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# Experimental Study on Effects of Litter Material and its Quality on Foot Pad Dermatitis in Growing Turkeys

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**Abstract:** Since turkeys are in continuous contact with the litter, the potential effects of bedding materials and their quality are of major concern in the etiology of Foot Pad Dermatitis (FPD). Two week-old female turkeys were allotted to four groups, with 29 in each and housed either on wood shavings, lignocellulose, chopped straw or dried maize silage over a period of four weeks without artificial climatisation. The birds in all groups were fed identical commercial diets. Half of the turkeys in each group were additionally exposed for 8 h/d to corresponding wet (27% DM; by adding water) litter in adjacent separate boxes. Foot pads of the birds were examined macroscopically and histologically at the start and end of the experiment as well as at weekly intervals. Lignocellulose showed the lowest severity of FPD on dry and wet litter treatments, whereas chopped straw was associated with high FPD scores on dry treatment. Foot pad scores were similar on wood shavings and dried maize silage whether dry or wet. The DM content of litter materials was determined and the highest moisture content among dry treatments was observed in straw (about 31%) which was paralleled with FPD severity. The severity of FPD was overall much higher (>2 times) on wet than on dry litter. Exposure of the birds to wet litter for 8 h/d was sufficient to develop FPD. Lignocellulose could reduce the FPD severity, probably due to higher water binding capacity and faster release of water, while straw may increase it due to lower water evaporation. The physical form of litter either soft (lignocellulose) or with sharp edges (chopped straw) may also affect the onset of FPD. The litter moisture appears to be the dominant factor resulting in the development of FPD and should be kept lower than about 30% to minimise the prevalence and severity of FPD in turkeys.

**Key words:** Foot pad dermatitis, litter type, litter quality, turkeys, litter moisture

## INTRODUCTION

Foot Pad Dermatitis (FPD) is of great concern in turkey production (Berg, 1998; Hafez *et al.*, 2004), as it affects not only the quality of the product, but also the welfare of the animals. It was claimed that FPD may result in pain and discomfort for the birds in severe conditions. The FPD lesions range from discolouration at an early stage, then hyperkeratosis and necrosis of the epidermis develop which progress to ulcers in severe cases (Greene *et al.*, 1985; Ekstrand *et al.*, 1997). The etiology of FPD is complex, but many interacting risk factors have been suggested, such as flock management, stocking density, litter quality and nutrition.

Birds are mostly in close contact with litter during their life. Thus, type and quality of the litter are of special interest in the development of FPD. The type of litter appears to have a marked effect on the incidence of FPD in turkeys (Hester *et al.*, 1997). Bedding materials with sharp edges (such as large particle-size wood chips, chopped straw, etc.) may contribute to FPD due to their abrasive action which can lead to entry of bacteria and eventually to FPD (Bilgili *et al.*, 2009). However, bacterial invasion is not usually seen histopathologically in foot pad lesions, suggesting that FPD is primarily not a response to bacterial infection (Mayne *et al.*, 2006b). Besides the influence of the bedding material, the litter quality also affects the incidence of foot pad dermatitis. Several studies suggested that there is a strong association between "poor" litter conditions and foot pad dermatitis (Geraedts, 1983; Martland, 1984; Martrenchar *et al.*, 2002; Spindler *et al.*, 2005; Mayne *et al.*, 2007; Meluzzi *et al.*, 2008). Litter quality is affected by many factors such as drinker design, amount and consistency of excreta (affected by diet), type, depth and moisture content of the litter (Mayne, 2005). FPD is thought to be caused by a combination of moisture and chemical irritants in the litter (Nairn and Watson, 1972; Martland, 1985).

The effects of litter material on FPD are thought to be due either to the physical structure (hard or soft) or different water binding capacity (higher or lower) of the litter. The most common bedding materials used for turkeys are wood shavings and/or cereal straw, but there are currently further litter types which can also be used as lignocellulose and dried maize silage. Therefore, the aim of the present study was to assess the potential

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impact of these bedding materials on foot pad dermatitis in turkeys. The effects of different litter materials were evaluated not only on dry, but also on wet litter conditions simultaneously.

## MATERIALS AND METHODS

**Birds and housing:** A total of 126, day-old, female turkey poults (BUT- Big 6) obtained from a commercial hatchery were housed in floor pens (1.50 m x 1.32 m). The birds were randomly allotted to four groups. The pens were littered with wood shavings to a depth of approximately 4 cm. The litter was kept clean and dry before the experiment by removing the top layers of the litter with excreta daily and substituting these with fresh dry clean litter. All the pens were provided with tube feeders and bell drinkers. The pens were equipped with a suspended heat lamp for the first 4 weeks and air temperature was kept at 34-36°C during the first 2 days. The temperature was lowered 1°C every 2 days, reaching about 19°C at the end of the experiment (d 42). The poults were provided with 24 h light during the first 4 days, the photoperiod from d 5 onwards being 16 h of light and 8 h of darkness. The birds in all groups were fed *ad libitum* on identical commercial-turkey diets: a starter diet (phase 1) during the first week, then switched to a commercial diet (phase 2) from the 2nd to 5th week and then to phase 3 during the last week of the experiment (6th week). The experimental treatments were conducted on turkeys at 15 d of age and continued till d 42. At the onset of the treatments, the number of birds totalled 29 birds in each group. Three birds per group were sacrificed on day 0 for histopathology of foot pads. The birds were housed on different dry litter materials: wood shavings, lignocellulose (SoftCell®), chopped straw (Strohfix®; obtained from wheat, rye and triticale with split of stems) or dried maize silage (by drying the maize silage at 80°C for 4 days). Half of the turkeys (n = 13) in each treatment were additionally exposed to corresponding wet (27% DM content) litter, in adjacent separate boxes, daily for 8 h throughout the experimental period (4 weeks). During this period, the excreta were not removed from dry or wet litter treatments to simulate field conditions. The depth of tested litter materials at the start was identical (approximately 4 cm) in dry or wet (before applying water) pens. The wet litter was experimentally maintained at a Dry Matter (DM) content of about 27% by adding water as required. The wetted maize silage had to be changed weekly (not intended) due to the fact that it became mouldy after 5-7 days of wetting. The different wet litter treatments were turned daily throughout the experiment to avoid compactions of the top litter layers. Feed and water were offered to turkeys *ad libitum*. Samples of the commercial diets used during the experiment period were analysed according to VDLUFA (2004). The energy (ME) and protein contents of these diets were 11.5/11.6 MJ ME and 258/212 g CP/kg diet in feeding phase 2/3, respectively. The particle size of litter materials was measured (in mm) and length/thickness were: 5-15/0.78-1.5, 14-57/0.15-0.45 and 6-57/0.5-10 for wood shavings, chopped straw and dried maize silage respectively, while lignocellulose was formulated in crumble-form particles of about 3-8 mm. This product of lignocellulose is characterized by containing insoluble cellulose and had a finer structure and therefore larger surface. The crude fibre content (%) of wood shavings, lignocellulose, chopped straw and dried maize silage was determined and the values were 64.0, 66.0, 40.0 and 18.5, respectively.

