Literature Featherpecking - All

Alm, M., et al. (2015). "Welfare and performance in layers following temporary exclusion from the litter area on introduction to the layer facility." Poultry Science **94**(4): 565-573.

When introduced to the laying facility, pullets are sometimes temporarily excluded from the litter area in order to help them locate food and water, and to prevent floor-laid eggs. This procedure is not permitted in Sweden, because it involves denying access to both litter and space, which may have a negative effect on bird welfare. The present study investigated how the welfare and performance of layers were affected by this temporary exclusion on introduction of hens to the laying facility. The study included 600 floor-reared Dekalb White layers obtained at 16 wk age and housed in 6 groups of 100 in a conventional single-tier floor-laying system. Birds were either given full access to the litter area during the whole study or were excluded from the litter area during the first 2 wk after transfer to the laying facility. From 18 to 72 wk age, birds in both treatments had full access to the litter area. Excluding birds from the litter area for 2 wk resulted in better feather cover and reduced fearfulness, according to novel object and tonic immobility tests. Furthermore, birds initially excluded from the litter area produced eggs with a lower proportion of shell irregularities than birds with full access to the litter area throughout. No difference was found in corticosterone metabolites in droppings rate of lay, mortality, or proportion of floor-laid eggs. In conclusion, none of the parameters studied indicated that the welfare of laying hens was compromised by temporary exclusion from the litter area on introduction to the laying facility. In fact, some of the data suggested that bird welfare had improved.

Altan, O., et al. (2005). "Heritabilities of tonic immobility and leucocytic response in sire and dam layer lines." Turkish Journal of Veterinary & Animal Sciences **29**(1): 3-8.

Fearfulness reaction was examined using tonic immobility (TI) response and differential leucocyte counts as physiological indicators of distress from sire and dam brown layer lines. The study was performed on 20 male and 131 female chickens from the sire line and 24 male and 116 female chickens from the dam line. The duration of TI, the time interval until the bird righted itself, and the number of inductions (15 s periods of restraint) necessary to attain TI were recorded. If TI could not be induced after 5 attempts, a score of 0 was recorded. After the TI test, blood samples were collected from 16 male and 45 female chickens in the sire line and 17 sires and 42 dams in the dam line and leucocyte parameters were examined. After the normality test, TI, tonic immobility per number of inductions (TI/Ind) and the heterophil:lymphocyte (H/L ratio) showed deviations from normality. After applying the Box-Cox transformation all data were analysed by a general linear model using JMP. Heritabilities and phenotypic correlations were also obtained. Significant line differences were obtained from TI reactions. There were no significant differences in the leucocytic parameters between lines, except for eosinophils. The H/L ratio was significantly higher in males than in females. Heritability estimates for the duration of TI and TI/Ind were low to moderate in the sire line, but moderate to high in the dam line. The results suggest that fearfulness could be controlled through selection.

Bestman, M., et al. (2009). "Influence of farm factors on the occurrence of feather pecking in organic reared hens and their predictability for feather pecking in the laying period." Applied Animal Behaviour Science **121**(2): 120-125.

Feather pecking is one of the most obvious welfare problems in laying hens. It is seen in all types of housing systems. Although banned in some countries, beak trimming is generally used to reduce the damage caused by this behaviour. In organic farming, where beak trimming is prohibited, the animals are being kept in a less intensive way than in conventional farming in order to improve their welfare. However, feather pecking is also seen in organic laying hens. Generally, rearing circumstances play an important role in the development of this behaviour. Therefore, rearing flocks were monitored for feather pecking and the relations between rearing factors and feather pecking at a young and at an adult age were analysed. Also the correlation between feather pecking during the rearing period and feather pecking during adult life was studied. Twenty-eight commercial flocks of rearing hens were monitored. These flocks split into 51 flocks of laying hens. Flocks were scored for signs of feather damage during rearing at the ages of 7, 12, and 16 weeks and on the laying farms at 30 weeks. On the rearing as well as the laying farm, data were collected on the housing system. Logistic regression was used to analyse our data. Feather damage was seen in 13 out of 24 (54%) of rearing flocks. Logistic regression showed that a higher number of pullets being kept per square meter in the first 4 weeks of life were associated with feather damage during the rearing period (Chi square = 8.49, df = 1, p = 0.004). Moreover, the combination of not having litter at the age of 1-4 weeks and the absence of daylight at the age of 7-17 weeks was a significant predictor of feather damage during the laying period (Chi square = 13.89, df = 4. p = 0.008). In 71% of the cases that pullets did not show feather pecking damage during rearing, they did not show feather pecking damage in the laying period either. When flocks of pullets did show feather damage, in 90% of the cases they did so during adult life. These results lead to suggestions on how to improve the rearing conditions of laying hens and increase their welfare not only during rearing but also during later life. Although the observations were done on organic farms, the results can be applied for other non-cage systems too. (C) 2009 Elsevier B.V. All rights reserved.

Bilcik, B. and L. J. Keeling (1999). "Changes in feather condition in relation to feather pecking and aggressive behaviour in laying hens." British Poultry Science **40**(4): 444-451.

1. The aim of this experiment was to describe and examine the relationship between pecks received by individual birds and the feather and skin damage of those birds at different ages. The effect of group size was also studied. 2. Laying hens were raised in floor pens in group sizes of 15, 30, 60 and 120 birds, each with 4 replicates. Behavioural observations were performed at the ages of 22, 27, 32 and 37 weeks. Detailed feather scoring was carried out at the ages of 18, 23, 28 and 33 weeks. 3. Behavioural observations focused on the number of feather pecks (gentle and severe) and aggressive pecks received, and on the past of the body that was pecked. Scoring of feather and skin damage focused on the same 11 parts of the body 4. Increasing numbers of aggressive pecks received were associated with decreased body weight and increased feather damage at the ages of 27 and 32 weeks. 5. The number of severe feather pecks received was significantly related with feather damage at all ages; however, no relation with gentle feather pecks received was found. 6. Group size had a significant effect on feather condition, with large group sizes hating most feather damage.

Bilcik, B. and L. J. Keeling (2000). "Relationship between feather pecking and ground pecking in laying hens and the effect of group size." Applied Animal Behaviour Science **68**(1): 55-66.
The aim of this experiment was to study the relationship between feather pecking and ground pecking in laying hens and the effect of group size on feather pecking behaviour. Hisex White hens were kept in floor pens in group sizes of 15, 30, 60 and 120 birds, each with four replicates. Behavioural observations were performed at four different ages and focused on the number of feather pecks and aggressive pecks, both given and received. The part of the body pecked and the location of the bird was recorded as well as the number of pecks made to the floor, feeder and drinker. The results showed that most feather pecking activity occurred in the largest group size (120 birds) and there was some evidence of an increasing frequency of aggressive pecks with increasing group size. The parts of the body which were targets for feather pecking varied depending on the location of the bird giving the peck and the bird receiving it. When looking at the behaviour of individuals, birds doing a lot of feather pecking also showed more ground pecking. (C) 2000 Elsevier Science B.V. All rights reserved.

Blokhuis, H. J. (1986). "Feather-pecking in poultry: Its relation with ground-pecking." Applied Animal Behaviour Science **16**(1): 63-67.
It was shown that the motivation for non-aggressive pecking at conspecifics varies along with ground-pecking motivation. This supported the view of a common regulating mechanism. It was concluded that feather-pecking is to be considered as redirected ground-pecking, and hence that the latter is an important parameter in experiments comparing the risk of different environmental factors concerning the development of feather-pecking.

Blokhuis, H. J. (1989). The development and causation of feather pecking in the domestic fowl. [S.l.], Blokhuis.
Uitgaande van de hypothese dat verenpikken in de leghennenhouderij beschouwd kan worden als een vorm van omgericht bodempikken, is divers gedragsonderzoek verricht op strooisel- of roostervloeren, of een combinatie van beide. Ook werd het effect van snavelkappen op het bodem- en verenpikken bestudeerd. Thesis: http://edepot.wur.nl/202211.

Bolhuis, J. E., et al. (2009b). "Effects of genetic group selection against mortality on behavior and peripheral serotonin in domestic laying hens with trimmed and intact beaks." Physiology & Behavior **97**(3-4): 470-475.
Severe feather pecking is a maladaptive behavior in laying hens that may result in cannibalism and ultimately death of the victims. Selection methods in which the genetic effect of an animal on the survival of its group members is taken into account, i.e. 'group selection', have been shown to be very effective in reducing mortality due to feather pecking and cannibalism in laying hens. It has been suggested that fearfulness and serotonergic functioning are involved in the causation and development of feather pecking. We investigated effects of selection based on survivability in non-beak trimmed groups on fear-related behavior and peripheral 5-HT concentration and uptake in hens with trimmed or intact beaks, in a 2x2 factorial arrangement. Hens from the second generation of the low mortality line showed less fear-related behavior than control line hens. In addition, they displayed higher whole blood 5-HT concentrations and a lower platelet 5-HT uptake, indicating differences in functional activity of the 5-HT system. Beak trimming resulted in lowered levels of fear, and in a reduction of feather damage. Hens with trimmed and intact beaks did, however, not differ in peripheral 5-HT. The results imply that fearfulness and 5-HT activity are related to feather pecking without distinguishing between cause and effect. However, given that selection altered fear-related behaviors and peripheral 5-HT concentration and uptake, whereas beak trimming affected fearfulness and feather damage, but not 5-HT parameters, we suggest that peripheral 5-HT activity might reflect the predisposition to develop severe feather pecking under adverse conditions in laying hens. (C) 2009 Elsevier Inc. All rights reserved.

Bright, A. (2007). "Plumage colour and feather pecking in laying hens, a chicken perspective?" British Poultry Science **48**(3): 253-263.
1. This study investigated whether feather damage due to feather pecking and bird behaviour were influenced by plumage colour in Oakham Blue laying hens (black, white, grey colour variants). The reflectance properties of feathers and spectral composition of light environments experienced by the hens were also examined. 2. Nine hundred and seventy-nine birds were inspected and scored for feather damage; 10 center dot 5h of video recordings were examined to record feather pecking and bird behaviour. Feathers and light environments were measured using a USB-2000 spectrometer and DH-2000-CAL-DTH lamp. 3. Oakham Blue birds with white plumage had less feather damage due to feather pecking than black or grey birds. There was more severe feather pecking in the mornings than

in the afternoon. White birds feather pecked severely more than black or grey birds, although there were no other behavioural differences between plumage colours. 4. White feathers reflected at a higher intensity than black or grey feathers. However, black and grey feather spectra were relatively flat and the contribution of UV wavelengths to plumage reflection was proportionally greater than that for white feathers. 5. Light intensity inside a poultry house was 100 x (UW/cm(2)/nm) less than on the range and there was low or no UV reflectance. Under the dim, artificial lights inside a poultry house, Oakham Blue hens with black and grey feathers may be less visible to conspecifics than white birds because their plumage reflects at a lower intensity. Furthermore, the lack of available UV light inside vs. outside and the higher contribution of UV reflectance to black and grey plumage may make black and grey birds appear more different inside the house than white birds. It is possible that this novel/unusual appearance may make black or grey Oakham Blue hens more susceptible to feather pecking.

Bright, A., et al. (2011). "Canopy cover is correlated with reduced injurious feather pecking in commercial flocks of free-range laying hens." Animal Welfare **20**(3): 329-338.

Injurious feather pecking in non-cage systems is a serious economic and welfare concern for the egg-producing industry. Here, we describe the first results from an ongoing collaborative project to improve range environment and welfare of laying hens (Gallus gallus domesticus) within the McDonald's Restaurants Ltd, UK supply base. The objective of this study was to investigate, in a commercial situation, the correlation between: i) proportion of range cover and ii) proportion of canopy cover, with plumage damage of end-of-lay hens. The assessment of plumage damage due to injurious feather pecking is a key animal-based welfare indicator for laying hens in non-cage systems. In 2007 and 2008, all laying-hen producers within the McDonald's Restaurants Ltd egg-supply base, were required to plant (if not present already), 5% of the total range area with blocks of trees either side, and between 20-25 m from the laying hen house. Plumage damage at end of lay was positively correlated with mortality and flocks depleted in summer had less plumage damage at end of lay than flocks depleted in autumn or winter, possibly because of weather conditions at the time of placement There was no correlation between the proportion (5-90%) of range cover and plumage damage at the end of lay, however, plumage damage was negatively correlated with percent of canopy cover within tree-planted areas. Providing a minimum of 5% tree cover, planted close to the house but with good canopy coverage, may be a feasible and practical method enabling producers to reduce plumage damage due to injurious feather pecking in their laying-hen flocks. Tree cover provision may also provide environmental benefits, such as soil stabilisation, reduced nutrient leaching and carbon sequestration.

Brunberg, E., et al. (2011). "Feather pecking behavior in laying hens: Hypothalamic gene expression in birds performing and receiving pecks." Poultry Science **90**(6): 1145-1152.

Feather pecking (FP) is a welfare and economic problem in the egg production sector. Beak trimming, the current method used to reduce FP, is also criticized. The present study used gene expression to explore the biological mechanisms underlying this behavior, which could lead to a greater understanding of the cause and a tool to mitigate the problem. White Leghorn hens performing and receiving FP, as well as neutral control birds, were identified on a commercial farm. Hypothalamic RNA from 11 peckers, 10 victims, and 10 controls was hybridized onto GeneChip Chicken Genome Arrays (Affymetrix Inc., Santa Clara, CA) to compare gene expression profiles in the different groups. Eleven transcripts corresponding to 10 genes differed significantly between the 3 groups (adjusted $P < 0.05$). Eight of these transcripts differed in the peckers compared with the controls, 1 was upregulated in the victims compared with the controls, and 6 differed significantly in the peckers compared with the victims. Additionally, 5 transcripts showed a trend (adjusted $P < 0.1$) to differ in the pecker-victim comparison. Some of the products of the differently expressed genes are involved in disorders, such as intestinal inflammation and insulin resistance, which fit well with the previously proposed hypothesis that FP is an abnormal foraging behavior. Other findings may also support the proposal that FP is linked to immune mechanisms and may serve as an animal model for obsessive compulsive disorder in humans. In conclusion, this study provides a gene list that may be useful in further research on the mechanisms behind FP.

Buitenhuis, A. J. and J. B. Kjaer (2008). "Long term selection for reduced or increased pecking behaviour in laying hens." Worlds Poultry Science Journal **64**(4): 477-487.

Feather pecking in laying hens is an important issue in animal welfare. Four studies in laying hens were selected which investigated increased or reduced pecking behaviour using direct or indirect measures of feather pecking behaviour. Direct comparison of the selected experiments is difficult, as the selection criteria and even the selection procedures varied. Keeping these differences in mind, the results of the experiments showed that a) It is possible to change pecking behaviour in the desired direction using selection, b) Aggressive pecking is not related to feather pecking, c) There is no clear consensus as to the relation between selection on pecking behaviour and laying performance and egg quality, d) Plasma serotonin level in the blood was reduced in the lines selected against pecking behaviour in both the individual selected lines and the group selected lines and there were indications that dopamine also plays a role in the regulation of pecking behaviour, and finally e) There are differences between the selected lines and their control lines with regard to the immune parameters both in the individual selected lines as the group selected lines, indicating that direct as well as indirect selection for reduced pecking behaviour changes the immune response.

Buitenhuis, A. J., et al. (2006). "Altered circulating levels of serotonin and immunological changes in laying hens divergently selected for feather pecking behavior." Poultry Science **85**(10): 1722-1728.

The aim of this study was to investigate the changes in immunological parameters as well as changes with respect to plasma levels of serotonin and tryptophan in lines selected for and against feather pecking (FP) behavior [high FP (HP) line and low FP (LP) line] for 5 generations. The hens from the HP line had a higher plasma serotonin level than those from the LP line (0.059 VS. 0.037 mu mol/L, F-2,F-27 = 0.031, P < 0.05). The plasma level of tryptophan was, on average, 67.30 mu mol/L and did not differ between the lines (68.3 vs. 66.3 mu mol/L, F-2,F-28 = 0.36, P > 0.05). The HP line had a higher response to infectious bursal disease virus vaccination after 1 wk post-vaccination compared with the control and LP lines. The number of white blood cells (P < 0.0001) and the expression of MHC class I molecules on CD4 (P < 0.02), CD8 beta (P < 0.006) and on B cells (P < 0.03) were highest in the LP line compared with the control and HP lines. Selection for or against FP, therefore, changes the number of white blood cells and the expression of MHC class I molecules on T and B cells, which may influence the health status of the birds.

Buitenhuis, B., et al. (2009). "Differentially expressed genes for aggressive pecking behaviour in laying hens." Bmc Genomics **10**.

Background: Aggressive behaviour is an important aspect in the daily lives of animals living in groups. Aggressive animals have advantages, such as better access to food or territories, and they produce more offspring than low ranking animals. The social hierarchy in chickens is measured using the 'pecking order' concept, which counts the number of aggressive pecks given and received. To date, little is known about the underlying genetics of the 'pecking order'. Results: A total of 60 hens from a high feather pecking selection line were divided into three groups: only receivers (R), only peckers (P) and mixed peckers and receivers (P&R). In comparing the R and P groups, we observed that there were 40 differentially expressed genes [false discovery rate (FDR) P < 0.10]. It was not fully clear how the 40 genes regulated aggressive behaviour; however, gene set analysis detected a number of GO identifiers, which were potentially involved in aggressive behavioural processes. These genes code for synaptosomes (GO: 0019797), and proteins involved in the regulation of the excitatory postsynaptic membrane potential (GO: 0060079), the regulation of the membrane potential (GO: 0042391), and glutamate receptor binding (GO: 0035254). Conclusion: In conclusion, our study provides new insights into which genes are involved in aggressive behaviours in chickens. Pecking and receiving hens exhibited different gene expression profiles in their brains. Following confirmation, the identification of differentially expressed genes may elucidate how the pecking order forms in laying hens at a molecular level.

Campo, J. L. and M. T. Prieto (2009a). "Association between plumage condition and fluctuating asymmetry and between feathers removal, heterophil-to-lymphocyte ratio and tonic immobility duration in chickens." Archiv Fur Geflugelkunde **73**(4): 250-+.

The purpose of this study was to analyze the relationship between plumage condition and fluctuating asymmetry and between removal of feathers and heterophil-to-lymphocyte ratio and tonic immobility duration of chickens. in experiment 1, cocks (n = 46; 36 wk old) from 2 Spanish breeds (Black Castellana and Red Villafranquina), and hens (n = 40; 36 wk old) from the Quail Castellana breed, having bad or good plumage condition were used. The fluctuating asymmetry of several traits (middle toe length, leg length, wing length, wattle length, and leg width) was measured in these birds. in cocks, the effect of plumage condition on the relative asymmetry of leg width and the combined asymmetry depended on the genotype, differences being significant (P < 0.05) in the Red Villafranquina breed. In this breed, the relative asymmetry of cocks with bad plumage condition was significantly larger. The relative asymmetry of leg width in females with poor plumage condition was significantly (P < 0.05) larger than that of females with good pulmage condition. In experiment 2, cocks from the Birchen Leonesa breed (n = 40; 36 wk old) in which five feathers of the hackle and five feathers of the saddle have been removed at one instance or not, were used. The heterophil-to-lymphocyte ratio and the duration of tonic immobility were measured in these birds. The effect of feathers removal was not significant, suggesting that the levels of stress and fear were similar in both groups of birds. TWO housing system (deep litter and free range) were used in this experiment, the tonic immobility duration being significantly longer (P < 0.05) within the group of birds housed in deep litter than within the group of free-ranged birds. Thus, plumage condition can be negatively associated with some measures of stress depending on the genotype, whereas a single event of feathers removal was not associated with these indicators of the stress and fear levels of males.

Campo, J. L., et al. (2008). "Association between vent pecking and fluctuating asymmetry, heterophil to lymphocyte ratio, and tonic immobility duration in chickens." Applied Animal Behaviour Science **113**(1-3): 87-97.

The purpose of the present study was to analyze the relationship between incidence of vent pecking, fluctuating asymmetry, heterophil to lymphocyte ratio, and tonic immobility duration in chickens. The experiment (140 birds in three different replicates) measured the fluctuating asymmetry of several traits (middle toe length, leg length, wing length, wattle length, and leg width), the heterophil to lymphocyte ratio, and the tonic immobility duration in 20-week-old pullets of five Spanish breeds of chickens (Blue Andaluza, Quail Castellana, White-faced Spanish, Red-barred Vasca, and Birchen Leonesa), and a White Leghorn population, with and without evidence of suffering from vent pecking. The number of birds per breed was 20, 24, 12, 20, 18, and 46, respectively. There was a significant difference between vent pecked and non-vent pecked birds on the relative fluctuating asymmetry of middle toe length (P < 0.05), the relative fluctuating asymmetry of birds who suffered from vent

pecking being larger. The combined relative fluctuating asymmetry of the five traits approached levels of statistical significance (P = 0.08). There was a significant difference (P < 0.001) in heterophil to lymphocyte ratio and tonic immobility duration between vent pecked and non-vent pecked birds, the ratio being higher and the duration being longer in the group of birds that suffered from vent pecking. Thus, vent pecked birds were more asymmetrical, stressed and fearful than non-vent pecked birds, having increased relative fluctuating asymmetry, heterophil to lymphocyte ratio and tonic immobility duration. Differences were consistent across the breeds. Results indicate that vent pecking is associated with other measures of stress e.g. fluctuating asymmetry. heterophil to lymphocyte ratio, and tonic immobility duration. (c) 2007 Elsevier B.V. All rights reserved.

Cheng, H. (2006). "Morphopathological changes and pain in beak trimmed laying hens." Worlds Poultry Science Journal **62**(1): 41-52.

Beak trimming is routinely practiced in the poultry industry to reduce the incidence of feather pecking, aggression, and cannibalism in egg layers. Feather pecking is painful to birds and potentially induces cannibalism. Cannibalism happens in all current housing environments, cage- and free-production systems, and is one of the major causes of bird death in commercial laying hens without beak trimming. However, beak trimming has solicited a great deal of debate concerning the relative advantage and disadvantage of the practice and its impact on welfare. A bird's beak is a complex functional organ with an extensive nerve supply and various sensory receptors. Beak trimming may cause pain (acute, chronic, or both) in trimmed birds due to tissue damage and nerve injury. The complexity and plasticity of the nervous system and the animal's inability to communicate verbally make pain difficult to measure directly. However, pain in animals can be recognized and assessed using physiological and behavioural parameters in response to noxious events. When evaluating whether an animal is experiencing pain, a distinction should be made between what an animal may feel and what a human observing the animal may feel. It should be noted that beak trimming-induced pain in birds is genetic-, lesion-, and age-dependent. Based on the updated information, the author would like to indicate that 1) with some genetic flocks of laying hens, if beak trimming is needed to prevent feather pecking and cannibalism, it should be conducted at hatchery or younger than 10 days of age; 2) however, the most desirable approach is to eliminate beak trimming through a genetic selection of birds with less cannibalistic and aggressive tendencies, and 3) another solution is to develop an alternative means of trimming that has fewer painful implications and safeguards welfare before non-cannibalistic stocks are commercially available.

Cheng, H. W. and W. M. Muir (2007). "Mechanisms of aggression and production in chickens: genetic variations in the functions of serotonin, catecholamine, and corticosterone." Worlds Poultry Science Journal **63**(2): 233-254.

The neuroendocrine systems, such as dopamine (DA) and serotonin (5- HT) as well as corticosterone (CORT), are involved in regulating behavioural patterns and reproduction in humans and other mammals. Similar functions of neuroendocrine system may present in laying hens. To test the hypothesis, two divergent chicken lines were used in the study. Each line has distinct levels of aggressiveness and productivity at a group setting and exhibits differen susceptibility to various environmental stressors. We found that, at 21 wks of age, LGPS (Low Group Productivity and Survivability) birds had significantly higher blood concentrations of DA and epinephrine than the KGB birds (Kind Gentle Birds, also previously termed HGPS, birds with a High Group Productivity and Survivability) (P< 0.01, respectively). The blood concentration of norepinephrine was not significantly different between the lines but the ratio of epinephrine to norepinephrine was higher in LGPS birds (P< 0.01). The blood concentration of 5- HT was also significantly higher in LGPS birds compared to KGB birds (P< 0.01). In contrast, KGB birds tended to have a higher level of blood CORT (P= 0.1). The results suggest that genetic selection for productivity and survivability with domestic behaviours alters the birds' neuroendocrine homeostasis. The selection-associated plasticity of the neuroendocrine system in controlling animal aggression and productivity were discussed in the article.

