Feather pecking and injurious pecking in organic laying hens in 107 flocks from 8 European countries

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Abstract

Feather pecking and cannibalism may reduce the potential of organic husbandry to enhance the w of laying hens.We report risk factors for these issues based on a large survey of 107 commercial flocks in eight European countries. Information was collected regarding housing, management and flock characteristics (age, genotype). Near the end of lay, 50 hens per flock were assessed for plumage

condition and wounds. Potential influencing factors were screened and submitted to a multivariate model. The majority of the flocks (81 %) consisted of brown genotypes and were found in six countries. Since white genotypes (19 %) were found only in the two Scandinavian countries, a country effect could not be excluded. Therefore separate models were made for brown and white genotypes. Feather damage in brown hens could be explained by a model containing a lower dietary protein content and no daily access to the free range (30 % of the variation explained). For feather damage in white hens no model could be made. Wounds in brown hens were associated with not having daily access to free range (14 % of the variation explained). Wounds in white hens were explained by a model containing not topping up litter during the laying period (26 % of the variation explained). These results suggest that better feeding management, daily access to the free range area and improved litter management may reduce incidence of plumage damage and associated injurious pecking, hence enhancing the welfare of organic laying hens. Since this was an epidemiological
study, further experimental studies are needed to investigate the causal relationships.

Keywords: Animal welfare; free range; poultry; layers; management; clinical scoring

Introduction

Overall in Europe, 3.8 % of all commercially farmed laying hens are kept on organic farms. In some northwestern European countries this percentage is higher: in Denmark for example 22 % of the hens are organic (*Marktinfo Eier und Geflügel* 3/9/2015). One reason for this might be consumer expectation that organic production is more welfare friendly compared to cage, barn or free range systems. The organic regulations aim for a higher level of animal welfare by giving the birds more space, access to outdoor areas and access to roughage. The European regulation (EC No 834/2007) prescribes a maximum group size of 3,000 hens per compartment, 6 hens per m^2 indoors, a free range area of 4 m^2 per hen, 18 cm perch per hen and one third of indoor floor surface covered with litter. It also prohibits beak trimming, a widespread practice routinely performed in the conventional laying hen industry. Moreover, the hens should be fed organically grown feed, e.g. no synthetic amino acids are allowed. In the period 2012 - 2014, when the data presented were collected, the minimum requirement was that 95

% of the feed should be from organic origin. In some countries additional regulations exist, for example concerning the rearing of organic hens or a free range area of 10 m² per hen.

Despite these presumed welfare enhancing requirements in the organic regulations, welfare and health problems have been reported in flocks of organic laying hens (Bestman and Wagenaar 2003; Hegelund *et al* 2006; van de Weerd *et al* 2009; Leenstra *et al* 2012; Bestman and Wagenaar 2014). Two major issues are feather pecking and injurious pecking. Feather pecking consists of forceful pecks and gripping/pulling of feathers, resulting in feather loss on the back, vent and tail area. Bald patches can be subjected to tissue pecking, which we regard as injurious pecking and which leads to wounds (Rodenburg *et al* 2013). Injurious pecking may be considered a behavioural pathology, comparable to human psychopathological disorders (van Hierden *et al* 2004) and it reflects reduced welfare in both the bird performing the feather pecking and the victimized bird (the latter because pulling out feathers is painful). The behaviour has strong relationships with stress (El-Lethey *et al* 2000) and fear (Rodenburg *et al* 2004). There is a reduced welfare in the victim because pulling out feathers is painful and hens with feather damage are more susceptible to further feather and injurious pecking (McAdie and Keeling 2000). The prevalent theory for feather pecking is that this maladaptive behaviour is redirected ground pecking that originates from insufficient foraging opportunities (Blokhuis 1986; Huber-Eicher and Wechsler1997; Rodenburg *et al* 2013). Feather pecking and injurious pecking may be caused by the same environmental risk factors (Pötzsch *et al* 2001). Apart from being an animal welfare issue, feather pecking is also an economic problem: hens with feather/plumage damage may need up to 27 % more feed in order to maintain their body temperature (Tauson and Svensson 1980). Another economic issue is that higher mortality, as caused by cannibalism, reduces egg production and thus farm income.

The aim of this epidemiological study was to identify risk factors for feather pecking and injurious pecking in commercial organic laying hens.

Animals, materials and methods

For this cross-sectional study, 114 organic layer farms were recruited across eight European countries: Austria, Belgium, Denmark, Germany, Italy, The Netherlands, Sweden and The United Kingdom. The inclusion criteria were that farms should have at least 500 hen places and that the housing should be permanent. Mobile housesrelocated more frequent than every 14 days was excluded. Farms purchasing commercial rations were preferred in order to be able to use feed declarations as an information source. A random spatial distribution of farms within countries was not always feasible due to travelling distance and the willingness of organic farmers to participate in the study.