### Investigations

**Foot pad lesions:** The foot pads of all birds were examined on d 0, 7, 14, 21 and 28 of the treatment and assessed for gross lesions according to the scoring system of Mayne *et al.* (2007) which varied from score 0 (no evidence of FPD) to score 7 (over half of the foot pad covered in necrotic scales). Three birds were selected from each group on d 0, then 6 birds (3 from each litter form) per group on d 7, 14 and 28 (to achieve a first rough information on the development process) and 8 birds on day 21, for histopathology assessment of foot pads. The birds were selected from each group representing low, medium and high FPD scores, by taking one bird from the average of each score, except on d 21 when 2 birds were taken from a high score average and one from each medium and low score average.

After slaughter, foot pads were removed and stored in 10% buffered neutral formalin. Sections from the skin of foot pads were prepared and processed using standard protocols for tissue processing. Paraffin-embedded tissues were cut into 2-3 µm sections using a microtome and stained using haematoxylin and eosin (H and E). Sections were examined under a light microscope and evaluated according to the histopathological scoring system of Mayne *et al.* (2007) which also ranged from score 0 (normal) to score 7 (ruptured epidermis and widespread inflammatory cells).

### Litter sample measurements

**(a) Dry matter (DM) and pH value:** The DM content and pH of the litter were measured at the start and end of the experiment and once a week throughout the experimental period. Five samples were collected from each pen (4 near to the corners and one from the middle) and were obtained from the full depth of the litter. The samples from each pen were pooled and thoroughly mixed. Then, two sub-samples were taken; one was measured for pH and the second for DM content. The pH values were monitored using a pH meter, while the DM content was detected by drying at 103°C until a constant mass was obtained (VDLUFA, 2004). The wet litter was experimentally kept at a moisture content of about 73% by adding water as required and this moisture content was checked every 3 days.

**(b) Atmospheric ammonia determination:** Atmospheric ammonia was measured using a handheld Draeger meter tube (Ammonia 2/a) attached to a Draeger pump (Draeger Safety AG and Co. KGaA, Luebeck, Germany). Ammonia concentrations were recorded from each pen, whether dry or wet, at the start and end of the experimental period as well as at weekly intervals. The ammonia was detected in the middle of the pen at about 3 cm above the litter surface.

**(c) Water binding capacity:** Samples of 10 g from each fresh litter material were placed in plastic containers and fully submerged in water for 24 h and for 2 and 4 weeks. At the end of each interval, the litter was sieved using previously weighed dried sieves (100 or 200 µm), allowed to air-dry for 30 min and subsequently reweighed. Then, the water binding capacity (i.e. amount of water bound by the litter) of each litter material was calculated by subtracting the litter weight before soaking in water from that after soaking.

**(d) Water release through air-ventilation:** Samples of 1 kg from each fresh bedding material were thoroughly mixed with 1 litre water in previously weighed plastic troughs and maintained at a depth of about 4 cm. These samples were exposed to air at room temperature and reweighed after 4, 8 and 24 h. The amount of water loss was calculated by subtracting the difference in weight of samples at these intervals from the initial weight.

**(e) Water loss by physical pressure on litter:** Wet litter samples prepared from fresh bedding materials at 27% DM content were put in sieves (100 or 200 µm) with a depth of about 4 cm. To simulate the pressure of turkeys on the feet which are in direct contact with the litter, a weight of 16 kg was put on plates placed over these samples within the sieves for a period of 1 h. This weight was calculated based on the size of feet (about 45 $cm^2$) of turkeys (6 weeks old) as well as their body weight (about 2337 g). Dividing the weight of the animals by the size of their feet resulted in the required weight per 1 $cm^2$ which was multiplied by the size of the sieve to obtain the total weight load on the samples.

**DM content and pH of excreta:** It was suggested that the turkeys may consume some particles of litter especially maize silage. Therefore, the DM and pH of the excreta were measured. The excreta of the birds were collected once a week from the original pens, before transporting the animals to wet litter, by putting a plastic sheet in each pen for about 1 h until about 50-100 g fresh pure excreta per pen was amassed. The collected excreta from each pen were taken, thoroughly mixed and then one sample was measured for pH value and the remainder was dried at 103°C to determine the DM content.

**Animal performance:** The weight of the birds was recorded individually at the start and end of the experimental period as well as at weekly intervals during the examination of foot pads. The daily feed and water intake of the birds in each group were determined. Additionally, the feed conversion rate of the animals was calculated weekly on a group basis (feed intake/weight gains of all individuals).

**Statistical analysis:** The results were analysed using the statistical SAS program (SAS Institute, 2002). The foot pad scores of both feet of each bird were averaged. Nonparametric one-way analysis was used for calculating the differences between treatments (four independent treatment groups) in external and histopathological FPD scores within dry or wet litter forms. For that the Kruskal-Wallis-Test for unpaired observations was used. For post hoc calculation of pair-wise differences between two different groups, the Wilcoxon two sample test for unpaired observations within procedure NPAR1WAY was used. Furthermore, pair-wise differences between dry and wet litter through treatment groups were calculated using the Wilcoxon two sample test for unpaired observations within the procedure NPAR1WAY.

