Are practice recommendations for the prevention of feather pecking in laying hens in non-cage systems in line with the results of experimental and epidemiological studies?

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Abstract

Feather pecking (FP) in laying hens is an important animal welfare problem in practice, despite extensive research and increasing sources of advice for farmers. We aimed to give an overview over results from experimental and epidemiological studies. We included non-cage systems, covering the rearing and laying phase. The investigated factors were categorised into those with either good, contentious or no evidence regarding preventive effects on FP. Moreover, we wanted to know to what extent recommendations for farmers are based on this scientific evidence. We extracted 62 potential preventive factors from 88 experimental and 21 epidemiological studies. 17 factors during rearing, and 32 factors during the laying phase significantly affected the risk to develop FP or plumage damage (PD). Factors were counted as significant if other studies found no or at most one opposite result. Seven factors during rearing and 16 factors during laying were confirmed by more than one study, with no or at most one opposite result. Provision of dry litter on the floor and sufficiently high perches during rearing and laying or a high use of the free range area during the laying phase were among these influencing factors. In the reviewed 15 practice recommendations, almost all of these factors have been taken up, although no recommendation comprises all factors and most miss more than the half of them. This leaves ample room for improvement of the recommendations. On the other hand, they altogether recommend 15 contentious as well as eight non-significant or 12 not yet investigated factors for which further scientific investigation is necessary.

Keywords: Laying hens; Feather pecking; Plumage damage; Recommendations

1 Introduction

Feather pecking (FP) is still a significant problem in laying hens (e.g. Heerkens et al., 2015; Nicol et al., 2013; Rodenburg et al., 2013). In literature, distinction is being made between six different types of allopecking behaviour: (1) aggressive pecking which is to be differentiated from FP (Savory, 1995), (2) gentle FP without removal of feathers (Bilĉík and Keeling, 2000; Savory, 1995), (3) severe FP leading to feather loss (Bilĉík and Keeling, 2000; Savory, 1995), injurious (4) tissue pecking in denuded areas, (5) vent pecking (Savory, 1995) and (6) pecking at toes, which can also be regarded as a type of cannibalistic allopecking behaviour (Krause et al., 2011). Furthermore, regarding gentle FP, Rodenburg et al. (2004) suggest distinguishing (1) 'normal' gentle feather pecking from (2) stereotyped gentle feather pecking, and (3) gentle pecking at particles on the plumage (which is no FP behaviour). It is still unclear whether only some or all forms of gentle FP may develop into severe FP (Newberry et al., 2007). Severe feather pecking may result in economic losses because of increased food consumption in defeathered birds (Leeson and Morrison, 1978; Tullett et al., 1980), increased mortality (El-Lethey et al., 2000) as well as in reduced animal welfare since FP is painful (Gentle and Hunter, 1990). Consequently, it can lead to cannibalism (Green et al., 2000) and the victims` death (Fossum et al., 2009; Heerkens et al., 2015). Only severe FP behaviour or the resulting plumage damage will be considered in this paper.

Non-cage systems are increasingly used in the EU, making up about 45% of the hen places in 2014 (Wing, 2015); and having increased from 26.7% in 2005 to 89.3% in 2014 in Germany (Statistisches Bundesamt, 2015). While the risk of problems due to feather pecking is increased in these systems (Rodenburg et al., 2004), the major symptomatic measure to control damage due to feather pecking, namely beak trimming, is heavily debated for animal welfare reasons (Defra Animal Welfare Team, 2015). In several European countries beak trimming is either already forbidden by law (Sweden, Norway and Finland) or by label guidelines (Austria), or shall be phased out in the near future, with dates between 2017 (UK, Germany) and 2018 (Netherlands). Alternatively, individual egg producers voluntarily refrain from beak trimming, like in Denmark since 2014 (Defra Animal Welfare Team, 2015).

Therefore, the demand for practice recommendations on how to prevent feather pecking is increasing.

There is an abundance of experimental studies on possible risk factors for this undesirable behaviour (e.g. reviewed by Kjaer and Bessei, 2013; Nicol et al., 2013; Rodenburg et al., 2013). However, as feather pecking is a multifactorial problem and the various influencing factors may interact differently on each individual farm, the successful transfer of the results of experimental studies into farm practice is difficult (Lambton et al., 2013). This is one reason why epidemiological studies have been increasingly undertaken. For this review we examined (1) epidemiological and (2) experimental studies as well as (3) practice recommendations which are easily accessible to laying hen farmers in terms of consistency within and between the three categories. On this basis we aimed to identify influencing factors regarding FP for which there is either good, contentious or no evidence.

2 Material and Methods

For the search of epidemiological and experimental studies in the electronic databases Web of Science, scienceDirect, CAB Abstracts, pub.med. and organic eprints the keywords `laying hens' in combination with 'feather pecking' or 'plumage damage' were applied. Only studies concerning the species *Gallus gallus domesticus* in non-cage systems and the topics 'damaging feather pecking' or 'plumage damage' were included. In addition, reference lists of retrieved papers were searched for further studies.

Recommendations were sought using the internet search engine 'Google' with the keywords 'laying hens' and 'feather pecking' which were used in combination with 'recommendations', 'management guidelines' or 'references'. Also, the German keywords 'Federpicken' and 'Legehennenhaltung' were applied in combination with 'Empfehlungen', 'Prävention', 'Managementempfehlungen', or 'Haltungsempfehlungen'. Selection criteria for the recommendations were that they must be freely available, that they covered rearing, placement or the laying period and that they are related to non-cage systems.

Recommendations which were directly derived from an individual epidemiological study were excluded.

Influencing factors (for the sake of clarity concerning the direction of influence, we call them preventive factors in this paper) which were found in the reviewed studies were grouped into categories and listed in tables, together with further relevant information, e.g. whether FP or plumage damage (PD) had been studied, size of the study, age of hens at scoring or beak status.

