Evaluating the effects of bedding materials and elevated platforms on contact dermatitis and plumage cleanliness of commercial broilers, and on litter condition in broiler houses

Short title: Footpad dermatitis in broilers

Authors:

Kaukonen Eija[a*], Norring Marianna[a], Valros Anna[a]

[a] Research centre for animal welfare, Department of Production Animal Medicine, University of Helsinki, 00014 Helsinki, Finland.

***Corresponding author**

Eija Kaukonen, Myllärintie 25, 29250 Nakkila, Finland. Tel. +358 40 5597278.

E-mail: eija.kaukonen@helsinki.fi.

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Abstract

1. Experiment 1, comparing wood shavings and ground straw bedding with peat, was performed on seven broiler farms over two consecutive batches during the winter season. Experiment 2, assessing the effect of elevated (30 cm) platforms, was conducted in three farms replicated with six consecutive batches.

2. Footpad lesions were inspected at slaughter following the Welfare Quality® (WQ) protocol and official guidelines. Hock lesions, plumage cleanliness and litter condition were assessed using the WQ-system. Litter height, pH, moisture and ammonia were determined.

3. Footpad condition on wood shavings appeared worse compared to peat with both assessing methods, accompanied by inferior hock skin health. WQ-assessment resulted in poorer footpad and hock skin condition on ground straw compared to peat. Farms differed in footpad and hock skin condition. Footpad and hock lesions were not affected by platform treatment. Peat appeared more friable than ground straw. The initial pH of wood shavings was higher and moisture lower than in peat but at the end of production period there were no differences. Ground straw exhibited higher initial and lower end pH, and was drier in the beginning than peat. Litter condition and quality was not affected by platform treatment.

4. This study provides new knowledge about the applicability of peat as broiler bedding and shows no negative effects of elevated platforms on litter condition or the occurrence of contact dermatitis in commercial environment. The results bring up a complicated relationship between litter condition, moisture and contact dermatitis. Furthermore, we underline the importance of the farmer's ability to manage litter conditions, regardless of the chosen litter

material. Peat bedding was beneficial for footpad and hock skin health compared to wood shavings and ground straw.

Introduction

Contact dermatitis is, to a large extent, caused by poor litter quality or otherwise unsuitable material affecting broiler's footpad or hock skin (Greene *et el.*, 1985; Martland, 1985). The presence and severity of footpad and hock skin lesions in broilers is considered to reflect housing conditions, management and bird health in a broad sense (Haslam *et al.*, 2006). Thus, evaluating the prevalence of contact dermatitis provides a well-established approach to assess the welfare of broiler flocks (Ekstrand *et al.*, 1998; the EU Broiler welfare directive 2007/43/CE) and the assessment of footpad and hock lesions is also adopted in the Welfare Quality assessment protocol for poultry (WQ) applied for broiler chicken as one of the animal-based indicators determining the absence of injuries (Welfare Quality®, 2009). In Finland, the Government Decree (375/2011) on the protection of broiler chicken includes footpad lesion scoring as one of the indicators of broiler welfare. The monitoring system employed in Finland is based on the Swedish 3-point scoring method (Ekstrand *et al.*, 1998), which is currently applied in a number of other European countries (de Jong *et al.*, 2012a; Kyvsgaard *et al.*, 2013). The Finnish Decree regulates the evaluation of footpad lesions for each slaughter batch, and in case of repeatedly poor scores, the authorities may further restrict the maximum stocking density of the house.

Contact dermatitis in broilers typically appears first on the footpads, followed by hock burns. Both lesions develop in a similar way (Greene *et al.*, 1985), starting with superficial hyperkeratosis, which in severe situations develops into deep ulcers covered with a dark deep crust (Michel *et al.*, 2012). In extreme cases, large areas of the foot and toe pads are affected (Martland, 1985). Lesions can develop quickly, in less than a week (Greene *et al.*, 1985) and may start to heal within two weeks if the causative circumstances improve (Greene *et al.*, 1985; Martland, 1985, Cengiz *et al.*, 2011).

Several factors affect footpad condition (Shepherd and Fairchild, 2010); however, good litter quality is considered the most important factor preventing contact dermatitis (Bruce *et al.*, 1990; Haslam *et al.*, 2007). In addition to the damaging effect of litter wetness on footpad skin (Mayne *et al.*, 2007; Bassler *et al.*, 2013; de Jong *et al.*, 2014), damp litter also reduces the dustbathing of broilers (Moesta *et al.*, 2008). Moreover, wet litter conditions result in dirty plumage (Martland, 1985; de Jong *et al.*, 2014) and decreases broiler growth and feed efficacy (de Jong *et al.*, 2014). Thus, poor litter condition negatively impacts the general welfare of birds (de Jong *et al.*, 2014). Fast-growing broilers spend most of their time resting, which increases the importance of litter condition for their welfare (Weeks *et al.*, 2000). The evaluation of litter quality is included in the WQ-protocol as one of the resource- and management-based measures, and the assessment of plumage cleanliness as one of the animal-based measures assessing comfortable resting (Welfare Quality®, 2009).

The most common bedding material for broilers varies from country to country. In Europe, wood shavings and straw appear to be the most popular materials (Jones *et al.*, 2005; Kyvsgaard *et al.*, 2013). In Finland peat is the standard bedding material in broiler production; it is easily available at acceptable price and used peat litter is readily usable as a fertilizer in the fields. *Sphagnum* peat is naturally acid, with pH 3.9-4.3 (Cocozza *et al.*, 2003). Although numerous studies have been conducted on the effect of different litter materials on footpad condition, peat has been involved only seldom (Enueme and Waibel, 1987). We also lack information about the influence of peat on hock burns and litter quality.