Nonparametric one-way analysis of repeated measurements was used for determining the differences in external FPD scores along several time points. For that Friedman's chi-square, calculated by Cochran-Mantel-Haenszel Statistics within procedure Frequencies was used. For post hoc calculation of pair-wise differences between two time points, the signed rank test (Wilcoxon two sample test for paired observations) within the procedure Univariate was used. Nonparametric one-way analysis of independent measurements (because analysis was performed on slaughtered animals) was used for detecting the differences in histopathological FPD scores along several time points. For that the Kruskal-Wallis-Test for unpaired observations was used. For post hoc calculation of pair-wise differences between two time points, the Wilcoxon two sample test for unpaired observations within the procedure NPAR1WAY was used.

The other data were analysed using the General Linear Models (GLM) procedure for analysis of variance. Differences were considered to be significant when $p<0.05$. Significant differences are denoted with different superscripts. Values are presented as arithmetical means with standard deviation (Mean±SD).

## RESULTS

**Animal performance:** The feed and water intake of turkeys housed on lignocellulose, chopped straw or dried maize silage were higher than those of turkeys raised on wood shavings (Table 1). Moreover, the feed conversion ratio of birds reared on straw

Table 1: Performance of turkeys as well as DM content (%) and pH of their excreta throughout the experiment (d15 - d42)

| | Wood shavings | Lignocellulose | Chopped straw | Dried maize silage |
|---|---|---|---|---|
| Feed intake (g/bird/day) | $109^{a}$±34.6 | $116^{b}$±38.1 | $119^{b}$±40.6 | $117^{b}$±35.8 |
| Water intake (ml/bird/day) | $224^{a}$±68.1 | $252^{b}$±83.5 | $250^{b}$±84.1 | $243^{b}$±64.1 |
| Weight gain (g/bird/day) | $68.8^{a}$±8.48 | $67.1^{a}$±6.19 | $72.4^{a}$±5.60 | $72.0^{a}$±5.35 |
| FCR* | $1.51^{a}$±0.17 | $1.63^{b}$±0.20 | $1.61^{b}$±0.28 | $1.60^{ab}$±0.17 |
| DM of excreta (%) | $18.0^{a}$±1.87 | $19.7^{a}$±0.98 | $19.2^{a}$±1.10 | $17.1^{a}$±1.12 |
| pH of excreta | $6.36^{a}$±0.19 | $6.26^{a}$±0.23 | $6.43^{a}$±0.13 | $6.34^{a}$±0.27 |

$^{a,b}$Means in the same row with different superscripts are significantly different (p<0.05). *FCR: Feed Conversion Ratio (kg/kg)

Table 2: DM content (%), pH value and atmospheric $NH_3$ concentration (ppm) of the litter throughout the experiment

| Litter | | | | |
|---|---|---|---|---|
| Type | Form | DM (%) | pH | $NH_3$ (ppm) |
| Wood shavings | Dry | $76.7^{a}$±3.09 | $6.68^{a}$±0.51 | $0.74^{a}$±0.36 |
| | Wet | $27.8^{d}$±1.39 | $8.36^{b}$±1.19 | $3.66^{b}$±1.94 |
| Lignocellulose | Dry | $83.2^{b}$±4.63 | $5.99^{ac}$±0.75 | $0.74^{a}$±0.36 |
| | Wet | $27.5^{d}$±0.47 | $7.77^{b}$±1.66 | $2.26^{c}$±1.37 |
| Chopped straw | Dry | $68.8^{c}$±9.79 | $7.58^{b}$±1.06 | $2.60^{bc}$±2.28 |
| | Wet | $27.0^{d}$±0.95 | $8.34^{b}$±0.92 | $3.06^{bc}$±1.75 |
| Dried maize silage | Dry | $75.0^{a}$±9.21 | $6.15^{ac}$±1.58 | $1.08^{ac}$±0.73 |
| | Wet | $26.6^{d}$±1.53 | $5.64^{c}$±1.06 | $1.14^{ac}$±0.49 |

$^{a,b}$Means in the same column with different superscripts are significantly different (p<0.05)

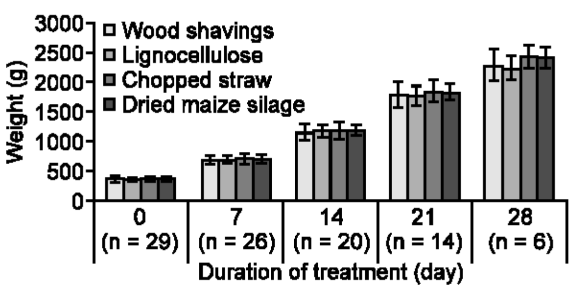


Fig. 1: Weight of turkeys (g) housed on dry and wet litter materials throughout the experiment

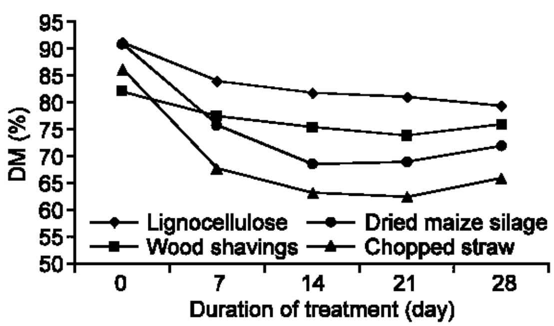


Fig. 2: DM content (%) of bedding materials throughout the experiment (values of dry treatments only)

and lignocellulose was higher compared to those on wood shavings. However, no differences in body weight or weight gain of animals housed on different litter materials throughout the experiment were observed (Fig. 1). The DM content and pH of the excreta did not differ between the birds as the diets were identical in each feeding phase. No mortality was found between the different treatments.