3 Results

We identified 21 epidemiological, 88 experimental studies and 15 recommendations fulfilling the criteria described above. Altogether 82 potential preventive factors regarding FP were extracted from the reviewed recommendations and studies. The housing and management systems investigated included organic or conventional systems with barn, aviary or free range housing, and beak trimmed as well as non-beak trimmed birds. Sometimes no information about housing systems or beak status was given. The dependent variables were FP (yes/no), the amount of feather pecking observed (total number of feather pecks), partly with differentiation of forms of FP, plumage damage scores, the percentage of birds with plumage damage or the time when FP started.

3.1 Epidemiological studies

From the identified epidemiological studies, 17 are published peer-reviewed articles, two are conference papers, one is a PhD-thesis and one pilot study is available as pdf in the Internet. Table 1 gives information on important aspects of the study designs. Most studies (20) focused on the laying phase while eight also considered rearing. Huber-Eicher and Audigé (1999) focused only on rearing. Lambton (2010a) as well as Pötzsch (2001) additionally collected data concerning rearing, without showing them. Two studies explicitly included information about the placement of the hens (Bestman, 2000; Bestman and Wagenaar, 2003). The number of potential preventive factors taken into account per study varied from

one to 28, leading to altogether 51 factors, from which 46 were found to significantly affect FP or PD in at least one study (Table 2).

Table 1 and table 2 near here

On average a factor was investigated by three studies. The factors most frequently considered were ‘small flock size’ (9x), ‘high use of range’ (9x), ‘suitable hybrid’ (7x), ‘access to perches’ (7x), ‘low stocking density’ (6x) and ‘low light intensity’ (6x).

The preventive potential of quite a number of factors was unanimously confirmed in different studies at least concerning one phase of the hens’ life, during the rearing or laying phase. These were ‘use of pullets without FP in rear’ (5x), ‘high percentage of sheltered areas’ in the free range during laying (4x) and ‘measures encouraging hens to go outside’ (3x), ‘low stocking density’ during rearing (3x), but not always during laying (1x significant (sign.) and 3x non-significant (n.s.)), ‘prevention of diseases’ (3x), feeding ‘mash instead of pellets’ (3x laying, 1x rearing), ‘low sound level’ during laying (2x), but not unequivocally during rearing (2x sign., 1x n.s.) and ‘provision of dry litter on the floor’ during rearing (2x), but not unequivocally during laying (3x sign., 1x n.s.). For ‘spreading grain on floor’ during laying a significant, but risk increasing effect was confirmed three times, while during rearing no effect was found (2x). Predominantly a ‘high use of range’ was found to be significantly beneficial in the laying period (6x sign, 1x n.s), but not during rearing (2x n.s.).

‘Early placement before 20 weeks of age’, ‘different barn areas/levels in the laying house’, ‘nests without lighting’ and an ‘appropriate feed company’ were all identified as preventive factor in two studies, while one found no significant effect. For ‘less feed phases’ during laying results are balanced (2x sign., 1x n.s., 1x increased risk). Several other factors had only been investigated in one study during rearing or laying, but were found to significantly affect FP or PD (‘rearing own pullets’, ‘sufficient uniformity in weight’, ‘presence of cockerels’, ‘adjusted management’, ‘sufficient litter height’, ‘sufficiently high perches (>35 cm) ’, ‘wood as material for perches’, ‘uninterrupted light period’, ‘no flickering light’ (during rearing), ‘spelt as

nest material', 'provision of a platform in front of the nests', 'sufficient drink places/hen', 'more sugar, less starch in ration', 'less feed phases' (during rearing). In one case, 'even distribution of light', the significant effect was contrary to expectations.

For the remaining factors displayed in bold in Table 2, however, different studies yielded balanced (1x sign, 1x n.s.) or predominantly non-significant results or sometimes contrary effects. They comprised 'suitable hybrid', 'good expert knowledge', 'regular checks of hens', 'small flock size', 'good air quality', 'suitable air temperature', 'provision of hay and straw', 'access to perches', 'daylight', 'low light intensity', 'dawn phase', 'individual nest boxes', 'chain feeders', 'nipple drinkers', 'provision of feeders/drinkers in litter area', 'sufficient methionine in the laying period' and 'daily access to range'. For the five factors 'start of lay not before 20 weeks of age' (1x), 'matching of rearing and laying environment' (2x), 'early access to litter' in the rearing unit (1x), 'additional vitamins' (2x) and 'spreading seashells on floor' (2x) studies yielded only non-significant results.

3.2 Experimental studies

The majority of the included 88 experimental studies are peer-reviewed articles; six are conference papers, two are PhD-theses and two are research reports.

The experimental studies were carried out during rearing in 48 cases and during the laying phase in 52 cases. Nine times the effects of management strategies during rearing on the laying period were investigated. The observed birds were between 1 day and 69 weeks old.

Of the 29 factors in total, most frequently investigated were 'suitable hybrid' in 22, 'provision of dry litter on the floor' in 16 and 'provision of enrichment material' in nine experiments; ten factors were only taken into account once (Table 3).

Table 3 near here

The factors unanimously confirmed as reducing FP or PD by all respective experiments were 'provision of dry litter on the floor' in rearing (13x) and laying (4x), 'provision of enrichment material' during rearing (4x), but not unequivocally during laying (4x sign., 1x n.s.), 'access to

range' during laying (3x), but not during rearing (1x n.s.), access to 'sufficiently high perches (>60 cm)', provision of 'nests without lighting', 'nipple instead of bell drinkers' and 'roughage feeding' (all 4 x during laying) as well as 'low stocking density' in rearing (2x), but not in laying (1 sign., 1x increased risk, 3x n.s.). The preventive effect of the 'use of dark brooders in rearing' was confirmed three times, but in one further study only on FP, not on PD.

'Mash instead of pellets' (during laying) was identified as preventive factor in two studies, while one found no effect.