The studied flocks were visited twice during the laying period, namely at peak of lay and at end of lay. Management data were collected during the farm visit at the peak of lay around 36 weeks of age, by interviewing the farm manager or person responsible for hen care using predefined questions. Questions concerned general farm information (e.g. number of hen places), flock information (e.g. age at placement, hybrid), vaccinations and medical treatments, feeding (e.g. composition, phase feeds), housing and range management and specific problems (e.g. parasites, smothering). At the second visit, which took place around 62 weeks of age, there was a short interview covering changes made and any noticeable problems and treatments between both visits. Data on housing conditions were additionally recorded by taking measures of the hen house, covered veranda (if present) and free range area, including the housing equipment (e.g. feeders, perches). Information on the feed composition was taken from the declarations from ready mixed rations or from standardized Near-Infrared (NIR) feed analysis where farms mixed their own feed.

The use of the free range and veranda was evaluated as follows. At each visit the total numbers of birds within the free range area and the veranda were counted 3 times: 5h15min – 4h30min before sunset, 3h30min – 2h45min before sunset and 1h45min – 0h45min before sunset. With these numbers the proportions of hens using the veranda and the free range area were calculated. In the statistical analysis only the highest percentage figures for bird use of the free range area and the veranda were used.

The sampling and assessment of endoparasites in manure and in guts is described in Thapa *et al* (2015). Ectoparasite burden was screened using 10 cardboard mite traps per flock at either the summer visit (all farms) or both visits (58 farms). The traps were fixed on the underside of the cross supports carrying the perches or the perches next to the cross supports in the evening and left in place for 7 days. After removing the traps in the morning they were transferred individually into zip-lock plastic bags and placed in a freezer at -20°C for at least 24 hours. Each sample was tapped out and distributed evenly in a petri-dish with a grid painted on. The grid served to estimate the number of mites by counting the number of mites within one square and multiplying this by the number of occupied squares. Based on this number, a score from 0 to 5 was assigned (0 = no mites, 1 = 1 to 10 mites, 2 = 11 to 100, 3 = 101 to 1,000, 4 = 1,001 to 10,000 and 5 = more than 10,000). In the statistical analysis the maximum score found for mites from every flock was used.

At the end of lay visit, a random sample of 50 hens per flock was caught and clinically scored regarding plumage condition and wounds at the neck, back, vent and tail using a modified four point scoring scheme (table 1), originally developed as a deliverable in the LayWel project (Tauson *et al* 2005).

Table 1: Explanation of scores and definitions used for scoring feather damage and wounds

The percentage of hens with feather damage was calculated per flock and a hen was regarded as having feather damage if the mean feather score of the 4 body parts was ≤ 3.00. The percentage of hens with wounds was calculated per flock and a hen was regarded as having a wound if the mean wound score of the two body parts was ≤ 3.50.

The data were analyzed with SPSS 19.0. A list of potential influencing factors was compiled for the dependent variables, percentage of hens with feather damage and percentage of hens with wounds. Independent categorical- and dichotomous variables were not taken into the analyses if one or more categories were not present in at least 20 % of the sample. All continuous independent variables were transformed by means of ln (x + 1) to correct for zeros and to meet the assumptions of normality and homogeneity of variance. Potential factors were screened by means of partial correlation analyses for all continuous and categorical variables and controlled for country and genotype. Dichotomous independent variables were screened by means of linear regression. A p-value ≤ 0.07 was used as threshold for inclusion of the variable in a multivariate model (GLM). Associations, by means of regression analyses, between independent variables were calculated to avoid variance inflation. Models were built by means of automated stepwise backward selection (SPSS 19.0), by removing variables from the model with $p > 0.05$. Variables with $p \leq 0.05$ were retained in the model. Parameter estimates were back transformed for interpretation.

Results

Data recording was performed between February 2012 and March 2014 on 114 organic laying hen farms at peak of lay (between 29 and 44 weeks of age), and on 110 farms a second time towards the end of lay (between 52 and 73 weeks of age). Thus, four farms dropped out before the 2nd visit because the hens were slaughtered earlier than originally planned or because induced moulting was performed. Because of lack of essential information, data from another 3 farms could not be used. Due to missing values, for some of the calculations we had information from fewer than 107 farms.

Beak treatments

In total 14 flocks had treated beaks to varying degrees (in Italy, The United Kingdom and Belgium). The Italian flocks that were beak treated, were either treated with the infrared method on the first day of life at the hatchery or with a hot blade within the first 9 days of life at the farm. The UK flocks and Belgium flocks were mildly treated with infrared as day old chicks. Since no significant differences appeared in feather damage and wounds between flocks with or without beak treatment, the beak treated flocks were not excluded from statistical analysis.

