

The prevention and control of feather pecking in laying hens: identifying the underlying principles

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Feather pecking (FP) in laying hens remains an important economic and welfare issue. This paper reviews the literature on causes of FP in laying hens. With the ban on conventional cages in the EU from 2012 and the expected future ban on beak trimming in many European countries, addressing this welfare issue has become more pressing than ever. The aim of this review paper is to provide a detailed overview of underlying principles of FP. FP is affected by many different factors and any approach to prevent or reduce FP in commercial flocks should acknowledge that fact and use a multifactorial approach to address this issue. Two forms of FP can be distinguished: gentle FP and severe FP. Severe FP causes the most welfare issues in commercial flocks. Severe FP is clearly related to feeding and foraging behaviour and its development seems to be enhanced in conditions where birds have difficulty in coping with environmental stressors. Stimulating feeding and foraging behaviour by providing high-fibre diets and suitable litter from an early age onwards, and controlling fear and stress levels

through genetic selection, reducing maternal stress and improving the stockmanship skills of the farmer, together offer the best prospect for preventing or controlling FP.

Keywords: laying hen; feather pecking; ontogeny; fearfulness; environmental enrichment; foraging

Introduction

Feather pecking (FP), *i.e.* the pecking, pulling out and eating of feathers of conspecifics, remains an important welfare issue in laying hens. With the ban on conventional cages in the EU from 2012 following Council Directive 1999/74/EU and the expected future ban on beak trimming in many European countries in the future (Van Horne and Achterbosch, 2008), addressing this welfare issue has become more pressing than ever. In large group housing systems, such as large furnished cages but especially non-cage systems, FP is much more difficult to control than in conventional cages (Rodenburg *et al.*, 2012). It is challenging to identify and remove the feather peckers in these systems and feather peckers have many more potential victims compared with cage systems. Also FP may spread through the flock by social transmission. The aim of this review paper is to provide a detailed analysis of the underlying principles of FP. We shall describe different forms of FP and their causes. Then we shall move to the relationships between FP, feeding and foraging behaviour and describe the link with dietary aspects. Further, we will explore the role of the parental environment and its effect on maternal hormones. Finally, we shall focus on the role of individual behavioural characteristics and the relationship between the ability to cope with fear and stress and the development of FP. Taken together, this enables us to formulate promising strategies to reduce FP in commercial flocks of laying hens.

Forms of feather pecking

Two different forms of FP can be distinguished: gentle and severe FP (Savory, 1995). Gentle FP (GFP) consists of gentle pecks to the tips of the feathers. This type of FP usually does not result in much damage and is generally ignored by the recipient, although stereotyped gentle FP can indicate a welfare problem in the bird performing the behaviour. Severe FP (SFP) is the most problematic type of FP in terms of damage to the recipient. It consists of forceful pecks and pulls of feathers that are frequently eaten and results in feather loss on the back, vent and tail area. Victims of SFP often initially show a behavioural response to receiving SFP, either by moving away or by confronting the pecker. If SFP continues, however, victims have also been observed to surrender to being pecked and remain still. SFP results in damage to the feathers and feather loss which leads to bald patches and can be followed by tissue pecking, a form of cannibalistic pecking where pecking continues on the skin, leading to wounds. Tissue pecking can eventually lead to the victim's death due to excessive blood loss and tissue damage. A separate form of cannibalistic pecking is vent pecking, where the pecker pecks at the vent of the victim and may pull out the inner organs. This type of cannibalistic pecking can also develop in well-feathered birds and is sometimes seen around the onset of egg laying (Newberry, 2004). Cannibalistic pecking can also be observed in the form of toe pecking (Glatz and Bourke, 2006; Rodenburg *et al.*, 2009b). There is some evidence that victims of FP are also more likely to receive high levels of

toe pecking (Leonard *et al.*, 1995). Aggressive pecking is a separate form of bird-to-bird pecking which, together with threatening behaviour, is used to establish and maintain dyadic relationships between birds, resulting in a stable dominance hierarchy. Aggressive pecks are forceful pecks directed at the head or neck of the recipient, but usually these pecks do not result in much feather damage (Savory, 1995). FP is not a form of aggressive behaviour.

