Literature Featherpecking - Risk factors - Feed

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.

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.

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. (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.

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.

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.

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.

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.

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.

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.

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. (2005). "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. (2005). "Impact of feeding management on feather pecking in laying hens." Worlds 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. 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.

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).

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. (C) 2010 Elsevier B.V. All rights reserved.

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.

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.

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.

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.

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.

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.