A number of studies found lasting effects of rearing conditions on the laying period. These were 'provision of dry litter on the floor' (4x, 1x n.s.), 'use of dark brooders in rearing' (2x) and 'spreading grain on the floor' (1x).

Six factors were only investigated once, but significantly affected FP or PD ('familiarization of hens with people', 'feeding ad libitum' and 'spreading grain on the floor' during rearing; 'provision of refuge sites' and 'no flickering light' during laying). For 'no exclusion from litter after placement' a significant, but risk increasing effect was found.

For the remaining factors displayed in bold in Table 3 results of different studies were rather variable. These were 'suitable hybrid' for rearing (9x sign., 5x n.s.) and for laying (8x sign., 4x n.s.), 'small flock size' during rearing (1x sign., 1x n.s.) and during laying (3x sign. but once risk increasing, 3x n.s.), 'low light intensity' in rearing (1x sign., 2x n.s.) and in laying (1x sign., 1x n.s.), as well as the 'high amounts of certain essential amino acids' during laying (2x sign., 2x n.s.) or rearing (2x n.s.), which included from 25 weeks of age onwards a generally higher protein content (Dixon and Nicol 2008; Elwinger et al., 2008), a higher methionine and cystine content (Elwinger et al., 2002 and 2008) or only a higher methionine content (Elwinger et al. 2008, Kjaer and Sørensen, 2002, van Krimpen et al., 2015) or an increase of dietary L-tryptophan (van Hierden et al., 2004) as well as the use of animal protein and synthetic amino acids (Keppler et al., 2001). Further ambiguous preventive factors during

laying were ‘access to perches’ (1x sign., 1x n.s.) and ‘low energy and non-starch polysaccharide content in feed’ (2x sign. but once increasing risk, 1x n.s.)

No significant effects were found for: ‘use of broody/mother hens’ (2x), ‘provision of dust-bath’ (1x), ‘less feed phases’ (2x), all during rearing, and the ‘use of pullets without FP in rearing’ (1x), the ‘presence of cockerels’ (1x) during laying, as well as ‘high amounts of certain minerals’ during rearing (1x) and laying (1x) and ‘animal protein’ during rearing (1x) and laying (2x). The investigated minerals were Aluminium, Barium, Chromium, Copper, Lead, Molybdenum, Nickel, Silver, Tin, Titanium and Zirconium (Willimon and Morgan, 1953).

3.3 Recommendations

The 15 identified recommendations relate specifically to the prevention of FP or PD as a whole (11) or in parts (4) (Table 4). They are either internet resources or available in printed form; eight are in English, seven in German. They were published by administrations (5), associations (4), universities (3), breeding companies (2) and a food label (1). Only information explicitly referring to the prevention of FP was extracted, although we realized that a general improvement of management could be regarded as a preventive factor, too. And some recommendations provide extensive general management guidance.

About half of the recommendations do not refer to a specific housing or management system and all except two include the rearing period (Table 4). Five sources provide information about different pecking forms (AssureWel project, no year; Bassett, 2009; Lugmair et al., 2005; Staack et al., 2010; University of Bristol, 2013).

Table 4 near here

On average, 36 potential preventive factors were counted per recommendation, summing up to a total of about 100 different, partly very detailed measures. We classified them into 62 more general factors, based on the ones defined in Tables 2 and 3 plus 12 factors which were not investigated yet. The following information about the contents of the recommendations is subdivided into three categories:

recommended factors supported by study results which means that there is no more than one opposing result (Tables 5 and 6), recommended factors based on contentious evidence (Table 7), and recommended factors not supported by any study result, either because they have never been investigated or their effects could not be confirmed.

Table 5, 6 and 7 near here

Almost all preventive factors confirmed in the studies have been taken up in the recommendations. Only two factors, each confirmed by only one study, ‘more sugar, less starch in ration’ and ‘provision of a platform in front of the nests’ as well as two further factors with balanced results (1x sign, 1x n.s.), ‘individual nest boxes’ and ‘provision of feeders/drinkers in litter area’, were not mentioned. However, no single recommendation includes all factors. Most frequently cited preventive factors (in 12 recommendations) are ‘prevention of diseases like IB or egg peritonitis’, ‘provision of dry litter on the floor’, ‘high use of range’ and aspects concerning feed ingredients, phases and form. On the other hand, recommendations comprise 15 contentious preventive factors (Table 7), and eight factors not confirmed by study results: ’start of lay not before week 20’, ‘matching of rearing and laying environment’, ‘provision of dust-bath’, ‘early access to litter’, ‘higher amounts of certain minerals`, ‘additional vitamins’, ‘spreading seashells’, ‘access to free range in rearing’. Further 12 factors have not yet been investigated: ‘minimizing stress at placement’, ‘sufficient perch length per pullet’, ‘uninterrupted period of darkness’, ‘no direct sunlight in laying house’, ‘no reduction of length of daylight during laying’, ‘sufficient nest space per hen’, ‘sufficient sodium’, ‘provision of grit’, ‘trough should be completely empty once a day’, ‘nipple instead of bell drinkers during rearing’, ‘access to covered veranda’, ‘provision of good shelter in free range during rearing’.

4 Discussion

Results of our review clearly underline the notion that FP and PD are multifactorial caused (e.g. Bestman, 2000; Hartcher et al., 2013; Nicol et al., 2013). Of the 51 factors investigated in epidemiological studies, 46 were found to be affecting FP or PD significantly in at least one study. Of the 29 factors addressed in experimental studies, 21 were influencing FP significantly. Altogether, these results led to a list of 62 different factors, whereof 17 factors regarding the rearing unit and 32 factors with respect to laying were confirmed by experimental or epidemiological studies with no or at most one opposite result. Seven factors regarding the rearing unit and 16 factors with respect to the laying unit were confirmed by at least two studies with no or at most one opposite result. .