Chow, A. and J. A. Hogan (2005). "The development of feather pecking in Burmese red junglefowl: the influence of early experience with exploratory-rich environments." Applied Animal Behaviour Science **93**(3-4): 283-294.

This study examines the development of feather pecking and its relationship to exploration in Burmese red junglefowl (Gallus gallus spadiceus). Ten groups of four chicks each were raised from hatching on wire mesh floors (home pen). Two of the four chicks in each group received experience in exploratory-rich environments four times a week for 5 weeks, and the other two chicks remained in the home pen. Observations conducted in the home pen revealed that chicks deprived of experience in exploratory-rich environments performed significantly more gentle feather pecking, and tended to show more severe feather pecking than the experienced birds. Experience in the exploratory-rich environments did not affect the frequency of environmental pecking or food pecking. These results suggest that chicks deprived of exploratory-rich environments may come to perceive pen mates as appropriate exploratory stimuli and subsequently direct exploratory behavior toward conspecifics. This tendency to peck pen mates may lead to the development of feather pecking. We suggest that forceful pecks may be reinforcing, and that the more likely pecks are directed to a conspecific, the more likely feather pecking will develop. (c) 2005 Elsevier B.V. All rights reserved.

Cronin, G. M., et al. (2011). A retrospective study of the impact of injurious pecking on stress response in hens, measured via egg corticosterone. Sydney, Poultry Research Foundation.

This paper describes the temporal change in egg corticosterone concentrations around a minor outbreak of injurious pecking by laying hens. The event occurred during an experiment in which we were measuring corticosterone concentrations in egg albumen at weekly intervals, as an indicator of physiological stress response. For the experiment, a total of 96 Hy-Line Brown birds were housed in two adjacent controlled environment rooms, enabling the imposition of different photoperiod treatments. Six identical 8-bird cages were used per room. Injurious pecking occurred in one of the two rooms, in two cages (situated back-to-back) containing birds aged 18-23 weeks. Affected birds were treated by swabbing the injured area(s) with Stockholm tar. Corticosterone concentrations were elevated in eggs from these cages, as well as the two abutting cages, even though those birds were neither handled nor treated with Stockholm tar. The findings suggest that the elevated corticosterone was elicited by aversive stimuli (stressors) experienced by the hens. It is also possible that disturbance caused by the stockpeople catching and treating birds in the affected cages, induced a stress response in birds in the abutting cages. In the more-distant cages in this room, and in the other room, corticosterone concentrations were not elevated.

Daigle, C. L., et al. (2014). "Use of dynamic and rewarding environmental enrichment to alleviate feather pecking in non-cage laying hens." Applied Animal Behaviour Science **161**(0): 75-85.

Abstract Feather pecking (FP) can cause feather loss, resulting in physical injuries, which may lead to cannibalism. FP appears to be a redirection of foraging behavior, which intensifies when hens have difficulty coping with stress and fear. Dynamic environmental enrichment (EE) may allow expression of natural foraging behavior thus reducing conspecific pecking behavior and alleviating hen injury. Three treatments (plastic box: BOX; hay bale: HAY; and no enrichment: CON) were randomly applied to 30 identical floor pens (10 hens/pen; 10 pens/trt). At the pen level, hen behavior, and the number of severe FP (SFP), gentle FP (GFP), aggressive pecks (AP), and enrichment pecks (EP) were recorded from video prior to (21 wk) and after (24 wk) treatment implementation, and when hens were 27, 32, and 37 wk of age. A manual restraint test (MR) was performed immediately after behavioral observations and levels of blood serotonin (5-HT) and glucocorticoids (GC) measured. Short-term (ST) and long-term (LT) analyses identified the impact of EE over the ST (21 vs. 24 wk of age) and LT (21 vs. all other ages) at the pen level. At the pen level, HAY (3.18 ± 0.33) tended to reduce GFP compared to CON (4.10 ± 0.34) over the ST (P = 0.15) and LT (P = 0.09), but did not impact the number of SFP, or AP over the ST or LT. More EP was observed in HAY (3.56 ± 0.14) than BOX (1.61 ± 0.18) throughout the study (P < 0.0001). More HAY hens perched (P = 0.05) at 24 wk (0.28 ± 0.12) compared to 21 wk (0.19 ± 0.11), and more HAY hens (3.69 ± 0.25) performed dust bathing compared to CON (4.14 ± 0.22, P = 0.05) throughout the study. CON performed more struggles (1.13 ± 0.04, P = 0.04) and were quicker to vocalize (4.87 ± 0.07 s, P = 0.05) during MR than HAY (latency to vocalize(s): 5.16 ± 0.05; number of struggles: 0.96 ± 0.05), counter-intuitively suggesting CON were less fearful. Treatment did not affect 5-HT or GC. HAY appears to be a promising EE for mitigating GFP in non-cage laying hens. Future studies should examine the impact of EE on individual, rather than group-level responses. These results suggest that the presence of a hay bale is stimulating and may reduce GFP while encouraging hens to redirect pecking towards a dynamic and manipulable EE.

Dawkins, M. S. (1989). "Time budgets in Red Junglefowl as a baseline for the assessment of welfare in domestic fowl." Applied Animal Behaviour Science **24**(1): 77-80.

A study of the way in which semi-wild junglefowl allocate their time between different activities showed that in 60% of all minutes during the active part of the day, hens were seen to be ground pecking and in 34%, ground scratching. The fact that such a high proportion of time was spent in foraging activities is discussed in relation to the welfare of domestic fowl unable to perform such activities.

de Haas, E. N., et al. (2014). "Predicting feather damage in laying hens during the laying period. Is it the past or is it the present?" Applied Animal Behaviour Science **160**(0): 75-85.

Abstract Feather damage due to severe feather pecking (SFP) in laying hens is most severe during the laying period. However, SFP can develop at an early age and is influenced by early rearing conditions. In this study we assessed the risk factors during the rearing and laying period for feather damage at 40 weeks of age, in ISA brown and Dekalb White laying hens. Variables related to housing conditions during the rearing and laying period, and variables related to fearfulness (response to novel object, stationary person, and social isolation) and feather pecking (SFP, feather damage and feather eating) were tested to affect feather damage at 40 weeks of age. Feather damage on the neck, back and belly region was assessed on 50 hens, resulting in a total body score, and averaged per flock (based on Welfare Quality ®, 2009). First, analysis was conducted by a two-way ANOVA to assess separate factors to influence feather damage at 40 weeks of age. Hereafter, the final GLM for predicting feather damage at 40 weeks of age included only variables which had P < 0.1 in the two-way ANOVA. Risk factors during the rearing period were high levels of SFP at five weeks of age and elevated fear of humans (explained variance 29% and 5.3%, resp.). Risk factors during the laying period were a large group size (explained variance: 1%), distance to stationary person (explained variance: 16%), floor housing compared to aviary housing (1.27 ± 0.18 vs. 0.75 ± 0.07, explained variance: 21%) and a standard management compared to adjusted management such as a radio, pecking blocks, round drinkers and/or roosters (0.98 ± 0.31 vs. 0.51 ± 0.04, explained variance: 26%). Approximately 49% of the laying flocks and 60% of the rearing flocks in this study showed high SFP or severe feather damage. This high incidence emphasizes the severity of the problem and the importance of finding a

solution. The results of this study may aid in providing practical solutions to this serious animal welfare problem.

de Haas, E. N., et al. (2014). "Parents and Early Life Environment Affect Behavioral Development of Laying Hen Chickens." Plos One **9**(3): e90577. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3948370/.

Severe feather pecking (SFP) in commercial laying hens is a maladaptive behavior which is associated with anxiety traits. Many experimental studies have shown that stress in the parents can affect anxiety in the offspring, but until now these effects have been neglected in addressing the problem of SFP in commercially kept laying hens. We therefore studied whether parental stock (PS) affected the development of SFP and anxiety in their offspring. We used flocks from a brown and white genetic hybrid because genetic background can affect SFP and anxiety. As SFP can also be influenced by housing conditions on the rearing farm, we included effects of housing system and litter availability in the analysis. Forty-seven rearing flocks, originating from ten PS flocks were followed. Behavioral and physiological parameters related to anxiety and SFP were studied in the PS at 40 weeks of age and in the rearing flocks at one, five, ten and fifteen weeks of age. We found that PS had an effect on SFP at one week of age and on anxiety at one and five weeks of age. In the white hybrid, but not in the brown hybrid, high levels of maternal corticosterone, maternal feather damage and maternal whole-blood serotonin levels showed positive relations with offsprings' SFP at one week and offsprings' anxiety at one and five weeks of age. Disruption and limitation of litter supply at an early age on the rearing farms increased SFP, feather damage and fearfulness. These effects were most prominent in the brown hybrid. It appeared that hens from a brown hybrid are more affected by environmental conditions, while hens from a white hybrid were more strongly affected by parental effects. These results are important for designing measures to prevent the development of SFP, which may require a different approach in brown and white flocks.

de Haas, E. N., et al. (2010). "Selection on feather pecking affects response to novelty and foraging behaviour in laying hens." Applied Animal Behaviour Science **124**(3-4): 90-96.

Feather pecking (FP) is a major welfare problem in laying hens, influenced by multiple factors. FP is thought to be redirected foraging behaviour, however fearful birds are also known to be more sensitive to develop FP. The relationship between fear-responses, foraging and FP is not well understood, therefore we studied the behaviour of 16 birds from a high feather pecking (HFP) line and 16 birds from a low feather pecking (LFP) line at 35 weeks of age inside a plus-maze. Birds were from the 10th generation of selection for either high or low FP. First exposure to the maze was used to measure birds' fear-responses to a novel barren environment. Hereafter, birds were trained three times in the maze with four different food-items that were offered in one of the four arms (i.e. regular food-pellets, feathers, grass, and mealworms hidden in wood-shavings). On the fifth day, birds were tested in the maze for 10 min during which they could choose to eat from all available food-items. When exposed for the first time in the maze HFP birds walked a longer distance, vocalized sooner and had more exploratory pecks compared to LFP birds who showed more wing-movements and defecations. When given a choice of food inside the maze both lines preferred eating worms, but HFP birds had more worm-eating bouts and ate faster than LFP birds. The results of this study indicate that HFP birds respond actively to fear-eliciting situations, which may originate from a proactive coping style. Instead of a clear preference for eating feathers, this study supports earlier findings that HFP birds have a stronger pecking motivation than LFP birds. (C) 2010 Elsevier B.V. All rights reserved.

de Jong, I. C., et al. (2013). "Can substrate in early rearing prevent feather pecking in adult laying hens?" Animal Welfare **22**(3): 305-314.

In The Netherlands, laying hen chicks are often reared without litter on the raised slatted area of a barn system or confined in the aviary system during the first two to five weeks after hatching, with chick paper or chicken wire on the floor. In the absence of a suitable pecking substrate, chicks may redirect their pecking behaviour to other birds, which possibly increases the risk of developing feather-pecking behaviour. The aim of this study was to determine whether housing on wood-shavings (WS treatment; n = 15 groups) as compared to housing on chicken wire (CW treatment; n = 15 groups) between day 1–20 could reduce feather pecking in adult birds. After day 20, all chickens were allowed wood-shavings as litter. Behavioural observations showed that CW chicks performed significantly less ground-pecking behaviour compared with WS chicks up to day 20. More CW chicks showed gentle feather pecking at day 7 and 14 as compared to WS chicks, and more CW chicks pecked at the feeder or drinker than WS chicks up to day 20. CW chicks showed rebound behaviour: the day after they were introduced to wood-shavings they displayed more ground-pecking behaviour compared to the WS chicks. Later on in the rearing period no noticeable differences between treatments were found in frequency of gentle and severe feather-pecking bouts. During laying, more gentle feather-pecking bouts were observed in CW than in WS groups but no differences in severe feather-pecking bouts were observed, nor in feather damage at the end of the trial. The results indicate that hens can display substantial flexibility in their pecking behaviour and that, despite more gentle feather pecking in CW hens in laying, the absence of substrate in early rearing does not increase the risk of developing severe feather-pecking behaviour when adult.

de Jong, I. C. and T. G. C. M. van Niekerk (2014). Verkorte protocollen voor het meten van de effecten van niet-snavelbehandelen bij leghennen, vleeskuikenouderdieren en kalkoenen. Wageningen, Wageningen UR Livestock Research.

Met ingang van 1 september 2018 zal in Nederland snavelbehandelen bij leghennen, vleeskuikenouderdieren en kalkoenen verboden worden. Doel van dit onderzoek was om op basis van

beschikbare literatuur, ervaringen van onderzoekers en ervaringen uit de praktijk protocollen op te stellen waarmee op relatief eenvoudige, maar wel betrouwbare wijze een monitoring van het effect van niet-snavelbehandelen uitgevoerd kan worden. Op basis van literatuuronderzoek, expert consultatie en een beknopt haalbaarheidsonderzoek bij praktijkkoppels zijn protocollen ontwikkeld voor het vastleggen van het effect van het niet-snavelbehandelen bij leghennen (opfok en productie), vleeskuikenouderdieren (opfok en productie) en kalkoenen (vleeskalkoenen). Deze protocollen staan vermeld in de bijlage van dit rapport.

Dennis, R. L. and H. W. Cheng (2010). "Effects of beak trimming on pecking force." International Journal of Poultry Science **9**(9): 863-866.

Beak trimming of the production laying hen has come under great scrutiny by welfare and consumer advocacy groups as a potential source of acute and chronic pain as well as having the potential to inhibit the freedom to express normal behaviors such as feeding behaviors. Although several studies have shown evidence of immediate pain response from beak trimming, the long term effects on bird welfare are not well understood. In the present study we investigated the force with which chicks peck during feeding. Chicks were beak trimmed using hot blade trimming at 2 days of age and were tested on a force plate at 3, 4 and 5 weeks of age. Both the time spent pecking and the forces of those pecks were measured. Beak trimmed birds spent significantly less time pecking at the feed and used less force than untrimmed birds at 3 weeks of age ($p<0.05$). However, at 4 and 5 weeks of age the difference was no longer significant ($p>0.05$). Beak trimmed birds also had a higher pecking ratio (peck force:time, $p<0.05$) than untrimmed birds. The difference was no longer apparent at 4 and 5 weeks of age ($p>0.05$). Our data suggest that beak trimming alters feeding behavior at a young age. However, changes in pecking force and time spent feeding were not long lasting and became similar to those of untrimmed birds after 3 weeks post-trimming.

Dennis, R. L. and H. W. Cheng (2011). "The dopaminergic system and aggression in laying hens." Poultry Science **90**(11): 2440-2448.

The dopaminergic system is involved in the regulation of aggression in many species, especially via dopamine (DA) D1 and D2 receptor pathways. To investigate heritable differences in this regulation, 2 high aggressive strains [Dekalb XL (DXL) and low group egg productivity and survivability (LGPS)] and one low aggressive strain (low group egg productivity and survivability; HGPS) of laying hens were used in the study. The HGPS and LGPS lines were diversely selected using group selection for high and low group production and survivability. The DXL line is a commercial line selected through individual selection based on egg production. Heritable differences in aggressive propensity between the strains have been previously assessed. The birds were pair housed within the same strain and labeled as dominant or subordinate based on behavioral observation. For both experiments 1 and 2, behavioral analysis was performed on all 3 strains whereas neurotransmitter analysis was performed only on the most aggressive (DXL) and least aggressive (HGPS) strains. In experiment 1, the subordinate birds were treated with D1 agonist, D2 agonist; or saline controls ($n = 12$). In experiment 2, the dominant birds from a separate flock were treated with D1 antagonist, D2 antagonist, or saline controls ($n = 12$). Treatment-associated changes in aggressive behaviors and central neurotransmitters were measured. Aggression was increased in all strains in response to D1 agonism but increased only in the less aggressive HGPS birds with D2 agonism. Aggression was decreased and hypothalamic serotonin and epinephrine were increased in birds from all strains treated with D2 receptor antagonist. The D1 receptor antagonism elicited different behavioral and neurotransmitter responses based on the aggressive phenotype of the genetic strains. Aggressive strains DXL and LGPS but not the HGPS strain decreased aggressiveness following antagonism of the D1 receptor. The data show evidence for distinct neurotransmitter regulation of aggression in high and low aggressive strains of hens through different receptor systems. These chicken lines could provide new animal models for the biomedical investigation of the genetic basis of aggression.

Dennis, R. L., et al. (2009). "Infrared beak treatment method compared with conventional hot-blade trimming in laying hens." Poultry Science **88**(1): 38-43.

Infrared lasers have been widely used for noninvasive surgical applications in human medicine, and their results are reliable, predictable, and reproducible. Infrared lasers have recently been designed for the express purpose of providing a less painful, more precise beak-trimming method compared with conventional beak trimming. This study was designed to examine the potential of the infrared (IR) beak treatment to provide a welfare-friendly alternative to the conventional hot-blade method for chickens. The birds were beak trimmed by IR at the hatchery or by hot blade at 7 to 10 d of age in a commercial production setting, in accordance with standard procedures. The beak morphology and associated physiological characteristics, including production and aggressive behavior of the birds, were analyzed at 30 wk of age. There was no difference in egg production or bird BW between the 2 beak-trimming treatments. Birds also exhibited no difference in stress physiology measured in the study, such as fluctuating asymmetry and heterophil and lymphocyte profiles. However, birds receiving the IR treatment showed a superior feather condition and reduced aggressiveness under high light intensity, even though they had longer beak stumps. The results may indicate that the IR beak treatment may reduce the damage done by aggressive pecking and feather pecking. Indeed, IR trimming may provide a more welfare-friendly alternative to conventional beak trimming without compromising productivity.

Dixon, L. M. (2008). "Feather pecking behaviour and associated welfare issues in laying hens." Avian Biology Research **1**(2): 73-87.

Feather pecking, the pecking at or removal of feathers from one bird by another, is a problem in the poultry industry. Elimination of damaging feather pecking from flocks is made especially difficult by the numerous factors that appear to influence its prevalence. This review outlines the various contributors to feather pecking organised around Tinbergen's four questions on causation, ontogeny, phylogeny and function. There is growing evidence that feather pecking (especially severe feather pecking) is related to foraging motivation and gut function. However, other factors, such as improper early experiences, strain and individual differences and perseveration of the behaviour help explain its continued occurrence, even if the birds are kept in enriched environments. To date, methods of dealing with feather pecking are inadequate and involve welfare concerns of their own and alternate solutions, such as provision of forages, are not usually successful in abolishing feather pecking behaviour. The problems of excessive pelage/plummage removal or redirected oral/foraging related behaviour are not unique to poultry and seem to occur in other species in which foraging and forage intake is important. Between species comparisons of related behaviour patterns may improve our understanding of feather pecking and help to design effective solutions. In order to solve the problem of feather pecking, the factors discussed in this review need to be accounted for or we risk applying 'band-aid' solutions, which may appear outwardly to be solving the problem. However, the underlying cause(s) may still be present and the animal's welfare may still be compromised.

Dixon, L. M. and I. J. H. Duncan (2010). "Changes in Substrate Access Did Not Affect Early Feather-Pecking Behavior in Two Strains of Laying Hen Chicks." Journal of Applied Animal Welfare Science **13**(1): 1-14.

Feather pecking, commonly found in flocks of laying hens (Gallus gallus), is detrimental to bird welfare. Thought to cause this problem is the normal housing of layers without a floor substrate. Some evidence suggests that early substrate access decreases later feather pecking. However, there has been little research on the immediate effects of a change in substrate availability on bird welfare, although environmental modifications like this are often done when brooding and rearing laying hen chicks. To investigate this, the behavior of two strains of laying hen chicks was recorded for 4 weeks. The study kept the birds on either wire or peat moss for 14 days and then switched half the chicks to the other flooring. Early feather pecking was not significantly different for birds started on peat moss and switched to wire than for birds only on wire (p .05). Because moving chicks from peat moss to wire did not cause additional welfare problems, the study recommends that chicks be kept on a substrate when young as feather-pecking levels are lower and immediate welfare is improved compared with birds kept only on wire.

Dixon, L. M., et al. (2008). "What's in a peck? Using fixed action pattern morphology to identify the motivational basis of abnormal feather-pecking behaviour." Animal Behaviour **76**: 1035-1042.

Like many captive animals, hens, Gallus gallus, used for agricultural production perform abnormal behaviours. They are particularly prone to feather pecking, the severest form of which involves the pecking at and removal of feathers, which can cause bleeding and even stimulate cannibalism. The two main hypothesized explanations for feather pecking concern frustrated motivations to forage or, alternatively, to dust-bathe, leading to redirected behaviour in the form of pecks at plumage. Previous work on pigeons has shown that the detailed morphology of pecks involved in drinking and feeding, or in working for food or water, involves motivationally distinct fixed action patterns. We therefore used methods similar to these fixed action pattern studies to quantify the motor patterns involved in foraging and in dustbathing pecks, for comparison to feather pecking. We videoed 60 chickens pecking at a variety of forages and dustbaths, along with novel objects, water and bird models that could be feather pecked. We recorded the durations of the head fixation before the peck, between the head fixation to beak contact with each stimulus and of the whole peck sequence. We used mixed models to assess whether the motivation underlying a peck affected its morphology and whether severe feather pecks resembled or differed from either dustbath or foraging pecks (or even novel-object pecking or drinking). The motor patterns involved in pecks at forages, dustbaths, novel objects and water all varied significantly; importantly, the motor patterns involved in pecking during dustbathing and foraging differed ($P < 0.0001$ for all measures). Severe feather pecks proved similar to foraging pecks (NSD: power > 0.95) but different from all other pecks, including dustbathing ($P < 0.0001$ for all measures). These results indicate that severe feather pecking derives from frustrated motivations to forage, not to dustbathe. More broadly, they suggest that finely analysing fixed action pattern morphology can help elucidate the motivational bases of puzzling abnormal behaviours in captive animals.

Dixon, L. M., et al. (2010). "The effects of four types of enrichment on feather-pecking behaviour in laying hens housed in barren environments." Animal Welfare **19**(4): 429-435.

Severe feather pecking, a potentially stereotypic behaviour in chickens (Gallus gallus), can be reduced by providing enrichment. However, there is little comparative information available on the effectiveness of different types of enrichment. Providing forages to birds is likely to decrease feather-pecking behaviour the most, as it is generally thought that feather pecking stems from re-directed foraging motivation. Yet, other types of enrichment, such as dustbaths and novel objects, have also been shown to reduce feather pecking. In order to develop a practical and effective enrichment, these different possibilities must be examined. Using a Latin Square Design, 14-week old birds were given each of four treatments: i) forages; ii) novel objects; iii) dustbaths; or iv) no enrichment. The amount of feather-pecking behaviour and the number of pecks to the enrichments were recorded. Results showed feather pecking to be highest when no enrichment was present and lowest when the forages were present, with the other two enrichments intermediate. This was despite the fact that the numbers

of pecks birds gave to the forages and dustbaths were not significantly different, suggesting that they were similarly used. Thus, we suggest here that forage enrichments are most effective at alleviating feather pecking at least in the short term and attempts should be made to develop poultry housing that allows for natural foraging behaviour. Following this, providing any kind of enrichment will increase bird welfare and is therefore still beneficial.

Donaldson, C. J. and N. E. O'Connell (2012). "The influence of access to aerial perches on fearfulness, social behaviour and production parameters in free-range laying hens." Applied Animal Behaviour Science(0).

The aim of this trial was to determine the influence of aerial perches on welfare and production parameters in free-range laying hens. Five commercial free-range houses, each containing between 7000 and 8000 birds, were used. Each house and range area was split in half to create two treatments. In half of the house the birds had access to aerial perches (P) and in the other half they did not (NP). Perches were provided from the start of the lay cycle at 16 weeks of age, and remained in place until the end of the lay cycle (at approximately 74 weeks). Behavioural observations took place over two day periods at intervals between 17 and 70 weeks of age. During day 1, tests of fearfulness and observations of aggressive and feather pecking behaviours were performed. In addition, twenty birds per replicate were randomly selected and weight, body condition, feather coverage and resistance to handling were measured. The use of the range area by birds was assessed on day 2. The percentage of eggs laid out of nest boxes ('floor eggs') was recorded continuously on three of the farms, and egg quality was assessed from a sample of eggs every 10 weeks across the production cycle on all farms. Access to aerial perches significantly reduced the level of aggression in the slatted and litter areas of the house (P < 0.05). P birds had a significantly lower flight distance from the observer than NP birds (P < 0.05). In addition, NP birds resisted more to being handled than P birds (P < 0.01). P birds were heavier (P < 0.01) and had a greater body condition score (P < 0.05) than NP birds. There was no effect of treatment on feather coverage (P > 0.05), egg quality parameters (all P > 0.05), or the proportion of floor eggs (P > 0.05). In conclusion, these results suggest that the provision of aerial perches in commercial free-range farms leads to welfare benefits in terms of reduced fearfulness and aggression, and improved body condition.