Frequency of feather damage and wounds

Figure 1 shows that in 42 flocks (39 %) more than half of the hens had feather damage. Figure 2 shows that in 17 flocks (16 %) more than half of the hens had at least one wound.

Figure 1: Percentage of hens with feather damage in 107 flocks

Figure 2: Percentage of hens with wounds in 107 flocks

Genotype

Genotypes were categorized as white, brown or silver. The majority of the flocks (82 out of 107) were brown genotypes. In Austria, Belgium and Italy only brown flocks joined the study. White genotypes (20 out of 107) were only seen in Sweden and Denmark. Silvers (5 out of 107) were only seen in Germany, The United Kingdom and The Netherlands. The small number of silver flocks was included in the category of brown flocks. Although silver hens have a white appearance, they lay brown eggs and their body weight is closer to that of brown hens. For the remainder of this article 'brown hens', 'brown flocks' or 'brown genotypes', refer to both brown and silver hens, flocks or genotypes. White flocks had a significantly ($P \leq 0.001$) higher percentage of hens with feather damage (mean 72 % (min – max 2-100); SD 32) than brown flocks (mean 33 % (min – max 0-100); SD 36). Concerning the percentage of hens with wounds, no differences were found between white and brown flocks: mean 20 % (min – max 0-64; SD 17) in white hens and mean 22 % (min – max 0-100); SD=28) in brown hens. Since white flocks were only present in the 2 Scandinavian countries, a country effect could not be excluded when interpreting the results of the white genotypes. On the other hand, brown and silver genotypes were used in more countries and that were more different from each other. Therefore it was decided to discriminate between brown and white genotypes and thus build 4 models: Feather damage in brown hens, wounds in brown hens, feather damage in white hens and wounds in white hens.

Feather damage in flocks of brown hens

After screening and selecting the factors as described in the `Animals, materials and methods` section, the variables as shown in tables 3 and 4 were retained in the model for feather damage in brown hens.

Table 3: Univariate associations of continuous nutritional and management variables and percentage of hens with feather damage in brown genotypes

Table 4 contains the univariate associations between percentage of brown hens with feather damage and a number of nutritional and management factors that showed to be significant and which were used in the final model.

Table 4: Univariate associations of categorical and dichotomous nutritional and management variables for percentage of hens with feather damage in brown genotypes

Since several of the variables were correlated with each other, some of them were not taken into the multivariate analyses. This was the case for dietary protein content at weeks 25, 35 and 55. Dietary protein content at week 55 was used, as this was the closest to hen assessment. Number of weeks pre-lay diet was fed was included in the model, while the age until pre-lay diet was fed and the presence or absence of pre-lay diet after placement was left out. The multivariate analysis reveals that the outcome variable 'percentage of hens with feather damage' for brown genotypes can be explained by the 'protein content at 55 weeks of age' (P = 0.004) and by 'daily access to free range' (P = 0.001), together explaining 30 % of the variation based on a sample size of 53 flocks. This means that an increased percentage of brown hens with feather damage was related to decreased dietary protein content at 55 weeks of age and to the absence of daily access to the free range. The model is as follows:

Percentage of brown hens with feather damage =
134 - 6.8 * (dietary protein content at week 55) + 21.6 * (daily access free range=0)

Dietary protein content of the feed at 55 weeks of age varied between 14.6 and 22.2 %.

Feather damage in flocks of white hens

After screening and selecting the factors as described in the `Animals, materials and methods` section, the variables as shown in table 5 and in the paragraph below were used to make the final model.

Table 5: Univariate associations of continuous nutritional and management variables and percentage of white hens with feather damage

If there was no needle vaccination at placement (n=8), then a mean of 93 % (min 70, max 100) of the hens had feather damage. If there was a needle vaccination (n=9), then a mean of 66 % (min 15, max

100) of the hens had feather damage. Correlation coefficient -0.48; P 0.049; n=17). The outcome variable ‘percentage of hens with feather damage’ for white genotypes could not be further explained if the above mentioned continuous and dichotomous variables were submitted in the GLM.

Wounds in flocks of brown hens

After screening and selecting the factors as described in the `Animals, materials and methods` section, the variables as shown in tables 6 and 7 were retained in the model for brown hens with wounds.

Table 6: Univariate associations of continuous nutritional and management variables and percentage of hens with wounds in brown genotypes

Table 7 gives an overview of the correlations found between percentage of brown hens with wounds and the presence or absence of a number of nutritional and management factors.