Introducing perches to broilers' environment is believed to increase locomotion (Cornetto and Estevez, 2001; Bizeray *et al.*, 2002) and contribute to improved leg health (Kaukonen *et al.*, 2016b). Several studies have, however, demonstrated a low use of conventional perches by broilers (Su *et al.*, 2000; Hongchao *et al.*, 2014; Norring *et al.*, 2016), and elevated platforms with slopes have proven to serve better as perches for broilers (Oester *et al.*, 2005; Norring *et al.*, 2016). Perches could have various effects on footpad and hock skin: Birds could escape wet litter to the perches, hence perch availability may decrease the prevalence of contact dermatitis (Oester *et al.*, 2005; Ventura *et al.*, 2010; Ohara *et al.*, 2015). On the other hand, extra equipment in the broiler house might interfere with air flow near the floor level, compromising litter condition and adversely affecting footpad and hock skin. Furthermore, any added equipment, if not used, unnecessarily occupies floor space contributing to diminished welfare due to increased stocking density (Tablante *et al.*, 2003; Ventura *et al.*, 2010). Wet wooden perches (Wang *et al.*, 1998), unsuitable perch design (Pickel *et al.*, 2011) or unsuitable slat material (Sander *et al.*, 1994) could also directly affect footpad skin. However, research is scarce on the influence of perches on contact dermatitis in broilers and litter condition in broiler houses under commercial scale broiler production.

This study analyzed the influence of bedding material and elevated platforms on litter quality in broiler houses, and contact dermatitis and the plumage cleanliness of fast-growing broilers under intensive conventional rearing conditions. We compared peat with wood shavings and ground straw as broiler litter. A subsidiary objective was to compare two different assessment methods of footpad lesions. We predicted that peat, due to its low pH, would be most favorable for both litter condition and contact dermatitis. Moreover, we assumed that adding extra equipment, in the form of elevated platforms, would negatively affect litter condition and possibly also contact dermatitis.

Materials and methods

This study was conducted with the approval of the University of Helsinki Viikki Campus Research Ethics Committee.

Study design and treatments

In experiment 1 the litter condition of three bedding materials and the impact of litter condition on the frequency and severity of contact dermatitis and level of plumage cleanliness was examined on seven commercial broiler farms over two consecutive batches in 2013-2015 between November and April, each year. On six farms two houses and on one farm four houses were included. In one of the houses a test bedding material, wood shavings or ground straw, was used and in the other house the standard bedding material, peat, was used as control. On the second round the roles of the houses were reversed. Ground straw was very fine wheat or rye straw crushed from pellets, finished with heat treatment. Altogether 8 flocks on wood shavings, 8 flocks on ground straw, and 16 control flocks (8 per comparison) were monitored.

Experiment 2 studied the effect of elevated platforms on contact dermatitis and plumage cleanliness of broilers, as well as on litter condition in the house. The study was performed on three commercial broiler farms replicated with six consecutive batches during the period from September 2013 to September 2014. On each farm two houses were included. Elevated plastic platforms with slope access at each end (Figure 1) were offered in one house, the other house being a control. Every other batch the roles of the houses were reversed. Peat was used as bedding material. Platforms were made of plastic slats commonly used in laying hen and breeder houses (Figure 1). The holes in the slats measured 20x25 mm, while the surrounding plastic grid was 8 mm wide. The platforms covered about 10 % of the floor area at the height of 30 cm offering birds a possibility to use also the floor space under the structures. The platforms were evenly spread across the floor area during the first week (3-7 days of age) and collected away one day before slaughter.

Figure 1 here

Housing

Experiment 1 and 2 were conducted in separate farms located in South-West Finland. All farms practiced the all in all out production system without thinning. Thorough cleaning and disinfection of the houses and the equipment was performed between the flocks. The flocks were reared in insulated, ventilation controlled houses equipped with heating and misting systems according to the normal routine of each farmer. The farmers were asked to report any additional effort to manage litter condition. The studies were performed with Ross 508 chicks obtained from a commercial hatchery. Drinking water and feed were available *ad libitum*. Feeding included three or four stage commercial diet accompanied with whole wheat from the first week until slaughter. Detailed information on houses and flocks is provided in Table 1. In both experiments the bird density in several flocks was affected by increased mortality due to

Escherichia coli infection or inclusion body hepatitis. Mortality rates or the severity of disease outbreaks did not differentiate between any of the treatments.

Table 1 here

Scoring

Footpad lesions were visually inspected at slaughter with two methods: Firstly, the official veterinarians of the slaughterhouse assessed one footpad per bird from 100 birds per batch following the guidelines of the Finnish Food Safety Authority Evira (Table 2; Evira, 2011). Secondly, the researcher assessed footpads based on the example photos of WQ applied for broiler chicken (Welfare Quality®, 2009). Hock lesions and plumage cleanliness were visually assessed at slaughter according to the example photos of WQ-protocol. The scoring scale was based on the presence, size and severity of lesions on footpads and hocks: score 0= healthy skin, scores 1 and 2= slight lesion on footpads or hocks, scores 3 and 4= clear indication of footpad dermatitis or hock burn. Plumage cleanliness was assessed from the ventral side of the bird with scores: 0= completely clean feathers, 1= slight dirtiness and 2= moderate dirtiness on the central part of abdomen, and 3= extensive dirt on abdomen and wings. The skin lesions and plumage cleanliness were assessed at the slaughter line during the first and second half of the slaughter batch over two separate monitoring periods of 5 minutes for each. Plumage cleanliness was estimated after stunning and hanging, and footpads and hocks of both legs were evaluated after scalding and plucking at the meat inspection station.

Litter condition was assessed and litter height measured before chick delivery and 1-3 days before slaughter in 6 different locations per house (Figure 2). Litter condition was evaluated using the WQ-method (Table 3; Welfare Quality®, 2009).