Drake, K. A., et al. (2010). "Influence of rearing and lay risk factors on propensity for feather damage in laying hens." British Poultry Science **51**(6): 725-733.

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 the prospect of a ban on beak-trimming. 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.

Fahey, A. G., et al. (2007). "Relationship between body weight and beak characteristics in one-day-old white leghorn chicks: Its implications for beak trimming." Poultry Science **86**(7): 1312-1315.

Beak trimming is a routine practice used in laying hens to prevent feather pecking and cannibalism. The effect of beak trimming on bird well-being depends on multiple factors, including the amount of beak that is trimmed and the quality of the procedure. The aim of this work was to determine if a relationship existed between BW and beak characteristics in 1-d-old chicks, with a future aim to develop an automated system for standardizing beak trimming. Three hundred forty-four 1-d-old chicks (Hy-Line W-36) were sorted into 3 categories based on their BW (heavy, intermediate, and light), and their beaks were photographed. Dimensional measures of beaks, including the lengths of the culmen, gonys, maxillary tomia, mandibular tomia, and the width of the upper mandible and lower mandible measured at 2, 3, and 4 mm from the tip of the upper and lower beaks, were calculated using imaging software. Correlations between BW and beak measures were evaluated using Pearson product-moment, Spearman rank-order, Kendall's tau, and Hoeffding's dependency tests. Results showed there were no significant correlations between beak dimensions and BW in the light BW group. In contrast, correlations were present between BW and the width of the upper mandible measured at 4 mm from the tip of the upper beak ($P < 0.05$) and the width of the lower mandible measured 2 to 4 mm from the tip of the lower beak ($P < 0.05$) in the intermediate BW group. In the heavy BW group, BW was positively correlated with mandibular tomia, gonys, and the width of the lower mandible measured at 2 mm from the tip of the lower beak ($P < 0.05$). However, in general, these correlations

were too low (all below 0.23) to have any practical use for predicting beak size. Overall, the data indicated that BW cannot be used as a reliable predicator of beak size in 1-d-old Hy-Line W-36 chicks.

Fiks-van Niekerk, T. G. C. M. and A. Elson (2005). Abrasive devices to blunt the beak tip. Poultry welfare issues - Beak trimming. P. C. Glatz. Nottingham, Nottingham University Press**:** 127-131.

Although beak-trimming is performed to minimise feather and injurious pecking in laying hens and thus will reduce stress induced by these behaviours, the treatment itself is a stressor to the birds as well, especially because part of the living tissue of the beak is removed (refer to Chapter 3 and 4). It is however very difficult to mechanically shorten the tip of the beak without touching sensitive beak tissue. Also, the treatment may need to be repeated frequently as the tip can be expected to regrow. In both the Netherlands and the UK research has been conducted to blunt the tip of the beak by using abrasive materials in the feed trough. The idea for beak blunting by abrasion came from claw shortening by abrasion, which has been a requirement of the EU Council Directive 1999/74/EC for laying hens in cages since 01/01/03. A variety of abrasive materials have been found to be effective for claw shortening when fitted to the anti-egg eating baffle plates of laying cages. The idea was that hens blunt the tips of their beaks themselves and will continue to keep the beaks blunt. The reason for placing the abrasive device in the feeder is because hens spend a lot of time pecking the feed, the feed trough and flicking their beaks over the inner surfaces of the feeder.

Fiks - van Niekerk, T. G. C. M. and B. F. J. Reuvekamp (2004). Proef met touwbosjes tegen pikkerij: afdoende afleiding blijft uit. Pluimveehouderij. **34:** 18-19.

Touwbosjes in verrijkte kooien hielpen niet tegen pikkerij. De bosjes werden weliswaar flink aangepikt, maar de uitval door pikkerij was ook hoog.

Flisikowski, K., et al. (2009). "Variation in neighbouring genes of the dopaminergic and serotonergic systems affects feather pecking behaviour of laying hens." Animal Genetics **40**(2): 192-199.

Feather pecking is a behavioural disorder of laying hens and has serious animal welfare and economic implications. One of the several aetiological hypotheses proposes that the disorder results from redirected exploratory behaviour. Variation in the gene encoding the dopamine D4 receptor (DRD4) has been shown to be associated with exploratory behaviour in several species, including in a passerine bird species. We therefore considered DRD4 as a candidate gene for feather pecking. We have annotated DRD4 in the chicken genome and have re-sequenced it in 140 animals belonging to: experimental layer lines divergently selected for high and low propensity to feather pecking; the unselected founder population; and two commercial lines with low and high propensity to feather pecking. We have identified two sub-haplotypes of DRD4 that are highly significantly associated with feather pecking behaviour in the experimental (P = 7.30 x 10(-7)) as well as in the commercial lines (P = 2.78 x 10(-6)). Linkage disequilibrium (LD) extends into a neighbouring gene encoding deformed epidermal autoregulatory factor 1 (DEAF1). The product of DEAF1 regulates the transcription of the gene encoding the serotonin (5-hydroxytryptamine) 1A receptor. Thus, DEAF1 represents another candidate gene for feather pecking. Re-sequencing of five animals homozygous for the 'low-pecking' sub-haplotype and of six animals homozygous for the 'high-pecking' sub-haplotype delineated an LD block of 14 833 bases spanning the two genes. None of the variants in the LD block is obviously functional. However, the haplotype information will be useful to select against the propensity to feather pecking in chicken and to elucidate the functional implications of the variants.

Gentle, M. and S. Wilson (2004). Pain and the laying hen. Cambridge, Cabi Publishing.

Pain in animals can best be defined as 'an aversive sensory experience caused by actual or potential injury that elicits protective motor and vegetative reactions, results in learned avoidance, and may modify species-specific behaviour, including social behaviour'. Freedom from pain is essential for animal welfare. The ability to respond in an appropriate manner to aversive environmental stimuli is a basic characteristic of animals. Noxious stimuli excite cutaneous receptors (nociceptors), leading to reflex or non-reflex behavioural responses. While nociceptor activity cannot in isolation be considered indicative of pain, there is a clear relationship between nociceptor responses and pain experienced in humans. In animal studies of pain, it is necessary to combine nociceptive information with a range of behavioural and physiological measurements in order to estimate the probability of pain. In the life of a modern commercial hen, pain is likely to arise from acute traumatic injury caused by shackling, beak trimming or skeletal fracture, or from chronic pain caused by disease. Nociceptors, the most common of which were mechanothermal nociceptors, have been identified and physiologically characterized in the chicken beak, wattles, scaly skin, joints, mouth and nasal cavity. These send information to the CNS via small unmyelinated nerve fibres (C-fibres) and have differing properties according to location; those in the beak have lower thermal but higher mechanical thresholds than those in the scaly skin. A second group of mechanothermal nociceptors, the small myelinated A-delta fibres, occur in both the scaly skin and joints of the chicken and are similar to those only previously reported in the hairy skin of humans and primates. The combination of these nociceptors is thought to be responsible for a double pain sensation; the A-delta fibres being responsible for the immediate pain sensation and rapid reflex response to the stimulus while the second, qualitatively different pain sensation modulated by the slower C-fibres would prevent repetition. The nociceptors in the chicken ankle joint show little spontaneous activity or response to normal flexion or extension but respond to excessive lateral or rotational movements, thus serving as protection against joint damage. The forces applied to the legs of chickens during shackling have been shown to exceed the mechanical threshold required to excite the C-fibre mechanothermal nociceptors in the skin of the leg. Stimulus response curves for these nociceptors demonstrated that the maximum response in 63% of these was below the force applied in

shackling, providing evidence that the process is likely to be painful. The initial pain resulting from beak trimming probably lasts for between 2 and 48 s and is followed by a pain-free period of several hours, Thereafter, the painful consequences of beak trimming vary according to the age at which the procedure was conducted. If beak trimming occurs before 10 days of age, pain-related behavioural changes do not occur immediately: pecking is not reduced 6 h post-procedure but is reduced significantly by 26 h. Beak trimming in adults has more pronounced effects. Both beak-related and non-beak-related activities are affected for at least 5 weeks postprocedure. Electrophysiological recordings from the beak stump support this; in the weeks following beak trimming. large numbers of spontaneously active nerve fibres were recorded. There was no beak regeneration and extensive neuroma formation was observed adjacent to the scar tissue at the end of the beak. While skeletal fracture is common in laying hens, and pain following fracture in humans is common, there is no published information on the electrophysiological or behavioural responses to fracture. In view of the proposed ban on conventional cages, and with the fact that skeletal fracture is more common in aviary systems. there is a clear requirement for research on the welfare consequences of fracture in laying hens. Although widespread spontaneous arthropathies leading to loss of locomotor function are more common in meat-type poultry than layers. the latter do develop gout, bacterial and mycoplasma infections. The painful consequences of these conditions in the chicken have been investigated in experiments involving intra-articular injection of sodium urate or mycoplasma. After the injection of sodium urate, joint capsule C-fibre nociceptors became sensitized and birds exhibited behavioural changes indicative of pain, including one-legged standing, limping and sitting dozing, but rapidly returned to normal following the injection of local anaesthetic into the treated joint. Injection of killed Mycobacterium tuberculosis into the ankle joint produced a severe inflammatory arthropathy with a pronounced synovitis together with destructive cartilage damage. Recordings from the sensory receptors in the ankle joint showed that they were clearly sensitized and that inflammatory arthropathies found in the chicken are likely to be painful. This technique, when combined with quantitative gait analysis, showed that histological and electrophysiological changes were accompanied by a quantifiable, severe limp in the early stages (7-21 days after infection). At the more chronic stage of the disease (49-56 days after infection), while pathological changes were still observed in the joint capsule, the sensory fibres responded normally to mechanical stimulation and joint movement, and gait analysis showed that the birds were not lame.

Ghareeb, K., et al. (2008). "Individual differences in fear and social reinstatement behaviours in laying hens." International Journal of Poultry Science **7**(9): 843-851.

Individual differences in behavioural responses are of growing interest in behavioural studies. The present study investigated the consistency of the individual differences over time and across social (social reinstatement responses) and non social test situations (tonic immobility response). Three breeds of commercial hybrid layers (ISA Brown, Lohmann Tradition and Lohmann Silver) were reared from hatch to 37 weeks of age. Individual birds were subjected to tonic immobility test at 3, 5, 7, 10, 11, 15, 16, 20, 24, 35 and 37 weeks old and to runway test of sociality at 3, 5, 10, 16, 20 and 37 weeks old. Fearfulness did not show breed differences either in the overall means or in a certain tested age. However, ISA Brown had a higher latency to emerge to a runway than LT (16 and 20 weeks) and LS (at 37 weeks). In addition, ISA Brown hens had a higher latency to reinstate with their companion than LS (10 and 37 weeks). The individual ranks for behavioural traits of fear and sociality were consistent over time. These results indicate that fear and sociality responses are behavioural strategies used by individuals in certain test situation when repeated. Moreover, the duration of TI response was positively correlated to both sociality traits (latency to emerge and reinstate with a companion) indicating that birds had overall behavioural traits that were consistent across different contexts. This suggests that hens can be categorized into behavioural types or styles based on their test responses. The highly fearful birds (longer TI duration) had a higher latency to emerge and reinstate with their companions (reactive style) and the less fearful birds (shorter TI duration) had a lower latency to emerge and socially reinstate with their companions (proactive style). In conclusion, these individual differences are consistent over time and the behaviour of hens in one test can predict their behaviour in other test situation. Thus it could be used to assess individual hens and potentially be used in a breeding programme to select a hen with more desirable personality traits.

Gilani, A.-M., et al. (2012). "The effect of dark brooders on feather pecking on commercial farms." Applied Animal Behaviour Science **142**: 42-50.

Commercial laying hen chicks experience continuous light for up to 24 h/day in the first week of life. Under these conditions, active chicks disturb, and may direct feather pecks towards resting ones. Previous experimental work with small groups showed that both problems were reduced in chicks brooded by dark brooders (heaters). The current study aimed to extend these small-scale trials by examining the use of dark brooders on two commercial rearing farms. Each farm contributed two identical houses, one of them equipped with dark brooders and the other with regular brooders. The experiment comprised five replicates, each consisting of one dark brooder flock and one control flock (total of 10 flocks). Each flock contained 2000 Columbian Blacktail chicks with intact beaks, which were reared to organic standards. Observations took place three times during the rearing period at 1, 8 and 16 weeks and three of the five replicates were also followed into lay, with observations at 25 and 35 weeks. Bird weights, the evenness of body weight, mortality at the end of rear, feather pecking, the percentage of the flock with missing feathers and individual feather scores were measured, as well as the flock's reaction to a novel object and an approaching human in selected areas of the house. Apart from mortality, which was analysed as a paired t-test in PASW Statistics 18, data were ordered in three (or four) levels (visits within (flock within) replicate within farm) and were

analysed using the multilevel statistical software MLwiN 2.25. Treatment and age were entered in the model as explanatory variables. On average, across observations taken at all ages, dark brooder flocks performed significantly less severe feather pecking than control flocks ($\chi 2 = 12.215$, df = 1, P = 0.0005) and had a significantly lower percentage of birds with missing feathers ($\chi 2 = 7.380$, df = 1, P = 0.007). Individual feather condition deteriorated faster in the control treatment (treatment × age2: $\chi 2 = 12.148$, df = 1, P = 0.0005). There was also an interaction between treatment × age for weight ($\chi 2 = 11.087$, df = 1, P = 0.0009) which meant that dark brooded birds ended up slightly heavier than birds from the control treatment. Mortality at the end of rear, gentle feather pecking and evenness of the weight were not measurably affected by treatment. The novel object and human approach test gave mixed results. In conclusion we found no detrimental effects of dark brooding on commercial farms and suggest this is a promising approach to reducing problems with feather pecking and generally improving the welfare of commercial pullets.

Gilani, A.-M., et al. (2013). "The effect of rearing environment on feather pecking in young and adult laying hens." Applied Animal Behaviour Science **148**(1–2): 54-63.

Abstract Although the rearing period has an important influence on the development of feather pecking in laying hens, few studies have quantified the risk factors operating on commercial farms during this time and identified their long-term impact. Our aim was to conduct a longitudinal study to investigate the effect of rearing environment on feather pecking in young and adult laying hens. Thirty-four flocks from 29 rearing farms were recruited and visited at the beginning, middle and end of the rearing period and once at lay (35 weeks). Twelve flocks were beak trimmed. Information on rearing environment was used to create models predicting feather pecking and plumage damage during rear and lay, using the multilevel statistical software MLwiN 2.25. Across all flocks, gentle feather pecking (GFP) was observed during 94% of the visits at both rear and lay, at 1.3 and 1.0 bouts/bird/h respectively. Severe feather pecking (SFP) was observed during 27% of the visits during rear and during 65% of the visits at lay, with a mean rate of 0.4 pecks/bird/h during rear and 1.9 pecks/bird/h at lay, across all flocks. The mean percentage of the flock with missing feathers was 12% at 16 weeks and 49% at lay. The mean individual feather score at lay was 21 (range 6–24 (best)). The study confirmed that feather pecking and feather damage occur during the rearing period. Statistical modelling further showed that the percentage of the flock with missing feathers was significantly lower and individual feather scores significantly higher (better) at lay, in flocks where feather pecking had not started at the end of rear. The three models on the effect of rearing environment on GFP, SFP and the percentage of the flock with missing feathers during rear contained 21 significant variables. Approximately a third of those related to house climate (temperature, humidity, sound, light and dust levels), while another third related to foraging. Foraging itself appeared in all three models, confirming that good foraging is one of the major factors in reducing feather pecking. The four models on the effect of rearing environment on GFP, SFP, the percentage of the flock with missing feathers and individual feather scores at lay contained 17 significant variables and sound level was significant in three of the four. The analysis further indicated that experienced rearing staff was protective against feather pecking at both rear and lay and that feather pecking increased with an increasing number of diet changes during rear.

Glatz, P. and M. Bourke (2006). Beak trimming handbook for egg producers: best practice for minimising cannibalism in poultry. Collingwood, CSIRO Publishing.

This handbook is a practical guide to beak trimming of egg-laying hens to minimize cannibalism. It provides comprehensive information on why birds peck and how pecking can lead to problems like cannibalism; the methods available to beak trim birds; why a particular method should be chosen; and at what age birds may be trimmed. The book addresses quality control enabling egg producers to be confident that equipment is properly set up, that birds are handled and trimmed according to best practice and farm biosecurity is maintained. Management of birds following beak trimming, to protect the welfare of the birds and to ensure maximum productivity, is covered in detail. Best-practice, current methods of beak trimming, costs and ways to reduce the use of trimming are examined, along with expected future developments. The advantages and disadvantages are fully explored, covering both public and industry attitudes to the operation. Alternatives are canvassed to understand how the use of fitted devices, enrichment devices, abrasives, low lighting and the choice of low-pecking strains of birds can reduce the need for beak trimming.

Guinebretière, M., et al. (2014). "The choice of litter material to promote pecking, scratching and dustbathing behaviours in laying hens housed in furnished cages." Applied Animal Behaviour Science **155**(0): 56-65.

Gunnarsson, S., et al. (1999). "Effect of rearing factors on the prevalence of floor eggs, cloacal cannibalism and feather pecking in commercial flocks of loose housed laying hens." British Poultry Science **40**(1): 12-18.

1. Effects of rearing conditions on behavioural problems were investigated in a cohort study of commercial flocks of laying hens housed in 2 different loose housing systems. The sample population was 120 385 laying hens from 59 flocks of various hybrids at 21 different farms. 2. Logistic regression modelling was used to test the effects of selected factors on floor eggs, cloacal cannibalism and feather pecking. In addition to early access to perches or litter, models included hybrid, stocking density group size, housing system, age at delivery, identical housing system at the rearing farm and at the production farm and, in models for floor eggs and cloacal cannibalism, nest area per hen. Odds ratios were calculated from the results of the models to allow risk assessment. 3. No significant correlations were found between the prevalence of floor eggs, cloacal cannibalism and feather pecking. 4. Access to perches from not later than the 4th week of age decreased the prevalence of floor eggs during the

period from start-of-lay until 35 weeks of age, odds ratio 0.30 (P<0.001). Furthermore. early access to perches decreased the prevalence of cloacal cannibalism during the production period, odds ratio 0.46 (P=0.03). 5. No other factor had a significant effect in these models. Although it was not significant, early access to litter had a non-significant tendency to reduce the prevalence of feather pecking.

Gunnarsson, S., et al. (2000). "The demand for straw and feathers as litter substrates by laying hens." Applied Animal Behaviour Science **65**(4): 321-330.

Consumer demand theory has been applied to investigate behavioural demands and environmental requirements of farm animals. Recent research with laying hens has shown that the demand for various floor litters (peat, sand, wood-shavings) is inelastic. Other types of litter (e.g., straw and feathers) are available to laying hens in some housing systems. This study aimed to determine the importance of straw and feathers to laying hens by measuring demand functions for these items. In 1 h sessions individual birds (n = 6) were given the opportunity every second day to work on fixed ratio (FR) schedules (FR5 to FR200) for access to either straw or feathers. The number of responses made and reinforcers delivered was recorded, All birds worked to gain access to straw but only three worked for feathers. None of the hens dustbathed consistently in either litter. The mean elasticities of the demand were significantly different from zero and were -0.48 (s.e, 0.04; p < 0.001) for straw and -0.45 (s.e. 0.05; p < 0.001) for feathers. The results imply that even if a substrate does not stimulate dustbathing, caged laying hens have a high demand for a litter substrate. (C) 2000 Elsevier Science B.V. All rights reserved.

Guzmán, P., et al. (2015). "Inclusion of fiber in diets for brown-egg laying pullets: Effects on growth performance and digestive tract traits from hatching to 17 weeks of age." Poultry Science **94**(11): 2722-2733.

We investigated the effects of fiber inclusion in the diet on growth performance and digestive traits in pullets from hatching to 17 wk of age. The control diets of the 3 feeding periods (0 to 5 wk, 5 to 10 wk, and 10 to 17 wk) were based on corn and soybean meal and did not include any additional fiber source. The experimental diets included 2 or 4% of cereal straw or sugar beet pulp (SBP) at the expense (wt:wt) of the control diet. From 0 to 5 wk of age, fiber inclusion did not affect pullet performance. From hatch to 17 wk of age, the inclusion of straw had little effect on pullet performance but the inclusion of 4% SBP reduced (ADG) (P < 0.05) and reduced feed conversion ratio (FCR; P < 0.001). Pullets fed straw had greater ADG (P < 0.05) and better energy conversion ratio (P < 0.01) than pullets fed SBP. An increase in fiber from 2 to 4% reduced FCR (P < 0.05). Body weight uniformity was not affected by diet. Fiber inclusion increased the relative weight (% BW) of the gizzard at 5 wk (P = 0.056) and 10 wk (P < 0.01) of age, but no differences were detected between fiber sources. At same ages, the relative length (cm/kg BW) of the pullets (P = 0.058 and P < 0.01, respectively) and tarsus (P = 0.079 and P < 0.05, respectively) was higher in pullets fed SBP than in pullets fed straw. Fiber inclusion, however, did not affect any of these traits at 17 wk of age. In summary, the inclusion of 2% straw at the expense (wt:wt) of the whole diet did not affect pullet performance at 17 wk of age. An increase in the level of straw from 2 to 4% reduced FCR but did not affect ADG. The inclusion of SBP, however, reduced pullet growth, with effects being more pronounced at the higher level.

Haas, E. N. d., et al. (2010). "Selection on feather pecking affects response to novelty and foraging behaviour in laying hens." Applied Animal Behaviour Science **124**(3/4): 90-96.

Feather pecking (FP) is a major welfare problem in laying hens, influenced by multiple factors. FP is thought to be redirected foraging behaviour, however fearful birds are also known to be more sensitive to develop FP. The relationship between fear-responses, foraging and FP is not well understood, therefore we studied the behaviour of 16 birds from a high feather pecking (HFP) line and 16 birds from a low feather pecking (LFP) line at 35 weeks of age inside a plus-maze. Birds were from the 10th generation of selection for either high or low FP. First exposure to the maze was used to measure birds' fear-responses to a novel barren environment. Hereafter, birds were trained three times in the maze with four different food-items that were offered in one of the four arms (i.e. regular food-pellets, feathers, grass, and mealworms hidden in wood-shavings). On the fifth day, birds were tested in the maze for 10 min during which they could choose to eat from all available food-items. When exposed for the first time in the maze HFP birds walked a longer distance, vocalized sooner and had more exploratory pecks compared to LFP birds who showed more wing-movements and defecations. When given a choice of food inside the maze both lines preferred eating worms, but HFP birds had more worm-eating bouts and ate faster than LFP birds. The results of this study indicate that HFP birds respond actively to fear-eliciting situations, which may originate from a proactive coping style. Instead of a clear preference for eating feathers, this study supports earlier findings that HFP birds have a stronger pecking motivation than LFP birds.

Harlander-Matauschek, A., et al. (2006). "The demand of laying hens for feathers and wood shavings." Applied Animal Behaviour Science **101**(1-2): 102-110.

Feather eating is related to feather pecking in laying hens. The aim of this study was to investigate the birds demand for feathers compared to their demand for food and litter as feather pecking has been described as redirected ground pecking/foraging. The maximum price in terms of the number of pecks that individual animals were prepared to pay was recorded to determine the importance of food (as a standard), feathers and wood shavings in operant conditioning test. Birds were also tested in a session in which no reward was given. Nine low feather pecking birds and I I high feather pecking birds were used for this study and tested under progressive ratio 10 schedules (PR), where ratio values were progressively incremented by 10 each time reward was carried. Both high (HFP) and low (LFP) feather

pecking birds completed the highest maximum ratios with feed as a reinforcement followed by wood shavings, feathers and "no reward" pecking. HFP and LFP birds did not differ in their achieved maximum PR with feed as reinforcement. HFP birds achieved higher maximum prices than LFP birds with feathers as reinforcement. No line differences were found in maximum ratios completed with wood shavings. The maximum price paid by HFP birds was higher than that of LFP birds in sessions where no reward was offered. The operant technique showed that HFP and LFP birds found feathers and wood shaving reinforcing when presented as a food component. For feathers, this was more pronounced in HFP birds. (c) 2006 Elsevier B.V. All rights reserved.

