Impact of nutritional factors on feather pecking behaviour of laying hens in non-cage housing systems

M.M. Van KRIMPEN¹, R.P. KWAKKELE², G. ANDRÉ¹, C.M.C. van der PEET-SCHWERING¹, L.A. DEN HARTOG³,⁴ and M.W.A. VERSTEGEN²

¹Animal Production, Animal Sciences Group, Wageningen UR, PO Box 65, NL-8200 AB Lelystad, The Netherlands; ²Animal Nutrition Group, ³Animal Production Systems Group, Department of Animal Sciences, Wageningen University, PO Box 338, NL-6700 AH Wageningen, The Netherlands and ⁴Nutreco R&D, PO Box 220, NL-5830 AE Boxmeer, The Netherlands

*Corresponding author: marinus.vankrimpen@wur.nl

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.

Keywords: nutrition; welfare; feather pecking; laying hens; diet composition; feeding management

Introduction

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. Feather pecking in layers is a multi factorial problem, which can be caused by environmental, genetic or nutritional factors (Blokhuis, 1989). The objective of the current study is to provide an overview of the relationship between feather pecking behaviour and nutritional factors, such as diet composition and feeding strategies. It has been demonstrated many times that dietary deficiencies stimulate explorative behaviour and may increase feather pecking (e.g. (Ambrosen and Petersen, 1997). Some authors have shown that the addition of fibre to the diet or feeding roughages could decrease feather pecking and cannibalism (e.g. (Steenfeldt et al., 2001). The relative importance and possible mode of actions of specific nutritional factors in layer diets will be examined and discussed in this review.

Factors affecting feather pecking behaviour

Many factors that affect feather pecking behaviour are related either to internal factors like the genetic nature or the physiological status of the birds, or to external factors like housing conditions of the birds or nutritional factors or to a combination of these factors. The interaction between internal and external factors also can increase feather pecking behaviour. It appears that feather pecking is initially
performed by frustrated birds. An overview of factors that affect feather pecking behaviour is given in Figure 1. This paper is mainly focused on these nutritional factors within the circled part of the figure that could reduce feather pecking behaviour.

**Figure 1**  Factors affecting feather pecking behaviour

**Dietary Energy content**

Dietary energy concentration may affect feather pecking behaviour. Increasing the dietary energy content of layer diets (10.7, 11.2, 11.7 and 12.2 MJ/kg) resulted in increased energy consumption, a tendency to higher mortality and a significant decrease in feather condition (Elwinger, 1981). Feeding non-debeaked laying hens a low density diet (11.05 MJ ME/kg, 51 g/kg crude fat), in which all nutrients were decreased by 5%, improved plumage condition compared to hens that were fed a standard diet (11.55 MJ ME/kg, 65 g/kg crude fat) (Lee et al., 2001). Laying performance was not adversely affected by the lower density diet. Feed intake of the low density diet was higher, resulting in an almost similar energy intake in both diets. This suggests that laying hens fed energy diluted diets spent more time on feed intake, and yet less time is remaining for feather pecking behaviour. This is in accordance with the results of Savory (1980) who fed male Japanese quail diluted (with 40% cellulose) and undiluted diets. Those receiving the diluted mash consumed about 40% more feed (14.9 vs 10.8 g/d), spent a higher proportion of total time (24 h) on feed intake (23.8 vs 9.1%), had a longer meal length (1.54 vs 0.87 min), a shorter inter-meal interval length (4.98 vs 8.92 min) and more meals per day (128 vs 86). Despite meal length being longer with diluted mash, the weight eaten per meal (av. 0.116 g) was similar to the amount with undiluted mash. However, the two diets had different densities and a much greater volume per meal was consumed with diluted mash than with undiluted mash (0.409 cm³ vs 0.182 cm³); this suggests that the difference in meal length was related to dietary bulk. The passage rate through the digestive tract and the emptying of the crop were both about 1.5 times faster with diluted compared to undiluted mash. The undiluted mash was 1.5 times better digestible than the diluted mash (Savory, 1980). The length of the inter-meal interval was closely associated with the difference in rate of feed passage. Savory (1980) suggested that gut-emptying, and particularly filling and emptying of the gizzard or duodenum, could be the main activating mechanism in meal initiation and termination.

A low energy content of the diet seems to reduce feather pecking behaviour and to improve plumage condition. However, the different energy levels often are confounded with changes in other ingredients, like protein and NSP levels, and with differences in meal length and frequency, as well as in passage rate and emptying of gut segments. The optimal dietary energy level for reducing feather pecking while maintaining laying performance remains unknown.