This overview has certain methodological limitations owing to the manageability of the broad body of literature. First, we refrained from a systematic quality control of the studies included. The aim was, to provide an overview over the scientific work done, and on tendencies regarding the evidence provided. We do not claim to finally proof validity or invalidity of any of the potentially preventive factors, as we secondly have not assessed power and effect sizes. This would have been a tremendous undertaking, as rather different indicators and measures of FP with different scales have been used and often relevant information is missing in the papers. Thus, we do not conclude in case of non-significant study results that no influence exists, but rather that further investigation is necessary, as non-significant results can just be due to insufficient power, confounding factors or the specific combination of different factors in the individual study. Moreover, the different methods assessing FP or PD might have caused different results. In addition to the different dependent variables used (e.g. pecking behaviour vs. plumage damage), the methods of assessment varied, e.g. plumage scoring was done in different body areas (2 to 11 areas) with three to six point scoring scales, from the distance or after taking hens up, from samples of 20 hens per group or farm (Lugmair, 2009; Velik et al., 2005) to 200 hens, and often without reported reliability testing.

Nevertheless, we allocated the potentially influencing factors to three categories: firstly, those supported by study results with no or at maximum one opposite result, secondly, those with contentious results and lastly factors not supported by any study result, either because they have never been investigated or could not be confirmed. This should provide some structure and orientation, but it is obvious that other possibilities of categorisation exist (e.g. requiring a minimum of studies or not accepting opposite or non-significant results). We also had to categorise partly comprehensive recommendations into distinct factors. More detailed information, e.g. concerning the design of the outdoor run (bushes, shelters, pop holes), was lost by applying this categorisation.

As said, contentious results may be due to a multitude of interactions between the different factors (Gunnarsson, 1999). For instance, investigated group sizes may have affected outcomes concerning further factors (such as the availability of different resources), and are likely confounded with factors such as housing design, feeding technique or human-bird interactions in practice. In some experimental studies (e.g. Liste et al., 2015; Nicol et al., 1999), for instance stocking density and group size were confounded. Further examples are feeding trough and drinker form, where interactions can be expected with bird to feeding or drinking place ratios, ad libitum or restricted feeding, height of feeders and drinkers, their location and the general system design or management. For instance, water troughs in littered areas may lead to wet litter by spilling of water, (Green at al., 2000) which could in turn result in fewer opportunities for foraging and dust-bathing (Kim-Madslien and Nicol, 1999). On the other hand, feeders and drinkers in the litter area may allow birds waiting for access to redirect pecks at litter instead of other birds. Alternatively, they may be related to smaller farm systems in general, with a number of further factors being concurrently different. The latter was the assumption of Bestman (2000) who found certain effects of type and location of feeders and drinkers.

Also concerning the importance of essential amino acids, study results were contentious and thus contrary to expectations in 60% of the recommendations. Interestingly, van Krimpen et al. (2005) came to the same conclusion, also including experiments in cage systems in their

review. Again, reasons may be interaction effects, for instance between diet and strain (Al Bustany and Elwinger, 1986; Ambrosen and Petersen, 1997; Hughes and Duncan, 1972), diet and brooding temperature (Hughes and Duncan, 1972) or between methionine and energy content (Lugmair, 2009). However, also ceiling effects may play an important role. No further plumage improvement was found when reaching a lysine level of 850-950 mg/hen/day (Al Bustany and Elwinger, 1987) or a protein level of 15.2% (Ambrosen and Petersen, 1997); van Krimpen et al. (2015) postulated a methionine content of at least 356 mg/hen/d to prevent plumage damage. Therefore, the range of the investigated factors will often affect results, but was in general frequently not reported in epidemiological studies.

Other indications for non-linear relationships relate for example to flock size. Lugmair (2009) found a higher PD risk in flocks with 1,001-2,999 hens, compared to flocks of 3,000 hens or more. No differences were found in flocks with 1,000 hens or less and 3,000 hens or more. These results are in accordance with findings of Zimmermann et al. (2006) who observed higher FP rates in flocks of 2,400 compared to 4,200 hens, but did not investigate smaller flock sizes. In general, experimental studies used smaller group sizes, ranging from two to three hens (Dixon and Nicol, 2008) to a maximum of around 4,000 hens (Donaldson and O`Connell, 2012) and 30,000 chicks (de Haas et al. 2014b). The most common group sizes used in experiments were around 10 to 150 hens. In epidemiological research, group sizes varied from 80 to 5,400 hens (Bestman and Wagenaar, 2014) up to between 500 and more than 60,000 hens (Heerkens et al., 2015).

There was also a great variety concerning age of the investigated birds (1 to 74 weeks of age). As it can be expected that FP and PD increase with age (Lambton et al., 2010b; Nicol et al., 1999; Pötzsch et al., 2001), possible effects might therefore have been more or less conspicuous. For instance, the effect of broody hens on FP was only investigated up to an age of 28 days (Shimmura et al., 2010) or 8 weeks (Roden and Wechsler, 1998), while it cannot be excluded that effects become apparent also later in life, as found for the use of dark brooders (Brinch Jensen et al., 2006, Gilani et al., 2012). Furthermore, contradictory results of epidemiological studies concerning effects of the number of feed phases may

relate to the way the feed is changed rather than to the feed change itself. A feed change involves risks, but this may also be true for feed not adjusted to different needs of the hens in their life-cycle.

While in scientific studies and recommendations genetic aspects were most frequently addressed, studies yielded contentious results with an especially high number of non-detectable effects in epidemiological studies. Beside the likely important interaction effects mentioned above, this may be due to rather different hybrids being compared in experimental and epidemiological studies or very uneven distributions of different hybrids on the farms (e.g. Bright et al., 2011), but also to genetic changes and differences within birds with the same plumage colour or even within the same hybrid line over the years. It thus appears that the scientific basis for hybrid recommendations is very weak, even though experimental evidence clearly shows the general importance of genetics for the predisposition to develop FP.