Harlander-Matauschek, A., et al. (2009a). "Taste aversion learning to eliminate feather pecking in laying hens, Gallus gallus domesticus." Animal Behaviour **78**(2): 485-490.

Feather pecking in laying hens is a redirection of normal pecking behaviour. There is clear evidence that severe feather pecking is influenced by the motivational system of foraging and feeding. Feather pecking is positively associated with feather eating, indicating that feathers are seen as a feeding substrate by laying hens. Feed choice may be affected by many factors, including learning processes. In this experiment, feathers of other birds were made distasteful by adding a bitter taste (quinine). We investigated whether laying hens could detect quinine and learn to avoid the feather cover of conspecifics. We also examined the effects of quinine on birds' own feather-related activity (preening). Six groups of 10 high feather-pecking birds and six groups of 10 low feather-pecking birds were kept on litter. Half of these groups were quinine treated. Each bird of the quinine-treated groups was individually sprayed with a quinine solution. We investigated whether the presence of quinine on birds' feather cover affected severe and gentle feather pecking, aggressive pecking and preening. In the present study, severe and gentle feather pecking decreased when feathers were made distasteful, suggesting that learning occurred. Furthermore, the results suggest that quinine is an effective reinforcing agent to alter feather-pecking behaviour. Distasteful feathers did not influence preening, whereas aggressive behaviour was reduced. Our experiment showed that birds in the quinine treatment were able to learn that feathers from conspecifics were not attractive to peck at and they learned to avoid them for a period of time. (C) 2009 The Association for the Study of Animal Behaviour. Published by Elsevier Ltd. All rights reserved.

Harlander-Matauschek, A., et al. (2007a). "The relative preferences for wood shavings or feathers in high and low feather pecking birds." Applied Animal Behaviour Science **107**(1-2): 78-87.

High feather pecking birds (HFP) have been reported to be attracted by feathers of their pen mates while low feather pecking birds (LFP) direct most of their pecking activities towards litter. This raises the question if HFP birds show a preference for pecking at and/or ingestion of feathers over wood shavings and if LFP birds have a preference for wood shavings over feathers and secondly if birds housed alone in cages exhibit stronger motivation for feathers, in the case of HFP birds and wood shavings than birds who are group-housed on shavings. Ten LFP birds and 10 HFP birds were kept in individual cages. Three groups of five HFP birds and three groups of five LFP birds were kept on litter. Each bird was given access to a test arena equipped with four identical bowls. Each bowl was filled with mash, wood shavings, downy feathers and an empty bowl as a standard, respectively. After habituation to the test arena each bird was tested in a food and a non-food deprived state. The amount of substrate eaten, the total duration at each substrate, the latency to eat from each substrate and the number of visits to the different substrates was recorded. The lines did not differ in their relative preference for wood shavings. Caged birds ate more shavings and visited the bowl with wood shavings more often than birds from floor pens. Food deprived HFP birds and non-food deprived caged HFP birds ate more feathers than LFP birds. Our results showed that hens were motivated to eat feathers and wood shavings and that HFP birds had a stronger preference for feathers than LFP birds. (C) 2006 Elsevier B.V. All rights reserved.

Harlander-Matauschek, A. and U. Feise (2009b). "Physical characteristics of feathers play a role in feather eating behavior." Poultry Science **88**(9).

Feather pecking is positively associated with feather eating in laying hens; however the criteria of the birds for pecking, plucking, and eating feathers has not yet been systematically examined. In the present study, we investigated if laying hens show preferences for feathers of different lengths and regions. Twenty Lohmann Selected Leghorn hens with a high feather pecking activity were used in the present experiment. Ten birds were individually given access to 4 plastic elements, each perforated with 4 feathers 2, 4, 6, or 8 cm in length (i.e., 1 flat piece of plastic for each feather length). Another 10 hens were given access to 3 identical plastic elements, each perforated with 4 pieces of feather 2 cm in length from the calamus (part of the shaft closest to the bird body), middle (shaft with outer and inner vane), or tip (part of the shaft with vane furthest from bird body) of the feathers, respectively. The number of feathers of different lengths and regions plucked and eaten from each plastic element was recorded. Birds were tested over a period of 10 d on a daily basis. Laying hens preferred shorter feathers over longer ones. A rank ordering of preferred feather regions from the most to the least important using the number of pieces eaten gives a sequence of the tip, middle, and calamus of the feathers. The results clearly show that physical texture or appearance, or both, of feathers plays a role in feather pecking-eating behavior in laying hens.

Harlander-Matauschek, A., et al. (2007b). "A note on the relative preferences of laying hens for feathers from different body parts." Applied Animal Behaviour Science **108**(1-2): 186-190.

It is generally known that damage of the feather cover of laying hens by feather pecking is focused on particular body areas. The factors influencing this observation are not known. The aim of the present

experiment was to elucidate preferences for feathers extracted from different body areas when the feathers were presented independently of the pecked hen in a choice situation. Eleven high (HFP) and 13 low (LFP) feather pecking birds were kept in individual cages. Birds were individually given access to a test arena equipped with three identical plastic elements. Three feathers from either the vent, breast or neck region were inserted into small holes in the respective elements (i.e. one element for vent, breast and neck feathers, respectively). The number of visits to the elements, the latency to move towards one of the elements and the number of feathers eaten from each element were recorded. Birds were tested four times. HFP visited the elements containing breast feathers more frequently than LFP. There was no significant difference in the preference for feathers eaten from different body areas. There was, however, a development of preferences for feathers of the breast versus neck in HFP while feather of the vent took an intermediate position. The results indicate that the characteristics of the feathers of different body areas play a role in the feather damages observed in the poultry practice. (C) 2006 Elsevier B.V. All rights reserved.

Harlander-Matauschek, A. and T. B. Rodenburg (2011). "Applying chemical stimuli on feathers to reduce feather pecking in laying hens." Applied Animal Behaviour Science **132**(3-4): 146-151.

Recent studies have shown that spraying a distasteful substance (quinine) on a bird's feather cover reduced short-term feather pecking. The present experiment evaluated if other substances offer similar or better protection against feather pecking. One hundred and twenty birds were divided into 12 groups of 10 birds each. Over a period of 10 days the birds' response to 10 feathers coated with one of the 11 distasteful substances was observed and recorded. Feathers were soaked in a 1% garlic solution, 1% almond oil, 1% clove oil, 1% clove solution, quinine sulphate solution in four concentrations (0.1%, 1%, 2%, 4%), 0.6 mol magnesium chloride solution, anti-peck spray or an angostura solution. The control group received uncoated feathers. The number of feathers plucked, rejected or eaten was counted 60 min after presenting the feathers. All substances reduced feather plucking ($p < 0.0001$) and consumption ($p < 0.0001$) significantly, compared to uncoated feathers. Quinine concentrations of 2% and 4% were most effective. This study was the first to investigate the aversive potential of different substances to deter feather peckers from the feathers of other birds. The findings may be useful in the development of spraying devices to prevent feather pecking when other management tools fail. (c) 2011 Elsevier B.V. All rights reserved.

Harlander-Matauschek, A., et al. (2008). "Laying hens learn to avoid feathers." Poultry Science **87**(9): 1720-1724.

Previous work demonstrated an association between feather pecking and feather eating in laying hens. This raised the question if digestive feedback affects feather eating or feather pecking in laying hens. We hypothesized that feathers enriched with sugar form a positive feedback and feathers enriched with quinine sulfate form a negative feedback. Forty-eight laying hens were kept in individual cages and fed a pelleted diet ad libitum. Twenty-four birds were offered feathers on a daily basis; 12 of these birds were offered feathers soaked in 4% quinine sulfate solution (Q), and the other 12 were offered feathers soaked in 4% sucrose solution (S). The other 24 birds were kept as a control (C) without access to feathers. After a 10-d feather feeding period, 3 groups of 4 S and 4 C birds each and 3 groups of 4 Q and 4 C birds each were assembled. Feather-pecking behavior was recorded over a period of 8 d. The number of Q feathers eaten was significantly lower than the number of S feathers. Birds that were offered Q feathers in the feather feeding phase showed significantly less severe feather pecking than S and C birds. The results clearly show that Q as an unpalatable substance was the signal the animal used to avoid damaging the feather cover in laying hens.

Hartcher, K. M., et al. "Plumage damage in free-range laying hens: Behavioural characteristics in the rearing period and the effects of environmental enrichment and beak-trimming." Applied Animal Behaviour Science(0).

Abstract Severe feather-pecking, whereby birds peck at and pull out the feathers of other birds, is one of the greatest welfare concerns and the most prevalent behavioural problem in laying hens. It can be extremely difficult to control, especially in non-cage laying flocks. Despite a multitude of studies on the topic, the principal underlying causes remain unclear and not much is known about why certain birds are affected more than others. Literature suggests that rearing is an important period for the development of behaviours later in life. Although severe feather-pecking is not usually a welfare concern in the rearing period, behavioural tests when performed early in life may be predictive of plumage damage due to severe feather-pecking in adulthood. This experiment aimed to investigate whether behavioural tests during the rearing period could be predictive of plumage damage later in life. Sixteen pens of 50 ISA Brown laying hens were used, with four birds per pen selected at random as focal birds. Focal birds were subjected to behavioural tests during the rearing period including the open-field test, tonic immobility test and tests for a novel food reward. Two treatments, beak-trimming and environmental enrichment, were applied in a 2 × 2 factorial arrangement in rearing. The non-trimmed birds vocalised more (P = 0.02, 91.5 vs. 83.6%) and at louder volumes (P = 0.02, 71.4 vs. 47.0% of vocalisations categorised as loud rather than soft or silent) in the open-field test at 5 weeks of age. There was no difference between treatments in duration of tonic immobility (P = 0.99). Non-trimmed birds exhibited more plumage damage at 43 weeks of age (P < 0.001, 5.2 vs. 72.9% of birds with feather loss or wounds). Ordinal regression with treatments and treatment interactions as fixed effects and pens and blocks (sides of the shed) as random effects indicated no significant associations between behavioural test reactions and plumage damage (all P > 0.1). Thus while beak-trimmed birds made fewer vocalisations in an open-field test and had less plumage damage in adulthood as expected, there is no evidence that reactions to the behavioural tests were predictive of plumage damage. Instead, results indicate that environmental enrichment affected bird behaviour

during the rearing period but did not affect plumage damage due to severe feather-pecking later in life. The test responses including more vocalisations in the open-field test, but no difference in the tonic immobility responses, indicate that the differences may be due to motivation for social reinstatement rather than fearfulness.

Hemsworth, P. H. (2009). Impact of human-animal interactions on the health, productivity and welfare of farm animals. Wageningen, Wageningen Academic Publishers.
While technical skills and knowledge are important attributes of the work performance of stockpeople, two other important but less well recognised characteristics of stockpeople are their attitude and behaviour towards farm animals. Research has shown that the attitude of the stockperson, by affecting the stockperson's behaviour, can affect animal fear and stress and in turn animal productivity, health and welfare. While fear thresholds have been reduced by domestication, fear responses to humans have not been eliminated in farm animals. Indeed there is considerable variation within farm animal species in their fear responses to humans and this variation highlights both limitations to animal productivity, health and welfare and the opportunities to reduce these limitations in the livestock industries. This chapter examines the impact of human-animal interactions on farm animals and discusses the opportunities to improve human-animal interactions to improve animal health, productivity and welfare. The chapter concludes that there is a strong case for utilizing stockperson training courses that target stockperson attitudes and behaviour.

Hierden, Y. M. v., et al. (2004). "Chronic increase of dietary L-tryptophan decreases gentle feather pecking behaviour." Applied Animal Behaviour Science **89**(1/2): 71-84.
Many studies show the involvement of the serotonergic (5-HT) system in the performance of abnormal behaviour in both human and animals. Recently, we showed that acute reduction of 5-HT turnover in the forebrain, increased gentle and severe feather pecking behaviour in chicks from a high (HFP) and low feather pecking (LFP) line of laying hens, suggesting that the performance of feather pecking behaviour involves low 5-HT neurotransmission. In the present study, we postulated that if low 5-HT is causally underlying feather pecking, increasing 5-HT turnover in the forebrain will decrease the development and performance of feather pecking. Augmentation of 5-HT neurotransmission in the brain was induced by chronically increasing dietary levels of the essential amino acid L-tryptophan (TRP) from which 5-HT is synthesised. From the age of 34 days, LFP and HFP chicks were fed a diet containing 2% TRP, whereas control birds of both lines were continuously fed with the normal rearing feed (0.16% TRP). From 35 days of age, litter was removed from the pens (10 pens/line-treatment) and all chicks (10 chicks/pen) were housed on a slatted floor until the end of the experiment. At 49 days of age, feather pecking behaviour was studied for 30 min. At 50 days of age baseline corticosterone, TRP and other large amino acids (LNAAs) were measured in the blood plasma of decapitated chicks (10 chicks per line-treatment). Furthermore, plasma corticosterone and central 5-HT turnover levels in response to manual restraint (5 min) were determined (10 chicks/line-treatment). For neither gentle nor severe feather pecking a significant line x treatment interaction was found. However, TRP treatment resulted in a significant [P=0.02] overall decrease of the frequency of gentle feather pecking. For severe feather pecking a similar but not significant pattern was found. Significant line effects were found for gentle and severe feather pecking. HFP birds showed significantly higher levels of gentle and severe feather pecking behaviour than LFP birds [P<0.001]. TRP treatment significantly increased the TRP/LNAA ratio in the plasma of the chicks. Furthermore, TRP treatment overall increased baseline and stress-induced levels of plasma corticosterone (although more pronounced in the LFP line). TRP supplementation significantly increased 5-HT turnover in the hippocampus and archistriatum and tended to do so in the remainder of the forebrain. The results confirm our hypothesis that feather pecking behaviour is triggered by low serotonergic neurotransmission, as increasing serotonergic tone, by increasing dietary TRP, decreases gentle feather pecking behaviour.

Holcman, A., et al. (2008). "Porous concrete block as an environmental enrichment device increases activity of laying hens in cages." Poultry Science **87**(9): 1714-1719.
The purpose of this study was to consider the influence of simple and cheap environmental enrichment such as porous concrete on the behavior of laying hens in conventional cages. Forty brown laying hens were housed in individual wire mesh cages: 20 in experimental cages with porous concrete block provided for pecking and 20 in a control group without concrete block provided. Porous concrete block (5 cm length x 5 cm width x 5 cm height) was mounted on the side wall at the height of the hen's head. Behavior was studied from 42 to 48 wk of age. A group of 8 hens was filmed for 24 h, and the camera was moved each day so that all 40 hens were recorded over 5 d each wk. Video-taping was performed in wk 1, 3, 5, and 7 of the experiment. States (long-term behavior) were observed with 5-min interval recording (feeding, preening, resting, and remaining inactive), whereas events (short-term activities) were observed with instantaneous recording (drinking, pecking concrete, pecking neighbors, pecking cage, and attempting to escape). Data were analyzed with generalized linear mixed model with binomial distribution for states, and Poisson distribution for events. Monte Carlo Markov Chain methods were used to estimate model parameters. Because posterior distributions of quantities of interest were skewed, medians and standard errors are reported. Hens in experimental cages were more active in long-term behavior than controls (64.9 +/- 1.9 and 59.3 +/- 1.9% of the light period, respectively). Correspondingly, hens in the control group showed more long-term inactivity. In addition to pecking the porous concrete block, hens in experimental cages also showed other short-term activities with greater frequency (4.10 +/- 0.31 and 3.51 +/- 0.25 events per h, respectively). Our hypothesis that hens in enriched cages would have a greater level of activity was confirmed.

Provision of a piece of porous concrete block as a pecking substrate enriched the environment of the birds at negligible cost.

Janczak, A. M. and A. B. Riber (2015). "Review of rearing-related factors affecting the welfare of laying hens." Poultry Science.

Laying hens may face a number of welfare problems including: acute and chronic pain caused by beak trimming; exaggerated fearfulness that may cause stress and suffocation; difficulties in locating resources, resulting potentially in emaciation and dehydration; frustration and boredom, caused by an environment that is barren; feather pecking; cannibalism; foot lesions; and bone fractures. In Europe, a greater proportion of laying hens are housed in non-cage systems compared to the rest of the world. The extent of the different welfare problems may therefore vary between countries as the type of housing system influences the risk of suffering. More generally, many of these welfare problems are influenced by the rearing environment of the pullets. This article therefore focuses on welfare problems in laying hens that can be traced back to rearing. Factors that have been studied in relation to their effects on bird welfare include beak trimming, housing type, furnishing, enrichment, feeding, stocking density, flock size, sound and light levels, concentration of gasses, age at transfer from rearing to production facilities, similarity between rearing and production facilities, competence of staff, and interactions between bird strain and environment. The present review aims to summarize rearing-related risk factors of poor welfare in adult laying hens housed according to European Union legislation. It aims to identify gaps in current knowledge, and suggests strategies for improving bird welfare by improving rearing conditions. Two main conclusions of this work are that attempts should be made to use appropriate genetic material and that beak trimming should be limited where possible. In addition to this, the rearing system should provide constant access to appropriate substrates, perches, and mashed feed, and should be as similar as possible to the housing system used for the adult birds. Finally, young birds (pullets) should be moved to the production facilities before 16 weeks of age. The measures outlined in this review may be useful for improving the welfare of pullets and adult laying hens.

Jendral, M. J. and F. E. Robinson (2004). "Beak trimming in chickens: historical, economical, physiological and welfare implications, and alternatives for preventing feather pecking and cannibalistic activity." Avian and Poultry Biology Reviews **15**(1): 9-23.

Beak trimming is a commonly practiced procedure in the poultry industry and usually involves partial amputation of the upper and lower beak. Beak trimming is performed to reduce mortality and production losses associated with feather pecking and cannibalistic behaviour. Although the procedure is traumatic and may cause acute and chronic pain, the consequences of feather pecking and cannibalistic activity may be more detrimental to bird welfare than the act of beak trimming. This review addresses the predisposing factors for feather pecking and cannibalism, and the historical and legislative developments of beak trimming. Beak anatomy is reviewed and post-trimming physiological effects are considered, as they relate to pain. Methods of beak trimming and alternative solutions are presented.

Jensen, A. B., et al. (2006). "Effect of brooders on feather pecking and cannibalism in domestic fowl (Gallus gallus domesticus)." Applied Animal Behaviour Science **99**(3-4): 287-300.

Several studies have shown that the tendency to feather peck is influenced by events early in life and preventive measures should therefore be introduced at hatching. Separating inactive chicks from active chicks by providing dark electrical brooders was predicted to reduce the risk of chicks developing pecking preferences for conspecifics. Twelve groups of 15 layer hen chicks (Lohmann Tradition) were reared in pens (2.55 m(2)); during the first 5 weeks after hatching six pens were provided with dark brooders and six pens with heating lamps. All pens were observed continuously for 30 min per pen once a week until the chickens were 23 weeks old, and each bout of severe feather pecks was recorded. The chickens were observed several times daily, and all injured individuals were removed from the experiment. Faecal samples were collected from the pens when the chicks were 16, 17 and 18 days old and analysed for corticosterone metabolites. At the end of the experiment, the plumage and skin damage were scored. Data were analysed using repeated measures ANOVA. The dark brooders completely prevented severe feather pecking in the dark brooder pens, whereas the frequency of severe feather pecking rose with age in the heating lamp pens (treatment x age: $P < 0.0001$). At the last observation (week 23), the frequency of severe feather pecking bouts in the dark brooder pens was 0.3 +/- 0.4 (mean S.E.) compared to 31.3 +/- 10.1 in the heating lamp pens. The frequency of gentle feather pecking was significantly higher in the heating lamp pens at all ages ($P < 0.0001$). Mortality followed the same pattern as severe feather pecking; it was almost nonexistent in the dark brooder pens, whereas from point of lay it continued to rise with age in the heating lamp pens (1 versus 24 casualties, treatment x age: $P < 0.0001$). The high level of severe feather pecking in the heating lamp pens was also reflected in the scores of plumage and skin damage as both were found to be significantly higher in the heating lamp pens (plumage: $P = 0.0004$; skin: $P = 0.0273$). There was no difference between treatments in concentrations of faecal corticosterone metabolites ($P = 0.8146$). The results suggest that the provision of dark brooders has a long-lasting reducing effect on the frequency of feather pecking and cannibalistic attacks, resulting in reduced mortality and an improved condition of both plumage and skin.

Jensen, P., et al. (2005). "Feather pecking in chickens is genetically related to behavioural and developmental traits." Physiology & Behavior **86**(1-2): 52-60.

Feather pecking (FP) is a detrimental behaviour in chickens, which is performed by only some individuals in a flock. FP was studied in 54 red junglefowl (ancestor of domestic chickens), 36 White Leghorn laying hens, and 762 birds from an F-2-intercross between these two lines. From all F-2-birds, growth and feed consumption were measured. Age at sexual maturity and egg production in females, and corticosterone levels in males were also measured. From 333 F-2-birds of both sexes, and 20 parental birds, body composition with respect to bone mineral content, muscle and fat was obtained by post-mortem examinations using Dual X-Ray Absorptiometry (DXA). In femurs of the same birds, the bone density and structure were analysed using DXA and Peripheral Quantitative Computerized Tomography (pQCT), and a biomechanical analysis of bone strength was performed. Furthermore, plumage condition was determined in all birds as a measure of being exposed to feather pecking. Using 105 DNA-markers in all F2-birds, a genome-wide scan for Quantitative Trait Loci (QTL), associated with the behaviour in the F-2-generation was performed. FP was at least as frequent in the red junglefowl as in the White Leghorn strain studied here, and significantly more common among females both in the parental strains and in the F-2-generation. In the F-2-birds, FP was phenotypically linked to early sexual maturation, fast growth, weak bones, and, in males, also high fat accumulation, indicating that feather peckers have a different resource allocation pattern. Behaviourally, F-2 feather peckers were more active in an open field test, in a novel food/novel object test, and in a restraint test, indicating that feather pecking might be genetically linked to a proactive coping strategy. Only one suggestive QTL with a low explanatory value was found on chromosome 3, showing that many genes, each with a small effect, are probably involved in the causation of feather pecking. There were significant effects of sire and dam on the risk of being a victim of feather pecking, and victims grew faster pre- and post-hatching, had lower corticosterone levels and were less active in a restraint test. Hence, a wide array of behavioural and developmental traits were genetically linked to FP.

Jones, R. B. (2004). Environmental enrichment: the need for practical strategies to improve poultry welfare. Cambridge, Cabi Publishing.

The banning of traditional battery cages for laying hens in the European Community from 2012 largely reflects consumers' wishes for their food to be produced with greater respect for animal welfare. However, farmers also need to make a living and alternative housing systems can generate their own welfare and production problems. Therefore, to ensure sustainability of European agriculture, we must identify practical ways of minimizing major behavioural problems, like fear and feather pecking. Environmental enrichment may help in this respect. However, the birds ignore many so-called enrichment devices and others exert undesirable effects. Rather than relying on human preconceptions to guide the development of enrichment, we should establish the birds' preferences. Enrichment procedures must satisfy critical requirements; these include practicality, sustained interest, promotion of desirable behaviours and reduction of harmful ones. This chapter provides an overview of recent findings. Televised stimuli attracted chickens; their regular presentation reduced fear, and effective images incorporated movement, brightness, colour, and moderate complexity. Although we cannot introduce televisions into poultry houses, projecting images on to the walls might be practicable. Farmers reported that playing the radio reduced aggression, improved the birds' health and increased productivity; this strategy also enriches the farmers' environment. The presence of a familiar odorant reduced chicks' fear of novel places, birds and food; indicating that olfactory therapy might minimize certain behavioural problems. Ultraviolet light might be used as enrichment because it reduced injurious pecking in turkeys and the basal corticosterone level in chicks; this merits further investigation. Providing chickens with string promoted foraging, sustained lengthy interest, and reduced feather pecking and feather damage in the laboratory and at a commercial farm. Clearly, extraneous stimulation is important to chickens. Although environmental enrichment should not be regarded as a panacea for welfare problems, the provision of appropriate visual, auditory, olfactory and tactile enrichment is likely to improve their quality of life.

