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Reduction of feather pecking behaviour in laying hens by feeding management – a review

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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.

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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.

KEY WORDS: diet composition / feather pecking / feeding management / laying hens / nutrition / welfare

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 multifactorial 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 of specific deficiencies in layer diets, as well as the effectiveness and possible modes of action of certain nutritional factors, 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

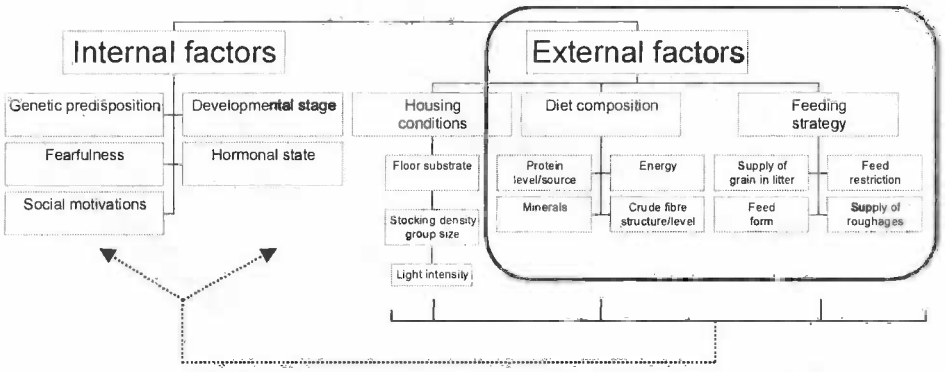

Fig. 1.Factors affecting feather pecking behaviour.

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 (Tables 1-4).

Diet composition

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 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 [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. It can be concluded that high levels of dietary tryptophan might decrease feather pecking behaviour.

Energy content (Tab. 1)

The energy content of the diet may also 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 equal energy intake in both diets. This suggests that laying hens fed diets with a lower energy density 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%

Table 1. Effect of dietary energy levels (MJ/kg) on plumage condition, occurrence of feather pecking and mortality in birds

Type of bird	Period of age (weeks)	Beak-trimmed	Energy content		Plumage condition[1]		Level of feather pecking	Mortality (%)		Authors
			Exp. 1	Exp. 2	Exp. 1	Exp. 2		Exp. 1	Exp. 2	
SCWL, Hisex, LSL	18-70	unknown	10.7	10.7	4.4	3.7	not recorded	8.8	7.4	Elwinger, 1981
			11.2	11.2	3.4	4.2		13.0	10.5	
			11.7	11.7	4.0	2.9		12.0	10.4	
			12.2	12.2	3.3	3.0		11.7	11.0	
Laying hens (LSL and Bovans Goldline)	30-52	no	11.05		8.1		not recorded	not recorded		Lee *et al.*, 2001
			11.55		7.3					

[1]Original data recalculated to a scale of 0 to 10 where 0 indicates almost naked and 10 an intact plumage.

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 (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 equal 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 cm^3 *vs* 0.182 cm^3); 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] suggests 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, protein and fibre 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.

Crude fibre content and particle size of fibre fraction (Tab. 2)

Non Starch Polysaccharides (NSP) help to maintain normal structure and function of the gastrointestinal tract and prevent 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 pullets and laying hens can markedly reduce feather pecking and cannibalism. Increasing the crude fibre content from 29 to 123 g/kg (by substituting corn with oat hulls) decreased feather pecking and cannibalism. The oat hull fibre fraction (obtained by dilute acid digestion of the hulls) was as effective as the oat hulls themselves in preventing feather pecking and cannibalism, while the ash of the dilute acid extract and the water extract of oat hulls were of little value in preventing cannibalism. Increasing the crude fibre content in diets of chickens up to 180 g/kg, by substituting oat mill feed by corn, reduced feather pecking rate and mortality, and also improved plumage condition. At a crude fibre content of over 130 g/kg a low incidence of feather pecking and cannibalism was recorded, whereas a high incidence of feather pecking and cannibalism was shown at a crude fibre content of below 80 g/kg.

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 and Choct 2003]. 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].