Table 2, Table 3 and Figure 2 here

Litter quality was evaluated as moisture, pH and ammonia levels. Litter samples of 1 litre each were taken from the full depth of the litter layer in moisture proof plastic bags before chick delivery and 1-3 days before slaughter at the same 6 locations as litter condition was assessed. All samples taken before chick delivery were pooled together, mixed manually and a sample of 1 litre was taken. Before slaughter all 6 samples were taken and stored separately. Samples were stored, handled and analysed according to the protocol described in Kaukonen *et al.*, (2016a).

Statistical analysis

All statistical analyses were performed with SPSS vs 22.

Experiment 1 – Litter material

The effects of farm and litter materials on mean footpad scores and the severity of footpad dermatitis assessed with both scoring systems, mean hock burn and mean cleanliness scores, and the distribution of hock burn and cleanliness scores were analysed with general linear univariate models for each of these dependent variables separately. Wood shavings and ground straw were compared to their controls (peat) in separate models. The models included farm and litter material as fixed factor.

Since the data of litter condition and quality did not meet the assumptions of normality, effects of litter material, farm, time and sampling location on litter condition and quality (i.e. height, moisture, pH and ammonia) were analysed using nonparametric tests. Effects of litter material and farm on litter condition and quality were analysed with the independent samples Mann-Whitney U-test and Kruskal-Wallis test, respectively. The changes in litter height, moisture and pH over time were analysed with the Wilcoxon signed rank test. The analyses of sampling location effects on litter condition and quality was carried out using the Kruskal-Wallis test and further pairwise significance levels were adjusted with Bonferroni-correction. All 16 control batches with peat were pooled together for analyses of sampling location.

Experiment 2 – Platform treatment

The effects of farm and platform treatment on mean footpad score and the severity of footpad dermatitis in both scoring systems, mean hock burn and mean cleanliness scores and the distribution of hock burn and cleanliness scores were analysed using separate general linear univariate models for each of these dependent variables. Models included farm and platform treatment as fixed factors.

Since the data of litter condition and quality did not meet the assumptions of normality effects of platform treatment, farm, time and sampling location on litter condition and quality (i.e. height, moisture, pH and ammonia) were analysed using nonparametric tests. The effects of platform treatment and farm on litter condition and quality were analysed with the independent samples Mann-Whitney U-test and Kruskal-Wallis test, respectively. The changes in litter height, moisture and pH over time were analysed with the Wilcoxon signed rank test. The analyses of sampling location effects on litter condition and quality was carried out using the Kruskal-Wallis test and further pairwise significance levels were adjusted with Bonferroni-correction.

Comparison of footpad lesion scoring systems

The comparison of the percentage of healthy footpads in official and WQ-assessment methods was conducted with T-test for paired samples combining data of both experiments.

Results

Contact dermatitis

Overall 87 % ±2.6 (mean ± SE) of the birds assessed according to the official protocol and 82 % ±3.0 of the birds assessed according to the WQ-protocol showed healthy footpads (score 0) in experiment 1. General footpad condition appeared somewhat worse in experiment 2, with 83 % ±3.4 of the birds assessed according to official protocol and 74 % ±3.2 of the birds assessed according to the WQ-method exhibiting healthy footpads. Furthermore, the severest lesions of WQ-assessment (score 4) were absent in experiment 1, but were detected in two farms in experiment 2 (0.02 % ±0.02). Mean hock burn score in both experiments was 0.3 ±0.02. However, the most severe lesions (score 4) were undetected in all flocks of experiment 1, but were found in one farm in experiment 2 (0.02 % ±0.02).

Wood shavings and peat comparison

Mean official footpad score for wood shavings was 0.13 ±0.01 and for the corresponding peat controls 0.02 ±0.01 (P = 0.001). The prevalence of footpad dermatitis was influenced by litter material for scores 0 and 1 (P = 0.001, each; Figure 3a), but severe lesions (score 2) were found only in 1 out of 4 farms. Mean footpad scores and the distribution of scores 0 and 1 differed between farms (P = 0.006, P = 0.011 and P = 0.017; respectively). There was an interaction between farm and litter material for mean official footpad score and for scores 0 and 1 (P = 0.004, P = 0.007 and P = 0.012; respectively).

Mean WQ footpad score on wood shavings was 0.28 ±0.02 and on the respective peat controls 0.06 ±0.02 (P = 0.001). On wood shavings a lower number of healthy footpads (score 0) were found than on peat (P = 0.001; Figure 3b). Mean footpad score and the distribution of footpad scores 0, 1 and 2 differed between farms (P = 0.007, P = 0.006, P = 0.008 and P = 0.026; respectively). An interaction between farm and litter material was found for mean WQ footpad score and scores 0, 1 and 2 (P = 0.010, P = 0.010, P = 0.012 and P = 0.037; respectively).

Mean hock burn score appeared inferior on wood shavings compared to peat (0.4 ±0.03 on wood shavings and 0.3 ±0.03 on peat; P = 0.046). Litter material had no influence on the distribution of scores 1 and 2, however, there was a tendency of litter material affecting the percentage of hock burn score 0 (P = 0.052). On wood shavings 64.7 % ±2.2 of the birds exhibited healthy hock skin and on peat 71.6 % ±2.2 of the birds. Although score 3 was detected only seldom, litter material affected the percentage of score 3 (0.1 % ±0.002 of the birds on wood shavings and 0.01 % ±0.002 on peat, P = 0.006). Mean hock burn score and the occurrence of scores 0, 1 and 3 differed between farms (P = 0.004, P = 0.002, P = 0.001 and P = 0.025; respectively).