Table 7: Univariate categorical and dichotomous associations of the presence or absence of nutritional and management variables and percentage of brown hens with wounds

The presence or absence of pre-lay diet after placement was correlated with the number of weeks this diet was given. The number of weeks pre-lay feed after placement was not taken into the multivariate model, as its association was weaker than the presence or absence of pre-lay diet after placement. Only one diet till 55 weeks was exchangeable with the number of feed phases till end of lay. The latter was taken into the analysis as a stronger association was found for this variable. The outcome variable ‘percentage of brown hens with wounds’ could be explained by ‘daily access to free range’ (P = 0.001), explaining 14.4 % of the variation. An increased percentage of brown hens with wounds was seen if there was no daily access to the free range. The model is as follows:

Percentage of brown hens with wounds = 10.9 + 11.5 * (daily access free range =0)

Wounds in flocks of white hens

Univariate analyses on the percentage of white hens with wounds revealed that an increased calcium content at 25 weeks of age ($r = -0.49$; $P = 0.053$; mean 3.64; min. 3.50; max. 3.90) was related to a decreased percentage of white hens with wounds. The topping up of litter during the laying period was correlated with a decreased percentage of white hens with wounds ($r = -0.48$; $P = 0.021$; litter topping = 0: mean 94 % (min. 84, max.100); litter topping=1: mean 65 % (min. 2, max.100)).

The outcome variable 'percentage of white hens with wounds' could be explained by 'litter topping' ($P = 0.022$), explaining 26 % of the variation. An increased percentage of white hens with wounds was associated with farms that did not top up litter. The model was as follows:

Percentage of white hens with wounds = 14.9 + 19.1 * (litter topping = 0)

Discussion

Beak trimming is prohibited in organic animal husbandry (EC No 834/2007), but at least in the UK there is a derogation that allows non-organic chicks to be converted to organic. Therefore, farmers can buy conventional chicks that have been beak trimmed. Beak trimmed flocks were included in the statistical analysis, because no differences were found in feather damage between beak trimmed and non-beak trimmed flocks. Whay *et al* (2007) also found in a study in 25 free range flocks in the UK that neither feather pecking nor feather loss was affected by the severity of beak trimming.

Our data show that feather damage and wounding is a serious issue for organic egg production.

Through the application of best practice, managers can reduce the risk of feather pecking and cannibalism to facilitate good welfare in the hens. It was difficult to compare the frequency and degree of damage we found with other studies, because we determined the degree of feather damage in a flock as % of hens with a certain degree of feather damage, while other studies that used the same Laywel/Tauson scoring method, expressed it in a mean flock score. Moreover, the studies differ in the characteristics of the study flocks, such as number of countries involved (country effect being an important factor; see below), genotype, housing, and beak treatments.

The majority of the flocks, 81 %, were brown or silver hens and 19 % were white hens. The white hens were found in only Sweden and Denmark. We found significant differences between brown and white genotypes concerning the percentages of hens with feather damage, the mean for brown and white flocks being 33 % and 72 %, respectively. The differences found between white and brown flocks in the present study could also be explained by other factors than genotype, e.g. geographical location and its consequence for the availability of the free range area. In Scandinavian countries the hens are usually kept indoors for a longer period because of snow or other unfavorable winter conditions. In the present study no daily access to the free range area was significantly associated to an increased percentage of hens with feather damage. Leenstra *et al* (2012) investigated the performance of commercial laying hen genotypes on free range and organic farms in three European countries and found differences between genotypes: white genotypes in organic systems showed less feather pecking. However, in that study a country effect could have explained the results as well.

As in all epidemiological studies, associations found do not imply a causal relation between the factors studied. Associations found were used for practical recommendations as we attempted to test an existing hypothesis and explain some of our findings. However, confounding factors cannot be ruled out completely.

Feather damage irrespective of genotype

A higher dietary protein content of the feed at 55 weeks of age contributed to the multivariate model explaining feather damage in brown hens. Inappropriate or insufficient protein and amino acid levels are well known risk factors for feather pecking (van Krimpen *et al* 2005). Another motivation for feather pecking, may be to increase the fibre content of the diet, as most commercial laying hen diets have a relatively low fibre content. The consumption of feathers may be related to their positive effect on gut motility, which may be similar to the effect of fibre, illustrating that hens may indeed eat feathers to increase satiety (Harlander-Matauschek *et al*. 2006).

Also, daily access to the free range area was significantly correlated with a decreased percentage of brown hens with feather damage. Daily access contributed to a multivariate model explaining feather damage and wounds in brown hens. Lack of association for white flocks in the present study could be related to the fact that all the flocks with white hens were kept in Denmark and Sweden. Short day length in northern latitudes means that during the winter hens have restricted access to the outdoors, especially if the weather is inclement. In Sweden the hens are allowed to be kept inside for the whole winter. A relation between higher percentage of hens using the free range area and less feather damage has been found in several other studies (Bestman and Wagenaar 2003; Green *et al* 2000; Lambton *et al* 2010; Mahboub *et al* 2004; Nicol *et al* 2003). A free range area can be considered as environmental enrichment. Another explanation is that if a flock is distributed over a larger area, the stocking density decreases. Lower stocking density (in combination with a smaller group size) is also associated with less feather pecking (Huber-Eicher and Audigé 1999; Nicol *et al* 1999; Savory *et al* 1999). An increased percentage of hens using the free range area could be achieved by providing shelter (Zeltner and Hirt 2003; Bestman and Wagenaar 2003).