Table 2. Effect of dietary fibre levels (g/kg) on plumage condition, occurrence of feather pecking and mortality in birds

Type of bird	Period of age (weeks)	Beak-trimmed	Fibre source	Fibre content (g/kg)	Plumage condition[1]	Level of feather pecking[2]	Mortality (%)	Authors
Laying hens (ISA Brown)	17-20	50% yes 50% no	Control (73% wheat) Millrun[3] (32%) and Sorghum (48%) Barley (76%) Barley + enzyme (76%)	29.3 43.4 51.6 51.6	not recorded	not recorded	13.2 3.9 5.8 4.1	Hartini *et al.* 2002
Laying hens (ISA Brown)	21-24	50% yes 50% no	Control (73% wheat) Millrun[3] (32%) and Sorghum (48%) Barley (76%) Barley + enzyme (76%)	29.3 43.4 51.6 51.6	not recorded	not recorded	28.9 14.3 15.9 17.8	Hartini *et al.* 2002
Laying hens (LSL and Lohmann Brown)	20-80	no	Wheat diet 925% wheat, 10% oats) Oats diet (0% wheat, 33% oats)	44 64	not recorded	not recorded	18.4 13.4	Wahlstrom *et al.* 1998a (exp. 1) Wahlstrom *et al.* 1998b (exp. 2)
Laying hens (LSL and SLU)	20-80	no	Oats/wheat ratio: 0/60 12/48 24/36 36/24 48/12 60/0	 21.8 38.3 48.6 58.8 68.9 79.2	 7.8 8.1 8.3 8.9 9.0 9.1		 8.9 10.8 8.4 10.9 10.8 12.8	
Laying hens (ISA Brown and LSL)	18-80	unknown	Wheat/barley ratio 50/13.7 25/38.7	 36.0 40.0	 3.6 5.1	not recorded	ns 15.8 16.5	Abrahamsson *et al.* 1996
Laying hens (LSL and L324)	20-73	unknown	Wheat diet (72% wheat) Barley diet (74% barley) Oats diet 975% oats)	25.5 39.0 69.0	3.8 4.1 5.1	not recorded	8.8 8.8 7.2	Al. Bustany and Elwinger 1988
Laying hens (Single Comb White Leghorn)	2-40	unknown	Corn (81% corn) Corn/oat hull fibre (23% oat hull fibre) Corn/oat hulls (34.5%oat hulls)	29.1 110.7 122.6	not recorded	100[4] 5.8 2.3	3.9/8.7[5] 4.0/13.4 0.8/3.7	Bearse *et al.* 1940
Laying hens (Single Comb White Leghorn)	2-40	unknown	Wheat (80%) Corn (80%) Barley (78%) Oats (81%)	32.9[6] 31.2 51.2 100.1	not recorded	92.3[4] 97.0 73.2 0.0	0.0 1.7 0.0 0.0	Miller and Bearse 1937

[1]Original data recalculated to a scale of 0 to 10 where 0 indicates almost naked and 10 an intact plumage. [2] Number of pecking interactions per bird per hour. [3](2/3 wheat bran, 1/3 wheat pollard). [4]Percentage of birds pecked at 40 weeks of age. [5]Percentage mortality due to cannibalism in growing period and after 16 weeks of laying period respectively. [6]Based on own recalculation of the diets.

No effects of substitution of corn by wheat in diets for growing and laying pullets on feather pecking and cannibalism were found. Feather pecking and cannibalism were reduced slightly by substituting barley for corn, and markedly when substituting oats for corn. The crude fibre content of barley (46 g/kg) and oat (105 g/kg) is substantially higher than that of corn (22 g/kg) and wheat (24 g/kg).

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 and Choct 2003]. Feeding a supplement of wood shavings (an insoluble NSP-rich raw material) to laying hens fed wheat-based diets increased starch digestibility [Hetland and Choct 2003]. The improvement of starch digestibility may, in part, be due to enhanced emulsification of lipids as a result of a higher content of bile acids in the gizzard. The total content of bile acids in the gizzard increased in proportion to the amount of wood shavings retained in the gizzard. Consumption of 4% of feed as wood shavings 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 have 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. The fact that feeding a mash diet that was diluted with 10% powdered cellulose (an insoluble NSP source) to growing bantams did not affect pecking damage scores compared to an undiluted mash could possibly be explained by the small particle size of the powder. 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 and Choct 2003]. 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 and Choct 2003]. 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 and Choct 2003]. 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.

Feeding strategy

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 (Tab. 3)

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 >2 mm) compared to laying hens fed a finely ground meal (0-13% of particles >2 mm). Based on the results

Table 3. Effect feed structure on plumage condition, occurrence of feather pecking and mortality in birds

Type of bird	Period of age (weeks)	Beak-trimmed	Fibre structure	Plumage condition[1]	Level of feather pecking[2]	Mortality (%)	Authors
Laying hens (LSL and Shaver)	16-68	no	Pellets Pellets; whole wheat (40%) in mixer before pelleting	2.4 3.7	not recorded	8.8 8.8	Hetland *et al.* 2003a
Laying hens (LSL)	19-27	no	Pellets Mash	7.8 9.4	3.9 0.7	not recorded	Aemi *et al.* 2000
Bantams	1-6	unknow m	Pellets Mash Diluted Mash (40% cellulose powder)	6.5 9.4 9.6	not recorded	not recorded	Savory *et al.* 1999
Laying hens (LSL and L324)	20-73	unknown	Mash and whole cereals Barley Wheat Oats	Mash/whole 4.9/3.3 4.6/3.1 n.r./5.1	not recorded	Mash/whole 6.6/10.9 8.1/9.4 n.r./7.2	Al. Bustany and Elwinger 1988

[1]Original data recalculated to a scale of 0 to 10 where 0 indicates almost naked and 10 an intact plumage.
[2]Number of pecking interactions per bird per hour.