Ground straw and peat comparison

Mean official footpad score for ground straw was 0.3 ±0.06 and for peat 0.1 ±0.06 ($P > 0.05$). Litter material affected the percentage of healthy footpads ($P = 0.049$; Figure 3c), but there was only a tendency of litter material affecting score 1 percentage ($P = 0.051$). Severe lesions were detected in three out of four farms. Mean official footpad score, and the occurrence of healthy footpads and superficial lesions differed between farms ($P = 0.026$, $P = 0.016$ and $P = 0.012$; respectively).

Mean WQ footpad score on ground straw was 0.4 ±0.06 and on peat 0.2 ±0.06 ($P = 0.028$). Litter material affected the distribution of footpad scores 0 and 1 ($P = 0.028$ and $P = 0.046$; respectively; Figure 3d), but scores 2 and 3 were not affected. Mean WQ footpad score and the distribution of scores 0, and 1 differed between farms ($P = 0.006$, $P = 0.005$, $P = 0.009$; respectively).

On ground straw mean hock burn score was 0.4 ±0.02 and on peat 0.3 ±0.01 ($P = 0.007$). Litter material had no effect on the severity of hock lesions. The hock skin was healthy in 66.9 % ±1.7 of the birds on ground straw and in 70.4 % ±1.7 of the birds on peat. Mean hock burn score and the distribution of hock burn scores 0, 1 and 2 differed between farms ($P = 0.001$, $P = 0.001$, $P = 0.021$, $P = 0.012$; respectively).

Platform treatment

Footpad lesions and hock burns were not affected by platform treatment. Mean official footpad score and distribution of scores 0 and 1 differed between farms ($P = 0.001$, each). Also mean WQ footpad score and scores 0, 1 and 2 differed between farms ($P = 0.001$, $P = 0.013$, $P = 0.001$ and $P = 0.004$; respectively). The severity of hock burns was not influenced by farm.

Figure 3 a, 3b, 3c and 3d here

Plumage cleanliness

In both experiments overall 99 % ±0.1 of the assessed birds appeared at least slightly dirty (cleanliness score ≥1). Mean cleanliness score was 1.1 ±0.01. Mean cleanliness score and the level of cleanliness were not affected by litter material, platform treatment, or farm.

Footpad lesion scoring systems

Percentages of healthy footpads (score 0) in the official and WQ-assessments correlated positively (r = 0.82, *P* = 0.001). However, the percentage of healthy footpads was lower in the WQ-assessment than in the official assessment (76.4% ±2.4 and 84.5% ±2.2, respectively; *P* = 0.001).

Litter assessment

Wood shaving and peat comparison

None of the farmers reported any additional procedures to manage litter condition. Median litter condition score for wood shavings was 0.8 (range 0.3–1.2) and for peat 0.5 (0.2–0.8) (*P* > 0.05). The layer of wood shavings was thicker in the beginning compared to the peat layer (median height of wood shavings 6.4 cm (3.5–7.8 cm) and peat 3.7 cm (2.5–-4.7 cm), *P* = 0.001), but in the end no difference was measured (median height of wood shavings 4.9 cm (4.7–5.8 cm) and peat 4.8 cm (4.2–6.0 cm). In the beginning wood shavings had higher pH and lower moisture than peat (median pH of wood shavings 5.4 (5.1–5.9) and peat 4.0 (3.4–4.5), *P* = 0.001; median moisture of wood shavings 10.4 % (6.1–21.2 %) and peat 33.1 %

(18.5–61.1 %), $P = 0.001$) but in the end no difference was detected (median pH of wood shavings 8.1 (7.8–8.5) and peat 8.1 (7.7–8.4), and median moisture of wood shavings 32.3 % (27.8–34.4 %) and peat 31.2 % (27.2–39.1 %). Litter material did not affect ammonia content (median 2200 µg/g with range 1810–2760 µg/g). The thickness of the wood shavings layer decreased, and pH and moisture increased with time ($P = 0.05$, $P = 0.001$ and $P = 0.001$; respectively). Peat moisture remained unchanged over time, and height and pH rose during the production phase ($P > 0.05$, $P = 0.001$ and $P = 0.001$; respectively). Height, pH and moisture in the beginning and ammonia content differed between farms ($P = 0.001$, $P = 0.009$, $P = 0.001$ and $P = 0.016$; respectively).

Ground straw and peat comparison

All farmers reported adding fresh ground straw bedding at least once during the rearing phase, but no extra procedures were reported for peat litter. The median litter condition score for ground straw was 1.0 (0.5–1.7) and for peat 0.7 (0.2–0.8) ($P = 0.014$). At both sampling times ground straw layer was thinner than the peat layer (beginning median height of ground straw 1.3 cm (0.9–1.5 cm) and peat 4.7 cm (2.5–6.2 cm), $P = 0.001$ and end median height of ground straw 3.9 cm (3.2–5.0 cm) and peat 4.5 cm (4.2–6.7 cm), $P = 0.002$). Ground straw had higher initial pH and lower in the end (beginning median pH of ground straw 8.1 (7.6–8.5) and peat 4.1 (2.3–4.4), $P = 0.001$, and end median ground straw pH 7.4 (6.6–8.0) and peat pH 8.0 (7.6–8.4), $P = 0.015$). Ground straw was drier in the beginning than peat (median ground straw moisture 7.3% (4.6–10.9 %) and peat moisture 23.9 % (13.1–64.5 %), $P = 0.001$), but in the end there was no difference (median ground straw moisture 53.8% (42.1–63.1 %) and peat 50.8 % (31.6–59.3 %). Litter material did not affect ammonia content (median 2220 µg/g, 1560–2760 µg/g). The height and moisture of the ground straw layer increased during the growing period, while pH decreased (*P* = 0.001, *P* = 0.001 and *P* = 0.01; respectively). On the other hand, peat height did not changed over time, while moisture and pH rose during the production period (*P* > 0.05, *P* = 0.001 and *P* = 0.001; respectively). Initial pH, moisture content at both sampling times, and ammonia content differed between farms (*P* = 0.004, *P* = 0.039, *P* = 0.047, and *P* = 0.009; respectively).