Jones, R. B., et al. (2004). "Feather pecking in poultry: the application of science in a search for practical solutions." Animal Welfare **13**: S215-S219.

Traditional battery cages for laying hens will soon be banned in the EU but the increased risk of feather pecking (FP) hampers the adoption of alternative housing systems. FP can cause injury and lead to cannibalism and the painful death of target birds. Current management practices (beak trimming, low light) have associated problems. In a joint European project we sought alternative solutions. In our study of associated traits, birds from a line showing low (LFP) rather than high feather pecking (HFP) exhibited greater sociality (motivation to be near companions) and a passive 'coping' style. High sociality and passivity were also negatively associated with FP in adults. These findings may guide future breeding programs. Trimming hens' feathers to mimic the results of FP elicited pecking and some cannibalism, even by birds that had previously shown no FP. Social transmission of gentle but not severe FP occurred when LFP and HFP birds were housed together. Gentle pecking could conceivably lead to severe FP. We then examined chickens' pecking preferences to guide environmental enrichment strategies. Bunches of string elicited substantially greater interest than other stimuli, including feathers, and white or yellow string was the most attractive. The birds' manipulation of the string resembled preening. Incorporating silver beads or moving the devices reduced pecking. String sustained lengthy interest reduced FP in HFP birds, and decreased feather damage in caged layers on a commercial form. String offers effective, affordable and practicable environmental enrichment. The integrated application of appropriate environmental and genetic strategies is likely to attenuate the expression of FP and its harmful consequences.

Jordan, D., et al. (2010). "The influence of sequential feeding on behaviour, feed intake and feather condition in laying hens." Applied Animal Behaviour Science **127**(3-4): 115-124.

Feeding of whole-wheat grains and a protein-mineral concentrate in sequence had been shown to modify behaviour in broilers and performance in laying hens. The objective of this study was to test whether sequential feeding with wheat would induce changes in laying hen's behaviour, feed intake, feather condition, and egg production. These parameters were measured on 320 non-beak-trimmed ISA Brown laying hens from 30 to 37 week of age. The birds were placed in 64 standard cages (five birds/cage) and allotted to one of four treatments. The control (C) was fed a complete conventional diet. Three treatments were fed sequentially with whole wheat (SWW), ground wheat (SGW) or ground wheat with added vitamin premix + phosphorus + 2% oil (SGWI). In sequential treatments, 50% of the ration was fed as wheat and the remaining 50% as a protein-mineral concentrate (balancer diet). All treatments received their daily ration in two distributions: 09:00(4 h after light on) and 16:00 h (5 h before light off). During weeks 30,32 and 34, hens' behaviour was recorded using scan sampling method (once per week during the light period), while focal sampling was used between the 32 and 34 weeks (2 halter each feeding, and 2 h in between). Feather condition of individual hen was scored at 30 and 37 weeks, number of eggs and feed intake were recorded weekly. Sequential feeding delayed the oviposition for almost 1 h. When fed wheat-based diet (09:00-16:00 h) SWW birds spent less time feeding and stood still longer compared to birds in other treatments. Four hours after distribution of wheat diets, the occurrence of feather peaking was the highest in SWW and the lowest in the SGW treatment. The poorest feather condition was recorded in the SWW treatment. Total feed intake was the highest in the C treatment, while the intake of wheat diet and the ratio wheat diet intake/total feed intake was the highest in the SGWI treatment. We concluded that sequential feeding with whole wheat had detrimental effect on behaviour of laying hens probably due to long period of access to wheat used in this work. It is therefore suggested that wheat should be used either ground or presented on shorter time sequence. The time access should be reduced when whole wheat is used. (C) 2010 Elsevier B.V. All rights reserved.

Kalmendal, R. and W. Bessei (2012). "The preference for high-fiber feed in laying hens divergently selected on feather pecking." Poultry Science **91**(8): 1785-1789.

Earlier studies in laying hens have demonstrated a negative correlation between feather pecking and the dietary fiber content of the feed. However, the factors underlying this relationship are not fully understood. In the present experiment, we hypothesized that birds prone to feather pecking would prefer a diet supplemented with dietary fiber. Thus, the aim was to investigate the voluntary consumption of a wheat-soy control diet (CON) and a diet supplemented with 8% spelt hulls (FIB) on the expense of wheat in 20 individually caged hens selected for high feather pecking (HFP) behavior and 20 individually caged hens selected for low feather pecking (LFP) behavior. The proportional intake of FIB was 0.39 and significantly different from 0.50 ($P < 0.001$). As hypothesized, HFP had higher proportional intake of FIB (0.43) than LFP hens (0.36; $P < 0.05$). The HFP hens had inferior plumage condition ($P < 0.001$), higher BW ($P < 0.001$), and higher feed intake ($P < 0.01$) than LFP. The HFP hens plucked more feathers from a simple inanimate feather-pecking model, but the number of feathers being pulled out did not correlate with the proportional intake of FIB. It was concluded that the preference for feed supplemented with spelt hulls was different between hens displaying different feather-pecking behavior. The underlying reason for such a difference needs further investigation.

Kjaer, J. B. (2011). "Neonate pecking preferences and feather pecking in domestic chickens: investigating the 'changed template' hypothesis." Archiv Fur Geflugelkunde **75**(4): 273-278.

Domestic chickens from lines selected for low (LFP) or high (HFP) levels of feather pecking (FP) were reared in 14 bird groups and pecking to various forms presented on a computer screen was recorded at 2 weeks of age. HFP chickens delivered significantly more pecks (combined for all forms: circle, ellipse, rod, rods in feather like pattern and feather in colours: red, yellow, green) than LPF chickens, whereas no significant effects were found for form, colour, hatch or interactions. Total FP (sum of gentle and severe FP) was significantly higher in HFP chickens and decreased significantly with increasing age from 6 over 9 to 21 days. According to the 'changed template'-hypothesis, pecking preferences of HFP chickens would differ to those of LFP chickens but data could not support this hypothesis. Rather, the HFP chickens pecked at any form and colour with a much higher intensity than the LFP chickens lending support to the hyperactivity model of feather pecking in that genetic selection for a higher level of FP is paralleled by a higher level of arousal leading to increased pecking to animate (FP) as well as inanimate (i.e. forms on a screen) stimuli.

Kjaer, J. B. and D. Guemene (2009). "Adrenal reactivity in lines of domestic fowl selected on feather pecking behavior." Physiology & Behavior **96**(2): 370-373.

Domestic chicken lines of the White Leghorn layer type differing in their level of feather pecking have been developed by divergent selection specifically on feather pecking behavior. This paper describes an investigation of basal level. reactivity to manual restraint and maximal adrenal response to 1-24 ACTH in breeder birds of the sixth generation of selection (S6) and their control line. Birds from the three lines had comparable basal levels of corticosterone (1.6 ng/ml, anova $F(2.101)=0.62$, ns), whereas males had higher basal levels than females, Ismean 1.9 vs. 1.5 ng/ml (anova $F(1.103)=6.03$. $P<0.05$). Reactivity to handling and restraint for 10 min differed with HFP birds showing higher reactivity than LFP birds, Ismean 11.0 vs. 7.9 ng/ml ($t=-2.00$, $P<0.05$), while control birds showed intermediate levels (10.2 ng/ml). Males had higher reactivity than females, Ismean 11.2 vs. 8.2 ng/ml (anova $F(1.103)=3.96$, $P<0.05$). Maximal response did not differ between lines (average 35.7 ng/ml. anova $F(2.101)=1.38$, $P>0.05$). Males had higher maximal response than females, Ismean 41.3 vs.

33.6 ng/ml (anova F(1.103)=5.77, P<0.05). The present study shows that selection against feather pecking behavior have resulted in lower levels of feather pecking as well as lower sensitivity to human handling and restraint in White Leghorn laying hen lines. From an animal welfare point of view this is a positive relationship. (C) 2008 Elsevier Inc. All rights reserved.

Kjaer, J. B., et al. (2004). "Effects of haloperidol, a dopamine D2 receptor antagonist, on feather pecking behaviour in laying hens." Applied Animal Behaviour Science **86**(1-2): 77-91.

Two experiments investigating general behavioural activity and specific pecking behaviour in laying hens under the effect of a dopamine D2 receptor antagonist, haloperidol, were performed. In experiment 1, a total of 240 White Leghorn hens aged 70 weeks were housed in 30 floor pens. Fifty-five of these hens acted as subjects in a (Jose-response experiment. Behaviour was recorded 30 min before and 30 min after injection of haloperidol or saline. The changes in behaviour were corrected for the effect of saline treatment. The results showed that doses of 0.05,0.10,0.20 and 0.50 mg haloperidol/kg body weight (BW) did not give any clear sedative effect, while 1.0 mg haloperidol did so. Thus, the sedative effect seemed to arise at a dose between 0.50 and 1 mg halopeildol/kg and it was concluded that 0.50 mg haloperidol/kg could be used in White Leghorn hens without inducing sedation. In experiment 2, a total of 48 ISA Brown hens aged 118 weeks were used as subjects. The birds were paired with 82-week-old White Leghorn hens chosen at random from an experimental line selected against feather pecking and housed in battery cages. Feather pecking and aggressive pecking were recorded for a period of 50 min before and 50 min after injection of either saline or 0.50 mg haloperidol/kg BW. Feather pecking, but not aggressive pecking, was significantly reduced in the haloperidol treatment (from 1.7 to 0.29 bouts per bird/h, Mann-Whitney U-test N = 18, P < 0.05; 10.1 to -2.7 pecks per bird/h, P < 0.001). The negative value was due to correcting for effect of injection.The results supported our hypothesis that feather pecking behaviour in the adult hen is influenced by dopamine. (C) 2003 Elsevier B.V. All rights reserved.

Kjaer, J. B. and P. M. Hocking (2004). The genetics of feather pecking and cannibalism. Cambridge, Cabi Publishing.

Feather pecking and cannibalism are important welfare issues in the battery cage system and even more of a problem in alternative systems of egg production. Interest in the genetics of feather pecking and cannibalism has grown in the last few decades and a genetic solution might be more sustainable, efficacious and cost-effective than environmental modifications. Strain differences in the plumage condition of laying hens and feather pecking behaviour have been reported. More recently within-line genetic components of feather pecking and cannibalism have been quantified. Estimates of the heritability of plumage condition range from moderate (0.22) to high (0.54) and the heritability of observations of pecking behaviour from 0.06 to 0.38. Some selection experiments have produced little or no evidence of a response. However, in one experiment, group selection was very effective in reducing the incidence of beak-inflicted injuries in caged hens and realized family heritability was 0.65 +/- 0.13. Divergent selection for high and low feather pecking resulted in significant differences in feather pecking behaviour and plumage condition. There is uncertainty about the correlated responses to selection for low feather pecking and cannibalism, and this justifies more research. Molecular approaches may offer the opportunity for selection to decrease feather pecking and cannibalism without compromising the welfare of birds in the selected flock. However, the evidence so far is not encouraging, and future opportunities to change the propensity for damaging feather pecking and cannibalism in commercial laying hens will probably rely on conventional selection in appropriate environments.

Kjaer, J. B. and H. Jorgensen (2011). "Heart rate variability in domestic chicken lines genetically selected on feather pecking behavior." Genes Brain and Behavior **10**(7): 747-755.

Domestic chicken lines of the White Leghorn type differing in their level of feather pecking were developed by divergent genetic selection specifically on feather pecking behavior. We determined parameters of heart rate variability to elucidate the relative activation of the sympathetic and parasympathetic nervous systems during rest and stressful situations. A total of 48 hens were tested in 8 batches. Segments of 2 min were extracted from electrocardiograms recorded by radio-transmitter implants, before (basal undisturbed conditions) and during physical restraint and a social test. Under basal conditions mean distance between R-waves were shorter in the low and high lines compared to the control. During physical restraint, stress reactions [reduced root of the mean squares of successive differences (RMSSD), reduced high frequency (HF), high low frequency (LF/HF) and low vagal-sympathetic effect (VSE) compared to basal levels] were significant in all lines. During the physical restraint the high feather pecking (HFP) line reacted significantly stronger than control (CON) and low feather pecking (LFP) line. During social test the LFP line reacted different than the other two lines. Seemingly birds from LFP conceived the social test as less stressful than birds from the CON and HFP lines. From this it follows that (1) physical restraint generally induced higher stress reactions than the social test and (2) genetic selection for higher levels of feather pecking increased the autonomic nervous system reaction to physical restraint whereas selection against feather pecking has reduced the response to increased social contact.

Kjaer, J. B., et al. "Perseveration in a guessing task by laying hens selected for high or low levels of feather pecking does not support classification of feather pecking as a stereotypy." Applied Animal Behaviour Science(0).

Abstract Feather pecking is a behaviour by which birds damage or destroy the feathers of themselves (self-pecking) or other birds (allo feather pecking), in some cases even plucking out feathers and

eating these. The self-pecking is rarely seen in domestic laying hens but is not uncommon in parrots. Feather pecking in laying hens has been described as being stereotypic, i.e. a repetitive invariant motor pattern without an obvious function, and indeed the amount of self-pecking in parrots was found to correlate positively with the amount of recurrent perseveration (RP), the tendency to repeat responses inappropriately, which in humans and other animals was found to correlate with stereotypic behaviour. In the present experiment we set out to investigate the correlation between allo feather pecking and RP in laying hens. We used birds (N = 92) from the 10th and 11th generation (G10 and G11) of lines selectively bred for high feather pecking (HFP) and low feather pecking (LFP), and from an unselected control line (CON) with intermediate levels of feather pecking. We hypothesised that levels of RP would be higher, and the time taken (standardised latency) to repeat a response lower, in HFP compared to LFP hens, with CON hens in between. Using a two-choice guessing task, we found that lines differed significantly in their levels of RP, with HFP unexpectedly showing lower levels of RP than CON and LFP. Latency to make a repeat did not differ between lines. Latency to make a switch differed between lines with a shorter latency in HFP compared to LFP (in G10), or CON (in G11). Latency to peck for repeats versus latency to peck for switches did not differ between lines. Total time to complete the test was significantly shorter in HFP compared to CON and LFP. Thus, our hypotheses were not supported by the data. In contrast, selection for feather pecking seems to induce the opposite effects than would be expected from stereotyping animals: pecking was less sequenced and reaction to make a switch and to complete the test was lower in HFP. This supports the hyperactivity-model of feather pecking, suggesting that feather pecking is related to a higher general activity, possibly due to changes in the dopaminergic system.

Kriegseis, I., et al. (2012). "Feather-pecking response of laying hens to feather and cellulose-based rations fed during rearing." Poultry Science **91**(7): 1514-1521.

Recent studies in laying hens have shown that feather peckers eat more feathers than nonpeckers. We hypothesized that food pellets containing feathers would decrease the birds' appetite for feathers and thereby also decrease feather pecking. To separate the effect of feathers from that of insoluble fiber per se, additional control groups were fed pellets containing similar amounts of cellulose. Sixty (experiment 1) and 180 (experiment 2) 1-d-old Lohmann-Selected Leghorn birds were divided into 12 groups of 5 (experiment 1) and 15 (experiment 2) birds, respectively, and kept on slatted floors. During the rearing period, 4 groups each had ad libitum access to either a commercial pelleted diet, a pelleted diet containing 5% (experiment 1) or 10% (experiment 2) of chopped feathers, respectively, or a pelleted diet containing 5% (experiment 1) or 10% (experiment 2) of cellulose, respectively. In the consecutive laying period, all groups received a commercial pelleted diet. In experiment 1, feather pecking was recorded weekly from wk 5 to wk 16. In the laying period, observations were made in wk 18, 20, 22, 23, 24, 25, 26, 27, 28, and 30. In experiment 2, feather pecking was recorded weekly from wk 5 to 11, in wk 16 to wk 18, and in wk 20 and 21. At the end of the rearing period, plumage condition per individual hen was scored. Scores from 1 (denuded) to 4 (intact) were given for each of 6 body parts. The addition of 10% of feathers to the diet reduced the number of severe feather-pecking bouts ($P < 0.0129$) and improved plumage condition of the back area ($P < 0.001$) significantly compared with control diets. The relationship between feather pecking/eating and the gastrointestinal consequences thereof, which alter feather pecking-behavior, are unclear. Understanding this relationship might be crucial for understanding the causation of feather pecking in laying hens.

Krimpen, M. M. v., et al. (2007). Impact of nutritional factors on feather pecking behaviour of laying hens in non-cage housing systems. Beekbergen, World's Poultry Science Association (WPSA).

The expected bans on battery cages (EU) and beak trimming (e.g. The Netherlands) may cause an increased risk of feather pecking and cannibalism in layers. Many factors influence feather pecking behaviour, but in this review we will focus on nutritional factors. Dietary deficiencies, resulting in inaccurate delivery of nutrients, may increase feather pecking behaviour and cannibalism. Severe feather pecking has been demonstrated in birds that were fed too low mineral levels, protein levels or amino acid levels (methionine, arginine). Feeding high-NSP diets, low energy diets, or roughages reduced feather pecking. Providing additional grain or straw in the litter during rearing could result in lower levels of feather pecking behaviour in adult stages. Nutritional factors seem to reduce feather pecking behaviour in laying hens if these factors increase the time related to foraging, feed intake and satisfying. Laying hens may spend more time on these behaviours when they are fed (1) mash diets in stead of crumbles or pellets, (2) low energy diets, (3) high (in-)soluble fibre diets or (4) roughages. This paper gives an overview of the relationships between the occurrence of feather pecking behaviour and nutritional factors, such as diet composition and feeding strategies in laying hens.

Krimpen, M. M. v., et al. (2005a). "Impact of feeding management on feather pecking in laying hens." World's poultry science journal **61**(4): 663-685.

In the near future EU-legislation will ban the use of conventional battery cages, while national legislation in some countries in Western Europe will ban beak trimming as well. The ban on battery cages and beak trimming causes an increased risk of feather pecking and cannibalism in laying hens. Many factors influence feather pecking behaviour, but this paper focuses on nutritional factors. Nutritional factors can have positive and negative effects on feather pecking behaviour in laying hens. Severe feather pecking has been demonstrated in birds that were fed a too low mineral level in the diet, a too low protein level or a too low amino acid level (methionine, arginine). Sometimes somewhat more feather pecking was found when layers were fed diets with mainly vegetable protein sources as compared with diets with protein from animal origin. Also more feather pecking may occur when the diets were fed restrictedly, fed coarsely ground, or fed as pellets. Feeding high-fibre diets, low energy

diets, or roughages reduced feather pecking. Providing additional grain or straw in the litter during rearing could result in lower levels of feather pecking behaviour in adult stages. Some of these positive effects on feather pecking seem to be related to the time birds spend on feed intake and foraging. This paper gives an overview of the relationships between the occurrence of feather pecking behaviour and nutritional factors, such as diet composition and feeding strategies in laying hens.

Krimpen, M. M. v., et al. (2005b). "Reduction of feather pecking behaviour in laying hens by feeding management - a review." Animal Science Papers and Reports **23**(Suppl. 1): 161-174.

In the near future EU-legislation will ban the use of conventional battery cages, while national legislation in some countries in Western Europe will ban beak trimming as well. The ban on battery cages and beak trimming causes an increased risk of feather pecking and cannibalism in laying hens. Many factors influence feather pecking behaviour, but in this literature review we will focus on nutritional factors. Nutritional factors can have positive and negative effects on feather pecking behaviour in laying hens. Dietary deficiencies, resulting in an inaccurate delivery of nutrients may increase feather pecking behaviour and cannibalism. Severe feather pecking has been demonstrated in birds that were fed too low mineral levels in the diet, too low protein levels or too low amino acid levels (methionine, arginine). Sometimes somewhat more feather pecking was found when layers were fed diets with mainly vegetable protein sources as compared to diets with protein from animal origin. Also more feather pecking may occur when the diets were fed restrictedly, fed coarsely ground, or fed as pellets. Feeding high-fibre diets, low energy diets, or roughages reduced feather pecking. Providing additional grain or straw in the litter during rearing could result in lower levels of feather pecking behaviour in adult stages. Until now, the mode of action of these nutritional factors is not fully understood. Nutritional factors seem to reduce feather pecking behaviour in laying hens if these factors increase the time related to foraging, feed intake and digestive and metabolic processing. Laying hens may spend more time on these behaviours when they are fed: (1) mash diets instead of crumbles or pellets, (2) low energy diets, (3) high (in-)soluble fibre diets, or (4) roughages. Confounding effects of low energy diets, high fibre diets or feeding roughages mask a clear understanding of the underlying causal mechanism. Further research will start to provide a better understanding of the impact of nutritional factors on feather pecking behaviour and thus, the welfare of layers. This paper gives an overview of the relationships between the occurrence of feather pecking behaviour and nutritional factors, such as diet composition and feeding strategies in laying hens.

Krimpen, M. M. van, et al. (2010). "Effect of four processed animal proteins in the diet on digestibility and performance in laying hens." Poultry Science **89**(12): 2608-2616.

An experiment was performed to investigate the effect of animal vs. vegetable protein sources in the diet of laying hens on the development of hen performance. A diet containing protein sources of only vegetable origin was compared with 4 diets, each containing 1 of 4 processed animal proteins (PAP). Two PAP (Daka-58 and Sonac-60) were classified as meat meals, and the remaining 2 (Daka-40 and Sonac-50) were classified as meat and bone meals. First, fecal digestibility of nutrients in the PAP was determined in Lohmann Brown layers. Hens (n = 132) were housed in 22 cages (6 hens/cage) and allotted to 5 dietary treatments. In the PAP diets (4 replicates/treatment), 100 g/kg of CP of animal origin was added, replacing soybean meal and corn (Zea mays) in the basal diet (6 replicates/treatment). The PAP sources differed largely in chemical composition and digestibility coefficients. Energy content (AME(n)) varied from 1,817 (Daka-40) to 3,107 kcal/kg (Sonac-60), and digestible lysine varied from 15.4 (Daka-40) to 28.3 g/kg (Sonac-50). Subsequently, the effect of a control diet (without PAP) vs. 4 PAP diets (50 g/kg of CP of animal origin from the same batches as used in the digestibility study) on performance was determined. All diets were isocaloric (AME(n) = 2,825 kcal/kg) and isonitrogenous (digestible lysine = 6.8 g/kg). Hens were housed in 40 floor pens (12 hens/pen, 8 pens/treatment) from 20 to 40 wk of age. Feed intake levels of the hens fed the meat and bone meal diets were reduced compared with those of hens fed the meat meal diets, whereas the feed intake level of hens fed the control diet was intermediate. Laying hen performance differed between treatments, being was most favorable for the Sonac-50 treatment and most adverse for the Daka-40 treatment. Differences in laying hen performance seemed to be related partly to differences in feed intake and corresponding amino acid intake.

Krimpen, M. v., et al. (2011). "Effect of four processed animal proteins in the diet on behavior in laying hens." Applied Animal Behaviour Science **132**(3/4): 138-145.

An experiment was performed to investigate the effect of animal versus vegetable protein sources in the diet on the development of behavior in laying hens. A diet containing protein sources of only vegetable origin was compared with four diets, each containing one of four processed animal proteins (PAPs). Two PAPs (Daka-58 and Sonac-60) were classified as meat meals, whereas the remaining ones (Daka-40 and Sonac-50) were classified as meat and bone meals. The impact of a control diet (without PAP) versus four PAP diets (50 g/kg CP of animal origin) on behavior was determined. All diets were isocaloric (AME_n=11.8 MJ/kg) and isonitrogenous (dig. lysine=6.8 g/kg). Hens were housed in 40 floor pens (12 hens/pen, 8 pens/treatment) from 20 to 40 weeks of age. Supplementation of PAPs did not generally reduce feather pecking behavior. Nevertheless, Daka-40 and Sonac-50 fed hens showed a delay in the development of feather damage and, simultaneously, an increase in litter condition, foraging and walking behavior, and floor pecks compared to hens fed Sonac-60. These shifts seemed to be partly related with the intake of digestible glycine, available phosphorus, calcium, potassium, and sodium.

Kuenzel, W. J. (2007). "Neurobiological basis of sensory perception: Welfare implications of beak trimming." Poultry Science **86**(6): 1273-1282.