**Litter quality:** In spite of identical diets and stocking density, the DM content in the original pens of dry litter treatments was 76.7, 83.2, 68.8 and 75.0% for wood shavings, lignocellulose, chopped straw and dried maize silage, respectively (Table 2; Fig. 2). Accordingly, lignocellulose had the lowest moisture content (16.8%), whereas chopped straw showed the highest (31.2%) compared to other bedding materials. However, the litter moisture in other bedding materials was similar (about 24%). The moisture content in the wet litter treatments was identical (about 73%) as intended due to adding water.

For comparing the pH and $NH_3$ values in different bedding materials (Table 2), the results of wetted maize silage should be excluded (due to its weekly change), or it can be considered but only after 1 week from the start of treatments (i.e. before its change). The pH of dry treatment of straw was higher than other dry treatments (7.58 vs. 6.27) and was similar to that of wet straw. However, no difference in pH of dry treatments of wood shavings, lignocellulose and dried maize silage was detected. Apart from wet maize silage, there were no significant differences in pH between wet bedding materials. The pH value was higher in wet than in dry treatment in both wood shavings and lignocellulose only (8.07 vs. 6.34). Moreover, the atmospheric $NH_3$ concentration was higher on dry treatment of straw than on other dry litter types (2.60 vs. 1.0), but lower on wet lignocellulose than on wet wood shavings. In addition, the $NH_3$ emission was higher on the wet form of both wood shavings and lignocellulose than on the dry form (3.0 vs. 0.74), but no change was apparent on straw whether dry or wet (about 3.0). Nevertheless, on comparing the results of pH and $NH_3$ on wet litter on day 7 (before changing the maize silage), the values were found to be lower on wetted maize silage than other treatments (Fig. 3 and 4). Both of lignocellulose and

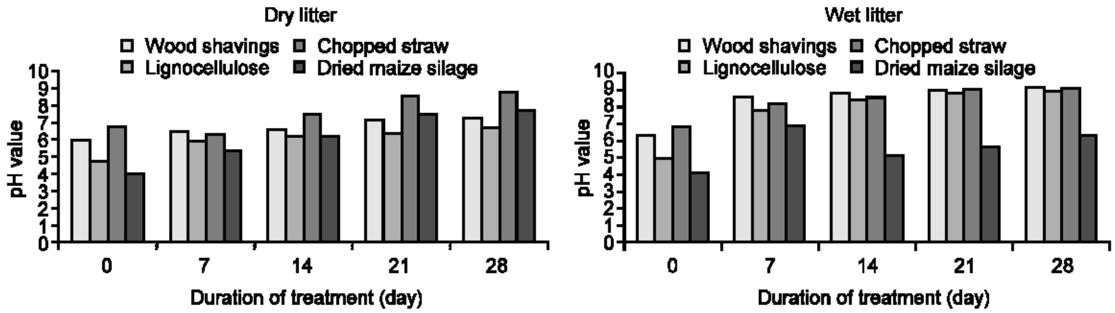


Fig. 3: pH values in dry or wet treatment of different bedding materials throughout the experiment

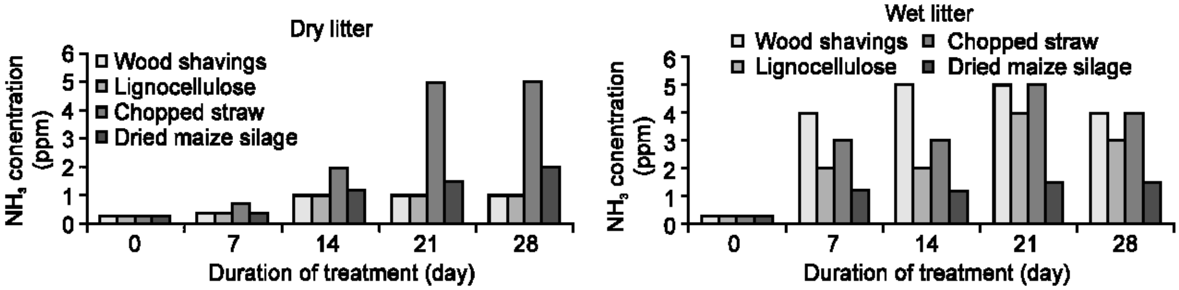


Fig. 4: Volatile $NH_3$ concentration (ppm) on dry or wet treatment of bedding materials throughout the experiment

straw showed a higher water binding capacity compared to other bedding materials (Fig. 5). However, the water evaporation was higher and faster in lignocellulose, but lower in straw and this effect increased with prolonged air exposure (Fig. 6). Wet wood shavings and maize silage released more water by pressure, related to their lower water binding ability, but small amounts were released from lignocellulose and straw (Fig. 7).

**Severity of foot pad lesions:** Concerning foot pad health, the severity of FPD was estimated using external and histological scores (Table 3 and 4). The results of the last two weeks of the experiment were combined together because of no marked changes in FPD scores between the treatments were found on d 21 and 28. This was also done to give more realistic information on the severity of foot pad lesions at the end of the experiment, especially when the number of investigated birds increased. The severity of FPD was overall markedly higher (> 2 times) on wet than on dry litter in each litter type.

**On dry litter:** Lignocellulose showed the lowest foot pad scores (externally and histologically) of all bedding materials, while straw indicated the highest scores. It was observed that straw showing the highest significant histological FPD score approached that achieved on wet straw or wet lignocellulose as well as having the highest external score numerically compared to other litter types. However, the external and histological scores on wood shavings and dried maize silage were similar.

**On wet litter:** The foot pad scores were also lower on wet lignocellulose as on dry treatment. The external FPD score was lower on maize silage, but this result should be excluded due to its weekly change. However, on comparing the external scores after 1 week of the treatments and before changing the maize silage, it was found that the scores were decreased on wetted maize silage. Nevertheless, the histological scores were similar on wet treatments of wood shavings, straw and maize silage throughout the experiment.