Platform treatment

Litter condition and quality was not affected by platform treatment (*P* > 0.05 for all). Median litter condition score in the end was 0.7 (0.2-1.7). Peat moisture increased over time (median 24.8 % (14.2-47.2) in the beginning and 33.8 % (25.8-44.7) in the end; *P* = 0.001). Litter pH raised over time (median 4.0 (3.5-4.5) in the beginning and 7.8 (7.1-8.6) in the end; *P* = 0.001), but height remained unchanged (median 5.0 cm (2.3-10.8 cm)). Litter height, moisture and pH in the beginning and at the end, and ammonia content and litter condition differed between farms (*P* = 0.001, *P* = 0.001, *P* = 0.047, *P* = 0.001, *P* = 0.001, *P* = 0.002, *P* = 0.001 and *P* = 0.001; respectively).

Effects of sampling location

Litter under drinker lines appeared stickiest and the litter quality under the feeder lines differed most from litter in other sampling locations in both experiments (Table 4).

Table 4 here

Discussion

Peat proved to be more beneficial for footpad health than either of the two test bedding materials, although the difference between peat and ground straw was not as obvious as between peat and wood shavings. Surprisingly, regardless of superior footpad condition on peat, the difference in litter condition between peat and wood shavings was not substantial whereas houses with ground straw displayed poorer litter condition compared to their peat-controls. This conflicting observation could arise from the overall inferior footpad health and slightly worse general litter condition in houses with ground straw and respective peat-controls compared to wood shavings and their controls. Supposedly, the farms of ground straw comparison struggled also to maintain peat in acceptable condition resulting in nearly similar footpad health on peat and ground straw. Friable and dry litter is recognized as the most important factor supporting footpad health (Greene *et al.*, 1985; Bassler *et al.*, 2013) but the litter material of choice also impacts footpad health (Su *et al.*, 2000; Bilgili *et al.*, 2009; Kyvsgaard *et al.*, 2013). Previous research has frequently demonstrated better footpad condition on wood shavings than on straw (Su *et al.*, 2000; Meluzzi *et al.*, 2008; Kyvsgaard *et al.*, 2013). However, it should be noticed that straw in earlier studies has typically been cut straw while we tested ground straw containing fine particles that, we assume, improved the water absorbing capacity of the product. Peat is not a globally common bedding material for poultry, thus it has been tested only in few studies, with contradictory results. Compared to wood shavings, more friable peat litter has been shown to deliver healthier footpads in broilers (de Baere *et al.*, 2009). In contrast, a large Danish investigation demonstrated insignificant differences in litter condition on wood shavings, straw and peat despite inferior footpad health on straw litter (Kyvsgaard *et al.*, 2013). Furthermore, turkeys on reed-sedge peat exhibited lesser footpad health even though peat bedding was found to be easier to sustain in friable condition than wood shavings (Enueme *et al.*, 1987). However, comparing the results of that and our study is questionable as we were testing *Sphagnum* peat.

Wet litter conditions compromise footpad health (Martland, 1985; de Jong *et al.*, 2014). Litter moisture over 30 % has been shown to drastically increase lesions in turkeys (Wu and Hocking, 2011), but a more recent study demonstrated a higher threshold moisture of 49 % in relation to greater risk for footpad dermatitis in turkeys (Weber Wyneken *et al.*, 2015). Our observation of the moisture of peat and wood shavings exceeding 30 % at the end of production period, with still acceptable litter condition and footpad health, is more in line with the latter conclusion. We also measured fairly high initial moisture in peat, with mean moisture over 30% in half of the houses. Interestingly, in the beginning, fresh peat was moister than either of the test bedding materials, but the moisture of exhausted litter did not differ from the other bedding materials. Yet, footpad health scored inferior on wood shavings compared to peat, without observed differences in litter condition and moisture in the end of production period. Moreover, the lack of difference in end moisture between ground straw and peat still resulted in poorer litter and footpad condition on ground straw. In an earlier study, comparing reed-sedge peat and wood shavings, in spite of indifferent moisture contents, peat litter was shown to keep its friability better than wood shavings (Enueme *et al.*, 1987). Based on our results, we hypothesize that the relationship between litter condition, moisture and footpad lesions is more complicated than previously stated.

In addition to litter wetness *per se*, also the ability of bedding material to absorb and release moisture has been demonstrated to be essential for footpad health (Bilgili *et al.*, 2009) and litter condition (Dunlop *et al.*, 2015); better absorbing and releasing capacities have been connected with enhanced footpad and litter condition. During the production period the water holding capability of wood shavings litter has been shown to increase, compared to fresh wood shavings. However, while the litter moisture content persists the same, the porosity of the litter layer decreases, leading to a more compact litter layer. Furthermore, the water releasing capacity of wood shavings bedding seems to improve along with increasing litter moisture (Dunlop *et al.*, 2015). *Sphagnum* peat exhibits high water absorbing ability (Feustel and Byers, 1936). A study, performed with peat as broiler litter, demonstrated that the high initial moisture of 40-50% was rapidly evaporated from the litter (de Baere *et al.*, 2009). We measured increased average moisture content in wood shavings and ground straw during the production phase. However, peat was showing constant average moisture in half of the houses, probably due to high initial moisture in peat in these houses. Our finding suggests that, in regard to footpad lesions and litter condition, peat may have higher level threshold for when moisture content becomes a risk factor for contact dermatitis. Peat may be able to more successfully maintain its friability and an acceptable moisture content through the production period. However, further investigation, preferably under more challenging conditions, is required to confirm this conclusion.