An important issue in FP research is to determine whether GFP can develop into SFP, in other words: is GFP a predictor or a precursor of the more damaging SFP? Most studies that have investigated this relationship would say that it is not (Rodenburg *et al.*, 2004b; Lambton *et al.*, 2007; Newberry *et al.*, 2007; Hughes and Buitenhuis, 2010). Rodenburg *et al.* (2004b) showed that although the vast majority of birds 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 (birds performing SFP would also show GFP). Similar results were found by Newberry *et al.* (2007), who further distinguished between exploratory GFP and stereotyped GFP. They found that SFP in adult birds was correlated with foraging and exploratory pecking when these same birds were young, but not with stereotyped GFP. Indeed, Lambton *et al.* (2007) studied the relationship between GFP and SFP in commercial flocks and found no evidence that high levels of GFP would lead to high levels of SFP. This is confirmed by a gene expression study by Hughes and Buitenhuis (2010), showing that GFP and SFP have distinct gene expression patterns. Conversely, Chow and Hogan (2005) suggested that GFP could develop into SFP, based on the observation that GFP decreased and SFP increased over time. This relationship was, however, not confirmed by correlating GFP in young birds and SFP in these same birds when adult. The distinction between GFP and SFP has not always been made in earlier studies.

Causes of feather pecking and the importance of litter

There are several theories about causes of FP behaviour. Vestergaard and Lisborg (1993) hypothesised that FP is related to pecking during dustbathing. They found that birds that were reared with substrates that are unsuitable for dustbathing, such as feathers, showed more FP. However, Blokhuys (1989) proposed that FP is more likely to be a form of redirected ground pecking behaviour, derived from foraging. He showed that laying hens will develop FP in the absence of a suitable foraging substrate. In line with his observations, Huber-Eicher and Wechsler (1997) found that access to straw, a foraging substrate, did decrease FP, but access to sand, a dustbathing substrate, did not or only to a limited extent. This is supported by a study showing that peat in early rearing (that is preferred for dustbathing but not for foraging) did not reduce early FP behaviour (Dixon and Duncan, 2010). In a study by Johnsen *et al.* (1998), pullets were raised on sand, straw, or wire between 0-4 weeks of age. Thereafter all groups were kept on sand and straw. Hens raised on wire had the poorest plumage condition, showed more FP, had a lower dustbathing activity, and had higher mortality rates due to cannibalism, compared to hens on litter. This may indicate that the first four weeks of life have a large influence on the development in FP behaviour. This could however not be confirmed by Nicol *et al.* (2001). In their study, birds were kept on wire floors, and, at different ages, wire was replaced by solid floors with wood shavings. Adult hens kept on wire floors during their entire life, showed more SFP compared to hens kept on floors with wood shavings. However, this study also showed that current substrate exposure played a major role: regardless of previous

experience, birds housed on shavings even later in rearing showed less FP and more foraging compared with birds housed on wire (Nicol *et al.*, 2001). Huber-Eicher and Wechsler (1997) further showed that age of exposure seemed to influence SFP rates. Pullets that had access to litter from the age of 10 days showed more FP, compared to pullets that had access to litter from one day after hatching. The importance of litter in early rearing was further studied in two experiments by De Jong *et al.* (2013). In the first experiment birds were housed on litter (wood shavings or sand) during the entire experiment, or on mesh matting or chick paper for the first three weeks and provided with either wood shavings or sand thereafter. Results showed that providing chicks with litter increased foraging and reduced FP until four weeks of age, but not after this time. It was suggested that, in line with Nicol *et al.* (2001), adult behaviour seemed to be strongly determined by the current substrate (De Jong *et al.*, 2013). In a second experiment, chicks were reared on mesh matting or wood shavings during the first three weeks of life, and thereafter both treatments received wood shavings. Frequency of SFP was low in both treatments, but birds reared on mesh did show more SFP at four and eight weeks of age, and more GFP as adults than birds reared on wood shavings (De Jong *et al.*, submitted). This indicates that early experience with substrate has a long-lasting effect on pecking behaviour. Blokhuis and Van Der Haar (1992) showed that supplying grain in the litter could be used to further stimulate foraging and reduce FP. Other devices such as bunches of white string, that encourage environmental pecking, also have been used successfully to reduce FP (McAdie *et al.*, 2005), confirming the link between FP and exploratory behaviour. These studies confirm that early access to litter for foraging, preferably straw or wood shavings, is an important factor in the reduction of FP. This approach could be combined with supplying grain in the litter or other pecking devices.