Obviously, the averages of external scores from d 0 to d 28 were 0.72, 0.37, 1.01 and 0.66 on dry treatments of wood shavings, lignocellulose, straw and dried maize silage, respectively, whereas these were 4.53, 3.44, 4.24 and 3.26 on wet treatments. Similarly, the averages of the histological scores were 1.45, 0.96, 2.03 and 1.64 on dry treatments of wood shavings, lignocellulose, straw and dried maize silage, respectively, while these were 5.48, 4.73, 5.32 and 5.10 on wet treatments. These values of external and histological scores also elucidate clearly the effects of tested bedding materials on the severity of FPD. Moreover, there was a strong association between these FPD scores and the litter moisture, indicated by a high correlation for external ($R^2$ = 0.96) and histological ($R^2$ = 0.99) scores with the moisture content of dry litter treatments (Fig. 8). A similar correlation was also observed between foot pad scores and the moisture of both dry and wet beddings ($R^2$ = 0.99).

The external scores on dry litter treatments were 0.06, 0.38, 0.65, 1.20 and 1.17 on day 0, 7, 14, 21 and 28,

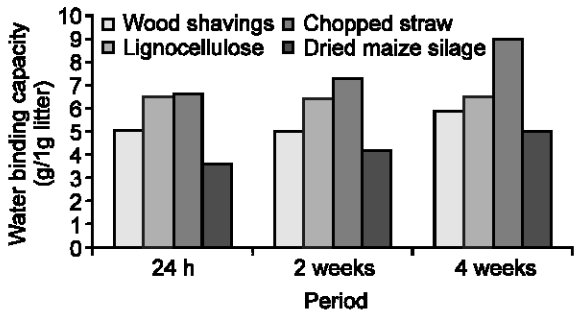


Fig. 5: Water binding capacity of different litter materials (g/1g fresh litter) at different intervals


Fig. 6: Evaporated water in the air (% of water amount in litter) from litter materials at room temperature

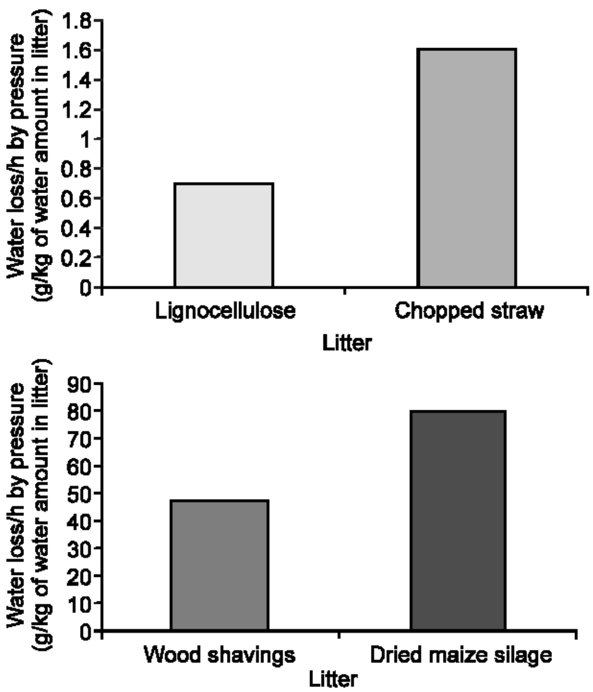


Fig. 7: Water losses per h (g/kg of water amount in litter) due to pressure on the litter (simulation of "wet litter" with animals standing on it; about 52 g/cm$^2$)

respectively, while these were 3.25, 4.03, 4.39 and 3.79 on day 7, 14, 21 and 28, respectively on wet treatments (Table 3). The respective histological scores at these different intervals were 1.25, 1.21, 1.34, 1.94 and 1.88 on dry litter, whereas these were 4.87, 5.29, 5.38 and 5.08 on wet litter (Table 4). Accordingly, the external foot pad scores increased in severity with time in all treatments (except dry lignocellulose) from the start of the treatments till d 21. Due to a smaller number of tested birds on d 28, it was difficult to compare the external scores on this day with those of the other days. However, the histopathological scores increased in severity at the beginning of the experiment, then remained relatively constant afterwards except on straw and wet wood shavings.

The higher FPD severity on wet litter did not negatively affect the weight of animals (Table 5). Regardless the effect of litter material, the body weight on wet litter did not differ to that on dry litter and the values on day 0, 7, 14, 21 and 28 were 0.37, 0.70, 1.19, 1.83 and 2.41 kg, respectively for dry litter, while these were 0.37, 0.69, 1.16, 1.77 and 2.25 kg, respectively for wet litter. Moreover, there were no differences in weight of turkeys on dry or wet treatment of each litter material except wood shavings, where the weight was lower on wet than on dry treatment. However, this was due to the lower body weight of these birds at the start of treatments.

## DISCUSSION

Since turkey feet are in direct contact with litter when the animals are kept in floor rearing, the litter type and quality are of major concern in the etiology of foot pad dermatitis.

**Litter quality:** In practice, feeding (diet composition), ventilation, turning of the litter and other environmental factors can affect the litter quality. In contrast, the present study was conducted under standardised identical conditions regarding diet, stocking density, housing and climatic conditions. Here, there was no need for artificial ventilation of the pens. Thus, any changes in the quality of litter should be related to the litter per se. In the original pens, lignocellulose had the lowest moisture content, whereas chopped straw showed the highest one. As the feed and water intake of birds housed on lignocellulose and straw was identical, thus the difference in DM contents of litter can only be attributed to a quick release of water from lignocellulose (due to larger surface of particles) and a lower water evaporation from straw. Additionally, it was observed that the excreta can be aggregated on the surface of straw forming compacted areas which may increase the retention of moisture, but not in other bedding materials. The higher moisture content in dry treatment of straw may be the reason for a higher volatile $NH_3$ and pH on this litter among dry litter treatments. However, Mayne *et*