As expected, peat delivered the lowest initial pH. However, in the end we observed no difference in pH between peat and wood shavings while ground straw litter exhibited even lower end pH than peat. Since pH was measured only twice, we are unable to conclude how quickly pH rose with time, but obviously, in contrast to our hypothesis, low pH alone cannot explain the superior footpad performance on peat. Earlier research, utilizing other bedding materials, has also revealed negligible impacts of litter pH on footpad health (Wang *et al.*, 1998; Meluzzi *et al.*, 2008; Wu and Hocking, 2011).

The observed profound variation between farms in litter quality and the prevalence of contact dermatitis agrees with the previous conclusions of the impact of farmer (McIlroy *et al.*, 1987; Jones *et al.*, 2005; de Jong *et al.*, 2012a). Farmers in this study, had long experience with managing peat bedding and handling a new material would probably have required some adapting time, which may partly explain the detected differences between litter materials, offering an advantage to peat. However, although farmers were familiar with peat, variation in peat bedding quality seems large, suggesting a remarkable effect of management skills, houses or equipment on the outcome. To improve moisture release from moist litter an accelerated ventilation rate is required (Weaver and Meijerhof, 1990; Dunlop *et al.*, 2015), thus the farmer's talent to manage house ventilation, temperature and humidity are the key factors to control litter moisture and sustain skin health (McIlroy *et al.*, 1987; Dawkins *et al.*, 2004; Jones *et al.*, 2005). Therefore we can speculate that, regarding footpad health, peat proved to be more forgiving bedding material in challenging circumstances, or for a less experienced farmer. Furthermore, misting systems in broiler houses have been connected with higher risk for contact dermatitis (Jones *et al.*, 2005). All houses in this study, were equipped with misting systems, thus the higher litter wetness in some houses could have been caused by the inappropriate management of misting systems.

The study indicated no effects of platform treatment on footpad health and litter condition, implying that this additional equipment did not adversely interfere with the airflow. However, it should be noted that this outcome was received on peat bedding, and thus does not necessarily apply with other litter materials. Yet, the familiar bedding material, peat, in the houses of the present study better assured impartial circumstances to test platform effect on litter condition and contact dermatitis. Limited and contradictory data is available on the influence of perching possibility on footpad health. One previous study found no effect of perches on footpads (Su *et al.*, 2000), but others have showed a tendency of improved footpad health in birds with perches (Hongchao *et al.*, 2014; Ventura *et al.*, 2010; Kiyma *et al.*, 2016). Ohara *et al.* (2015) suggested that more active use of perches or higher activity of females resulted in enhanced footpad health in female broilers with access to perches. However, none of these earlier studies offers information about perch presence on litter condition. Further research is required to ensure the effects of added equipment in broiler houses on litter and footpad condition.

Peat litter resulted in healthier hock skin than either of test materials but we saw no effect of platforms on hock skin condition. Previous research has verified that litter condition affects the incidence of hock burns (Bruce *et al.*, 1990; Haslam *et al.*, 2007; Allain *et al.*, 2008, de Jong *et al.*, 2014), which probably explains the observed differences between litter materials. Existing literature provides inconsistent information about the effect of perches on hock skin health. A Swiss research detected less hock burns in birds with access to elevated platforms (Oester *et al.*, 2005) but other studies have found no influence of perches on hock skin condition (Ventura *et al.*, 2010; Hongchao *et al.*, 2014).

We observed lesions on hock skin more frequently than on footpads, yet, most of the hock lesions were mild (score 1 and 2) and severe lesions were as scarce as in footpads. The data from UK and France have showed opposite results, more footpad lesions than hock burns (Haslam *et al.*, 2007; Allain *et al.*, 2009). Because hock burns appear more frequently in Finnish circumstances than footpad lesions, hock burn monitoring could provide a more sensitive indicator for litter condition. On the other hand, hock burn occurrence may reflect broiler leg health or simply different skin structure on hock area and footpads. The function of footpads is to be in constant contact with ground or perch, while hock skin is not, therefore hock skin structure and strength might differ from footpad skin. Modern heavy broilers rest most of their time, showing more resting with age (Weeks *et al.*, 2000) and while lying down hock skin is placed on the litter instead of only footpads (de Jong *et al.*, 2012a) increasing the risk for hock skin lesions. Several studies have shown a correlation between impaired walking ability and hock burns (Kestin *et al.*, 1999; Sørensen *et al.*, 2000; Kristensen *et al.*, 2006; Haslam *et al.*, 2007); hock burns may be triggered by walking difficulties inducing more resting, thus more time for skin in contact with litter, or the other way round, lameness could be caused by painful hock lesions (Sørensen *et al.*, 2000; Kristensen *et al.*, 2006).

Despite the overall satisfactory litter condition in all houses, we detected large variation in litter condition in different locations within a house. Logically, litter under the drinker lines appeared wettest accompanied with worse condition score. The number of drinkers (Jones *et al.*, 2005), drinker type (Bray and Lynn, 1986; Ekstrand *et al.*, 1997; Jones *et al.*, 2005) and the adjustment of the water pressure and height of drinker lines affect litter quality (Carey *et al.*, 2004). The incidence and severity of footpad dermatitis in birds on a certain location in a broiler house have been shown to depend on local litter condition (de Jong *et. al.*, 2012b). This effect is probably stocking-density related: in lower densities birds can more easily avoid wet areas, but the higher the density the greater the negative influence of wet locations in the house. At flock level, the size of compromised litter area may also impact the situation, larger area leading to worse outcome. It is possible that differences in footpad health between farms could indicate variation in wet area sizes under drinker lines between farms.

