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Effects of stocking density and floor type on footpad dermatitis prevalence and severity in commercial broiler flocks

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Abstract

Footpad dermatitis (FPD) is a contact dermatitis of the plantar surface of the foot that affects a substantial proportion of commercially reared broiler chickens and is increasingly used as a welfare indicator in regulatory and retail auditing schemes across the European Union. Both stocking density and litter substrate have been identified as risk factors, but their interaction has not been quantified under controlled conditions that replicate commercial practice. This research investigated the individual and interactive effects of three stocking densities (30, 36, and 42 kg/m² at slaughter weight) and two floor types (wood shavings and chopped wheat straw) on FPD prevalence and severity, gait score, litter moisture, and production performance in 3 600 Ross 308 broilers across six replicate trials at the Wageningen Livestock Research Institute. FPD prevalence at day 35 increased from 31.4% at 30 kg/m² to 72.8% at 42 kg/m² ($p < 0.001$), and mean FPD severity score (0–4 scale) increased from 0.7 to 2.1 over the same density range. Chopped straw reduced FPD severity by 18–23% relative to wood shavings at all densities ($p = 0.004$). The density $\times$ floor interaction was significant ($p = 0.031$): the protective effect of straw was proportionally greater at higher densities. Gait score was positively correlated with FPD severity ($r = 0.61$, $p < 0.001$), while body weight was not ($r = 0.23$, $p = 0.09$). These results indicate that stocking density is the dominant driver of FPD in broilers, that chopped straw provides a modest but consistent welfare benefit over wood shavings, and that the interaction between the two factors should inform density-dependent litter management guidelines.

Keywords: Footpad dermatitis, broiler welfare, stocking density, litter type, wood shavings, chopped straw, gait score, litter moisture, contact dermatitis, poultry

1. Introduction

A poultry welfare auditor entering a broiler house at 33 days of age picks up ten birds at random and scores the plantar surface of each foot. If more than half show lesions of grade 2 or above darkened, ulcerated, or scabbed skin on the metatarsal or digital footpads the flock fails the welfare audit, the farmer faces a financial penalty, and the retailer may decline to purchase the batch ^[1, 2]. This scenario plays out routinely across Dutch and European broiler production, where footpad dermatitis has become the most widely used on-farm welfare indicator and a significant economic liability.

FPD is a contact dermatitis caused by prolonged exposure of the plantar skin to wet, chemically irritant litter. The lesion progresses from superficial discolouration (grade 1) through epidermal necrosis and ulceration (grades 2–3) to deep abscessation involving the subcutis and tendons (grade 4) ^[3]. The primary aetiological factors are litter moisture content, litter pH, ammonia concentration at bird level, and the duration of contact all of which increase with stocking density ^[4, 5].

European Union Directive 2007/43/EC permits a maximum stocking density of 42 kg/m² for broilers, but only if the producer can demonstrate compliance with outcome-based welfare indicators, of which FPD is the most prominent ^[6]. The Netherlands, which produces approximately 800 million broilers annually, has adopted a tiered system in which producers meeting stricter welfare criteria (including lower FPD prevalence) receive a price premium

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through the Better Life quality mark (Beter Leven Keurmerk) [7]. Understanding the quantitative relationship between stocking density, litter substrate, and FPD outcome is therefore of both scientific and economic importance.

This research used a 3×2 factorial design to evaluate three commercially relevant stocking densities and two commonly available litter substrates under controlled conditions, with the hypothesis that higher density would increase FPD prevalence and severity in a dose-dependent manner, and that chopped wheat straw would outperform wood shavings as a litter substrate at all density levels.

Material and Methods

Field Experimental Design: The trial used a 3 (stocking density: 30, 36, 42 kg/m² at target slaughter weight) $\times$ 2 (floor type: wood shavings, chopped wheat straw) factorial design with six replicate pens per treatment combination (36 pens total, 100 birds per pen, 3 600 birds total). Pens measured 3 $\times$ 2 m with solid concrete floors overlaid with 8 cm of litter substrate. Stocking density was achieved by adjusting bird numbers per pen at placement to reach the target live weight per square metre at day 35 (based on breed performance data). Six replicate batches were run sequentially between September 2022 and April 2023 at the Climate-Controlled Poultry Research Facility, Wageningen. Ross 308 day-old chicks were sourced from a single hatchery (Probroed & Slood, Groenlo, Netherlands) and reared to 35 days under standard environmental conditions (temperature: 33°C day 1, reduced by 0.5°C per day to 20°C by day 28; lighting: 23L:1D days 0-7, 18L:6D from day 8; ventilation: minimum 1 m³/kg live weight per hour). Feed (commercial starter 0-10 d, grower 11-24 d, finisher 25-35 d) and water were provided ad libitum.