**NSP content and particle size of NSP**

NSP (Non Starch Polysaccharides) helps to maintain normal structure and function of the gastrointestinal tract and prevents cannibalism, and should therefore be included in poultry rations. For
decades it is known that an increase in crude fibre content in diets for growing and laying pullets can markedly reduce feather pecking and cannibalism (Bearse et al., 1940). Increasing the crude fibre content from 29 to 123 g/kg (by substituting corn with oat hulls) decreased feather pecking and cannibalism.

A number of studies have confirmed that the insoluble NSP fraction in the diets of laying hens is beneficial in preventing pecking behaviour (Aerni et al., 2000; El Lethey et al., 2000; Hartini et al., 2002; Hetland et al., 2004). One experiment showed that both insoluble (mill run) and soluble (barley) NSP sources were effective in reducing and controlling cannibalism in laying hens (Hartini et al., 2002).

Birds fed diets high in insoluble NSP spend more time eating and appear calmer than those fed low-NSP diets. Insoluble NSP plays an important role in modulating gut development and digestive function (Hetland et al., 2004). Feeding a supplement of wood shavings (an insoluble NSP-rich raw material) to laying hens fed wheat-based diets resulted in a 50% percent heavier gizzard of broiler chickens, whereas including 40% whole wheat in a wheat-based mash diet increased the gizzard weight by only 10%, indicating that wood shavings has a higher impact on gizzard weight than whole wheat. The insoluble NSP content in the gizzard of chickens fed wood shavings was twice as much as the content in the feed. This suggests that insoluble NSP accumulates in the gizzard and is retained longer than other nutrients, probably because it has to be ground to a critical particle size before entering the small intestine. Coarse NSP particles also decrease the passage time of fine particles when it is fed to broiler chickens. The fact that insoluble NSP accumulates in the gizzard may also indicate a slower feed passage rate when the level of coarse NSP is increased in the diet. This confirms that the gizzard is almost like a point of regulation for digestion, selectively retaining different feed particles and letting nutrients pass for further digestion. It is thought that accumulation of insoluble NSP in the gizzard triggers a temporary satiety, but once passed the gizzard, it passes through the gut quickly. This could make the bird feel more satisfied between feeding bouts, but more hungry after gizzard emptying (Hetland et al., 2005). It can be hypothesized that chickens prefer not just NSP, but coarse NSP. The attractiveness for coarse NSP sources, such as wood shavings and paper seems to be considerably higher for birds fed a wheat-based diet than for those fed an oat-based diet. Since oats contain considerably coarser NSP than wheat, the data indicate that the birds needed some coarse NSP in their diets, perhaps for gizzard activity (Hetland et al., 2005). In line with this, birds fed an oat-based diet had a significantly heavier gizzard and a larger content of the gizzard compared with those fed a wheat-based diet when housed in cages. The reverse was true for the gizzard weight when the birds were reared under a free range system. These results support the hypothesis that, given the opportunity, birds fed low NSP diets will search for coarse materials to satisfy their NSP need. The amount of feathers in the gizzard of individual housed laying hens was higher in laying hens fed a low-structure diet based on rice and casein than in hens fed a diet based on wheat or enriched with coarse NSP (Hetland et al., 2005). The gizzard content of the birds fed the rice-based diet, however, was markedly less than in hens fed the wheat-based or coarse NSP diets. Until now no causal factors for feather eating are known, but these results indicate that feather eating and pecking behaviour may be partly related to feed structure, which play a major role in the volume of gizzard contents. The relationship between fibre content of the ration and prevention of feather pecking is only partially understood. Conceivably, it may be related to the increased consumption of feed or the time occupied in eating. It was also postulated that ingestion of insoluble NSP would increase gut viscosity and gut fill (Hartini et al., 2002). However, the ideal dietary NSP content and NSP source for reducing feather pecking results while maintaining laying performance remains unknown.