Finally, our categorisation of factors may have been responsible for some contentious results. For instance, the category ‘air quality’ comprised various measures which reflect different aspects of air condition, namely ammonia and carbon dioxide concentrations in ppm at bird height (Drake et al., 2010), ammonia concentrations at human height (Lugmair 2009), scores concerning dust levels or difficulty to breathe at human height (Huber-Eicher and Audigé, 1999, Gilani et al., 2013) or the presence of natural ventilation (Green et al., 2000).

On a similar line, some factors not empirically confirmed, but with a theoretically high preventive potential like ‘good expert knowledge’ during laying or ‘minimizing stress at placement’, are difficult to operationalize. Epidemiological studies assessed the years of experience as a laying hen holder (Bestman, 2000; Bestman and Wagenaar, 2003; Heerkens et al., 2015), the number of people working with the hens (Gilani et al., 2013) or if inspections are done by one person or more (Green et al., 2000). We summarized these factors under ‘good expert knowledge’, although it is questionable whether all of them are true indicators of the extent and depth of the specific biological and farming knowledge. In

the same way, there is scientific evidence (though not without exception) of an association of FP with stress or fear (de Haas et al., 2014b; El-Lethey et al., 2000; Johnsen et al., 1998; Rodenburg et al., 2004). However, minimizing stress at placement is a much broader and rather vague recommendation that is difficult to test scientifically.

‘Spreading grain on the floor’ was recommended six times as a preventive measure, although epidemiological studies never found evidence of any preventive effect, in three cases even opposing effects were observed. It is possible though, that the associations were due to this measure being used in case of a pre-existing FP problem. Moreover, frequency, amount and place of scattering grain, as well as stocking density must be observed, in order to avoid stress and smothering risks for the hens.

The recommendations for which scientific evidence is contentious or not available pose a future task for research and practice to be either validated or discarded. In our view, especially the areas of feeding and caretaking deserve deeper investigation. Also more recent research showing connections between gut health and FP (Brunberg et al., 2016; Meyer et al., 2012) should be heeded. At the same time, in scientific studies reporting of study conditions, quality control such as reliability testing and of descriptive statistics should be improved. It is remarkable that existing recommendations include almost all preventive factors confirmed in studies. At the same time however, no recommendation refers to all of them. In fact, apart from two (Laves, 2013: 37 confirmed factors; Lugmair et al., 2005: 26 confirmed factors) the recommendations listed less than 50% of the confirmed factors. According to results from Lambton et al. (2013), farms following a higher number of recommendations have a decreased risk of FP in their flock. Therefore, there is room for improvement of recommendations available for farmers. We are, however, aware of constant development in this area. For instance, two new rather comprehensive recommendations were published (Keppler et al., 2017; Landwirtschaftskammer Niedersachsen, 2016) in Germany recently, which were not taken into account in this overview.

5 Conclusions

FP is influenced by a wide range of interacting factors. The comparison of 15 practice recommendations with results of 109 empirical studies revealed that on average each recommendation contained less than 50% of the 49 confirmed preventive factors. In total they also comprised 15 contentious and 12 not yet investigated factors. Therefore, on the one hand, recommendations should be amended. On the other hand, in future research unconfirmed factors from practice recommendation, e.g. in the areas of feeding or caretaking, should be further investigated.

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Table 1 Characterization of the identified epidemiological studies

No.	Reference	Age (weeks) of birds at visit	Beak trimmed (no. of flocks)	Dependent variable	Number of hens scored	Number of flocks	System[1] (number of flocks)
1	Bestman 2000	50	No information	PD	40	36 lay	Organic
2	Bestman and Wagenaar 2003	≥50	No information	PD	40 (20 in small flocks)	63 lay	Organic
3	Bestman and Wagenaar 2014	50-60	No information	PD	50	49 lay (information about rearing of 35 flocks)	Organic aviary (22 lay) and floor (27 lay); cage (6 rear), loose house (27 rear) with free range (26), unknown (2)
4	Bestman et al. 2009	7,12,16,30	No information	PD	100	28 rear, 51 lay	Organic
5	Bright et al. 2011	No information[2]	Yes (161), No (1)	PD	50	162 lay	Free range
6	de Haas et al. 2014a	1,5,10, 15, 40	Yes	SFP and PD	20 rear, 50 lay	35 rear, 35 lay	Conventional floor (7 lay), level (3 rear), aviary (32 rear, 28 lay),
7	Drake et al. 2010	<17,18-22,23-30,50	Yes	PD	200	12 rear, 84 lay	Conventional barn (10 lay) and free range (55 lay); organic (19 lay)
8	Gilani et al. 2013	1,8,16,35	Yes (12), No (22)	GFP and SFP and PD	20	34 rear, 34 lay	Conventional barn (17 rear, 1 lay) and free range (1 rear, 16 lay); organic (16 rear, 17 lay)
9	Gilani et al. 2014	8,16,35	Yes (11), No (22)	GFP and SFP	0	33 rear, 33 lay	Conventional barn (17 rear) and free range (1 rear, 17 lay); organic (15 rear, 16 lay)
10	Green et al. 2000	No information	No information	Any FP or PD[1]	No information	198 lay	Conventional barn (26) and free-range (172)
11	Gunnarsson et al. 1999	35	No	PD	100	59 rear/lay	Floor and aviary
12	Häne et al. 2000	40-80	Yes and No (no information)	PD	No information	96 lay	Floor, aviary and free-range
13	Heerkens et al. 2015	58-64	Yes (46), No (1)	PD	50	47 lay	Conventional aviary (47) with free range (9)
14	Huber-Eicher and Audigé 1999	No information	No information	Any FP or PD	No information	64 rear	Non-cage system
15	Huber-Eicher and Sebö 2001a	5, 14, 20, 32, 50	Yes (13), No (12)	Any FP and PD	10%	25 rear, 19 lay	Conventional floor (15 rear, 7 lay) and aviary (10 rear, 12 lay)
16	Lambton et al. 2010b	20-30, 35-45	Yes (79), No (21)	GFP and SFP and PD	100	119 lay	Conventional barn (3 lay) and free-range (50 lay); organic (66 lay)
17	Lambton et al. 2010a	25, 40	No information	SFP and PD	100	75 lay	Free range
18	Lugmair 2009	16, 21-82	No	PD	20	42 rear, 115 lay	Conventional floor (32 rear, 33 lay), aviary (9 rear) and free-range (56 lay); organic (1 rear, 26 lay)
19	Nicol et al. 2003	23-74	Yes	PD	15	112 lay	Free-range
20	Pötzsch et al. 2001	No information	No information	Any FP, PD[2]	No information	198 lay	Conventional barn (26) and free-range (172)
21	Velik et al. 2005	No information	No information	PD	20	21 (no infomation)	Conventional (9), organic (12)