The practice of beak trimming in the poultry industry occurs to prevent excessive body pecking, cannibalism, and to avoid feed wastage. To assess the welfare implications of the procedure, an emphasis of this paper has been placed on the anatomical structures that comprise the beak and mouth parts and a representation of the structures removed following beak trimming. Five animal welfare concerns regarding the procedure have been addressed, including the following: loss of normal beak function, short-term pain and temporary debilitation, tongue and nostril damage, neuromas and scar tissue, and long-term and phantom limb pain. Because all of the concerns involve the nervous system, the current knowledge of the avian somatosensory system was summarized. The critical components include touch, pain, and thermal receptors in the buccal cavity and bill, the trigeminal system, and neural projections mapped to the pallium (cortical-like tissue in the avian forebrain). At the present time, a need remains to continue the practice of beak trimming in the poultry industry to prevent head, feather, and vent pecking in some lines of birds. The procedure, however, should involve conservative trimming and be limited to young birds. Importantly, data show that removing 50% or less of the beak of chicks can prevent the formation of neuromas and allow regeneration of keratinized tissue to prevent deformed beaks and therefore positively affect the quality of life of birds during their lifetime.

Labouriau, R., et al. (2009). "Analysis of severe feather pecking behavior in a high feather pecking selection line." Poultry Science **88**(10): 2052-2062.

Even though feather pecking (FP) in laying hens has been extensively studied, a good solution to prevent chickens from this behavior under commercial circumstances has not been found. Selection against FP behavior is possible, but for a more effective selection across different populations, it is necessary to characterize the genetic mechanism associated with this behavior. In this study, we use a high FP selection line, which has been selected for 8 generations. We present evidence of the presence of a major dominant allele affecting the FP behavior by using an argument based on the presence of mixture in the distribution of the observed FP and by studying the evolution of the proportion of very high FP along the sequence of 8 generations. This hypothesis is further supported by the fact that the gene transcription profile of the birds performing high FP differs from the profile of the other birds performing FP (456 genes differentially expressed from a total of 14,077 investigated genes).

Lambton, S. L., et al. (2010). "The risk factors affecting the development of gentle and severe feather pecking in loose housed laying hens." Applied Animal Behaviour Science **123**(1-2): 32-42.

Injurious pecking remains one of the biggest problems challenging free range egg producers, with both economic implications for the farmer and welfare implications for the birds. The most widespread form of injurious pecking is feather pecking, the most damaging form of which is severe feather pecking (SFP) which has, as yet unclear, links with gentle feather pecking (GFP). The current prospective epidemiological study investigates the development of GFP and SFP oil 61 free range and organic UK farms (111 flocks). Flocks were visited at 25 (20-30) and 40 (35-45) weeks, when rates of GFP and SFP respectively and levels of feather damage were recorded. Environmental and management data were collected for each flock. Factors affecting the development of these behaviours were modelled using the multilevel modelling program, MLwiN (Rasbash et al., 2004). GFP was observed in 89.2% and 73% of flocks at 25 and 40 weeks, respectively, at a mean rate of 0.65 bouts/bird/h. GFP rates decreased with increased percentage range use (coeff.: -0.001 +/- 0.0006, p = 0.025) and temperature inside the laying house (coeff.: -0.005 +/- 0.001, p = 0.001). GFP was higher in flocks with soil or grass litter (chi(2) = 13.16, df = 4, p = 0.012). flocks which had no perch access (0.010 +/- 0.001 vs. 0.007 +/- 0.002 bouts/bird/min, p = 0.047) and flocks which were beak trimmed compared to those non-beak trimmed or retrospectively beak trimmed (0.013 +/- 0.002 vs. 0.003 +/- 0.001 and 0.002 +/- 0.001, p=0.007). SEP was observed in 68.5% and 85.6% of flocks at the 1st and 2nd visits. respectively, at a mean rate of 1.22 bouts/bird/h. SFP rates decreased with range use (coeff.: -0.001 +/- 0.0003. p = 0.003). Mean rates were highest in non-beak trimmed compared to beak trimmed flocks (0.032 +/- 0.003 vs. 0.017 +/- 0.003 bouts/bird/min, p=0.028), flocks observed to be feather pecking when they arrived oil farm compared to those that were not (0.062 +/- 0.018 vs. 0.019 +/- 0.002 bouts/bird/min, p=0.001), and flocks fed pelleted compared to those fed mashed food (0.042 +/- 0.002 vs. 0.016 +/- 0.002 bouts/bird/min, p = 0.005). Plumage damage was lower in beak trimmed compared to non-beak trimmed flocks (plumage score 1.00 +/- 0.0001 vs. 1.15 +/- 0.068, p=0.040), and flocks which were fed mashed feed, and showed a quadratic relationship with severe feather pecking (p = 0.003) which was positive over the observed ranges of the behaviours. In commercial Situations, feeding mashed feed and increasing range use may reduce severe feather pecking and therefore feather damage. (C) 2010 Elsevier B.V. All rights reserved.

Lambton, S. L., et al. (2015). "The risk factors affecting the development of vent pecking and cannibalism in free-range and organic laying hens." Animal Welfare. 24.

Injurious pecking remains one of the biggest animal welfare and economic challenges for free-range egg producers. This prospective epidemiological study investigated the development of vent pecking (VP) and cannibalism on 62 free-range and organic UK farms (119 flocks). Flocks were visited at 25 (± 5) and 40 (± 5) weeks of age. Rates of VP were recorded and farmers were asked whether they had observed cannibalism in their flocks. Environmental and management data were collected for each flock. Risk factors associated with these behaviours were modelled using MLwiN. VP was observed in 19.5 and 29.9% of flocks, at mean rates of 0.35 and 0.21 bouts per bird per h, at 25 and 40 weeks, respectively. Cannibalism was reported at 22.6% of visits. The odds of flocks showing VP or

cannibalism increased with rate of severe feather pecking (SFP). VP was more likely to be observed in laying houses with more and/or longer pop holes and where feed was scattered on the floor. Providing more aerial perch length, or perches > 0.5 m in height, was associated with increased risk of VP. When SFP was excluded from the model, likelihood of VP was higher in flocks fed pelleted feed. All of these may provide a useful basis from which to derive management strategies to reduce the risk of VP and thus improve the welfare of laying hens. However, it is important to remember that this study does not elucidate the causal relationships between these variables, and further work is needed to understand the mechanism behind these associations.

Lambton, S. L., et al. (2013). "A bespoke management package can reduce levels of injurious pecking in loose-housed laying hen flocks." Veterinary Record **172**(16): 423.

This study investigated the protective effects of an on-farm management package designed to reduce injurious pecking (IP) in loose-housed laying hens. A systematic review of scientific literature generated 46 potentially protective management strategies. Bespoke management packages were designed for treatment flocks (TF) using these management strategies. IP in 53 TFs was compared with IP in 47 control flocks (CF) where the management package was not employed. Scoring of plumage damage (PD) and observations of gentle and severe feather pecking (GFP; SFP), and vent and cannibalistic pecking (VP) were completed, and management strategy use was recorded, at 20, 30 and 40 weeks of age. Differences between treatment and CF were examined using multilevel modelling. Compared with CF, TF employed more management strategies (P<0.001), had lower PD (P=0.003) and SFP (P=0.019). Regardless of treatment or control flock status, the more of the 46 management strategies that were employed the lower was the PD (P=0.004), GFP (P=0.021), SFP (P=0.043), mortality at 40 weeks (P=0.025), and the likelihood of VP (P=0.021). Therefore, the provision of a bespoke management package was protective against the majority of forms of IP in commercial laying hen flocks.

Lee, H. J., et al. (2011). "Prediction of feather damage in laying hens using optical flows and Markov models." Journal of the Royal Society Interface **8**(57): 489-499.

Feather pecking in laying hens is a major welfare and production problem for commercial egg producers, resulting in mortality, loss of production as well as welfare issues for the damaged birds. Damaging outbreaks of feather pecking are currently impossible to control, despite a number of proposed interventions. However, the ability to predict feather damage in advance would be a valuable research tool for identifying which management or environmental factors could be the most effective interventions at different ages. This paper proposes a framework for forecasting the damage caused by injurious pecking based on automated image processing and statistical analysis. By frame-by-frame analysis of video recordings of laying hen flocks, optical flow measures are calculated as indicators of the movement of the birds. From the optical flow datasets, measures of disturbance are extracted using hidden Markov models. Based on these disturbance measures and age-related variables, the levels of feather damage in flocks in future weeks is predicted. Applying the proposed method to real-world datasets, it is shown that the disturbance measures offer improved predictive values for feather damage thus enabling an identification of flocks with probable prevalence of damage and injury later in lay.

Leeson, S. and T. Walsh (2004). "Feathering in commercial poultry - II. Factors influencing feather growth and feather loss." Worlds Poultry Science Journal **60**(1): 52-63.

In commercial production, there is often concern about the quantity and/or quality of feathering in both broilers and layers. For broilers, the concern is adequacy of protective feather cover, while in layers it is usually the necessary degree of feathering needed to optimise feed efficiency. Feather development is under the control of hormones such as thyroxine and oestrogen and indirectly by testosterone. Environmental or nutritional status that influences such hormonal output will indirectly affect feathering. In broilers, rate of feathering is influenced by genetics, since some 20 years ago there was a conscious decision to introduce slow (K) vs. fast (k) feathering as a means of sexing day-old chicks. With the relative "immaturity" of modern broilers, these genes influence feather cover well into the production cycle. In White Leghorn crosses, initial problems with apparent Leukosis susceptibility of the progeny of slow feathering dams had to be overcome by eradication of Leukosis before feather sexing could be generally introduced. Nutrition can influence rate of feathering as well as feather structure, colour and moulting. Amino acid balance and especially deficiencies of TSAA and branched chain amino acids will influence feathering in young birds. Deficiency of vitamins and certain trace minerals also induce characteristic feather abnormalities, as does the presence of dietary mycotoxins. A number of viruses, bacteria and mycoplasma can infect the feather follicle and so influence feather development. Feather pecking and feather licking are behavioural abnormalities, although these conditions can be induced by changes in environmental conditions or nutritional adequacy of the diet.

Lunam, C. A., et al. (1996). "The absence of neuromas in beaks of adult hens after conservative trimming at hatch." Australian Veterinary Journal **74**(1): 46-49.

Objective To determine the effects of the amount of beak removed and cauterisation time on neuroma formation in hens. Design A pathology study with controls. Animals Twenty domestic fowl were beak-trimmed. Three non-beak-trimmed domestic fowl were used as controls. Procedure Beaks of two age groups with two levels of beak removal and either 2 s or 4 s cauterisation, were investigated macroscopically and microscopically for deformities. Results Scattered trauma-associated neuromas were present in the beaks of pullets 10 weeks after moderate trimming at hatch, Neuromas were not

present in beaks of adult hens that had been similarly trimmed. Sensory corpuscles were present 10 and 70 weeks after moderate trimming, though fewer in number than in intact control hens. In contrast, trauma-associated neuromas persisted in beaks of 70-week-old hens that had been severely trimmed at hatch. A range of deformities that were absent in moderately trimmed, hens, were observed in hens with severely trimmed beaks. Receptors were not seen in severely trimmed beaks. Conclusion Beak-trimming al hatch induces the formation of neuromas, regardless of the amount of tissue removed. There is a critical amount of beak tissue that can be removed, beyond which trauma-associated neuromas will not resolve, but will persist in mature hens.

Mahboub, H. D. H., et al. (2004). "Outdoor use, tonic immobility, heterophil/lymphocyte ratio and feather condition in free-range laying hens of different genotype." British Poultry Science **45**(6): 738-744.

Movement (frequency of changes) between inside and outside housing areas, time spent in each area, tonic immobility (TI) and differential blood cell counts were studied in relation to feather condition in laying hens of two genotypes, white (LSL) and brown (LT). From 18 weeks of age, LSL and LT were kept in 4 groups of 50 birds in a poultry house with passages to a roofed scratching room and a grassland area with a stocking density of one bird/10 m². All birds had transponders to record the movements of each hen between inside and outside areas and the time spent in each area during 24 h. Feather scoring was carried out at 6 ages from 20 to 48 weeks. At 44 weeks of age, TI reactions of 40 hens (20 from each genotype) were quantified and blood smears from 20 hens (10 from each genotype) were analysed for differential leukocyte counts. LSL hens moved more frequently to outdoor areas than LT hens (44.66 vs 28.78 least square/d). However, the proportion of time spent on grassland was greater in LT than in LSL hens, whereas time (%) spent by LT hens in the roofed scratching area was less than for LSl hens. In LT hens TI was shorter while heterophil/lymphocyte ratio and basophilia were greater than in LSL hens. Total body feather score was poorer in LSL than in LT hens. Incidence of footpad inflammation was higher in LSL than LT hens. There was a positive association between TI and footpad inflammation. The percentage of time spent on grassland and feather damage were inversely correlated. More movement between the areas, as in LSL hens, was positively associated with fearfulness, whereas long periods on grassland, as in LT hens, were associated with indicators of increased stress. The negative correlation between feather damage and time spent outside suggests that feather pecking risk decreases in birds attracted to grassland.

Manteuffel, G., et al. (2004). "Vocalization of farm animals as a measure of welfare." Applied Animal Behaviour Science **88**(1-2): 163-182.

Emotionally relevant external events, hormone concentrations affecting mood and appetitive behaviour, thirst and hunger are able to stimulate a complex central nervous network that regulates endocrine feedback and behaviour in order to maintain or regain homeostasis. Particular states of mood or emotion may thus be accompanied by specific behaviours, vocalization being one of them. Hence, in farm animals vocalizations may supply us with hints on their well-being in an easy way, given that the meanings of the respective calls are well-established. Then, it is possible to judge acoustically uttered current needs and impaired welfare by non-invasive, continuous monitoring. Vocalizations may also modulate emotions of the receivers such that welfare may also be affected in conspecifics hearing distress utterances, e.g., in an abattoir. For these reasons, the analysis of farm animal vocalization has gained increasing interest in the last years and a variety of attempts to decode the meaning has been made. Concentrating on important farm animal species (pig, cattle, poultry) an overview of the present state-of-the-art in this discipline is given and present problems as well as possible future developments are discussed. Modern techniques of sound analysis have provided tools to discriminate, analyse and classify specific vocalizations. Taking advantage of this, future bioacoustical research for welfare assessment should focus on comprehensive studies of a broad spectrum of species specific distress vocalizations. Increasingly precise attributions of such utterances to environments, behavioural contexts and relevant physiological parameters will lead to a deeper understanding of their meaning and significance with respect to well-being of farm animals. The result will offer applicable acoustic tools for farming environments where non-invasive techniques for welfare judgements are urgently needed.

Marchant-Forde, R. M., et al. (2008). "Comparative effects of infrared and one-third hot-blade trimming on beak topography, behavior, and growth." Poultry Science **87**(8): 1474-1483.

This research examined the effects of infrared beak treatment on layer chicks. Seventy-two layer chicks were assigned to hot-blade trimming (HB), infrared treatment (IR), or a control treatment. Day-old chicks were pair-housed by treatment. Beak photographs, behavior, and production indices were obtained at intervals for 9 wk posttreatment. All beaks were normally shaped at the onset of the study, and no perceptible treatmentrelated differences in shape occurred over time ($P > 0.05$). Posttreatment, HB birds had shorter beaks relative to the other 2 groups ($P < 0.05$). Control and IR beaks remained comparable in length until tissue eroded in IR beaks at 1 to 2 wk posttreatment. Thereafter, beak length increased in all treatments over time ($P < 0.01$). Two weeks posttreatment, beaks were longest in control birds, intermediate in HB birds ($P < 0.001$), and shortest in IR birds ($P < 0.001$). The HB birds had abnormal deviations from a normal upper-to-lower mandible length ratio than the IR or control birds ($P < 0.05$). Notable effects of treatment on production emerged by +2 d and persisted for 5 wk. Growth and feed intake were lower in HB and IR birds compared with control birds ($P < 0.05$), with IR birds performing least well until the fourth week of the study ($P < 0.05$). Thereafter, they performed similarly to the HB group. Feed waste was lowest in the IR group and was generally greatest in the control group ($P < 0.05$). There was an overall effect of trimming, irrespective of method, on behavior, particularly eating and drinking behaviors ($P < 0.05$). Specifically,

IR birds were less active ($P < 0.01$) and spent less time eating ($P < 0.01$) and drinking ($P < 0.05$) than did control birds. Behavior in HB birds often ranked intermediate in duration and incidence, but was not significantly different compared with behavior measured in the control and IR groups. Effects of treatment on behavior were not present after 1 wk posttrimming. Results indicate that acute pain occurred with both trimming methods. Although the impact of trimming appeared to be greatest in the IR birds initially, these differences disappeared relatively quickly, and subsequent performance was similar in both trimmed groups.

Matauschek, A. H., et al. (2010). "Effect of an early bitter taste experience on subsequent feather-pecking behaviour in laying hens." Applied Animal Behaviour Science **127**(3-4): 108-114.

Recent studies showed that laying hens learn not to peck at bitter-tasting feathers from conspecifics. In the present experiment, feathers of newly hatched chicks were made distasteful by spraying them with a bitter-tasting substance (quinine). It was hypothesized that chicks could detect quinine and learn to avoid the downy feathers and the feathers of conspecifics later in life. Six groups of 10 high feather-pecking birds and six groups of 10 low feather-pecking birds were kept on litter. Half of each of these groups was quinine treated. Each bird in the quinine-treated groups was individually sprayed on a weekly basis for 25 weeks with a quinine solution. It was investigated whether the presence of quinine on the birds feather cover affected gentle and severe feather pecking. The result indicated that feathers made distasteful with quinine reduced severe feather pecking in young and adult birds as long as it was detected on birds feather cover.

McAdie, T. M., et al. (2005). "Reduction in feather pecking and improvement of feather condition with the presentation of a string device to chickens." Applied Animal Behaviour Science **93**(1-2): 67-80.

Feather pecking remains a serious problem in commercial egg production. It has been argued that feather pecking,occurs as a result of misdirected pecking, so a possible solution would be to increase the likelihood that such pecking was targeted at another object in the environment rather than to the feathers of conspecifics. Chickens of various strains and ages will readily peck at a device consisting of strands of white string but it is not yet known if pecking at that device would substitute for pecking at conspecifics. Therefore, the effects of providing string devices on feather pecking in an experimental situation (Experiment 1) and on feather condition under commercial conditions (Experiment 2) were examined. In Experiment 1, 300 chicks of a high-feather pecking strain of white leghorn-type layers were housed in groups of five in litter-floor pens. The 60 pens were randomly allocated to one of five treatments: devices incorporated in the chicks' pens continuously from 1 day of age till the end of the experiment at 57 days; devices presented for 4 h per day from 1 day of age; first presented from 22 days of age; first presented from 52 days of age; and finally, devices never presented. Feather pecking was virtually eliminated when the devices remained in the pens from 1 day of age or when they were presented for 4 h per day. Feather pecking was most pronounced among birds that had never received the device whereas its introduction at 22 or 52 days of age yielded intermediate results. This orderly pattern of more pecking at feathers when the device was added at later ages was significant ($p < 0.005$). In Experiment 2, 768 Lohmann LSL laying chickens were housed in rearing cages and 720 were transferred in groups of three to conventional laying cages when 16 weeks old. The birds were allocated to one of four treatments: devices present from 1 day of age; presented for 24 h every 4 weeks; continuously present from 16 weeks of age; and finally, devices never presented. At 35 weeks of age, hens with access to the device had significantly better plumage condition than those that had never received the device ($p < 0.05$). In conclusion, the addition of a simple string device to the pens of non-beak-trimmed high-feather-pecking birds decreased feather pecking behaviour (Experiment 1), and to the cages of non-beak-trimmed commercial layers significantly improved feather condition (Experiment 2).

Merrill, R. J. N. and C. J. Nicol (2005). "The effects of novel floorings on dustbathing, pecking and scratching behaviour of caged hens." Animal Welfare **14**(3): 179-186.

From the year 2012, conventional battery cages for laying hens will be banned under the European Union Council Directive 1999/74/EC Enriched cages, which include a perch, a nest area, and a pecking and scratching area will not be banned, and have certain advantages over other systems of egg production. Previous studies have shown that even when a pecking and scratching area is provided, most dustbathing occurs on the wire floor as sham dustbathing. This study investigated whether novel cage floor types could stimulate full expression of dustbathing behaviour, similar to that seen on loose litter. One hundred and forty four hens were housed in pairs in non-commercial enriched cages that differed only in that they contained one of four randomly allocated floor types. Floor types were conventional wire ('wire), wood shavings (litter), conventional wire wrapped with garden twine (string) and perforated rubber matting (rubber). Birds on litter or rubber performed fewer bouts of dustbathing than those on wire and string. However, bouts on litter were longer than those on the three other floor types. Overall, birds on litter or string showed a greater total duration of dustbathing than those on rubber, and birds on litter had a richer repertoire of dustbathing elements. Birds on litter performed significantly more pecking and scratching than those on string or rubber, which did not differ from those on wire. Birds on rubber and litter had poorer foot and feather condition than those on wire or string. Altering the cage floor produced minor changes in behaviour, and further novel floor types should be evaluated.

Meyer, B., et al. (2012). "Feather ingestion affects intestinal microbiota and microbial metabolites in growing leghorn-type chickens." Poultry Science **91**(7): 1506-1513.

Feather pecking in laying hens is a serious behavioral problem that is often associated with feather eating. The intake of feathers may influence the gut microbiota and its metabolism. The aim of this study was to determine the effect of 2 different diets, with or without 5% ground feathers, on the gut microbiota and the resulting microbial fermentation products and to identify keratin-degrading bacteria in chicken digesta. One-day-old Lohmann-Selected Leghorn chicks were divided into 3 feeding groups: group A (control), B (5% ground feathers in the diet), and C, in which the control diet was fed until wk 12 and then switched to the 5% feather diet to study the effect of time of first feather ingestion. The gut microbiota was analyzed by cultivation and denaturing gradient gel electrophoresis of ileum and cecum digesta. Short-chain fatty acids, ammonia, and lactate concentrations were measured as microbial metabolites. The concentration of keratinolytic bacteria increased after feather ingestion in the ileum ($P < 0.001$) and cecum ($P = 0.033$). Bacterial species that hydrolyzed keratin were identified as Enterococcus faecium, Lactobacillus crispatus, Lactobacillus reuteri-like species (97% sequence homology), and Lactobacillus salivarius-like species (97% sequence homology). Molecular analysis of cecal DNA extracts showed that the feather diet lowered the bacterial diversity indicated by a reduced richness ($P < 0.001$) and shannon ($P = 0.012$) index. The pattern of microbial metabolites indicated some changes, especially in the cecum. This study showed that feather intake induced an adaptation of the intestinal microbiota in chickens. It remains unclear to what extent the changed metabolism of the microbiota reflects the feather intake and could have an effect on the behavior of the hens.

Meyer, B., et al. (2013). "Differences in intestinal microbial metabolites in laying hens with high and low levels of repetitive feather-pecking behavior." Physiology & Behavior **110–111**: 96-101.

Abstract Feather pecking in laying hens is a serious behavioral problem and is often associated with feather eating. There is some evidence that ingested feathers affect gut function. The aim of the present study was to explore whether differences in intestinal microbial metabolites in laying hens with high and low levels of repetitive feather-pecking behavior exist. Sixty high feather-pecking birds (H) and sixty low feather-pecking birds (L) of the White Leghorn breed were used for behavioral recordings of feather pecking. Feather pecking activity was observed for 5 weeks, after which 22 H birds with the highest and 22 L birds with the lowest feather pecking activity were chosen. The number of whole feathers and feather parts in the gizzard and intestinal microbial metabolites in the ileum and ceca of these laying hens was examined. Biogenic amines, short-chain fatty acids, ammonia and lactate were measured as microbial metabolites. A higher number of feather parts and particles were found in H than in L birds. Putrescine and cadaverine concentrations were higher in the ileum of the hens with low pecking activity ($P < 0.001$ and $P = 0.012$). In the cecum the amounts of l-lactate, d-lactate and total lactate and SCFA were higher in H birds ($P = 0.007$, $P = 0.005$, $P = 0.006$, and $P < 0.001$). Acetate, i-butyrate, i-valeriate and n-valeriate all displayed significantly higher molar ratios in the cecal contents of L birds ($P = 0.001$, $P = 0.003$, $P = 0.001$, and $P < 0.001$). Propionate and n-butyrate showed higher molar ratios in H birds ($P < 0.001$ and $P = 0.034$). Ammonia was higher in the ileum and cecum of the L birds ($P < 0.001$ and $P = 0.004$). For the first time, this study shows that birds with high and low numbers of repetitive pecking movements to the plumage of other birds differ in their intestinal microbial metabolism. Further experiments should be conducted to investigate whether these differences alter behavior in H and L feather pecking birds. The present results, however, open new avenues of research into implications of gut bacteria, their metabolites and the polyamine system on brain and behavior in laying hens.