In general, footpad health in tested flocks appeared good in comparison to other studies, as over 70% of the birds exhibited healthy footpads and, more importantly, in both assessment methods the most severe lesions (score 2 in official and score 4 in the WQ-assessment) were detected only occasionally. This finding differs from several earlier observations made on commercial broilers with the majority (from about 50% to nearly 100%) of the birds showing footpad lesions (Ekstrand *et al.*, 1997; Allain *et al.*, 2009; de Jong *et al.*, 2012a; Kyvsgaard *et al.*, 2013; Saraiva *et al.*, 2016). Because this investigation was performed during winter, which is the season with higher risk for footpad dermatitis (Haslam *et al.*, 2007; de Jong *et al.*, 2012a), the difference between our and international situation is probably not due to a seasonal effect. A lower prevalence of footpad lesions has been linked with a lower incidence of severe footpad lesions (Pagazaurtundua and Warris, 2006) and our observation supports this conclusion. The farms voluntarily participated in this study and often the better performing farms show more active interested in research, which might have affected our results, however, the same concern probably applies to most field studies.

The two scoring systems utilized in this study defined healthy footpad (score 0) markedly differently. The official method accepts slight hyperkeratosis and discoloration on small areas in footpads scored as 0 (Evira, 2011) but the WQ-protocol excludes even the smallest visible changes (Welfare Quality®, 2009). Therefore, understandably, despite high positive correlation, the number of healthy footpads was significantly lower in the WQ-assessment. The WQ-approach offers a more reliable evaluation for healthy footpads, which is important in scientific research, but perhaps in practical situations the official system works accurately enough. The number of scored birds also considerably differs between these two systems (100 feet in the official and 1550 in the WQ-method). The presence and severity of footpad lesions varies depending on local litter condition in the house. To accurately display the footpad health at flock level varying litter condition areas should be thoroughly represented. If this is ensured, a lower number of birds need to be assessed (de Jong *et al.*, 2012b). When assessment takes place in the slaughterhouse a higher number of assessed birds may better assure the representation of different litter areas, thus improve the accuracy of assessment. Furthermore, flocks showing a high or low prevalence of footpad dermatitis appear to express enhanced scoring accuracy, compared to flocks with intermediate results (de Jong *et al.*, 2012b). In this study, the high proportion of healthy footpads may thus have enhanced the scoring accuracy, and thus the comparability of the two both scoring systems.

In conclusion, this study provides new knowledge about the applicability of peat as broiler bedding in comparison with wood shavings and ground straw, and shows no negative effects of elevated platforms on peat litter condition or the occurrence of contact dermatitis in a commercial production environment. Broilers on peat litter exhibited less contact dermatitis compared to both test bedding materials. However, footpad and hock skin health scored inferior on wood shavings than on peat without differences in litter condition and moisture in the end of production period. Moreover, the lack of difference in end moisture between ground straw and peat still resulted in poorer litter, footpad and hock skin condition on ground straw. Hence, our results suggest that the relationship between litter condition, moisture and contact dermatitis may be more complicated than previously stated. In contrast to our hypothesis, low pH cannot explain the superior footpad performance on peat. Furthermore, we underline the importance of the farmer’s ability to manage litter conditions, regardless of the chosen litter material.

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Table 1. Detailed information on houses and flocks in experiment 1 (comparing litter materials) and 2 (platform treatment).

Experiment	*1*	*2*
Floor area, m^2	750-1681	337-797
Chick number at the beginning	11772-27704	5147-13947
Average wheat % (min-max)	14 (12-15)	20 (14-28)
Slaughter age, days	37-39	37-39
Target / actual slaughter weight, kg	2.3-2.5 / 2.4 SD 0.1	2.3-2.5 / 2.4 SD 0.1
Mean bird density, kg/m^2 (min-max)	39 (35-44)	39 (36-43)

Table 2. Description of the footpad lesion scoring performed by the official veterinarian of the slaughterhouse following the guidelines of the Finnish Food Safety Authority, Evira.

Score	*Description*
0 healthy footpad	• smooth skin, no lesion • small superficial lesion • discoloration on limited area • slight hyperkeratosis • lesion size max 5 mm x 5 mm area
1 mild, superficial lesion	• superficial lesion of marked size covering several papillae • papilla structure still existing • discoloured or dark papillae • crust or ulceration on maximum 5 mm x 5 mm area • ulceration at the bottom of toe < 1 cm long
2 severe, deep lesion	• ulceration or crust of significant size, over 5 mm x 5 mm, without existing papilla structure • ulceration on the bottom of toes > 1 cm long

Table 3. Description of the scoring system used for assessing litter condition in broiler houses. Scoring follows the Welfare Quality® Assessment protocol for poultry.

Score	*Description*
0	Completely dry and flaky
1	Dry but not easy to move with boot
2	Leaves imprint of foot and can be shaped in a ball that easily falls apart
3	Sticks to boots and can be formed in a firm ball
4	Wet and sticky under hard crust

Table 4. Median (min–max) litter condition scores at the end of growing period assessed according to Welfare Quality® Assessment protocol for poultry, and litter quality in samples from different locations in broiler houses with different litter materials (peat, wood shavings and ground straw) and houses with peat litter in experiment 2.