PD= plumage damage, GFP= gentle feather pecking, SFP= severe feather pecking, FP= feather pecking, lay= laying, rear= rearing, [1] information as provided in the publications, [2] study based on information from questionnaires and assessments as reported by the farmers

Table 2 Potential preventive factors investigated in epidemiological studies (numbers of studies according to Table 1); factors in bold have been found to significantly affect feather pecking (FP) or plumage damage in at least one study (l = laying, r = rearing, ns = non-significant, ↑ = increases risk)

	Studies Factors	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Management	**Suitable hybrid**	ns^{l}	ns^{l}			l	ns^{l}					ns^{l}							l	ns^{l}		
	Use of pullets without FP in rearing				l		l		l							l	l					
	Rearing own pullets							l														
	Good expert knowledge	l↑	ns^{l}						r		l			ns^{l}								
	Regular checks of hens														ns^{r}				r/l	ns^{l}		
	Low stocking density	l	ns^{l}		r							ns^{l}			r				ns^{l} r			
	Sufficient uniformity in weight																		r			
	Low sound level						ns^{r}	r/l	r										l			
	Small flock size	l	l		ns^{r}	ns^{l}	ns$^{r/l}$		ns^{r}			ns^{l}		ns^{l}					l(↑)[1]			
	Prevention of diseases like IB or egg peritonitis										l			l					l			
	Start of lay not before 20 weeks of age										ns											
	Presence of cockerels		l																			
	Early placement before 20 weeks of age	l	l																	ns^{l}		
	[2]Adjusted management						l															
Housing	Matching of rearing and laying environment							ns^{l}				ns^{l}										
	Good air quality							r/l	ns$^{r/l}$		ns^{l}				ns^{r}				l			
	Suitable air temperature (>20 C°)							ns$^{r/l}$	ns^{r}		l						ns^{l}					
	Different barn areas (different levels)						l		r		ns^{l}								l			
Litter	Early access to litter											ns^{r}										
	Provision of dry litter on the floor				r		ns^{l}		r		l		l						l			
	Provision of straw and hay																ns^{l}		l			
Perches	**Sufficient litter height**																		l			
	Access to perches				ns^{r}				ns$^{r/l}$		ns^{r}	ns^{r}			r		ns^{l}		ns^{r} l			
	Sufficiently high perches (>35 cm)														r				l			
	Wooden perches																		l			

Table 2 continued Potential preventive factors investigated in epidemiological studies (numbers of studies according to Table 1); factors in bold have been found to significantly affect feather pecking (FP) or plumage damage in at least one study (l = laying, r = rearing, ns = non-significant, ↑ = increases risk)

	Studies / Factors	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Light	**Uninterrupted light period**								r													
	Daylight				r			r	ns^{r}													
	No flickering light							r↑										l		ns^{l}		
	Low light intensity						ns^{l}	l			ns^{l}				ns^{r}			l		ns^{l}		
	Dawn phase								ns^{r}										l	ns^{l}		
	Even distribution of light																		l↑			
Nests	**Individual nest boxes**	l									ns^{l}											
	Nests without lighting										l									ns^{l}	l	
	Spelt as nest material																		l			
	Provision of a platform in front of the nests													l								
	Mash instead of pellets																l	l	r/l			
	Chain feeders (instead of pan feeders or mixed feed systems)	l↑						r/l↑		l									ns^{l}			
	Nipple drinkers (instead of bell drinkers)						l↑				l								l↑	ns^{l}	l	
Feed and water	**Sufficient drink places/hen**																		l			
	Provision of feeders/ drinkers in litter area	l																		ns^{l}		
	More sugar, less starch in ration																		l			
	Additional vitamins										ns^{l}									ns^{l}		
	Sufficient methionine																		l			ns^{l}
	Spreading grain on floor	l↑			ns^{r}												l↑		l↑	ns^{l}		
	Spreading seashells on floor										ns^{l}									ns^{l}		
	Less feed phases								r		l			l↑						ns^{l}	l	
	Appropriate feed company																l		l	ns^{l}		
Free range	**High use of range**	l		l	ns^{r}		ns^{r}			$ns^{r/l}$	l			l			l			l		
	Daily access to range	l	ns^{l}																			
	Measures encouraging hens to go outside	l	l																l			
	High percentage of sheltered areas	l	l			l													l			

[1]No linear relationship was found, 1,001-2,999 hens showed more FP than less than 1,000 hens or more than 3,000 hens [2]Adjusted management: radio, pecking blocks, round drinkers and/or roosters

Table 3 Potential preventive factors investigated in experimental studies; factors in bold have been found to significantly affect feather pecking (FP) or plumage damage (PD) in at least one study in the expected direction (for l = effects of rearing conditions on laying, ↑ = increases risk)