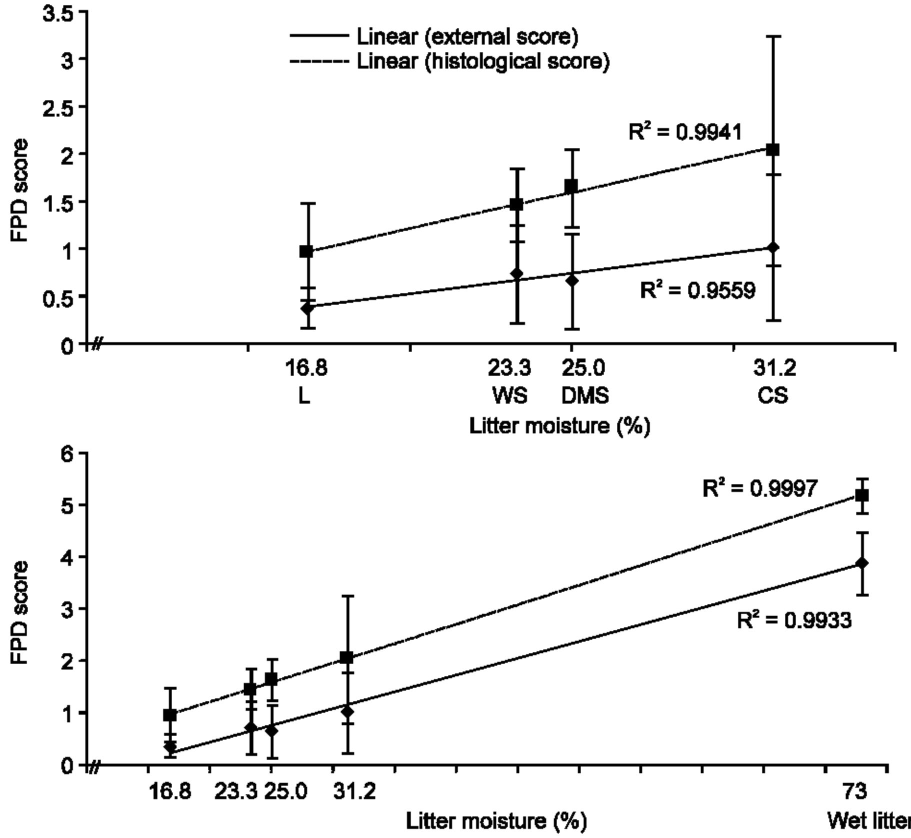


Fig. 8: Linear regression of external and histological FPD scores on moisture contents of bedding materials (above: dry litter; down: dry and wet litter). L: Lignocellulose, WS: Wood Shavings, DMS: Dried maize silage, CS: Chopped straw

*al.* (2007) found no differences in atmospheric ammonia concentrations on the surface of litter between straw and wood shavings whether the litter was dry (1.59 vs. 1.75 ppm) or wet (1.12 vs. 1.77 ppm). Also, no effect of wheat straw and wood shavings on $NH_3$ emission was observed by Elwinger and Svensson (1996). The higher pH values on wet forms of wood shavings and lignocellulose than corresponding dry treatments was related to a higher volatile ammonia within the wet litter as also reported by previous research (Lerner, 1996; Alchalabi, 2002). However, the $NH_3$ emission on wet lignocellulose was lower than on wet wood shavings or straw. Also, Paulus (2010) observed, in an experimental study with rabbits' excreta, a reduction of ammonia emission to 50% on lignocellulose by absorbing $NH_3$, compared to straw. The values of pH and $NH_3$ on wet maize silage were lower than other wet bedding materials, which may be due to it containing lactic acid or perhaps due to it being changed weekly.

**Severity of foot pad dermatitis:** Of all the bedding materials tested, lignocellulose litter showed the lowest severity of FPD on dry or wet treatment (excluding wet maize silage). This could be related to its higher water absorbing capacity and also to the rapid release of water. These results are consistent with those found in more recent studies (Berk, 2007; Berk and Hinz, 2010). In contrast, chopped straw was associated with high FPD scores on dry treatment which may be due to higher moisture content in this litter. Mayne *et al.* (2007) found that long barley straw was associated with high foot pad scores on wet and dry treatments. Also, Ekstrand and Algers (1997) observed that the prevalence of FPD was higher in turkey flocks reared on straw than those reared on wood shavings. Recently, many studies in broilers demonstrated that chopped straw was associated with the highest severity scores (Berk, 2009b; Baere de *et al.*, 2009; Bilgili *et al.*, 2009). Nevertheless, McIlroy *et al.* (1987) and Bruce *et al.* (1990) found no significant difference in the occurrence of hock and breast lesions in broilers reared on straw or wood shavings in commercial flocks. The physical structure of litter, either fine (lignocellulose) or with sharp edges (chopped straw) may also contribute to lowering or increasing the incidence of FPD. Turkeys reared on fine particleboard were found to have a lower incidence of FPD than those

Table 3: External scores of FPD severity in turkeys housed on different litter materials over 28 days