Individual variation in foraging behaviour

Apart from environmental factors, such as litter supply, variation in foraging behaviour will affect the risk of FP. Newberry *et al.* (2007) confirmed that birds that exhibited more foraging as chicks, were more likely to develop SFP as adults. However, they also showed that FP did not replace ground pecking behaviour: feather peckers continued to show high levels of ground pecking in their study. Line differences in foraging behaviour have also been found between lines characterised as high or low FP: birds from a low FP line spent more time on foraging and feeding behaviour and showed less (gentle) FP behaviour compared to a high FP line (Van Hierden *et al.*, 2002a; Rodenburg and Koene, 2003). Low FP birds may be less likely to redirect their pecks to the feathers of conspecifics. If FP is related to foraging motivation, then the provision of a suitable litter substrate should facilitate more normal foraging behaviour and discourage FP; and this is generally found to be the case. In the absence of litter, more FP occurs, although availability of litter will not eliminate FP completely (Blokhuis and Van Der Haar, 1992; Nicol *et al.*, 2001). When developing strategies to reduce FP, individual and strain differences in pecking motivation and in the risk of redirecting foraging pecks to feathers of conspecifics need to be taken into account.

Motivational background of gentle and severe FP

GFP and SFP each seem to have their own motivational background. GFP has also been suggested to be a form of social exploration, with pecks frequently directed at unfamiliar

individuals (Riedstra and Groothuis, 2002). This may partially explain why GFP is seen more frequently in young birds, where social relationships still have to be established, compared to adult birds (Chow and Hogan, 2005). In adult birds, GFP can be observed as stereotyped GFP, for instance in the form of frequent pecks on the tips of the tail feathers. McAdie and Keeling (2002) suggested that stereotyped GFP may develop from normal GFP as observed in young birds. However, Newberry *et al.* (2007) found no indications for this relationship, rather birds showing stereotyped GFP when adult were more likely to have displayed the same behaviour when young. SFP has been related to a range of dietary factors. It is certainly associated with feather eating (McKeegan and Savory, 1999; Ramadan and Von Borell, 2008; Harlander-Matauschek and Häusler, 2009). McKeegan and Savory (1999) showed that groups of hens with high levels of FP had fewer feathers on the floor. Indeed Ramadan and Von Borell (2008) found that removing loose feathers from the litter during rearing, and hence avoiding the development of feather eating, reduced FP during the laying period, thus confirming the relationship between SFP and feeding. If hens learn to eat feathers from the floor, it is possible that they will redirect this behaviour towards conspecifics when feathers on the floor are no longer present. A joint cause of SFP and feather eating may be the relatively low fibre content of most commercial laying hen diets. The different motivational background of GFP and SFP underlines the importance to distinguish between both behaviours.

Impact of dietary factors

Diet composition is known to influence FP behaviour. Protein, minerals, energy, and fibre levels can affect SFP (Van Krimpen *et al.*, 2005). Evidence was found in the literature that a dietary deficiency of crude protein (Ambrosen and Petersen, 1997), and, more specifically, of the amino acids lysine (Al Bustany and Elwinger, 1987a; 1987b) and methionine + cysteine (Elwinger *et al.*, 2002) increased SFP behaviour, as indicated by a poorer plumage condition. SFP increased when levels of crude protein, lysine or methionine + cysteine were reduced below 125, 8.2 and 5.1 g/kg, respectively. Dietary recommendations to realise maximal egg performances for these nutrients are 150, 6.9, and 5.8 g/kg, respectively (NRC, 1994), indicating that SFP is not expected to increase if the diets fulfil the standard crude protein and methionine + cysteine requirements. The desired dietary lysine content for realising optimal plumage condition, however, is higher than the lysine content required for maximal egg performances. Likewise, SFP increased in case of dietary deficiencies of magnesium (about 0 g/kg, whereas 0.5 g/kg is recommended) (Schaible *et al.*, 1947), sink (<10 ppm, whereas 40 ppm is recommended) (Sunde, 1972), and sodium (<0.3 g/kg, whereas 1.5 g/kg is recommended) (Hughes and Whitehead, 1974). This shows that dietary factors play an important role in the risk of FP.