	Results	Rearing		Laying	
	Factors	Significant	Not significant	Significant	Not significant
	Suitable hybrid (mostly high versus low feather pecking lines)	Bright 2007, de Haas et al. 2014b, Harlander-Matuschek et al. 2010, Keeling et al. 2004, Kjaer 2011, Kjaer and Sørensen 1997, Kjaer and Sørensen 2002, Klein et al. 2000, Rodenburg and Koene 2003	Albentosa et al. 2003, Hocking et al. 2004, Keppler et al. 2001, Rodenburg et al. 2003, van Hierden et al. 2002	Benda 2008, Elwinger et al. 2008, Harlander-Matuschek et al. 2010, Keppler et al. 2001, Kjaer 2000, Kjaer and Sørensen 2002, Rodenburg and Koene 2003, Wahlström et al. 2001	Albentosa et al. 2003, Mahboub 2004, Jensen et al. 2005, Rodenburg et al. 2003
Management	Use of pullets without FP in rearing				Newberry et al. 2007
Management	**Low stocking density**	Hansen and Braastad 1994, Keppler 2008		Hansen and Braastad 1994, ↑Zimmerman et al. 2006	Carmichael et al. 1999, Nicol et al.1999, Nicol et al. 2006
	Small flock size	Keppler 2008	Liste et al. 2015	Bilcik and Keeling 1999, Bilcik and Keeling 2000, ↑Zimmerman et al. 2006	de Haas et al. 2013, Nicol, et al. 1999,Nicol et al. 2006
	No exclusion from litter after placement			↑Alm et al. 2015	
	Use of broody/mother hens		Roden and Wechsler 1998, Shimmura. et al. 2010		
	Presence of cockerels				Odén et al. 1999
	Familiarization of hens with people	de Haas et al. 2014a		de Haas et al. 2014a	
	Provision of enrichment material such as pecking blocks, strings, vegetables, baskets, hay bales	Huber-Eicher and Wechsler 1998, Klein et al. 2000, Mc Adie et al. 2005, Zeltner et al. 2000	Hartcher et al. 2015 (for l)	Norgaard-Nielsen et al. 1993, Steenfeldt et al. 2007, Wechsler and Huber-Eicher 1997, Wechsler and Huber-Eicher 1998	Daigle et al. 2014
Housing	Provision of dust-bath		Huber-Eicher and Wechsler 1997		
Housing	**Use of dark brooders in rearing**	Brinch Jensen et al. 2006 (also for l), Gilani et al. 2012 (also for l), Johnsen and Kristensen 2001 for FP	Johnsen and Kristensen 2001 for PD		
	Provision of refuge sites			Freire et al. 2003	

Table 3 continued Potential preventive factors investigated in experimental studies; factors in bold have been found to significantly affect feather pecking (FP) or plumage damage (PD) in at least one study in the expected direction (for l = effects of rearing conditions on laying, ↑ = increases risk)

	Results	Rearing		Laying	
	Factors	Significant	Not significant	Significant	Not significant
Litter	**Provision of dry litter on the floor**	Aerni et al. 2000, Blokhuis 1989 (also for l), Blokhuis and van der Haar 1989 (also for l), de Haas et al. 2014b, de Jong et al. 2013b, El-Lethey et al. 2000, El-Lethey et al. 2001, Huber-Eicher and Sebö 2001b, Huber-Eicher and Wechsler 1997, Johnsen et al. 1998 (for l), Mathlouthi at al. 2011, Nicol et al. 2001 (also for l), Zeltner et al. 2000	de Jong et al. 2013a,b (for l)	Aerni et al. 2000, Blokhuis 1989, Blokhuis 1986, Blokhuis and van der Haar 1989	
Perches	**Access to perches**			Wechsler and Huber-Eicher 1998	Donaldson and O`Connell 2012
	Sufficiently high perches (>60 cm)			Wechsler and Huber-Eicher 1997, Wechsler and Huber-Eicher 1998	
Light	**No flickering light**			Mohammed et al. 2010	
	Low light intensity	Kjaer and Vestergaard 1999	Kjaer and Sørensen 2002, Keppler 2008	Mohammed et al. 2010	Kjaer and Vestergaard 1999
Nests	**Nests without lighting**			Nicol et al. 2006, Zimmerman et al. 2006	
Feed and water	**Mash instead of pellets**			Aerni et al. 2000, El-Lethey et al. 2000	Wahlström et al. 2001
	Nipple drinkers (instead of bell drinkers)			Nicol et al. 2006, Zimmerman et al. 2006	
	Feeding ad libitum	Mathlouthi et al. 2011			
	Low energy and non-starch polysaccharide content in feed			van der Lee et al. 2001, ↑van Krimpen et al. 2009	van Krimpen et al. 2008
	High amounts of certain minerals		Willimon and Morgan 1953		Willimon and Morgan 1953
	High amounts of certain essential amino acids or protein		van Hierden et al. 2004, Dixon and Nicol 2008	Elwinger et al. 2002, Elwinger et al. 2008	Kjaer and Sørensen 2002, van Krimpen et al. 2015
	Animal protein		Keppler et al. 2001		Elwinger et al. 2008, Keppler et al. 2001
	Roughage feeding			Kalmendal and Wall 2012, Steenfeldt et al. 2007	
	Spreading grain on floor	Blokhuis and van der Haar 1992 (for l)			
	Less feed phases		Dixon and Nicol 2008, Dixon et al. 2006		
	Access to range		Kjaer and Sørensen 2002	Mahboub 2004, Petek 2015, Shimmura et al. 2008	

Table 4 Identified recommendations with number of recommended factors either confirmed by epidemiological or experimental studies with at maximum one opposite or non-significant result or being contentious or not confirmed or not yet investigated.