| Litter | | Duration of treatment (day) | | | | | |
|---|---|---|---|---|---|---|---|
| Type | Form | 0 (n = 29) | 7 (n = 13) | 14 (n = 10) | 21 (n = 7) | 28 (n = 3) | 21/28 (n = 7)$^{1)}$ |
| Wood shavings | Dry | $0.07^{aA}\pm0.27$ | $0.38^{aB}\pm0.42$ | $0.70^{abBC}\pm0.35$ | $1.14^{aC}\pm0.24$ | $1.33^{a}\pm0.58$ | $1.29^{a}\pm0.39$ |
| | Wet* | | $3.58^{bB}\pm0.45$ | $4.45^{cC}\pm0.44$ | $5.07^{cC}\pm0.45$ | $5.00^{a}\pm0.50$ | $5.14^{c}\pm0.48$ |
| Lignocellulose | Dry | $0.07^{aA}\pm0.22$ | $0.23^{aA}\pm0.44$ | $0.39^{aA}\pm0.42$ | $0.64^{bA}\pm0.48$ | $0.50^{a}\pm0.50$ | $0.64^{b}\pm0.48$ |
| | Wet* | | $3.12^{bcB}\pm0.74$ | $3.80^{dC}\pm0.54$ | $4.00^{dC}\pm0.65$ | $2.83^{a}\pm0.76$ | $3.64^{d}\pm0.99$ |
| Chopped straw | Dry | $0.03^{aA}\pm0.19$ | $0.54^{aB}\pm0.43$ | $1.00^{bC}\pm0.62$ | $2.00^{aC}\pm1.26$ | $1.50^{a}\pm0.50$ | $2.07^{a}\pm1.21$ |
| | Wet* | | $3.46^{bB}\pm0.43$ | $4.35^{cC}\pm0.47$ | $4.64^{cdC}\pm0.38$ | $4.50^{a}\pm0.00$ | $4.64^{ce}\pm0.24$ |
| Dried maize silage | Dry | $0.07^{aA}\pm0.26$ | $0.38^{aAB}\pm0.58$ | $0.50^{abBC}\pm0.47$ | $1.00^{abC}\pm0.58$ | $1.33^{a}\pm0.29$ | $1.21^{a}\pm0.39$ |
| | Wet*(**) | | $2.85^{cB}\pm0.77$ | $3.50^{dC}\pm1.05$ | $3.86^{dD}\pm1.25$ | $2.83^{a}\pm1.26$ | $3.71^{de}\pm1.25$ |

*The birds were exposed to wet litter for 8 h/d. **Wet maize silage was changed weekly.

$^{1)}$Values of 4 animals (that were selected for histopathology of foot pads) on day 21 and of 3 animals on day 28 were averaged together.

$^{a,b}$Means in the same column with different superscripts are significantly different ($p<0.05$).

$^{A,B}$Means in the same row with different superscripts are significantly different ($p<0.05$)

Table 4: Histopathological scores of FPD severity in turkeys housed on different litter materials over 28 days

| Litter | | Duration of treatment (day) | | | | | |
|---|---|---|---|---|---|---|---|
| Type | Form | 0 (n = 3) | 7 (n = 3) | 14 (n = 3) | 21 (n = 4) | 28 (n = 3) | 21/28 (n = 7)$^{1)}$ |
| Wood shavings | Dry | $1.33^{aA}\pm2.31$ | $0.83^{aA}\pm0.29$ | $1.67^{aA}\pm0.58$ | $1.75^{abA}\pm0.96$ | $1.67^{aA}\pm0.58$ | $1.71^{a}\pm0.76$ |
| | Wet* | | $5.33^{aAB}\pm0.58$ | $5.00^{aA}\pm0.00$ | $5.75^{cB}\pm0.29$ | $5.83^{aAB}\pm0.76$ | $5.79^{d}\pm0.49$ |
| Lignocellulose | Dry | $1.83^{aA}\pm2.02$ | $0.67^{aA}\pm0.29$ | $1.00^{aA}\pm0.87$ | $0.63^{bA}\pm0.48$ | $0.67^{aA}\pm0.58$ | $0.64^{b}\pm0.48$ |
| | Wet* | | $4.33^{aA}\pm0.29$ | $5.17^{aAB}\pm0.29$ | $5.25^{cdB}\pm0.29$ | $4.17^{aA}\pm0.29$ | $4.79^{e}\pm0.64$ |
| Chopped straw | Dry | $0.50^{aAC}\pm0.87$ | $1.67^{aABC}\pm2.08$ | $1.50^{aA}\pm0.0$ | $3.50^{adB}\pm1.29$ | $3.00^{aCB}\pm0.00$ | $3.29^{c}\pm0.95$ |
| | Wet* | | $5.00^{aAB}\pm0.50$ | $5.33^{aAB}\pm0.76$ | $5.13^{cdB}\pm0.25$ | $5.83^{aAB}\pm0.29$ | $5.43^{de}\pm0.45$ |
| Dried maize silage | Dry | $1.33^{aA}\pm2.31$ | $1.67^{aA}\pm2.08$ | $1.17^{aA}\pm0.58$ | $1.88^{abA}\pm0.85$ | $2.17^{aA}\pm1.61$ | $2.00^{ac}\pm1.12$ |
| | Wet*(**) | | $4.83^{aAB}\pm0.76$ | $5.67^{aAB}\pm0.76$ | $5.38^{cdB}\pm0.48$ | $4.50^{aAB}\pm1.32$ | $5.00^{de}\pm0.96$ |

*The birds were exposed to wet litter for 8 h/d. **Wet maize silage was changed weekly.

$^{1)}$Values of 4 animals on day 21 and of 3 animals on day 28 were averaged together.

$^{a,b}$Means in the same column with different superscripts are significantly different ($p<0.05$).

$^{A,B}$Means in the same row with different superscripts are significantly different ($p<0.05$)

Table 5: Weight of turkeys (g) housed on dry or wet litter throughout the experiment

| Litter | | Duration of treatment (day) | | | | |
|---|---|---|---|---|---|---|
| Type | Form | 0 (n = 13) | 7 (n = 13) | 14 (n = 10) | 21 (n = 7) | 28 (n = 3) |
| Wood shavings | Dry | $387.0^{a}\pm33.5$ | $736.9^{a}\pm54.6$ | $1226.6^{a}\pm98.6$ | $1918.7^{a}\pm118.7$ | $2481.0\pm173.1$ |
| | Wet | $348.5^{b}\pm46.9$ | $646.5^{b}\pm92.9$ | $1078.4^{b}\pm163.1$ | $1631.3^{b}\pm185.3$ | $2070.0\pm157.1$ |
| Lignocellulose | Dry | $360.3^{bc}\pm42.5$ | $696.2^{ab}\pm80.6$ | $1192.9^{ab}\pm137.7$ | $1751.9^{ab}\pm155.0$ | $2346.3\pm136.3$ |
| | Wet | $363.8^{ab}\pm27.3$ | $691.2^{ab}\pm56.7$ | $1166.6^{ab}\pm84.6$ | $1747.7^{ab}\pm174.4$ | $2108.7\pm181.4$ |
| Chopped straw | Dry | $365.4^{ab}\pm45.9$ | $688.1^{ab}\pm73.5$ | $1171.4^{ab}\pm117.7$ | $1843.1^{a}\pm150.2$ | $2412.0\pm209.8$ |
| | Wet | $384.2^{a}\pm53.9$ | $714.2^{a}\pm98.9$ | $1185.6^{a}\pm155.0$ | $1838.3^{a}\pm231.8$ | $2425.7\pm204.1$ |
| Dried maize silage | Dry | $368.2^{ab}\pm39.5$ | $685.8^{ab}\pm65.8$ | $1181.8^{ab}\pm101.7$ | $1798.6^{ab}\pm152.5$ | $2402.7\pm248.9$ |
| | Wet | $384.8^{ac}\pm32.6$ | $713.0^{ab}\pm60.0$ | $1197.7^{a}\pm95.9$ | $1852.7^{a}\pm147.7$ | $2394.3\pm121.1$ |