Dilution of the diet and high fibre diets

Reduced energy levels in the feed can improve plumage condition (Van Der Lee *et al.*, 2001). This can be realised by diluting the diet, for instance by adding insoluble fibre. Dilution of the diet, leading to reduced energy content, led to increased feeding time in Japanese quail (Savory, 1980). This could result in decreased time spent on SFP, as this problem is related to feeding behaviour. In hens, it has been suggested that increasing the dietary fibre content above 80 g/kg could result in reduced FP occurrences and improved plumage (Esmail, 1997). Insoluble fibres, such as non-starch polysaccharides (NSP's), are

especially effective in increasing eating time in laying hens (Van Krimpen *et al.*, 2007). Fibre may have positive effects on gut motility and satiety. Due to the accumulation of fibre in the gizzard, the passage rate of the digesta through the gizzard was reduced when increased levels of coarse fibre were included in the diet, which may increase the feeling of satiety in the bird and reduce the propensity to peck and eat feathers of conspecifics (Hetland *et al.*, 2004; Van Krimpen *et al.*, 2011). Harlander *et al.* (2007) compared feather eating behaviour in birds selected for high and low FP and found that high FP birds were more motivated to eat feathers. They also showed that feathers had a positive effect on gut motility, which may be similar to the effect of NSP's (Harlander-Matauschek *et al.*, 2006), illustrating that hens may indeed eat feathers to increase satiety. The effects of feeding low energy diets or high NSP diets during the rearing and laying period were studied by Van Krimpen *et al.* (2009). Pullets that were fed low energy diets compensated for the level of nutrient dilution by a proportionally increased feed intake. In contrast to findings in adult laying hens, they increased their eating rate, without increasing eating time. Nevertheless, reduced energy levels during the rearing period reduced SFP behaviour during the laying period, indicating that the increased focus on feed in the rearing period reduced the preference for feathers of conspecifics during the laying period. Providing high insoluble NSP diets during the laying period, however, resulted in less feather damage compared to the hens that were given standard non-diluted diets. The positive effects of feeding NSP diluted diets on feather damage during the laying period were greatest if these diets were provided during both the rearing and laying period, rather than only during the rearing or the laying period (Van Krimpen *et al.*, 2010). A daily insoluble NSP intake of at least 10 g/pullet/d during the rearing period and 16 g/hen/d during the laying period was found to minimise the risk of SFP behaviour (Van Krimpen *et al.*, 2009; Van Krimpen *et al.*, 2012). Dietary factors that increase the time spent on feeding-related behaviour and induce satiety can be expected to reduce FP in rearing and laying hens. This is underlined by the finding by Webster (1995) that fasting indeed led to an increase in FP behaviour. Taken together these results indicate that dilution of the diet and feeding high fibre diets are promising routes to reduce SFP.

The role of maternal hormones

Apart from environmental effects, other factors also play a role in the behavioural development of the chick and the risk of developing FP. The avian egg yolk is the main source of nutrients for the developing chick embryo, and contains significant quantities of steroid hormones, such as oestrogens and androgens. These steroid hormones can have long lasting organising effects on the brain and behaviour of individuals (Schwabl, 1993; Von Engelhardt and Groothuis, 2011). The deposition of hormones in the yolk is a mechanism by which the mother can adjust the development of her offspring to the prevailing environmental conditions (Groothuis *et al.*, 2005). There are several reasons why studying hormone-mediated maternal effects is important for understanding FP (and behavioural pathologies in general): Firstly, laying hen parent stock is frequently housed in large flocks and thus birds encounter many conspecifics. Social interactions, such as aggressive challenges, stimulate androgen production, whereas both social and non-social challenges, such as stressful events in the environment, may influence glucocorticoid levels in the mother. Both experimental and correlational evidence shows that social factors such as social density can be reflected in the hormone content of the eggs (see Groothuis *et al.*, 2005). There may therefore be an association between the hormonal balance of the mothers and