**Tryptophan content**

Dietary supplementation with tryptophan in growing bantams (2.6, 12.6, and 22.6 g/kg), resulted in a suppression of pecking damage with the higher doses compared to the control dose (2.6 g/kg), at 4 and 6 weeks of age (Savory, 1998; Savory et al., 1999). This lower level of pecking damage is probably caused by a lower level of severe feather pecking behaviour. In line with this observation Van Hierden et al. (2003) reported reduced frequencies of gentle feather pecking in young chickens that were fed a diet with a very high tryptophan level (21 g/kg) compared to a diet with a standard tryptophan level (1.6 g/kg). Tryptophan is a precursor for serotonin synthesis (5-HT) and chickens from a high feather pecking line were found to display lower 5-HT turnover levels in response to acute...
stress than chickens from a low feather pecking line (Van Hierden et al., 2003). Increased dietary tryptophan stimulates serotonergic neurotransmission, resulting in a higher turnover of tryptophan to 5-HT in the brains. Thus feather pecking behaviour seems to be triggered by low serotonergic neurotransmission, because increasing serotonergic tone (higher levels of dietary tryptophan) decreases feather pecking behaviour.

Feeding strategy in the rearing period

The development of the digestive tract during the rearing period, resulting in an appropriate volume and digestive capacity of the gut at the beginning of lay, was suggested to be of great importance in the occurrence of feather pecking and cannibalism during the laying period. The volume of the digestive tract (mainly the gizzard) can be increased by feeding coarse particles and/or fibre-rich diets. Similarly, feeding whole wheat during the rearing period is thought to increase the digestive capacity of laying hens at the beginning of the lay. Supplementing extra straw or spreading 10% of the estimated feed intake as whole wheat into the litter had no effect on the development of body weight, plumage condition and mortality rate of the pullets, but markedly reduced feather damage in the layer period (Blokhuis and Van der Haar, 1992). Distributing grain in the litter during rearing also directed foraging-related behaviours like ground scratching and ground pecking, suggesting that the incentive value of the ground and the substrate covering it might be increased with grain during the rearing period (Blokhuis and Van der Haar, 1992). Although feeding strategy during rearing seems to be of importance for feather pecking behaviour in the laying period, few investigations studied this kind of nutritional carry-over effect.

Feed Form

The physical form of the diet, e.g. mash, crumble or pellet, and also the distribution of particle size in mash diets, can affect feather pecking behaviour, possibly due to differences in time spending on feed intake. More feather pecking was found in laying hens fed a coarsely ground meal (33-55% of particles > 2mm) compared with laying hens fed a finely ground meal (0-13% of particles > 2mm) (Walser and Pfrirter, 2001). Based on the results of this experiment an optimal mash structure should have a normal distribution pattern of fine particles between 0.25 and 2 mm. Addition of whole cereals to mash diets enlarges the average particle size of the diet, which may cause an increasing risk of feather pecking.

A number of studies have confirmed that laying hens fed pellets are more likely to develop feather pecking than birds fed on mash (Savory, 1974; Lindberg and Nicol, 1994; El Lethey et al., 2000; Walser and Pfrirter, 2001). Providing pellets may also decrease the age when feather pecking behaviour is initiated. Incorporating more coarse structure into pellets by adding whole wheat in the mixer before pelleting, however, positively affects plumage condition, gizzard weight and gizzard contents of laying hens, all indicators of better welfare. In contrast, when pullets were kept in pens with litter-covered floors, feed form (mash or pellet) exhibited no significant effect on feather pecking. In another study, feather pecking behaviour was equal in laying hens fed on crumbs or mash (Wahlstrom et al., 2001). Since feeding pellets had dissimilar effects on feather pecking in different studies, interaction effects of pellets with other factors, e.g. housing conditions, is highly probable.

There may be an interaction between feed form and available floor space: in pullets, feather pecking was only observed in two of the six groups receiving a pelleted diet and feather pecking stopped when these two groups were removed from the houses to yards where they had more floor space (Heywang and Morgan, 1944). Also a significant interaction was shown between foraging material (with or without long straw) and food form (mash or pellet) (Aerni et al., 2000). High rates of feather pecking and pronounced feather damage were only found in laying hens housed without straw and fed on pellets, indicating that laying hens (especially when fed pellets) should be provided with an adequate amount of foraging material. Laying hens with access to foraging material also had a lower heterophil-to-lymphocyte ratio and an increased immune response to immunisation than those without access to such materials, indicating lower stress in these birds.