$^{a,b}$Means in the same column with different superscripts are significantly different ($p<0.05$)

raised on coarse particleboard residue or hardwood shavings (Hester *et al*., 1997). Also, bedding materials with sharp edges such as chopped straw may contribute to FPD through its abrasive action (Bilgili, 2009). The type of litter material may affect the amount of moisture which is trapped within the litter (Berk, 2008). Accordingly, straw appears to trap moisture more readily and also has a considerable tendency toward caking formation as also reported by Bilgili *et al.* (2009). Pressing of straw by turkeys' feet probably resulted in the release of this trapped water which comes in contact with the skin of foot pads. The severity of FPD paralleled high litter moisture as indicated by the highly positive correlation of the external and histological scores with moisture contents of dry bedding treatments. In dry litter treatments (without adding water), straw was associated with the highest moisture content (about 31.2%) as well as with the highest FPD severity. This indicates that the severity of foot pad lesions begins to increase markedly when the litter moisture exceeds about 30%. It was also reported that moisture content in litter exceeding 35% often results in a higher incidence of foot pad dermatitis (Harms *et al*., 1977; Martland, 1984, 1985; Mayne *et al*., 2006a, 2007; Glebocka, 2008). Some studies found that the litter moisture should be maintained between 25-30% to reduce the prevalence of FPD (Jodas and Hafez, 2000; Glebocka, 2008). The increased foot pad scores on dry straw and the lower scores on lignocellulose were not related to higher or lower $NH_3$ concentrations on these litter treatments, but attributed to the moisture content and the capacity of litter to absorb or release water. It was found that the presence of volatile ammonia in the litter was not the cause of FPD (Mayne *et al.*, 2007; Youssef *et al.*, 2008).

The FPD scores on wood shavings and dried maize silage were similar on dry treatments. The same findings were also observed between wood shavings and straw on wet litter. The external FPD scores were lower on wetted maize silage but these results should be excluded due to the obligatory change of this litter. Comparing the external FPD scores on wet litter after one week from the onset of treatments and before the change of maize silage (Table 3), the scores were lower on wetted maize silage than wet wood shavings or wet straw. This suggests that wet maize silage may reduce FPD severity , but its drawbacks are high mould growth. Maize silage was reported to have a bactericide effect and can result in reduced counts and activity of bacteria in the shed. This is due to the low pH value and the lactic acid content of maize silage (Bosse and Meyer, 2007; Wilms-Schulze Kump, 2007), which may result in a lower incidence of FPD. However, the histopathological FPD scores on wet maize silage did not differ significantly from wet treatments of wood shavings or straw.

The severity of foot pad dermatitis was substantially higher on wet than on dry litter in each litter type, indicating that the high litter moisture is the major factor resulting in the development of FPD. In this study, the exposure of animals to wet litter for only 8 h/d was capable of provoking FPD. This period of exposure was suggested to simulate the litter quality in the field as about one third of the litter is very wet, especially around the drinkers and feeders.

**Animal performance:** The bedding material may have a little influence on the live performance as also reported by Bilgili *et al.* (2009) in broilers. On the contrary, Berk (2009a) found no effect of different litter types on the performance of male turkeys. The DM and pH of excreta did not show any differences between the birds, indicating that birds did not ingest the bedding materials especially maize silage or the amount consumed was insufficient to change pH or DM of the excreta. This also indicates that the difference in water intake between the birds is negligible.

According to the current results and those reported by others (Mayne *et al.*, 2007; Berk, 2008; Bilgili *et al.*, 2009), litter materials can influence the prevalence and severity of FPD. This effect may be directly associated with the ability of the litter to protect foot pads from continuous contact with moisture, which results in diminishing the softness of foot pads and susceptibility to irritation and inflammation. Therefore, the wet litter seems to be the major causative agent of FPD and the control of litter moisture is likely to be highly effective in minimising the incidence of FPD. The litter moisture can be controlled by good ventilation and maintenance of proper litter quality through regular turning of the litter or removal of wet litter and providing fresh dry bedding. Additionally, control of drinker design, humidity and correct choice of appropriate bedding material are also indicated. Moreover, feeding diets with a proper composition to avoid production of wet or sticky excreta should be considered.

**Conclusion:** The development and severity of FPD varied significantly between the bedding materials and correlated substantially to higher litter moisture content. The present results indicate that lignocellulose litter could reduce the severity of FPD, probably due to the higher binding capacity and also quick release of water (higher evaporation) from lignocellulose. Chopped straw may increase the incidence of FPD due to the higher moisture content resulting from lower water evaporation and caking formation. The physical structure of litter may also contribute to FPD. The ability of litter to bind and/or release water appears to be an important factor in the etiology of FPD. Exposure of animals to wet litter (27% DM) for only 8 h/d was sufficient to induce FPD. Thus, the litter moisture is the dominant factor affecting the development of FPD. The severity of foot pad lesions paralleled the high litter moisture and began to increase markedly at a moisture content exceeding 30%. Therefore, the moisture content in the litter should be kept lower than this percentage to minimise the prevalence and severity of FPD in turkeys.

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