Wounds irrespective of genotype

No daily access to the free range area was related to an increased percentage of hens with wounds. Possible explanations and similar findings have been discussed in the paragraph above. Moreover, this variable was also related to percentage of brown hens with feather damage. Pötzsch *et al* (2001) stated that vent pecking and feather pecking damage could be caused by common risk factors. The second variable contributing to the percentage of (white) hens with wounds, is the topping of litter during the laying period. Rodenburg *et al* (2013) reviewed underlying principles of feather pecking and stated that early (i.e. during rearing) access to litter is an important factor in the reduction of feather pecking. The importance of litter in the prevention of feather pecking has been recognized for some time (Blokhuis and van der Haar 1992). Also, in commercial flocks the importance of litter for the reduction of feather pecking has been shown. Green *et al* (2000) found that absence of loose litter at the end of lay increased the risk for feather pecking. Nicol *et al* (2003) found a relation between feather pecking and the restriction of hen access to the litter area in their case-control study of 100 commercial farms in the UK.

For most statistically significant variables the correlation coefficients were relatively low. Thus the proportion of variation explained by its associations is also low. For example, 30 % of the flocks plumage damage was explained in the model for brown birds by lower dietary protein content and no daily access to the free range. However, another 70 % needs to be accounted for, reinforcing the complex and multifactorial nature of this problem.

Conclusion and animal welfare implications

This study identified risk factors for plumage damage and, or wounds in organic laying hens. These findings could also apply to conventional laying hens, whereas some risk factors are more specific for organic or free range systems. Measures that could be recommended are feeding enough protein, providing daily access to the free range area and improved litter quality. Further research is needed for determining differences between white and brown genotypes.

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References

Bestman MWP and Wagenaar JP 2003. Farm level factors associated with feather pecking damage in organic laying hens. *Livestock Production Science* 80: 133–140.

Bestman M and Wagenaar J 2014. Health and welfare in Dutch organic laying hens. *Animals* 4: 374-390.

Blokhuis HJ 1986. Feather-pecking in poultry: its relation with ground-pecking. *Applied Animal Behaviour Science.* 16: 63–67.

Blokhuis HJ and Haar JW van der 1992. Effects of Pecking Incentives during Rearing on Feather Pecking of Laying Hens. *British Poultry Science* 33: 17–24.

EC No 834/2007 on organic production and labelling of organic products; implemented by EC No 889/2008 of 5 September 2008.

El-Lethey H, Aerni V, Jungi TW and Wechsler B 2000. Stress and feather pecking in laying hens in relation to housing conditions. *British Poultry Science* 41: 22-28.

Green LE, Lewis K, Kimpton A and Nicol CJ 2000. A cross sectional study of the prevalence of feather pecking damage in laying hens in alternative systems and its association with management and disease. *Veterinary Record* 147: 233–238.

Harlander-Matuschek, A, Piepho, HP and Bessei, W 2006 The effect of feather eating on feed passage in laying hens. Poultry Science 85: 21-25.

Hegelund L, Soerensen JT and Hermansen JE 2006. Welfare and productivity of laying hens in commercial organic egg production systems in Denmark. *NJAS* 54 (2): 147-155.

Hierden Y van, Boer M de, Sietse F, Koolhaas JM, Korte SM 2004. The control of feather pecking by serotonin. *Behavioral Neuroscience* 118(3): 575-583.

Huber-Eicher B and Audigé L 1999. Analysis of risk factors for the occurrence of feather pecking in laying hen growers. *British Poultry Science* 40: 599–604.

Huber-Eicher B and B. Wechsler. 1997. Feather pecking in domestic: its relation to dustbathing and foraging. *Animal Behaviour* 54: 757–768.

Krimpen MM van, Kwakkel RP, Reuvekamp BFJ, van der Peet-Schwering CMC, den Hartog LA and Verstegen MWA 2005. Impact of feeding management on feather-pecking in laying hens. *World's Poultry Science Journal* 61: 663-685.

Lambton SL, Knowles TG, Yorke C and Nicol CJ 2010. The risk factors affecting the development of gentle and severe feather pecking in loose housed laying hens. *Applied Animal Behaviour Science* 123: 32-42.

Leenstra F, Maurer V, Bestman M, van Sambeek F, Zeltner E, Reuvekamp B, Galea F and Niekerk T van 2012. Performance of commercial laying hen genotypes on free range and organic farms in Switzerland, France and The Netherlands. *British Poultry Science* 53 (3): 282-290.

Mahboub HDH, Müller J and Borell E. von 2004. Outdoor use, tonic immobility, heterophil/lymphocyte ratio and feather condition in free range laying hens of different genotype. *British Poultry Science* 45: 738–744.