Chickens engage in more feed directed behaviour when fed finely ground mash than when fed coarsely ground mash, crumbles or pellets (Aerni et al., 2000). Similarly, laying hens in individual cages spent more time on feed intake as the particle size of the diet decreased (100 minutes per day for pellets, 154 for crumbles and 234 for mash) (Tanaka et al., 1983). The frequency of feed pecking also
increased with decreasing particle size: 9,723 times per day for pellets, 15,874 for crumbles and 22,845 for mash, with an average feed intake of 11.8, 7.4 and 5.2 gram per peck. Laying hens that were fed a high volume mash pecked feed more frequently and feathers less than birds fed a low volume mash. Feeding pelleted diets resulted in two times more pecks directed to a bundle of feathers, or more time spent on perching, whereas more feeding directed behaviours (sum of time spent on feeding and foraging) were recorded in hens fed on mash (Aerni et al., 2000). Spending more time eating will fulfil the need of the foraging behaviour of the laying hens, which may lead to a decrease in feather pecking.

It seems that a too high amount of coarse particles or pellets in the diet may cause an increasing risk of feather pecking behaviour compared to mash diets, possibly due to spending less time on feed intake. Feeding strategies that result in laying hens spending more time on feed intake and foraging could decrease the risk of feather pecking behaviour.

Supplying roughages

Roughage supplements may reduce feather pecking in birds. Supplements of cut green clover and branches with green leaves as roughage sources, given to young pheasants (five and ten weeks old), led to significantly less feather pecking than in the controls (Hoffmeyer, 1969). Mutual comparison of the two roughage sources (branches with green leaves and cut green clover spread on the floor) in pheasants of ten weeks old showed markedly less feather pecking in the clover group. The amount of feather pecking was inversely correlated with the amount of pecking directed at the supplemented source. The pheasants treated the leaves and other roughages in the same way as feathers, indicating a great similarity between the behaviour shown in feather pecking and the normal feeding behaviour. Roughages, which are a normal target for the pheasant food pecking activity in natural habitats, must provide a sign for stimulating feeding behaviour. Feathers may provide some of the sensory stimuli (optical, tactile) to which the (innate) feeding response mechanisms of pheasants are specially attuned. Based on these experiments it was concluded that feather pecking is a substitute for normal feeding behaviour.

Carrots, maize-silage and barley-pea-silage were supplied to laying hens from 20-54 weeks of age to examine the effect of supplementing roughages on performance, gastro-intestinal health and feather pecking behaviour (Steenfeldt et al., 2001). At 24 weeks of age, treatments differed significantly in the incidence of feather pecking, with less gentle and severe feather pecking in hens fed carrots or maize-silage compared to the control group. At 53 weeks of age, differences in feather pecking were non-significant but similar tendencies were still observed. Hens fed the silage had the best plumage condition at 53 weeks of age. Roughage supplementation did not affect egg production (except for barley-pea-silage) and feed efficiency, but significantly decreased mortality rate (Steenfeldt et al., 2001). The positive effects of roughage supplementation could possibly be the result of a lower dietary density and/or an increased NSP content of the diet. Supplementing the diets with carrots (in the experiment of Steenfeldt et al. (2001) decreased the density of the diet by about 40%. This could be an explanatory factor, especially since the roughages increased the total consumption of the laying hens, which could be an indication of spending more time on feed intake. Regrettably, Steenfeldt et al. (2001) showed no data concerning distribution of time spent on different types of behaviour.

Hypothesis

Based on the results found in literature we hypothesised that nutritional factors will reduce feather pecking behaviour in laying hens if these factors increase the time spent on feeding behaviour. Eating time will be increased by feeding diets with low energy levels and/or high contents of coarsely ground insoluble NSP’s, resulting in reduced feather pecking behaviour, without negatively affecting egg performance. Therefore, a research project was started, focused on the interaction effects between energy level, insoluble NSP level and particle sizes of NSP on eating time and feed passage rate, as being assumed indicators for developing feather pecking behaviour (Van Krimpen et al., 2005).
First results of the project

Experiment 1

The aim of the first experiment of the project was to investigate the effect of certain nutritional factors (nutrient density, NSP-content, solubility and particle size of NSP-fraction, as well as feed form) on feed intake behaviour, eating time and performance of young layers. Laying hens, which are fed low nutrient density diets, will normally compensate for the lower nutrient concentration by increased feed intake (Savory, 1980; Lee et al., 2001). However, because of the decreased feed intake capacity in young modern layer strains, we would like to know whether these birds at the onset of lay are able to fully compensate for the dietary dilution by increased feed intake.