development of FP in their offspring. Indeed, Hughes (1973) found that the amount of FP and cannibalism could be reduced by administering testosterone to pullets. El-Iethy *et al.* (2001) showed that feeding young laying hens corticosterone led to reduced growth, increased flightiness and increased FP later in life. Janczak *et al.* (2007) found that chicks from a stressed mother, with elevated faecal corticosterone levels, were more fearful and less competitive than chicks from a non-stressed mother. Similar effects were found when eggs were treated with corticosterone (Freire *et al.*, 2006), indicating that indeed maternal stress translates to the offspring.

Secondly, there may be a mismatch between the environment in which the parental strains produce the fertile eggs containing the next generation and the environment in which the layer chick, and later hen, is reared and kept to produce consumer eggs. The most obvious difference is the presence of males in the parental generation and their absence in the laying hen flock. In addition the housing system can be quite different (for instance floor housing versus aviary housing). If indeed hormonal deposition in the yolk is adaptively tuned to the maternal environment (Groothuis *et al.*, 2005), then the laying hen flock may not be optimally adapted to their living environment. Thus the hormonal balance of the egg is a possible predictor for the development of later pathological behaviour. Studies are needed in commercial flocks, investigating the relationship between stress in the parent stock, the hormonal contents of their eggs and the behavioural development of their offspring. If such a relationship can be confirmed, reducing stress in parent stock flocks, for instance by lowering stocking density or group size, or creating a better match between parent stock and laying hen housing could be a viable way to reduce FP.

Behavioural traits and coping with fear and stress

Behavioural characteristics of individual birds, such as fearfulness and social motivation, also play a role in the development of FP. Fearfulness is an individual's likelihood of being easily frightened (Jones, 1996). Associations between fearfulness and FP or feather damage have been found (Hughes and Duncan, 1972; Jones *et al.*, 1995; Rodenburg *et al.*, 2004a). While fear can be increased due to FP (Blokhuys and Beutler, 1992; Vestergaard *et al.*, 1993), increased fearfulness can also be a predictor for the development of FP. Rodenburg *et al.* (2004a) found that fearful chicks in an open field (OF) test (as indicated by a long duration of freezing) showed more GFP and SFP as adults. Similarly, Jones *et al.* (1995) found that chicks from a high FP line were more fearful in an OF test (longer latency to vocalize and walk) than chicks from a low FP line. In a commercial line selected on reduced group mortality due to FP (Ellen *et al.*, 2007), six-week old chicks showed less fear in an OF test in comparison to a non-group selected control line (Rodenburg *et al.*, 2009b). Fear responses may differ between young and adult hens (Hocking *et al.*, 2001). In adult hens, high activity in an OF has been associated with FP in various genetic lines and crosses (Rodenburg *et al.*, 2004a; Jensen *et al.*, 2005; De Haas *et al.*, 2010). Positive associations have been found between the duration of TI (as measure of fearfulness) and GFP and between TI and feather damage (Blokhuys and Beutler, 1992), where birds with a longer duration of TI had more damage. Similarly, Campo *et al.* (2008) reported a longer TI duration in victims of vent pecking. When comparing commercial lines, hens from a white breed origin had a longer TI duration at 13 weeks of age (Albentosa *et al.*, 2003) and 44 weeks of age (Mahboub *et al.*, 2004) compared to hens from a brown breed origin. Uitdehaag *et al.* (2008a) found hens from a white breed origin to be more flighty and to show more FP than hens from a brown breed origin. They performed multiple studies with purebred genetic selection

lines from a White Leghorn (WL) and Rhode Island Red (RIR) origin (Uitdehaag *et al.*, 2008a; 2008b; 2009). RIR hens were less likely to withdraw from a novel object and had less feather damage than WL hens. For both WL and RIR lines a positive association between response to the novel object and feather damage at a later age was found (Uitdehaag *et al.*, 2008b). Rodenburg *et al.* (2010) performed the same test with hens selected for high FP and low FP birds at 30 weeks of age, but did not find differences in fear response between the lines. For both lines however, increased levels of feather damage were associated with a withdrawal response to the novel object.