Marktinfo Eier und Geflügel http://www.marktinfo-eier-gefluegel.de/EU-Mehr-als-jede-zweite-Henne-in-Kaefigen,QUlEPTQ4Mjg1MTYmTUlEPTcyNzY3.html?UID=125772D88E5B3AFF7472BC4792EB2DD2E402C6F8F65B95 (accessed 23/10/2015).

McAdie TM and Keeling LJ 2000. Effect of manipulating feathers of laying hens on the incidence of feather pecking and cannibalism. *Applied Animal behavior Science* 68: 215-229.

Nicol CJ, Gregory NG, Knowles TG, Parkman ID and Wilkins LJ 1999. Differential effects of increased stocking density, mediated by increased flock size, on feather pecking and aggression in laying hens. *Applied Animal Behaviour Science* 65: 137–152.

Nicol CJ, Pötzsch C, Lewis K and Green LE 2003. Matched concurrent case-control study of risk factors for feather pecking damage in hens on free range commercial farms in the UK. *British Poultry Science* 44: 515–523.

Pötzsch CJ, Lewis K, Nicol CJ and Green LE 2001. A Cross-sectional study of the prevalence of vent pecking in laying hens in alternative systems and its associations with feather pecking damage, management and disease. *Applied Animal Behaviour Science* 74: 259–272.

Rodenburg TB, Buitenhuis AJ, Ask B, Uitdehaag KA, Koene P, Poel JJ van der, Arendonk JAM and Bovenhuis H 2004. Genetic and phenotypic correlations between feather pecking and open-field response in laying hens at two different ages. *Behavior and Genetics* 34:407-415.

Rodenburg TB, Krimpen MM van, Jong IC de, Haas EN de, Kops MS, Riedstra BJ, Nordquist RE, Wagenaar JP, Bestman M and Nicol CJ 2013. The prevention and control of feather pecking in laying hens: identifying the underlying principles. *World's Poultry Science Journal* 69: 361-373.

Savory CJ, Mann JS and Macleod MG 1999. Incidence of pecking damage in growing bantams in relation to food form, group size, stocking density, dietary tryptophan concentrations and dietary protein source. *British Poultry Science* 40: 579–584.

SPSS, IBM Corp. Released 2010. IBM SPSS Statistics for Windows, Version 19.0. Armonk, NY: IBM Corp.

Tauson R and Svensson SA 1980. Influence of plumage condition on the hen's feed requirement. *Swedish Journal of Agricultural research* 10: 35-39.

Tauson R, Kjaer J, Maria GA, Cepero R and Holm KE 2005. Applied scoring of integument and health in laying hens. *Animal Science Papers Reports 23* (Suppl 1): 153–159

Thapa S, Hinrichsen LK, Brenninkmeyer C, Gunnarsson S, Heerkens JLT, Verwer C, Niebuhr K, Willett A, Grilli G, Thamsborg SM, Soerensen JT, Mejer H (2015). Prevalence and magnitude of helminth infections in organic laying hens (Gallus gallus domesticus) across Europe. Veterinary Parasitology 214: 118–124.

Weerd HA van de, Keatinge R, Roderick S 2009. A review of key health-related welfare issues in organic poultry production. *World's poultry science journal* 65: 649-684.

Whay HR, Main DCJ, Green LE, Heaven G, Howell H, Morgan M, Pearson A and Webster AJF 2007. Assessment of the behaviour and welfare of laying hens on free range units. *Veterinary Record* 161: 119–128.

Zeltner E and Hirt H 2003. Effect of artificial structuring on the use of laying hen runs in a free range system. *British Poultry Science* 44 (4): 533-537.

Table 1: Explanation of scores and definitions used for scoring feather damage and wounds

Score	**Feather damage on neck, back and vent**	**Feather damage on tail**	**Wounds on back and vent**
4	Very good plumage condition; no or very few feathers damaged	No or less than ≤ 5 tail feathers damaged	No wounds at all
3	Completely or almost completely feathered, few feathers damaged. Featherless areas < 5 cm².	Tail feathers moderate to lightly damaged	Wound < 0.5 cm in diameter or a hematoma. Blood filled follicle after a feather was pulled out, is not regarded as wound
2	Highly damaged feathers and/or featherless areas. Featherless areas ≥ 5 cm² (up to 75 % featherless)	Tail feathers highly damaged	Wound < 2.2 cm
1	Very high graded damage of feathers with no or very few feather covered areas. Featherless area ≥ 5 cm² AND almost bare (75 % featherless) up to completely featherless	Tail feathers highly damaged and almost bare quill.	Wound with diameter of > 2.2 cm (width of thumb)

Figure 1: The distribution of flocks based on the proportion of sampled hens with feather damage