No.	Reference	System[1]	Number of recommended factors			
			Confirmed Rearing	Confirmed Laying	Contentious/not confirmed/not investigated	Total
1	AssureWel project no year	No information	3	13	7/3/6	32
2	Bassett 2009	No information	1	12	4/2/2	21
3	Big Dutchman International et al. 2004	Non-cage	0	4	6/0/2	12
4	Defra 2005	No information	5	9	5/3/2	24
5	FAWAC 2011	Barn/alternative	0	7	4/1/0	12
6	Klosterhalfen 2010	No information	8	10	5/1/3	27
7	LAVES 2013	No information	15	22	10/0/14	61
8	Lohmann Tierzucht 2011	Non-cage	2	5	6/0/0	13
9	Lugmair et al. 2005	Non-cage	8	18	7/1/5	39
10	Macey 2009	Organic	6	13	8/0/6	33
11	Michael 2013	No information	3	4	4/0/1	12
12	Pickett 2008	No information	7	15	4/2/2	30
13	Staack et al. 2010	Organic	7	11	5/2/5	30
14	Thiele and Pottgüter 2008	Barn, free-range	0	2	2/0/0	4
15	University of Bristol 2013	Non-cage	8	13	7/2/7	37

[1]information as provided in the recommendations

Table 5 Proposed preventive factors for rearing concerning feather pecking from different recommendations which have been confirmed in epidemiological or experimental studies with at maximum one opposing result. Factors in bold have been confirmed in at least two studies, figures are presented as far as available

Preventive factors for rearing		Recommendations (numbered according to Table 4)														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Management	Good expert knowledge	✓			✓			✓		✓		✓	✓			✓
	Regular check of hens	✓	✓		✓		✓	✓		✓		✓	✓	✓		✓
	Low stocking density (birds/m² ground surface)						18[1]	35[2]			10[2]			13		
	Sufficient uniformity in weight	✓			✓		✓	✓	✓	✓	✓		✓			✓
	Low sound level				✓											
	Adjusted management[3]						✓	✓		✓	✓		✓	✓		✓
	Provision of enrichment material such as pick blocks, strings, vegetables, baskets, hay bales						✓	✓		✓	✓		✓	✓		✓
	Familiarization of hens with people				✓		✓	✓					✓			✓
	Use of dark brooders in rearing										✓					
	Different barn areas (levels)							✓		✓			✓			
Litter	**Provision of dry litter on the floor**						✓	✓	✓	✓	✓	✓	✓	✓		✓
Perches	Sufficiently high perches							✓		✓						
Light	Uninterrupted light period (hours)							8								
	Daylight							✓						✓		
Feed and water	Mash instead of pellets							✓						✓		✓
	Feeding ad libitum						✓	✓								

[1]for chicks older than 10 weeks, [2]for chicks older than 5 weeks, [3]radio, pecking blocks, round drinkers and/or roosters

Table 6 Proposed preventive factors for laying concerning feather pecking from different recommendations which have been confirmed in epidemiological or experimental studies with at maximum one opposing result. Factors in bold have been confirmed in at least two studies, figures are presented as far as available.

	Preventive factors for laying	Recommendations (numbered according to Table 4)														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Management	**Use of pullets without FP in rearing**				✓			✓		✓	✓		✓			
	Rearing own pullets	✓	✓													
	Regular check of hens		✓	✓	✓		✓	✓	✓	✓			✓	✓		✓
	Low sound level		✓													
	Prevention of diseases	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓		✓	✓
	Presence of cockerels										✓		✓			
	Early placement before 20 Weeks							18		18				17		
	Adjusted management[1]	✓	✓				✓	✓		✓	✓		✓	✓		✓
	Familiarization of hens with people				✓		✓	✓					✓			✓
Housing	**Provision of enrichment material such as pick blocks, strings, vegetables, baskets, hay bales**	✓	✓			✓	✓	✓		✓	✓	✓	✓	✓		✓
	Different levels	✓						✓		✓			✓			
Litter	**Provision of dry litter**	✓	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓		✓
	Provision of straw hay				✓			✓		✓			✓	✓		
	Sufficient litter height (cm)					10		1-2								
Perch	**Sufficiently high perches (cm)**	50				✓				35			70			40
	Perch with grip/wood as perch material							✓		✓						
Light	Dawn phase							✓								
	No flickering light			✓				✓	✓	✓				✓	✓	
Nest	**Nests without lighting**	✓						✓		✓	✓					✓
	Spelt as nest material					✓		✓								
Feed and water	**Mash instead of pellets**	✓	✓					✓	✓	✓	✓		✓	✓		✓
	Sufficient drink places/hen			1/10				✓	✓	1/10	0.9/1			✓		
	Roughage feeding	✓	✓				✓	✓		✓	✓	✓	✓	✓		✓
Free range	**High use of range**	✓	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓		✓
	Encouraging hens to go outside	✓	✓		✓	✓	✓	✓		✓	✓		✓			✓
	High percentage of sheltered areas	✓	✓		✓		✓	✓			✓		✓			✓

[1]radio, pecking blocks, round drinkers and/or roosters

Table 7 Proposed preventive factors concerning feather pecking from different recommendations with contentious results from epidemiological or experimental studies (l = laying, r = rearing), figures are presented as far as available

	Contentious preventive factors	Recommendations (numbered according to Table 4)														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Management	Suitable hybrid	r/l		l	l	l	LT/ LB[1]				l	White	l	r/l	l	
	Good expert knowledge (laying)	l	l		l	l		l								
	Small flock size in thousand							6 r/l			l		5 l	3 r		
Housing	Low stocking density (laying)			l		l	l		l	l	l					
	Good air quality	l		l			l	r/l	l	l		l		r/l		r/l
	Suitable temperature (in C°, laying)		l	18			l	16	18	16						
Perches	Access to perches (rearing)	r			r		r	r		r	r	r	r	r		r
Light	No flickering light (>2000 Hz)			l				r/l	l	l					l	
	Low light intensity (lux)				l			20	15		20					
Feed and water	Chain feeder															r
	Nipple drinker															r
	High amount of essential amino acids or protein	l	l	l				l	l	l	l			l		r
	Spreading grain on floor	l						r/l		l	l			r/l		r
	Less feed phases	l	3		l			l			l		l			l
Free range	Daily access											l				

[1] LT= Lohman Tradition, LB= Lohman Brown