Mielenz, N., et al. (2010). "Analysis of ordered categorical data with threshold models exemplified by plumage damage scores from laying hens differing in their genotype and rearing environment." Poultry Science **89**(11): 2521-2534.

Plumage damage scores (PDS) were assessed in laying hens of 2 genotypes (Lohmann Tradition and Lohmann Silver) at the 45th and 70th weeks of age, with scores ranging from zero (no damage) to 6 (completely denuded). This ordinally scaled categorical characteristic was recorded from different body regions of 365 hens that had experienced different housing environments (2 enrichment levels) during their rearing and laying periods. The so-called threshold model is an option for analyzing repeated ordered categorical data from individual animals. This model represents a generalized linear mixed model if the linear predictor additionally includes the animal as a random effect. This paper is intended to fill the gap between the theoretical aspects of generalized linear mixed models and their practical application in animal science. A cumulative probit model was adapted for analyzing plumage damage. The variation among birds was considered as a random effect for the analysis of cumulative probabilities. The numerical implementation of the methodology was done based on the NLMIXED procedure of the SAS statistical program. A threshold model with inhomogeneous residual variances for the latent variable was used because less plumage damages were observed up to the 45th week of age compared to the 70th week of age. Differences in PDS were evident between genotypes, age, and enrichment levels during housing periods. However, neither of the 2 enriched environments proved consistent superiority or inferiority across all traits. Major plumage damage (PDS larger than or equal to 5) was observed for the breast region in 56.6% of all birds with the Lohmann Tradition genotype and in 34.4% with the Lohmann Silver genotype when we look at the mean over all treatments. The most severe plumage damage was observed at the 70th week of age for the traits breast and housing environment without additional enrichment.

Miller, K. A. and J. A. Mench (2006). "Differential effects of 4 types of environmental enrichment on aggressive pecking, feather pecking, feather loss, food wastage and productivity in Japanese quail." British Poultry Science **47**(6): 646-658.

1. We examined the effects of 4 types of environmental enrichment (foraging opportunities, structural complexity, sensory stimulation/novelty, and social companionship) on aggressive and feather pecking, feather condition, food wastage, body weight, feed conversion, and egg production in adult Japanese quail. Sex differences were examined where possible. 2. GLM analysis was used to evaluate the effects of enrichment and housing, while test-retest reliability and the stability of measures over 18 d were assessed using partial correlation. 3. Foraging enrichment reduced food wastage. 4. Body weight, feed conversion, and egg production were not affected by enrichment. Rates of aggressive and feather pecking were also not significantly affected, but these behaviours were observed very infrequently in this study. 5. Socially-housed birds had poorer feather condition, lower body weight and less efficient feed conversion than singly-housed birds. Social housing did not affect food wastage. 6. There were no sex differences in feather pecking, feather condition, food wastage, or feed conversion. 7. All measures except feather pecking were reliable over 24 h, but only feather condition and body weight were stable over 18 d. The instability of the behavioural measures over time suggests that enrichment effects may vary with age.

Mul, M. and C. M. Koenraadt (2009). "Preventing introduction and spread of Dermanyssus gallinae in poultry facilities using the HACCP method." Experimental and Applied Acarology **48**(1-2): 167-181.

MUL, M., et al. (2009). "Control methods for Dermanyssus gallinae in systems for laying hens: results of an international seminar." World's poultry science journal **65**(04): 589-600.

Natt, D., et al. (2007). "Plumage color and feather pecking - Behavioral differences associated with PMEL17 genotypes in chicken (Gallus gallus)." Behavior Genetics **37**(2): 399-407.

An F(5) generation of an advanced inter-cross between red junglefowl (wild- type) and White Leghorn (domesticated) was used to investigate earlier findings suggesting that a mutation in the plumage color gene PMEL17 protects against victimization to feather pecking (FP). F(4) parents were selected according to genotype to produce PMEL17 homozygous offspring (i/i and I/I respectively). Birds were raised and their behavior recorded in groups of either two wild-type i/i (dark colored) and one white I/I, or two I/I and one i/i. In addition each bird was tested for feather preference, reaction to novelty, open-field activity, fear for humans, and tonic-immobility. In the home-pens, i/i birds were more feather pecked and had poorer feather condition than I/I birds. No pecking preference for immobile dark colored feathers was observed. In the open-field test i/i birds vocalized more and earlier than I/I birds, and in the fear-for-human test I/I birds had higher activity at 21 weeks of age. No other behavior differences were observed, but clearly, genotypes of PMEL17 affected some aspects of behavior. Such behavioral differences might be important aspects of the mechanism which predispose i/i individuals for being victims of FP.

Newberry, R. C. (2004). Cannibalism. Cambridge, Cabi Publishing.

Cannibalism is a serious welfare problem in laying hens which can cause high mortality. Cannibalistic behaviour is learned by individual birds and can spread to others through social learning. In this chapter, multiple factors influencing the risk of cannibalism are reviewed. These include beak form, light intensity, genetic predisposition, age, sex, timing of sexual maturation, nutrition, food form, availability of attractive foraging materials, learning opportunities, availability of preferred victims, use of perches and nestboxes, and group size. Strategies for controlling cannibalism without resorting to beak trimming are suggested, based on knowledge about factors affecting the motivation and opportunity to perform the behaviour.

Newberry, R. C., et al. (2007). "Behaviour when young as a predictor of severe feather pecking in adult laying hens: The redirected foraging hypothesis revisited." Applied Animal Behaviour Science **107**(3-4): 262-274.

It has been suggested that feather pecking in poultry results when foraging behaviour is redirected to feathers in the absence of adequate foraging incentives and that gentle feather pecking is a precursor of severe feather pecking. Associations have also been proposed between feather pecking and other behaviours including dust bathing and preening. Here, we present the results of a longitudinal study on the development of severe feather pecking in individual domestic fowl. We hypothesised that behaviour, and especially foraging and gentle feather pecking behaviour, of individual birds when young predicts severe feather pecking behaviour by the same birds when adult. To test this hypothesis, we used behavioural data collected from 192 individual White Leghorn hens (12 focal birds/group) housed continuously from hatch in 16 floor pens. Data on 34 behaviour variables recorded when the birds were young (3-15 weeks of age) were subjected to factor analysis. The resulting factors were entered as independent variables in a generalised linear model to determine their relationship with severe feather pecking by the same birds as adults (1737 weeks of age). We found a positive association between a factor describing foraging when young and severe feather pecking when adult, and a negative association between a factor describing dust bathing when young and severe feather pecking when adult ($P < 0.05$). Levels of severe feather pecking increased following the onset of lay and we found no significant. association between factors describing feather pecking when young and severe feather pecking by the same individuals when adult. Most of the birds were observed to perform exploratory gentle feather pecks when young. No evidence was found that exploratory or stereotyped gentle feather pecks consistently became more severe over time but factor analysis indicated that severe feather pecking by young birds was more closely correlated with exploratory, than stereotyped, gentle feather pecking, signalling utility in distinguishing between exploratory and stereotyped gentle feather pecking in future studies. We conclude that severe feather pecking did not substitute for foraging behaviour but, rather, was more likely to emerge in adult hens

that had performed relatively more foraging, and less resting and dust bathing, when young. However, none of the individual behaviour variables recorded when young could be used to identify precisely which individuals would exhibit severe feather pecking when adult. (C) 2006 Elsevier B.V. All rights reserved.

NICOL, C. J., et al. (2013). "The prevention and control of feather pecking: application to commercial systems." World's poultry science journal **69**(04): 775-788.
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.

Nicol, C. J., et al. (1999). "Differential effects of increased stocking density, mediated by increased flock size, on feather pecking and aggression in laying hens." Applied Animal Behaviour Science **65**(2): 137-152.
Six flocks of laying hens were housed in percheries at each of four stocking densities (6, 14, 22 or 30 birds m(-2)) from 14 to 30 weeks of age. Stocking density was manipulated by changes in nock size (72, 168, 264 or 368 birds) within percheries of the same floor and height dimensions. The pecking behaviour of birds was observed directly at 15, 22 and 30 weeks of age, and corrected for the number of birds in view. Egg production was recorded at 23 and 27 weeks of age, and plumage condition was scored at 30 weeks of age. At 23 weeks of age, egg production was greater at 6 birds m(-2) than at other stocking densities. The plumage condition of the birds was best at 6 birds m-2 and worsened with increased flock size and stocking density. The behavioural observations suggested that this was due to an increase in mild feather pecking with increased nock size and stocking density. Mild feather pecking increased with bird age and was most frequently observed on the perchery floor although, at higher flock sizes and stocking densities, it also occurred on the perches. Severe feather pecking was infrequent, especially at the lower flock sizes and stocking densities, but was most likely to occur near the nest boxes. Vent pecking was extremely rare. Aggressive pecking was most common in the smaller flocks at the lowest stocking densities, possibly because these birds attempted to form social hierarchies. Birds in the larger nocks at higher densities appeared to adopt non-social, non-aggressive behavioural strategies. (C) 1999 Elsevier Science B.V. All rights reserved.

Niekerk, T. G. C. M. v., et al. (2013). Noodmaatregelen tegen pikkerij, Wageningen UR Livestock Research.
Waaier met noodmaatregelen tegen verenpikkerij. http://edepot.wur.nl/283863

Niekerk, T. G. C. M. v., et al. (2011). Van kuiken tot kip, Wageningen UR Livestock Research.
Maatregelen ter voorkoming van verenpikken bij leghennen. http://edepot.wur.nl/189478

Parmentier, H. K., et al. (2009). "Does enhancement of specific immune responses predispose laying hens for feather pecking?" Poultry Science **88**(3): 536-542.
To mimic airborne immune challenges, layer hens were intratracheally and concurrently challenged with various doses of the protein antigen human serum albumin (HuSA) and the pathogen-associated molecular pattern lipopolysaccharide (LPS) at 7 and 13 wk of age. All groups received 1 similar dose of HuSA plus LPS at 11 mo of age. Evaluation of plumage and body condition at 12 mo of age revealed that birds that had undergone intratracheal immunization with a high dosage of HuSA, irrespective of the concurrent dose of LPS, had significantly more feather damage but less wounds to the vent region, as opposed to birds not receiving HuSA. On the other hand, a high dosage of LPS was related to comb damage. These results suggest that stimulation of specific (humoral) immune responses (to HuSA) rather than innate responses (to LPS) at a young age may predispose layers for feather pecking (FP) behavior at later ages. Involvement of immune mechanisms in FP or vent damage may differ. Predisposal for FP behavior by specific immunity can have consequences for health and vaccine management.

Persyn, K. E., et al. (2004). "Feeding behaviors of laying hens with or without beak trimming." Transactions of the Asae **47**(2): 591-596.
This study quantifies feeding behavior of W-36 White Leghorn laying hens (77 to 80 weeks old) as influenced by the management practice of beak trimming. The feeding behavior was characterized using a newly developed measurement system and computational algorithm. Non-trimmed (NT) and beak-trimmed (BT) hens showed similar daily feed intake and meal size. However the BT hens tended to spend longer time feeding (3.3 vs. 2.0 h/d, $P < 0.01$), which coincided with their slower ingestion rate of 0.43 g/min-kg(0.75) vs. 0.79 g/min-kg(0.75) for the NT counterparts ($P < 0.05$). The BT hens had shorter time intervals between meals (101s vs. 151s, $P < 0.01$). Selective feeding, as demonstrated by larger feed particles apparent in the leftover feed, was noted for the BT hens. The leftover feed had a lower crude protein/adjusted crude protein content for the BT birds than that for the NT birds (16.7% vs. 18.7%, $P < 0.05$). In addition, the leftover feed of the BT birds had lower contents in phosphorus, magnesium, potassium, zinc, and manganese ($P < 0.05$), although no significant differences were detected in calcium, sodium, or metabolic energy content. Baseline feeding

behavior data of this nature may help quantify and ensure the welfare of animals through exercising proper engineering design and/or management considerations.

Petek, M. and J. L. McKinstry (2010). "Reducing the prevalence and severity of injurious pecking in laying hens without beak trimming." Veteriner Fakultesi Dergisi, Uludag Universitesi **29**(1): 61-68.

Injurious pecking is a general term used to describe feather pecking, vent pecking, cannibalism and toe-pecking in laying hens. The severity of injurious pecking varies enormously, ranging from limited feather removal to cannibalism and death. Alternative housing systems for laying hens such as barn, free-range and aviary systems show much higher incidences of injurious pecking than with those birds housed in conventional caged system. From a welfare perspective injurious pecking can cause pain, stress, injuries, increased susceptibility to diseases, fear and death. Any major outbreak of injurious feather pecking can result in serious economic loss for the industry through decrease in egg production and feed efficiency. At present the egg industry uses both beak trimming of the birds and dim lighting methods to help reduce injurious pecking. However, both of these are being criticised from a welfare point of view. In fact a general ban on beak trimming already exists in some European Union countries, with other countries considering a ban by 2011. Moreover, The EU ban on conventional laying cages (2012), when combined with a ban on beak-trimming, will increase the risk of injurious feather pecking and cannibalism. It is therefore important for future to consider other ways of controlling injurious pecking. Injurious pecking is a multi-factorial problem, which can be caused by environmental, genetic or nutritional factors and can be largely prevented by the use of a combination of environmental and husbandry management programs. This paper is intended to give a general overview of the potential risk factors and possible control measures associated with injurious pecking in laying hens, and in particular those flocks housed in non-cage systems.

Prescott, N. B. and R. H. C. Bonser (2004). "Beak trimming reduces feeding efficiency of hens." Journal of Applied Poultry Research **13**(3): 468-471.

The ability of beak-trimmed and intact laying hens to ingest feed pellets was examined by highspeed video filming of feeding birds. The birds were exposed to either a deep layer of pellets or a single layer of pellets. In the single layer treatment, there was a negative correlation between mandible asymmetry and feeding success. These data have important implications for poultry welfare, since the degree of bill asymmetry caused by beak trimming may, under certain circumstances, result in inadvertent feed deprivation.

Prieto, M. T., et al. (2008). "Association between vent pecking and fluctuating asymmetry in hens." Itea-Informacion Tecnica Economica Agraria **104**(2): 180-185.

The purpose of the present study was to analyze the relationship between incidence of vent pecking, fluctuating asymmetry in chickens. The experiment (140 birds in three different replicates) measured the fluctuating asymmetry of several traits (middle toe length, leg length, wing length, wattle length, and leg width) in 20-week-old pullets of five Spanish breeds of chickens (Blue Andaluza, Quail Castellana, White-faced Spanish, Red-barred Vasca, and Birchen Leonesa), and a White Leghorn population, with and without evidence of suffering from vent pecking. The number of birds per breed was 20, 24, 12, 20, 18, and 46, respectively. There was a significant difference between vent pecked and non-vent pecked birds on the relative fluctuating asymmetry of middle toe length ($P<0.05$), the relative fluctuating asymmetry of birds who suffered from vent pecking being larger. The combined relative fluctuating asymmetry of the five traits approached levels of statistical significance ($P=0.08$). Thus, vent pecked birds were more asymmetrical than non-vent pecked birds, having increased relative fluctuating asymmetry. Differences were consistent across the breeds. Results indicate that vent pecking is associated with measures of stress like fluctuating asymmetry.

Ramadan, S. G. A. and E. v. Borell (2008). "Role of loose feathers on the development of feather pecking in laying hens." British Poultry Science **49**(3): 250-256.

The effect of the presence of loose feathers (on the floor) on the behaviour and plumage condition of laying hens (Lohmann Silver, LS) was studied during the rearing and laying periods. From one day old, 60 birds in each of 4 straw-bedded pens (n=240 in total) with 6.5 birds/m² were either kept under conventional rearing and management conditions (CT: control group with feathers on the floor; n=120) or in pens from which the feathers were collected from the floor 4 times/week (FR: feathers removed; n=120). Fifty birds from each of these 4 groups (n=200 in total) were randomly selected at the age of 16 weeks and allocated to 4 identical pens in a poultry layer house (PH; with perches and 1/3 slatted floor) with access to an outside area (winter garden, WG) at a stocking density of 6 birds/m² in both PH and WG. Observations on feather pecking and other behaviours (feeding, drinking, preening, standing, sitting, foraging, moving and dust bathing) were carried out at 8 ages: 6, 10, 15 (rearing period), 20, 25, 30, 35 and 40 weeks (laying period). Feather scoring was carried out at 15, 32 and 39 weeks of age. There were no differences in feather pecking rates, forms (gentle, severe and aggressive pecks) as well as in the plumage condition between groups at the end of the rearing period. Birds in the FR group exhibited lower rates and less severe feather pecking during the laying period. Accordingly, birds in the control group had worse feather condition at 32 and 39 weeks of age. Feather pecking rates within groups were, in general, greater in the afternoon compared to the morning periods. Birds in the control group were more active in walking. Wings, rump, tail and back were the main targets for feather pecking. The majority of feather pecking occurred on the floor (66%) followed by feeding area (26%), perches (4%) and slats (4%). Our results suggest that loose feathers on the floor may play an important role in the development and severity of feather pecking behaviour in laying hens and

support the hypothesis (McKeegan and Savory, 1999) that feather pecking can be viewed as redirected foraging behaviour.

Riber, A. B. and B. Forkman (2007). "A note on the behaviour of the chicken that receives feather pecks." Applied Animal Behaviour Science **108**(3-4): 337-341.

Basic knowledge of feather pecking on the individual level is still limited. The aim of this study was to investigate whether active and inactive individuals preferentially attract feather pecking. Female layer hen chicks were housed in six pens with each 15 chicks. Each occurrence of gentle and severe feather-pecking bout was recorded continuously in all pens for 30 min/pen/week when the chickens were 0-23 weeks of age. For each feather-pecking bout, the behaviour (active/inactive, dustbathing/non-dustbathing) of the recipient bird immediately before being feather pecked was recorded. Inactive individuals were more likely to become the targets of both gentle (when pecks directed to dustbathing chickens were excluded) and severe feather pecks (both when including and excluding feather pecks directed to dustbathing chickens) than active individuals. This knowledge may be used to reduce feather pecking by providing distinct resting areas such that mixing of active and inactive chickens is avoided. (c) 2006 Elsevier B.V. All rights reserved.

Riber, A. B., et al. (2007). "Effects of broody hens on perch use, ground pecking, feather pecking and cannibalism in domestic fowl (Gallus gallus domesticus)." Applied Animal Behaviour Science **106**(1-3): 39-51.

Previous work has shown that the tendency to feather peck in domestic fowl is influenced by experiences early in life; it was hypothesised that broody hens prevent development of feather pecking and cannibalism in their chicks by increasing their ground pecking activity and by motivating them to earlier perch use. Twelve groups of 10 layer hen chicks (Lohmann Tradition) were reared in pens (2.55 m(2)) with perches at heights of 20 and 40 cm; six groups were reared with broody hens and six with heating lamps. The hens and the heating lamps were removed when the chicks were 5 weeks old. A 13-day long stress period (i.e. increased light intensity, short-term feed deprivation) was introduced when the chickens were 25 weeks old, after which the experiment was terminated. The number of ground pecks performed during 2 min was recorded for all individuals, when they were 1, 8, and 20 weeks old. The position of each chick (floor, low perch, or high perch) was recorded using scan sampling 12 times a day on days 5-40. Feather pecking was recorded continuously for 30 min in each group when the chicks were 5, 10, 13, 17, 20, 24, and 27 weeks old. Data were analysed using repeated measures ANOVA. The brooded chicks ground pecked four times more in weeks 1 and 8 than the non-brooded chicks, whereas the amount was similar in week 20. The brooded chicks were on average 9.8 (+/- 0.6) days old when first observed on the low perch during day time and the non-brooded were 13.5 (+/- 0.8) days old. No difference was found between the two treatments in onset of night perching (low perch: brooded 19.2 (+/- 1.6) and non-brooded 22.5 (+/- 1.9) days old). Severe feather pecking was almost non-existent in both treatments throughout the experiment, although a rise in frequency was found in the non-brooded pens in weeks 20 and 24. Mortality due to feather pecking and cannibalism was found to be significantly higher for the non-brooded chickens. In conclusion, the provision of broody hens resulted in chickens having a higher ground pecking activity, an earlier day-use of perches, and a lower mortality. Because severe feather pecking only developed to a minor non-significant extent in the non-brooded chickens, no conclusion could be made on the effect of broody hens on chickens' feather pecking activity. (c) 2006 Elsevier B.V. All rights reserved.

Rodenburg, T. B., et al. (2010a). "Breeding amiable animals? Improving farm animal welfare by including social effects in breeding programmes." Animal Welfare **19**(Supplement): 77-82.

Social interactions between individuals, such as co-operation and competition, are key factors in evolution by natural selection. As a consequence, evolutionary biologists have developed extensive theories to understand the consequences of social interactions for response to natural selection. Current genetic improvement programmes in animal husbandry, in contrast, largely ignore the implications of social interactions for the design of breeding programmes. Recently, we have developed theoretical and empirical tools to quantify the magnitude of heritable social effects, ie the heritable effects that animals have on their group mates' traits, in livestock populations, and to utilise those effects in genetic improvement programmes. Results in commercial populations of pigs and laying hens indicate large heritable social effects, and the potential to substantially increase responses to selection in traits affected by social interactions. In pigs, including social effects into the breeding programme affected aggressive behaviour, both at mixing and in stable groups, indicating changes in the way dominance relationships are established and in aggressiveness. In laying hens, we applied selection between kin-groups to reduce mortality due to cannibalistic pecking. This resulted in a considerable difference in mortality between the low mortality line and the unselected control line in the first generation (20 vs 30%). Furthermore, changes in behavioural and neurobiological responses to stress were detected in the low mortality line, pointing to reduced fearfulness and stress sensitivity. These first results indicate that including social effects into breeding programmes is a promising way to reduce negative social interactions in farm animals, and possibly to also increase positive social interactions, by breeding animals with better social skills.

Rodenburg, T. B., et al. (2009a). "Maternal care and selection for low mortality affect post-stress corticosterone and peripheral serotonin in laying hens." Physiology & Behavior **98**(5): 519-523.

The aim of the present study was to investigate the effect of brooding and group selection for low mortality on post-stress corticosterone and peripheral serotonin in laying hens. Birds in the experiment originated from the same population and were either group-selected for low mortality (low mortality line) or randomly selected (control line) for two generations. Twelve groups of seven birds from each

line were used. Within each line, six groups were brooded by a foster mother and six groups were non-brooded. At 33 weeks of age, birds (n = 42/treatment) were manually restrained for 5 min, during which their behavioral response (number of struggles) was studied. Fifteen minutes after the start of the manual restraint, blood samples were drawn for assessment of plasma corticosterone and whole blood serotonin (5-HT) concentration. In the low mortality line, 80% of the birds struggled and vocalized vs. 72% in the control line (non significant). Birds from the control line had a higher plasma corticosterone concentration after manual restraint than birds from the low mortality line (7.7 vs. 6.0 nmol ml(-1)). Furthermore, birds from the control line that were reared without a mother had a lower whole-blood 5-HT concentration than birds from the other treatments (45 vs. 48 nmol ml(-1)). These results indicate that both brooding and selection for low mortality affect post-stress corticosterone and peripheral serotonin concentration, which may result in a reduced propensity to develop feather pecking. (C) 2009 Elsevier Inc. All rights reserved.

Rodenburg, T. B., et al. (2004a). "Genetic and phenotypic correlations between feather pecking and open-field response in laying hens at two different ages." Behavior Genetics **34**(4): 407-415.

The object of this research was to study the relationship between feather pecking and open-field activity in laying hens at two different ages. A population of 550 birds of a laying hen cross was subjected to an open-field test at 5 and 29 weeks of age and to a social feather pecking test at 6 and 30 weeks of age. Factor analysis was used to identify underlying factors for each test: pecking behavior (social test) and open-field activity (open-field test). In young birds, a positive phenotypic correlation of 0.24 was found between high open-field activity and high levels of pecking behavior (ground pecking, preening, gentle feather pecking, and wall pecking). In adults, a similar genetic correlation of 0.62 was found. At adult age, the factor pecking behavior consisted mainly of gentle and severe feather pecking. Between ages, a strong, negative genetic correlation of -0.65 was found between open-field activity at young age and pecking behavior at adult age, indicating that open-field activity levels in young birds may predict pecking behavior in adult hens.