An experiment with 480 ISA Brown layer strains was conducted to measure the effect of dietary dilution (11.8 versus 10.6 MJ/kg), particle size distribution of the NSP fraction (fine and coarse) and feed form (mash and crumble) on feed intake, eating time and egg-performance of laying hens in early lay (from 18 to 26 weeks of age). Energy reduction of the diet was realised by use of NSP-Low (sand, grit) or NSP-high raw materials (oat hulls, beet pulp, arbecel, soya hulls, and straw). NSP concentration of the diets varied between 128 and 207 g/kg, whereas soluble NSP content ranged between 64 and 85 g/kg. Twelve experimental diets were tested, each replicated four times. Laying hens in early lay that were fed low- or high-NSP diets were able to compensate for 10% dietary dilution by a 9.5 and 4.9% higher feed intake, respectively. Feeding crumble or coarsely ground mash did not affect feed intake. Eating time of the hens fed the undiluted diets increased over the experimental period from 16.4 to 24.6% of the observation period, but was not affected by NSP-low raw materials, particle size distribution or feed form. Feeding high-NSP diets increased eating time by 22% (Figure 2).

Egg performance and body gain of the hens that were fed low-NSP or high-NSP diets were similar or better compared to the undiluted diets, whereas coarse grinding of the diets showed 7-10% lower egg performance and body gain. Egg performance and body gain was not affected by feed form. It is concluded that hens in early lay, that were fed energy diluted diets, as a result of addition of sand or grit (low-NSP) or NSP-rich raw materials (high-NSP) to the control diet, were able to increase their feed intake, resulting in a comparable energy intake and egg performance as the control group (Van Krimpen et al., 2007).

![Figure 2](image-url)

Figure 2  Eating time (%) of the treatment groups Control, Low NSP, High NSP, Coarse grinding, Crumble and Soluble NSP over week 4, 7 and 9.

Experiment 2

A second experiment was conducted with 504 ISA Brown layer strains from 18 to 40 weeks of age to investigate the separate effects of energy concentration, NSP concentration and particle size of added NSP source on eating behaviour, feather pecking behaviour and egg performance of laying
hens. The experiment had a factorial design with the factors energy concentration (11.8 versus 10.6 MJ/kg), NSP concentration (133 versus 195 g/kg) and particle size of the added NSP source (fine versus coarse). Six experimental diets were tested, each replicated seven times. The control diet contained 11.8 MJ/kg and 133 g/kg finely ground NSP. Layers were feather pecking prone birds, because they performed already feather pecking behaviour during the 5th week of the rearing period. We hypothesised that eating time will be increased by feeding diets with a low energy concentration and/or a high concentration of coarsely ground insoluble NSP’s, resulting in reduced feather pecking behaviour, without negatively affecting egg performance.

Energy reduction, NSP addition and coarse grinding of NSP significantly increased average eating time by 14.2% ($P=0.001$), 17.2% ($P<0.001$) and 7.9% ($P=0.075$), respectively, compared with the control level of these factors. NSP addition decreased eating rate (g/min) with 21.0% ($P=0.010$), whereas eating rate was not affected by energy concentration and coarseness of NSP. Dietary treatments did not significantly affect maximal level of feather condition scores, but arise of feather damage was delayed by 10 weeks in hens fed low energy, coarsely ground high NSP diets compared to hens fed control diets. Figure 3 shows that hens fed control NSP diets showed reduced culling rates if energy concentration was decreased (44.1% versus 13.1%), whereas in high NSP diets culling rate not decreased when hens were fed low energy diets (31.6% versus 28.6%) ($P=0.071$). Hens that were fed low energy diets compensated for 10% reduction in energy concentration by 9.3% higher maximal feed intake (143.0 versus 130.8 g/d). Egg performance and body gain of the hens were not affected by dietary treatments.

From experiment 2, it is concluded that hens that were fed low energy or high (coarsely ground) NSP diets spend more time on feed intake, compared with hens that were fed control diets. As a result, some treatments showed less feather pecking behaviour, as appears from a delay in arise of feather damage (low energy, coarsely ground high NSP diet) or a decreased culling rate (low energy, standard NSP diet) (Van Krimpen et al., In progress).

**Experiment 3**

Experiment 2 was conducted with feather pecking prone layers. The aim of Experiment 3 was to investigate the preventive effects of reducing dietary energy concentration and increasing NSP concentration during rearing phase on feather pecking behaviour and performance during layer phase. The experiment comprised six treatments during rearing phase; 3 energy concentrations (0%, 10% and 15% dilution level) x 2 NSP levels (control and high). During layer phase, eight treatments were tested; 4 energy concentrations (0%, 10% , 15% and 20% dilution level) x 2 NSP levels (control and high). Experiment 3 is still going on and results will be presented at a later moment.

**References**