Litter sampling location	*under drinker line*	*middle house between feeder and drinker lines*	*rear corner*	*rear end of the house between feeder and drinker lines*	*wall side*	*under feeder line*
Litter condition						
Peat	1.0 (1-3)^{b}	0 (0-2)^{a}	0 (0-1)^{a}	0 (0-1)^{a}	0 (0-2)^{a}	0 (0-1)^{a}
Wood shavings	1.5 (1-4)^{a}	0 (0-2)^{b}	0 (0-2)^{b}	0 (0-1)^{b}	2.0 (0-3)^{ab}	0 (0-1)^{b}
Ground straw	2.5 (1-3)^{b}	0.5 (0-2)^{a}	0.5 (0-3)^{a}	1.5 (0-4)^{a}	1.5 (0-2)^{a}	0 (0-1)^{a}
Experiment 2‡	2.0 (0-4)^{c}	1.0 (0-3)^{a}	0.5 (0-3)^{ab}	1.0 (0-2)^{ab}	0 (0-3)^{ab}	0 (0-1)^{b}
Height cm						
Peat	5.0 (4-7)^{ab}	5.5 (2-12)^{a}	6.0 (3-8)^{a}	4.0 (2-7)^{ab}	4.0 (2-6)^{b}	4.0 (3-6)^{b}
Wood shavings	5.0 (4-7)^{a}	5.5 (5-6)^{b}	6.0 (4-7)^{b}	5.5 (2-7)^{ab}	5.0 (4-7)^{ab}	4.0 (2-6)^{b}
Ground straw	5.5 (3-7)^{a}	4.0 (3-10)^{ab}	4.0 (2-7)^{ab}	4.0 (2-7)^{ab}	3.0 (2-3)^{b}	3.0 (2-5)^{b}
Experiment 2‡	6.0 (4-12)^{a}	6.0 (2-11)^{ab}	6.0 (3-14)^{a}	5.0 (1-12)^{abc}	4.0 (2-9)^{c}	4.0 (2-10)^{bc}
Moisture %						
Peat	41 (25-63)^{a}	31 (23-43)^{a}	36 (25-51)^{a}	32 (29-50)^{a}	34 (26-48)^{a}	18 (14-23)^{b}
Wood shavings	40 (24-56)^{a}	26 (23-39)^{a}	37 (27-44)^{a}	31 (23-49)^{a}	40 (23-50)^{a}	19 (13-22)^{b}
Ground straw	54 (24-63)^{a}	32 (19-43)^{a}	37 (25-52)^{a}	45 (26-53)^{a}	42 (33-45)^{a}	18 (16-22)^{b}
Experiment 2‡	41 (27-59)^{a}	37 (22-59)^{ab}	33 (20-55)^{ab}	36 (18-58)^{ab}	33 (20-52)^{b}	23 (15-37)^{c}
pH						
Peat	8.0 (4.9-8.7)^{ac}	8.5 (7.9-8.9)^{ab}	8.3 (7.7-8.8)^{ab}	8.6 (7.1-8.8)^{b}	8.5 (7.8-8.8)^{b}	7.3 (6.4-7.8)^{c}
Wood shavings	8.3 (5.3-8.9)^{ab}	8.7 (8.2-8.8)^{a}	8.6 (8.2-8.8)^{a}	8.6 (8.2-8.8)^{a}	8.4 5.5-8.8)^{a}	7.6 (7.0-8.0)^{b}
Ground straw	5.6 (5.0-8.7)^{b}	8.5 (6.6-8.8)^{a}	8.3 (7.0-9.0)^{a}	7.4 (5.5-8.6)^{ac}	8.1 (6.3-8.5)^{a}	7.2 (6.2-7.9)^{bc}
Experiment 2‡	8.3 (5.1-8.8)^{ab}	8.5 (5.5-8.8)^{a}	8.3 (5.5-8.9)^{ab}	8.4 (6.4-9.0)^{ab}	8.3 (5.4-8.8)^{ab}	7.9 (6.2-8.7)^{b}
Ammonia μg/g						
Peat	2540 (1660-3650)^{a}	2430 (1740-3210)^{a}	2350 (1760-3580)^{a}	2360 (1810-2610)^{a}	2460 (1430-3250)^{a}	1760 (1080-2070)^{b}
Wood shavings	2890 (1310-4460)^{a}	1780 (1420-3180)^{ab}	2330 (1690-3320)^{a}	2000 (1370-2810)^{a}	2710 (1250-3130)^{a}	1350 (1140-1750)^{b}
Ground straw	2420 (1430-3640)^{a}	1700 (1200-2590)^{a}	2170 (1330-3130)^{a}	2440 (1720-3950)^{a}	2270 (1920-2630)^{a}	1400 (1040-1930)^{b}
Experiment 2‡	2590 (1350-4000)^{a}	2400 (1430-3570)^{a}	2400 (920-3680)^{a}	2340 (810-3200)^{a}	2290 (1140-3840)^{a}	1830 (1290-3150)^{b}

^{abc} Common letter within each row indicates non-significant difference at the 0.05 level, Kruskal-Wallis test, post hoc statistics adjusted with Bonferroni-correction.

‡ Houses equipped with elevated platforms and their controls, results are shown as overall as the treatments did not differ.

Figure 1. Illustration of the elevated platform structure.

Figure 2. Schematic layout of a broiler house showing the approximate litter assessment and sampling locations. 1= under the drinker line, 2= middle of the house between feeder and drinker lines or under the platform in equipped houses, 3= rear corner, 4= between feeder and drinker lines near the rear end of the house, 5= wall side, 6= under the feeder line.

Figure 3. Distribution of footpad lesion scores in broilers on wood shavings compared to peat assessed according to the Finnish official program (a) and the Welfare Quality® Assessment protocol for poultry (WQ) methods (b), and on ground straw compared to peat assessed with the official program (c) and the WQ-protocol (d).The official scoring scale varied from 0= healthy footpad to 3= deep lesion and the WQ-assessment scale from 0= healthy footpad to 5= clear indication of footpad dermatitis. Error bars indicate SE and line over bar significant difference (*$P < 0.05$ and *** $P < 0.001$).