Additional physiological information may help in understanding the total concept of how an animal's ability to cope with fear and stress may influence FP (Korte, 2001). For example, restraining birds for a predetermined time is known to induce a physiological stress response by increasing corticosterone levels. Hens of a second generation group-selected for low mortality due to FP had lower corticosterone levels post-restraint (Rodenburg *et al.*, 2009a), struggled more and had higher whole-blood serotonin levels compared to non-selected controls (Bolhuis *et al.*, 2009). Similarly, high FP hens (selected directly for high FP behaviour (Kjaer *et al.*, 2001)) showed higher corticosterone (Kjaer and Guëmené, 2009) and a higher heart rate with lower heart rate variability in response to restraint (Kjaer and Jorgensen, 2011) compared to low FP hens. In lines which coincidentally differed in FP, high FP hens also had a higher heart rate with lower heart rate variability in response to physical restraint (Korte *et al.*, 1999). Birds from the high FP line in this study, however, had lower corticosterone levels than birds from the low FP line, both basal and in response to restraint (Korte *et al.*, 1997). Hens originating from lines which have a higher propensity to develop FP seem to be more sensitive to stress-eliciting situations. However, we should be aware that the environment, especially the rearing environment (Rodenburg *et al.*, 2008) and possible genotype by environment interactions may cause discrepancies between different genetic lines of laying hens.

It has been proposed that individual variation in the predisposition to develop SFP is associated with differences in serotonergic neurotransmission in the brain (Van Hierden *et al.*, 2002b; 2004a). Distribution of serotonergic fibres in the chicken brain (Metzger *et al.*, 2002) suggests an important role for serotonin in fear-related and social behaviour (Gruss and Braun, 1997). Acute reduction of serotonin turnover in the chicken forebrain resulted in increased GFP and SFP, whereas supplementation with L-tryptophan led to decreased GFP and a non-significant reduction in SFP (Van Hierden *et al.*, 2004b), indicating that the display of FP may be related to low serotonin neurotransmission. In line with this, brain serotonin turnover in young chicks from a high FP line was lower compared to chicks from a low FP line (Van Hierden *et al.*, 2002b). Furthermore, dopaminergic neurotransmission may play a role in FP, as FP has been reported to decrease following injection with the dopamine antagonist haloperidol (Kjaer *et al.*, 2004). Chicks from a high and low FP line differed in dopamine turnover (Van Hierden *et al.*, 2002b) and in sensitivity for the dopamine-agonist apomorphine (Van Hierden *et al.*, 2005). These studies indicate that there is scope for genetic selection for birds that have an improved ability to cope with fear and stress and, as a result, show reduced levels of FP.

Conclusions

The aim of this review paper was to provide a detailed analysis of the underlying principles of FP. What we have shown is that FP is affected by many different factors and that any approach to prevent or reduce FP in commercial flocks should

acknowledge this and apply a multifactorial approach to address the issue. A central and important factor remains stimulating feeding and foraging behaviour, either by nutritional approaches such as diluting the diet or supplying high-fibre diets, or by offering suitable litter preferably enriched with some feed ingredients (*e.g.* wheat or alfalfa) to stimulate foraging behaviour from an early age onwards. Focus is needed on early-life experiences, as it is clear that experiences with the absence or presence of litter during rearing has implications during later life. Based on what is known on the transmission of maternal stress to the offspring in birds, we need to investigate further how maternal stress affects behavioural development of the offspring and whether reducing maternal stress affects levels of FP. Clearly, differences in behavioural characteristics between birds from different genetic backgrounds should be taken into account, as there are clear differences in the ability to cope with fear and stress between different commercial hybrids. Recent selection experiments provide further evidence for the relationship between the ability to cope with fear and stress and the development of FP. Here, management plays a role as the level of fearfulness is related to the stockmanship of the farmer (Hemsworth and Barnett, 1989). In conclusion, based on what is known on causes of FP, an approach that addresses 1) the role of feeding and foraging behaviour in young and adult birds, 2) the parental environment and the role of maternal stress, and 3) the role fear and stress in the development of FP, provides the most scope for a sustainable solution to the issue of FP in laying hens.

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