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. The type of whole cereal seems to be of importance in affecting feather pecking behaviour: laying hens fed diets containing whole wheat or barley had poorer performance, inferior plumage condition and a higher mortality rate than laying hens fed mash diets. In contrast with this, whole oats or mixtures of whole oats, whole barley and whole wheat resulted in better plumage than did mash diets with ground barley or ground wheat. Possibly, the favourable effects of the highly insoluble fibre content of whole oats compensate amply for the adverse effects of whole wheat and barley.

A number of studies have confirmed that laying hens fed pellets are more likely to develop feather pecking than birds fed on mash. 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 pelletizing, however, positively affects plumage condition, gizzard weight and gizzard contents of laying hens, all indicators of better welfare. The coarse wheat particles seem to accumulate in the gizzard, which possibly trigger a temporary satiety. 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 crumbles or mash. 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. 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 immunization 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 g per peck, respectively. Laying hens that were fed a high volume mash pecked feed more frequently and feathers less than birds fed a low volume mash. Feeding pelletized 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 (Tab. 4)

Roughage supplements may reduce feather pecking in birds (Steenfeldt *et al.*, 2001). 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. 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. In line with this, hens given *ad libitum* access to fresh grass had better plumage condition than those without. Roughage supplementation did not affect egg production (except for barley-pea-silage) and feed efficiency, but significantly decreased mortality rate [Steenfeldt *et al.* 2001]. Roughage supplementation significantly decreased pH in the caecum, probably caused by a higher fermentation rate in this part of the gastro-intestinal tract [Steenfeldt *et al.* 2001]. The positive effects of roughage supplementation could possibly be explained by a lower dietary density and/or an increased NSP content of the diet. In the experiment by

Table 4. Effect of roughage supply on plumage condition, occurrence of feather pecking and mortality in birds

Type of bird	Period of age (weeks)	Beak-trimmed	Source of roughage	Plumage condition[1]	Level of feather pecking[2]	Mortality (%)	Authors
Laying hens (ISA Brown)	20-54	unknown	Control diet (pellet)	5.9	1.08	15.3	Steenfeldt *et al.* 2001
			Maize-silage	8.9	0.36	1.5	
			Barley-pea-silage	9.5	0.71	2.5	
			Carrots	7.5	0.69	0.5	
Laying hens (Lohmann)	20-33	unknown	Control (all-mash)	6.6	not recorded	not recorded	Köhler *et al.* 2001
			Fresh grass	7.2			
Laying hens (LSL)	19-27	no	Without straw	7.8	4.2	not recorded	Aerni *et al.* 2000
			Long-cut straw (foraging material)	9.4	0.8		
Pheasant chickens	3	unknown	Control *vs* clove	6.5 *vs* 10.0	not recorded	not recorded	Hoffmeyer 1969
	5		Control *vs* clover	6.1 *vs* 8.8			
	10		Branches with leaves *vs* clover	5.5 *vs* 1.8			
	5		Green plastic band	4.8			
			Branches with green leaves	6.8			
			Green clover	8.4			

[1]Original data recalculated to a scale of 0 to 10 where 0 indicates almost naked and 10 an intact plumage.
[2]Pecks per bird per hour.

Steenfeldt *et al.* [2001] supplementing the diets with carrots decreased 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. Conceivably, the positive effects may be related to other nutrients than dietary density and/or NSP.

Supplying roughages to laying hens seems to be a promising approach to reduce feather pecking behaviour (though there is little literature on this). The relationship of roughage intake and feather pecking, however, is only partially understood.

Conclusion

Some investigations show that feather pecking behaviour is a substitute for normal feeding behaviour, while nutritional factors may positively or negatively affect feather pecking behaviour in laying hens. Until now, the mode of action of these nutritional factors is not fully understood. Dietary deficiencies, resulting in an inaccurate delivery of nutrients, such as protein, amino acids, or minerals, may increase feather pecking behaviour and cannibalism. Nutritional factors seem to reduce feather pecking behaviour in laying hens if they increase the time spent on feeding behaviour, by affecting foraging and feed intake. 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 NSP-diets or 4) roughages. Further research is needed to better understand the impact of nutritional factors on feather pecking behaviour and thus, welfare of layers.

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