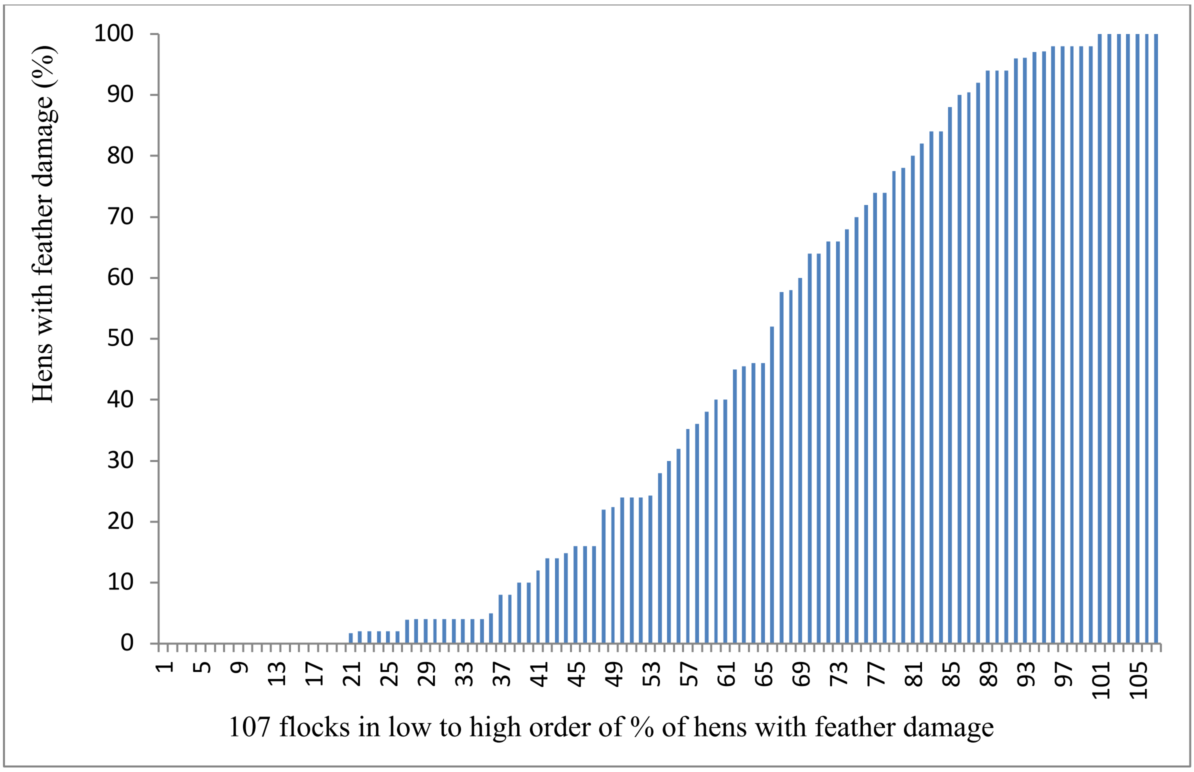

Figure 2: The distribution of flocks based on the proportion of sampled hens with wounds

