to tungsten bulbs. Gilani (2012) observed different sets of risk factors for GFP and SFP during rearing. The breed of bird and atmospheric conditions in the house (dust, noise, temperature) had a significant influence on GFP, whereas the risk was significantly increased if birds foraged less and if they experienced more than one or two diet changes during this period. Feeder type during rearing was a factor that continued to influence SFP throughout the laying period, with a mix of feeder types present at 16 weeks resulting in lower SFP than either chain or hopper feeders alone.

RISK FACTORS DURING THE LAYING PHASE

Housing system has an important effect on plumage condition, with generally better feathering is seen with furnished cages (FC) compared with non-cage (NC) systems (Blokhuis *et al.*, 2005; Sherwin *et al.,* 2010). In contrast, Rodenburg *et al.* (2008) found no difference in plumage condition in 13 flocks housed in FC and NC systems in the Netherlands, Belgium and Germany. Since FP is particularly prevalent in NC systems, where a pecking bird has access to a large number of conspecifics (Keeling and Jensen, 1995), increased plumage damage may be a consequence of the increased use of larger colony sizes in furnished cages in recent years (Rodenburg *et al.,* 2008).

In NC systems, stocking density and group-size effects can be important, although no clear conclusions can yet be drawn. When flock sizes varied between 72 and 368, Nicol *et al.* (1999) saw FP increase with increasing stocking density, but subsequent work on flock sizes of between 2,450 and 4,200 (Zimmerman *et al.,* 2006) showed the opposite relationship. Larger farms, with up to 30,000 birds, often subdivide flocks into smaller colonies in an attempt to prevent the spread of FP throughout the whole flock but there is no scientific evidence regarding the effectiveness of this practice.

Cross-sectional studies can provide an initial overview of factors associated with FP. Green *et al.* (2000) surveyed 198 flocks of hens housed in NC systems in the UK via a questionnaire. A greater risk of FP was associated with less than 50% of the flock using the range on fine sunny days; more than three diet changes during the laying period, one person inspecting the flock; increasing light intensity during flock inspections, no loose litter remaining at the end of the laying period; a house temperature of less than 20°C; the use of bell drinkers rather than nipple drinkers and the use of lights in nest boxes. The same dataset showed areas of overlap and difference in the risk factors for pecking (Pötzsch *et al.*, 2001); factors associated with an increased risk of VP were frequent diet change, the use of bell drinkers, early onset of lay and light in the nest-boxes.

Having an outdoor range can affect the occurrence of FP (Bestman and Wagenaar, 2003). However, the provision of a range itself is not sufficient to obtain a reduction in plumage damage (Häne *et al.*, 2000) birds must make maximal use of the range provided. Range use is facilitated by factors such as the amount of natural cover on the range (Bright *et al.,* 2011), or the provision of artificial shelters (Zeltner and Hirt, 2003). In small organic flocks, the presence of cockerels in a flock can encourage hens to use the range, as can relatively early placement on the laying farm (Bestman and Wagenaar, 2003). Early access to range during the rearing period can increase the proportion of the flock using the range as adults, though this does not seem to increase the distance that birds will go from the house (Gilani *et al.*, 2011).

Nicol *et al.* (2003) used a case-control design to increase the power of their study to identify risk factors for FP. Fifty case-study flocks, where FP had recently been detected, were compared with 50 similarly-aged control flocks, where FP was absent. FP flocks were more likely to be restricted from litter areas (in an attempt by the farmer to prevent floor eggs) and had wire staging rather than plastic staging in the house. The importance of range use was again highlighted as the risk of FP was reduced nine-fold where more than 20% of birds used the range on sunny days.

Prospective cohort studies allow an assessment of important risk factors at different life stages of a flock and two have been conducted during the laying period. Lambton *et al.* (2010) visited free-range flocks at 25 and 40 weeks of age and, in line with the results of cross-sectional and case-control studies, found that both GFP and SFP were associated with reduced range use. Other risk factors, such as a lower house temperature, increased local stocking density and no perch access were specifically associated with GFP, whilst spreading feed on the litter was specifically associated with increased SFP. Even though few farmers now feed pellets based on previous evidence of its potential to stimulate FP (Aerni *et al.,* 2000), this practice emerged as another specific risk for SFP. Plumage damage increased with age, was correlated with SFP and was 24 times more likely when flocks were kept on slats (without litter) during the early laying period, to discourage floor-laying. Drake *et al.* (2010) found plumage damage increased with the provision of raised chain feeders and with higher carbon dioxide, ammonia and light levels during early lay.

These epidemiological studies all reinforce the view that FP is a multifactorial problem in commercial situations. Risks identified in multiple studies include poor range use, pelleted feeds and restriction of access to litter, but these seem to act in combination with other features of house design and environment and with breed of bird. Thus management strategies must be considered holistically and approaches taken to improve the match between the commercial hybrid used and the system during both rear and lay.

Management tools to control FP

In a few cases, risk factors identified as part of epidemiological investigations have been subsequently tested under controlled conditions. Zimmerman *et al.* (2006) and Nicol *et al.* (2006) examined the influence of nipple rather than bell drinkers, and not using lights in the nest box (originally identified as risks by Green *et al.,* 2000) and confirmed the protective effect of these in reducing FP and plumage damage.

In the UK, a recent project examined the effects of using the scientific literature as a guide to devising practical interventions to reduce FP. More than forty strategies associated with reduced FP and damage, which could be implemented commercially on farms, were identified based on a review of over 500 papers. The benefits of using these management strategies were then studied in 100 flocks on UK free-range farms by monitoring pecking and plumage condition at 20, 30 and 40 weeks of age. For 53 of the flocks, information and resources were provided to encourage the uptake of the specific management strategies most relevant to that farm. This additional input led to the uptake of a further five and a half different strategies on average. The more management strategies that were employed the lower the rates of GFP and SFP, the lower the plumage damage at 40 weeks. GFP was lower when farmers used strategies that improved litter quality, such as using specialised bedding and scattering grit, and where nest box lights were not used. SFP was lower where natural shelters were provided on the range and where aerated breeze blocks were provided on the slats to encourage pecking and beak blunting (Lambton *et al.*, 2013).

In the Netherlands, initiatives are being developed to translate scientific findings into practical advice. Based on the findings of Bestman and Wagenaar (2003), for example, steps have been taken to persuade organic farmers to increase levels of daylight and to offer alfalfa as an additional roughage source throughout the rearing period. Future work should evaluate such programmes and present information about why farmers find some changes easy to make and others more difficult. Stakeholder meetings between researchers and farmers are now taking place in the UK and the Netherlands to identify farmers' views about the prospects and difficulties of keeping non beak-trimmed hens. The results of such studies should help to inform future policy decisions and highlight areas where advice and support is still required.

Conclusions

FP remains a significant problem on many laying hen farms. It is a sign of progress that information obtained from fundamental studies is now being used to design genetic selection and management programmes aimed at reducing FP on commercial farms. The next stage will be to evaluate systematically the success of such programmes and to determine whether the welfare of laying hens can be assured, when traditional methods of control (light reduction, beak trimming) are no longer employed.

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