Rodenburg, T. B., et al. (2010b). "Fearfulness and feather damage in laying hens divergently selected for high and low feather pecking." Applied Animal Behaviour Science **128**(1/4): 91-96.

Feather pecking (FP) remains a major welfare and economic problem in laying hens. FP has been found to be related to other behavioural characteristics, such as fearfulness. There are indications that fearful birds are more likely to develop FP. Furthermore, FP can lead to increased fearfulness in the victims. To investigate further the relationship between FP and fearfulness, feather damage and behavioural fear responses were recorded in three White Leghorn lines of laying hens: a line selected for high FP (HFP line), a line selected for low FP (LFP line) and an unselected control line (10th generation of selection). We used 64 birds per line housed in 16 four-bird cages (cage was the experimental unit). At 25 weeks of age, birds were subjected to a tonic immobility (TI) test and a combined human approach (HA) and novel object (NO) test, and plumage condition was recorded. Line differences in fear responses between the HFP and LFP lines were not found, neither in the TI-test, nor in the HA or NO test. As expected, birds from the HFP line had considerably more feather damage than birds from the LFP line and birds from the unselected control line were intermediate. Cages that withdrew from the NO 30 s after placement had more feather damage on the back compared with cages that did not show a withdrawal response. These results suggest that although relationships were found between feather damage and fear response at cage level, lines divergently selected on feather pecking behaviour do not differ in their fear responses. Divergent selection on feather pecking may have altered pecking motivation rather than fearfulness.

Rodenburg, T. B., et al. (2004b). "Feather pecking in laying hens: new insights and directions for research?" Applied Animal Behaviour Science **86**(3/4): 291-298.

The aim of this paper is to present new insights and promising directions for future research on feather pecking in laying hens. Our starting point was a multidisciplinary research program on feather pecking in The Netherlands, in which ethological, physiological, ontogenetic and genetic approaches were combined. The four topics addressed in this paper are: (1) the relation between gentle and severe feather pecking, (2) feather pecking and coping strategy, (3) causation of feather pecking, and (4) the possibility to solve the problem of feather pecking through genetic selection. When the relationship between gentle and severe feather pecking was studied, it was found that both forms of feather pecking are related at the same age. Gentle feather pecking at young age, however, could not be used as a predictor of feather pecking at adult age. Birds from high and low feather pecking lines that showed differences in feather pecking also differed in other behavioural and physiological characteristics. This may reflect line differences in coping strategy. Relating coping strategy with feather pecking may help us to better understand the motivations and characteristics underlying the development of feather pecking. On the causation of feather pecking, there is some evidence that it is redirected ground pecking, deriving either from a foraging or a dustbathing background. However, evidence was found that early feather pecking could also be interpreted as social exploration. Finally, the use of molecular genetics to help solving the problem of feather pecking seems promising. Feather pecking has been shown to be heritable and the first genetic regions (QTL) involved in feather pecking have been identified. To search for a solution for the feather pecking problem it is of importance to identify the mechanisms involved in the development of feather pecking. In this paper, we have combined approaches from different disciplines in order to study feather pecking. The results indicate that combined efforts of multidisciplinary research can be very useful in looking for possible ways to reduce feather pecking in practice.

Rodenburg, T. B. and P. Koene (2007). "The impact of group size on damaging behaviours, aggression, fear and stress in farm animals. (Special issue: Too many, too few: the effects of group size and density in captive animals.)." Applied Animal Behaviour Science **103**(3/4): 205-214.

The aim of this review is to discuss the impact of group size on damaging behaviours, aggression, fear and stress in farm animals and to identify housing- and management options that can help to reduce problems caused by suboptimal group sizes. Increasing group size was found to increase the risk of damaging behaviour, such as feather pecking in laying hens and vulva biting in sows. Aggression does not appear to be a problem in large groups, because dominance relationships in these groups are not based on individual recognition, but based on other signals such as body size, avoiding costly fights. There is evidence for increased fear and stress levels in large groups compared with small groups, but fearfulness is also strongly affected by type of housing. To minimise problems in large groups, is seems helpful to offer separate functional areas and to provide cover, reducing disturbance between animals. To minimise the risk of damaging behaviour, such as feather pecking in laying hens and tail biting in pigs, stimulating foraging, exploration and manipulation behaviour by providing sufficient substrate (straw, wood shavings and sand) offers perspective. Rearing the animals in a system which allows the development of all these behaviours is very important. Other solutions can be found in optimising the diet and offering extra foraging opportunities. Furthermore, genetic selection against damaging behaviour seems promising. In conclusion, group size mainly has an effect on damaging behaviour and fear and stress in pigs and poultry. The effect on aggressive behaviour is limited. To reduce damaging behaviour, fear and stress, it is important to provide a complex environment with ample behavioural opportunities and separate functional areas.

Rodenburg, T. B., et al. (2005a). "Can short-term frustration facilitate feather pecking in laying hens?" Applied Animal Behaviour Science **91**(1-2): 85-101.

Feather pecking is a major problem in laying hens. Frustration, i.e. the omission of expected reward, may play a role in the development of feather pecking. In two experiments, we studied if feather pecking could be facilitated by short-term frustration in birds with a high feather pecking phenotype and victims of feather pecking (experiment 1), and in birds with a high or low feather pecking genotype (experiment 2). Furthermore, the motivation to peck a key for a food reward was assessed in birds with a high or low feather pecking genotype in experiment 3, as birds that have a stronger motivation may also react stronger to the omission of a reward. We trained birds to peck a key for a food reward in an automated Skinnerbox and tested them in control and frustration sessions. During frustration, the feeder was covered with Perspex. Frustration did not facilitate feather pecking in either experiment. In experiment 1, birds with a high feather pecking phenotype did show more gentle feather pecking and aggressive pecking than victims of feather pecking during some of the control sessions. Furthermore, victims of feather pecking vocalised more than birds with a high feather pecking phenotype. In experiment 2, birds with a high feather pecking genotype scratched more than birds with a low feather pecking genotype, indicating differences in motivation for foraging or dust-bathing behaviour, which shows a relation to feather pecking. Birds with a low feather pecking genotype also had a stronger motivation to peck at a key for a food reward than birds with a high feather pecking genotype. No evidence was found that feather pecking could be facilitated by short-term frustration in a Skinnerbox. However, differences in reaction to frustration and in motivation to peck a key for a food reward in birds with a high or low feather pecking phenotype or genotype indicate that frustration may still play a role in the development of feather pecking.

Rodenburg, T. B., et al. (2004c). "Reaction to frustration in high and low feather pecking lines of laying hens from commercial or semi-natural rearing conditions." Behavioural Processes **65**(2): 179-188.

The effect of rearing conditions on feather pecking and reaction to frustration was studied in two lines of laying hens. From commercial rearing conditions (large group, no mother hen), seven birds from a high feather pecking line (HC birds) and eight birds from a low feather pecking line (LC birds) were used. From semi-natural rearing conditions (small group, mother hen present) seven birds from the high feather pecking line (HN birds) were used. Feather pecking behaviour of HC, LC, and HN groups was recorded for 30 min. After that, each bird was food deprived and trained to peck a key for a food reward in a Skinnerbox. After training, each bird was subjected to a frustration session in a Skinnerbox, where the feeder was covered with Perspex. Three HC birds showed severe feather pecking, compared with one HN bird and zero LC birds. Differences in reaction to frustration were found between birds from different lines, but not in birds from different rearing conditions. LC birds tended to put their head in the feeder more frequently than HC birds over all sessions. Although limited, this study indicates that rearing conditions influence feather pecking, but not reaction to frustration.

Rodenburg, T. B., et al. (2008a). "Selection method and early-life history affect behavioural development, feather pecking and cannibalism in laying hens: a review." Applied Animal Behaviour Science **110**(3/4): 217-228.

The aim of this review is to discuss the effects of selection method and early-life history on the behavioural development of laying hens. Especially in larger groups, laying hens often develop damaging behaviours, such as feather pecking and cannibalism, leading to impaired animal welfare. We hypothesise that the propensity to develop feather pecking and cannibalism is affected by a bird's genetic background and by its early-life history. The genetic background can be influenced by genetic selection. Laying hens are traditionally selected on individual performance, which may lead to co-selection of feather pecking and cannibalism. For hens kept in small groups, it has recently been

demonstrated that a novel group selection method, focusing on group performance, can help to reduce cannibalism. However, the biological background behind the success of group selection is unknown. It is also not known whether these results from small groups can be translated to larger groups of laying hens. Regarding early-life history, laying, brooding and rearing conditions have been shown to have major effects on behavioural development and on feather pecking and cannibalism. The presence of a hen during rearing has been shown to improve foraging- and social behaviour, to decrease feather pecking and to decrease fearfulness in chicks. Applying group selection and rearing laying hens in a more natural environment may be key factors in solving the problems caused by feather pecking and cannibalism, especially if the promising results of group selection from small groups in experimental settings can be translated to large-group housing systems.

Rodenburg, T. B., et al. (2009b). "The effects of selection on low mortality and brooding by a mother hen on open-field response, feather pecking and cannibalism in laying hens." Animal Welfare **18**(4): 427-432.

The aim of the present study was to investigate the effects of selection on low mortality in combination with brooding by a mother hen on open-field response at 5-6 weeks of age and on plumage and body condition at 42 weeks of age. Birds in the experiment were either selected for low mortality in group housing (low mortality line) or randomly selected (control line) for two generations. These lines originated from the same population. Twenty groups of 10 female birds from each line were used. Within each line, ten groups were brooded by a foster mother and ten groups were non-brooded. At 5-6 weeks of age, the chicks were tested in an open-field test for five minutes. At 42 weeks of age, plumage condition and incidence of comb lesions and toe wounds of all birds was recorded. It was found that both brooded chicks and chicks from the low mortality line were more active in the open-field test at 5-6 weeks of age, indicating that they were less fearful or had a stronger exploratory motivation. No interactions were found between selection on low mortality and brooding. Birds from the low mortality line also had a lower incidence of comb and toe wounds compared with the control line at 42 weeks of age. No effect of brooding on plumage condition or incidence of wounds was found. This study indicates that selection on low mortality is a promising way forward to reduce maladaptive behaviour in laying hens, especially if such an approach is combined with improved rearing conditions.

Rodenburg, T. B., et al. (2013). "The prevention and control of feather pecking in laying hens: identifying the underlying principles." World's poultry science journal **69**(02): 361-374.

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.

Ruis, M. A. W., et al. (2010). The effect of optimized lighting conditions on feather pecking and production of laying hens, Wageningen UR Livestock Research. **Report 335:** 25. http://edepot.wur.nl/137033

Savory, C. J., et al. (1978). "Feeding behaviour in a population of domestic fowls in the wild." Applied Animal Ethology **4**(1): 13-27.

In 1976 the diet of adult feral fowls on a Scottish island consisted mainly of grass from January to July and oats from August to December. Juveniles ate many invertebrates in their first two months of life, but otherwise their diet was similar to that of the adults. In contrast to the non-breeding adults, broods and their dams showed two distinct types of feeding behaviour, called “sporadic” and “intensive” feeding. These were directed towards scattered and concentrated food sources, and the type shown depended mainly on the dam's behaviour. The significance of these and other aspects of feeding behaviour is discussed.

Savory, C. J. (1995). "Feather pecking and cannibalism." Worlds Poultry Science Journal **51**(2): 215-219.

Sedlackova, M., et al. (2004). "Feather pecking in laying hens: Environmental and endogenous factors." Acta Veterinaria Brno **73**(4): 521-531.

Feather pecking, pecking directed to and damaging the feathers of other birds, is a behavioural disorder occurring in laying hens and other poultry species and breeds. Feather pecking is both a welfare and economic problem. Pulling out feathers causes pain, a higher risk of injuries and can trigger an outbreak of cannibalism. Extensive loss of feather cover is accompanied by increased heat loss that results in increased food consumption. The 1999 EU Directive laying down minimum standards for the protection of laying hens approved banning of conventional battery cages from 2012. Thus in the next few years major changes to the housing of laying hens in Europe will occur. Therefore there is an urgent need to develop feasible alternative housing systems-An increased risk of feather pecking is a main obstruction to the wide adoption of alternative housing systems, such as free range, aviaries or percheries. There is a continuous effort of many research teams in Europe and elsewhere to

expand our knowledge of this behavioural disturbance and maximize the chances to solve the problem. In this review we have attempted to summarise the present status of knowledge about feather pecking. Hypotheses on causation (redirected ground pecking or dustbathing), environmental factors (feeding, lighting, housing. group size, density) and endogenous factors (sex. age. genetic factors, physiological control mechanisms) are discussed and possible ways of prevention via changing environment, management practices or genetic selection are pointed out.

Scott, G. B. and P. Moran (1993). "Effects of visual stimuli and noise on fear levels in laying hens." Applied Animal Behaviour Science **37**(4): 321-329.

Conveyors have been proposed to improve bird welfare during handling procedures. Speeds of conveyors have been recommended, though the effects on bird welfare have not been addressed. During travel no horizontal forces are applied. Therefore visual perception of speed may play an important role if birds find movement frightening. Stationary birds were subjected to moving stimuli of 0.33, 0.67 and 1.00 m s−1 by being placed between side-wall conveyor belts to present a moving background. Fear levels were measured using tonic immobility and were compared with the fear levels of birds receiving no moving stimulus. The effect of the noise of the conveyors was also investigated. No significant difference was found between birds exposed to the noise of the conveyors compared with those receiving no noise. Similarly no significant differences were found in fear levels for groups exposed to the different visual stimuli, suggesting that fear does not increase with increased perceived speed. In fact trends in the data indicate that fear levels might decrease with the increased perceived speed. Further investigations could determine whether there is any real effect of perceived motion on induced fear levels and whether there is a maximum speed beyond which birds may become frightened.

Steenfeldt, S., et al. (2007). "Effect of feeding silages or carrots as supplements to laying hens on production performance, nutrient digestibility, gut structure, gut microflora and feather pecking behaviour." British Poultry Science **48**(4): 454-468.

1. An experiment was carried out to examine the suitability of using maize silage, barley-pea silage and carrots as foraging materials for egg-laying hens. Production performance, nutrient digestibility, gastrointestinal characteristics, including the composition of the intestinal microflora as well as feather pecking behaviour were the outcome variables. 2. The protein content of the foraging material (g/kg DM) was on average 69 g in carrots, 94 g in maize silage and 125 g in barley - pea silage. The starch content was highest in the maize silage (312 g/kg DM), and the content of non-starch polysaccharides (NSP) varied from 196 to 390 g/kg, being lowest in carrots. Sugars were just traceable in the silages, whereas carrots contained on average 496 g/kg DM. 3. Egg production was highest in hens fed either carrots or maize silage, whereas hens fed barley - pea silage produced less (219 vs. 208). Although the consumption of foraging material was high (33, 35 and 48% of the total feed intake on 'as fed' basis for maize silage, barley - pea silage and carrots, respectively) only a minor effect on nitrogen corrected apparent metabolisable energy (AME(n)) and apparent digestibility was seen. At 53 weeks of age, hens fed maize silage had AMEn and apparent digestibility values close to the control group (12.61 and 12.82, respectively), whereas access to barley - pea silage and carrots resulted in slightly lower values (12.36 and 12.42, respectively). Mortality was reduced dramatically in the three groups given supplements (0.5 to 2.5%) compared to the control group (15.2%). 4. Hens receiving silage had greater relative gizzard weights than the control or carrot-fed groups. At 53 weeks of age, the gizzard-content pH of hens receiving silage was about 0.7 to 0.9 units lower than that of the control or carrot-fed hens. Hens fed both types of silage had higher concentrations of lactic acid (15.6 vs. 3.2 mu moles/g) and acetic acid (3.6 vs. 6.1 mu moles/g) in the gizzard contents than the other two groups. The dietary supplements had a minor effect on the composition of the intestinal microflora of the hens. 5. Access to all three types of supplements decreased damaging pecking in general (to feathers as well as skin/cloaca), reduced severe feather pecking behaviour and improved the quality of the plumage at 54 weeks of age. 6. In conclusion, access to different types of foraging material such as silages and carrots improved animal welfare.

Tauson, R., et al. (2005). "Applied scoring of integument and health in laying hens." Animal Science Papers and Reports **23**(Suppl. 1): 153-159.

Different methods for scoring of birds' integument are often used to describe the effects of various treatments in research on the health and welfare of laying hens. Also in commercial egg production and breeding there is a need for having a tool to describe the status of a certain flock of birds or a pure line. Among the main traits to score are plumage and foot condition and pecking wounds on different parts of the body. Scores for these traits may describe problems of feather pecking, perch design and litter condition and cannibalistic or aggressive behaviours, respectively. There are important characteristics of a scoring system, such as the simplicity of the system for users to learn and to use at the same time being descriptive enough in details. This paper describes a scoring method for six body parts with regards to plumage condition, pecking wounds on comb and rear part of the body, and the condition of the foot with regards to bumble foot syndrome. The intention is that this system should be easy to use by scorers of different background, e.g. scientists, administrators, welfare inspectors, breeders and producer organizations. When used to the system, scoring a bird for all characters will not exceed 30 seconds for one person.

Thiele, H. H. and R. Pottguter (2008). "Management recommendations for laying hens in deep litter, perchery and free range systems." Lohmann Information **43**(1): 53-63. http://www.lohmann-information.com/content/l_i_43_artikel6.pdf

Uitdchaag, K. (2008). Effects of genetic background and social environment on feather pecking and related behavioural characteristics in laying hens. Wageningen, Wageningen Universiteit (Wageningen University).

To gain further insight in risk factors related to feather pecking, this thesis investigated the effects of genetic background and social environment on feather pecking and related behavioural characteristics in laying hens. In several experiments, behaviour, performance and physiology of cage-housed birds from purebred genetic lines was studied in different social environments at different ages. It was shown that birds from different purebred lines differed in feather damage due to severe feather pecking (an indicator for feather pecking) and in responses towards a novel object. This indicates that it is possible to select against high levels of both feather pecking and fear related behaviour. The tendency to develop feather pecking was also related to the response towards a novel object, although this relation differed between birds from different backgrounds and from different ages. Other results showed that the response in the novel object test was also related to performance, which should be taken into account if such a test would to be used in a breeding programme. Feather pecking and fear related behaviour were also affected by group mates (social environment): non-fearful birds became more fearful in presence of fearful birds. This effect could only be established at 18, but not at 5-6 weeks of age. At adult age, fearful birds showed more feather damage in presence of non-fearful birds, whereas the social environment during rearing had no effect on the occurrence of feather pecking. This indicates that fearful behaviour predisposes adult birds both to more easily develop and to be targeted by feather pecking. The changes in social environment were, however, not accompanied by physiological changes in brain serotonin or dopamine activity. These neurotransmission systems have been related to feather pecking. Results did indicate that the role of serotonin uptake does require further attention. According to the results from this thesis, laying hens should be kept in behavioural uniform groups to minimize the damage due to feather pecking. Additionally, reducing the expression of feather pecking could be achieved by breeding against expression of fearful behaviour, but possible correlated changes in performance should be accounted for. It remains to be investigated how the results with respect to social environment can be translated towards more extensive systems, such as floor-housing.

Uitdehaag, K. A., et al. (2009). "Mixed housing of different genetic lines of laying hens negatively affects feather pecking and fear related behaviour." Applied Animal Behaviour Science **116**(1): 58-66.

Adult laying hens from Rhode Island Red (RIR) origin both express lower levels of feather pecking and lower fear responses towards a novel object than laying hens from White Leghorn (WL) origin. The present study investigated whether mixed housing of RIR and WL laying hens would affect their behaviour in both an open field (at 17-18 weeks of age) and manual restraint test (at 24 weeks of age) and their feather damage due to severe feather pecking. In experiment A. 'pure' groups contained birds from one line only throughout the rearing and laying period. 'Mixed' groups contained an equal number of RIR and WL birds. Pure and mixed groups contained four birds, which were housed in battery cages. It was found that RIR birds were more active in the open field and manual restraint test than WL birds, although RIR birds from mixed groups became less active in the open field test than RIR birds from pure groups. This would indicate that RIR birds were less fearful than WL birds, but that they became more fearful in presence of these WL birds. In experiment B, RIR and WL birds were only housed together during the laying period, in varying ratios. It was found that WL birds from mixed groups had more feather damage due to severe feather pecking than WL birds from pure groups, whereas no effect of mixing was found in RIR birds. RIR birds from mixed groups therefore appeared to have developed relatively high levels of feather pecking, targeted at WL birds. This would indicate that, together with results from experiment A, fearful RIR birds from mixed groups were at higher risk to develop feather pecking than less fearful RIR birds from pure groups. This study clearly demonstrates that social factors have a strong influence on the development of feather pecking and related behavioural characteristics.

van Hierden, Y. M., et al. (2004). "Chronic increase of dietary L-tryptophan decreases gentle feather pecking behaviour." Applied Animal Behaviour Science **89**(1-2): 71-84.

Many studies show the involvement of the serotonergic (5-HT) system in the performance of abnormal behaviour in both human and animals. Recently, we showed that acute reduction of 5-HT turnover in the forebrain, increased gentle and severe feather pecking behaviour in chicks from a high (HFP) and low feather pecking (LFP) line of laying hens, suggesting that the performance of feather pecking behaviour involves low 5-HT neurotransmission. In the present study, we postulated that if low 5-HT is causally underlying feather pecking, increasing, 5-HT turnover in the forebrain will decrease the development and performance of feather pecking. Augmentation of 5-HT neurotransmission in the brain was induced by chronically increasing dietary levels of the essential amino acid L-tryptophan (TRP) from which 5-HT is synthesised. From the age of 34 days, UP and HFP chicks were fed a diet containing 2% TRP, whereas control birds of both lines were continuously fed with the normal rearing feed (0.16% TRP). From 35 days of age, litter was removed from the pens (10 pens/line-treatment) and all chicks (10 chicks/pen) were housed on a slatted floor until the end of the experiment. At 49 days of age, feather pecking behaviour was studied for 30 min. At 50 days of age baseline corticosterone, TRP and other large amino acids (LNAAs) were measured in the blood plasma of decapitated chicks (10 chicks per line- treatment). Furthermore, plasma corticosterone and central 5-HT turnover levels in response to manual restraint (5 min) were determined (10 chicks/line-treatment). For neither gentle nor severe feather pecking a significant line x treatment interaction was found. However, TRP treatment resulted in a significant [P = 0.02] overall decrease of the frequency of gentle feather pecking. For severe feather pecking a similar but not significant pattern was found.

Significant line effects were found for gentle and severe feather pecking. HFP birds showed significant of gentle and severe feather pecking behaviour than LFP birds [P < 0.001]. increased the TRP/LNAA ratio in the plasma of the chicks. Furthermore, TRP/LNAA and stress induced levels of plasma corticosterone (although more pronounced in the UP line). TRP supplementation significantly increased 5-HT turnover in the hippocampus and archistriatum and tended to do so in the remainder of the forebrain. The results confirm our hypothesis that feather pecking behaviour is triggered by low serotonergic neurotransmission, as increasing serotonergic tone, by increasing dietary TRP, decreases gentle feather pecking behaviour.

van Hierden, Y. M., et al. (2005). "Chicks from a high and low feather pecking line of laying hens differ in apomorphine sensitivity." Physiology & Behavior **84**(3): 471-477.

Proactive rodents show a larger behavioral response to apomorphine (APO) than reactive copers, suggesting a more sensitive DA system in proactive individuals. Previously, chicks from a high feather pecking (HFP) and low feather pecking line (LFP) have been suggested to display a proactive and reactive cooing strategy, respectively. therefore, at approximately 4 weeks of age, the behavior of 48 LFP and 48 HFP chicks in response to an APO injection Was studied using an open field. Another objective of the present study was to determine whether behavioral variation (in an open field) between HFP and UP birds, after APO injection, is also reflected by variation of D, and D, receptor densities in the brain. Receptor binding capacities were assessed by measuring specific binding of tritiated D-1 and D-2 receptor ligands in different regions of the brain of control HFP and UP chicks. In the present study, it is shown that indeed HFP chicks display a more enhanced behavioral response to acute APO treatment (0.5 mg/kg BW) than LFP birds an open field. This difference was not reflected by variation of D-1 and D-2 receptor densities in the brain between both lines.