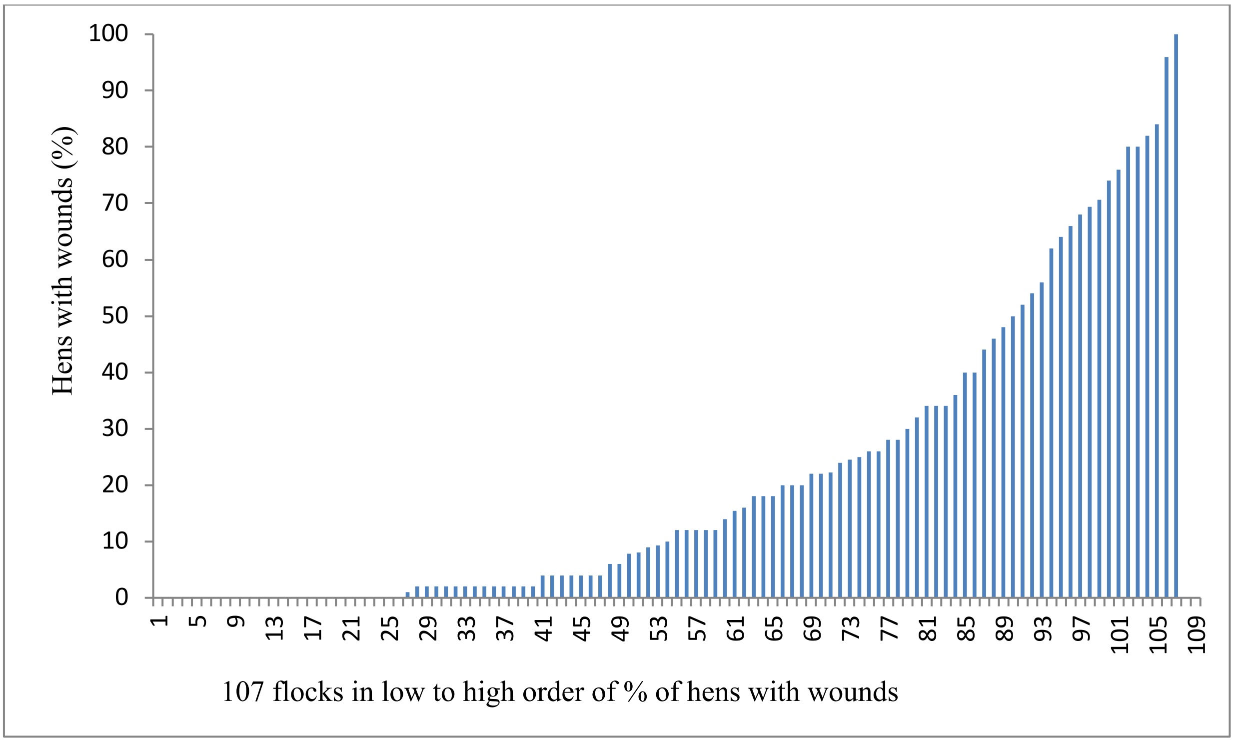

Table 3: Univariate associations of continuous nutritional and management variables and percentage of hens with feather damage in brown genotypes

Factor	**N flocks**	**Correlation coefficient**	**p-value**	**Mean (min-max)**
Number of weeks pre-lay feed after placement	81	0.33	0.014	1.0 (0-7)
Dietary protein content at placement	70	-0.34	0.011	18.0 (16-22.3)
Dietary protein content at 55 weeks	73	-0.40	0.003	17.9 (14.6 – 22.2)
Methionine content at 55 weeks	65	-0.32	0.021	0.35 (0.28 – 0.40)
Hens in veranda at 35 weeks (%)	84	-0.24	0.046	30 (0-83)
Hens in free range area at 35 weeks (%)	84	-0.25	0.038	18 (0 -64)
Number of deworming treatment	82	0.22	0.042	0.5 (0-3)
Number of alternative treatments[1]	82	0.20	0.062	0.5 (0-5)

[1]Alternative treatments include treatments with herbs, homeopathy, vitamins et cetera as a prevention or treatment of any health problem.

Table 4: Univariate associations of the categorical and dichotomous nutritional and management variables for percentage of hens with feather damage in brown genotypes

Variable	Correlation coefficient	p-value	No		Yes	
			Mean (min-max)	N	Mean (min-max)	N
Only 1 diet till 55 weeks	-0.31	0.004	45 (0-100)	38	23 (0-100)	47
Litter replacement	-0.33	0.020	39 (0-100)	50	15 (0-84)	30
Litter topping	-0.39	0.001	47 (0-98)	30	20 (0-100)	50
Daily access to free range	-0.28	0.012	36 (0-100)	56	16 (0-98)	24
Roughage during rearing	0.32	0.022	20 (0-84)	33	42 (0-100)	19
Daylight	-0.20	0.063	48 (0-100)	16	30 (0-100)	71
Needle vaccination after rearing	0.37	0.001	23 (0-84)	51	50 (0-100)	33

Table 5: Univariate associations of continuous nutritional and management variables and percentage of white hens with feather damage

Factor	**N**	**Correlation coefficient**	**p-value**	**Mean (min-max)**
No of feed phases till end of lay	20	0.52	0.033	2.3 (1-6)
Phosphorous content at 35 weeks	18	-0.53	0.050	0.55 (0.49-0.65)
Sodium content at 55 weeks	16	-0.52	0.058	0.16 (0.15-0.17)
Viability at 70 weeks	8	-0.78	0.040	93 (84-97)

Table 6: Univariate associations of continuous nutritional and management variables and percentage of hens with wounds in brown genotypes

Factor	N	Correlation coefficient	p-value	Mean (min-max)
Dietary protein content at placement	70	-0.33	0.066	18.0 (16 – 22.3)
Degree of presence of red mites[1]	82	0.22	0.050	2.3 (0-5)

[1] The highest score of 2 visits was used.

Table 7: Univariate categorical and dichotomous associations of the presence or absence of nutritional- and management variables and percentage of brown hens with wounds

Variable	**Correlation coefficient**	**p-value**	**No**		**Yes**	
			Mean (min-max)	**N**	**Mean (min-max)**	**N**
Needle vaccination at placement	-0.24	0.026	26 (0-100)	61	11 (0-68)	23
Daily access to free range	-0.21	0.063	22 (0-100)	56	11 (0-80)	24
Access to range restricted in poor weather	0.23	0.042	11 (0-80)	29	23 (0-100)	51