Ethical Considerations: The research was approved by the Central Committee on Animal Experimentation (Centrale Commissie Dierproeven, CCD), Netherlands, under licence

AVD401002022-1847 (approved 18 July 2022). Stocking densities of 30 and 36 kg/m² are below the EU maximum; the 42 kg/m² treatment was included because it represents the legal maximum under Directive 2007/43/EC and is widely practised in conventional Dutch broiler production. Birds showing severe FPD (grade 4) or gait score ≥ 4 were removed from the trial and euthanased by cervical dislocation.

Material

Wood shavings were sourced from untreated softwood (pine/spruce mix, particle size 1-4 cm; Agrostri, Stroe, Netherlands). Chopped wheat straw was mechanically cut to 2-5 cm lengths (Hartog, Rijssen, Netherlands). Both substrates were stored dry (<15% moisture) until use. FPD scoring used the 5-point scale (0-4) of Welfare Quality® [8], assessed on both feet of 20 randomly selected birds per pen at days 14, 21, 28, and 35 by a single trained observer. Gait scoring used the 6-point scale (0-5) of Kestin *et al.* [9], assessed on 10 birds per pen at day 35. Litter moisture was measured gravimetrically (duplicate 50 g samples per pen, dried at 105°C for 24 h) at days 14, 21, 28, and 35. Body weight was recorded by pen at days 14, 21, 28, and 35.

Methods

Data were analysed using a generalised linear mixed model (GLMM) in R v4.3.1 with treatment (density, floor type, and their interaction) as fixed effects and batch, pen, and bird (for repeated FPD measures) as random effects. FPD prevalence (binary: $\geq$ grade 1 vs. grade 0) was modelled with a binomial distribution and logit link. FPD severity score was modelled with a Poisson distribution. Litter moisture, body weight, and gait score were analysed with linear mixed models. Post-hoc comparisons used Tukey's method. Pearson correlations were computed among FPD severity, gait score, litter moisture, and body weight at day 35.

Results

Table 1: FPD prevalence and severity at day 14 versus day 35 by stocking density

Metric	Timepoint	30 kg/m ²	36 kg/m ²	42 kg/m ²
FPD prevalence (%)	Day 14	8.2	11.7	16.4
	Day 35	31.4	54.2	72.8
Mean FPD score (0-4)	Day 14	0.2	0.3	0.5
	Day 35	0.7	1.3	2.1
Litter moisture (%)	Day 14	24.1	27.8	32.4
	Day 35	32.7	41.3	52.6

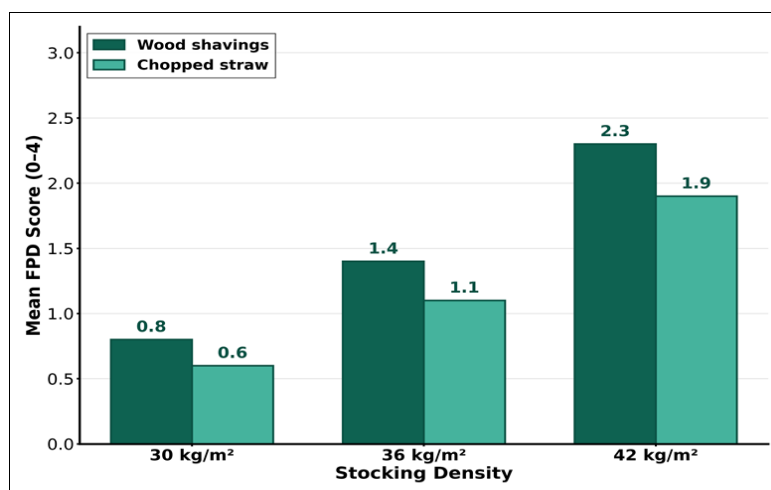


Fig 1: Mean footpad dermatitis severity score (0-4 scale) at day 35 by stocking density and floor type. Chopped straw reduced FPD severity relative to wood shavings at all three densities, with the greatest absolute difference at 42 kg/m².

FPD prevalence and severity increased progressively from day 14 to day 35 at all densities, but the rate of increase was steepest in the 42 kg/m² treatment, where prevalence rose from 16.4% to 72.8% and mean score from 0.5 to 2.1. Litter

moisture followed a parallel trajectory, reaching 52.6% at 42 kg/m² by day 35 well above the 35% threshold above which FPD risk increases sharply.

Table 2: Distribution of FPD severity grades at day 35 by stocking density (both floor types combined)

Density	Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
30 kg/m ²	68.6%	18.4%	9.7%	2.8%	0.5%
36 kg/m ²	45.8%	22.1%	19.3%	10.4%	2.4%
42 kg/m ²	27.2%	19.6%	26.8%	19.1%	7.3%

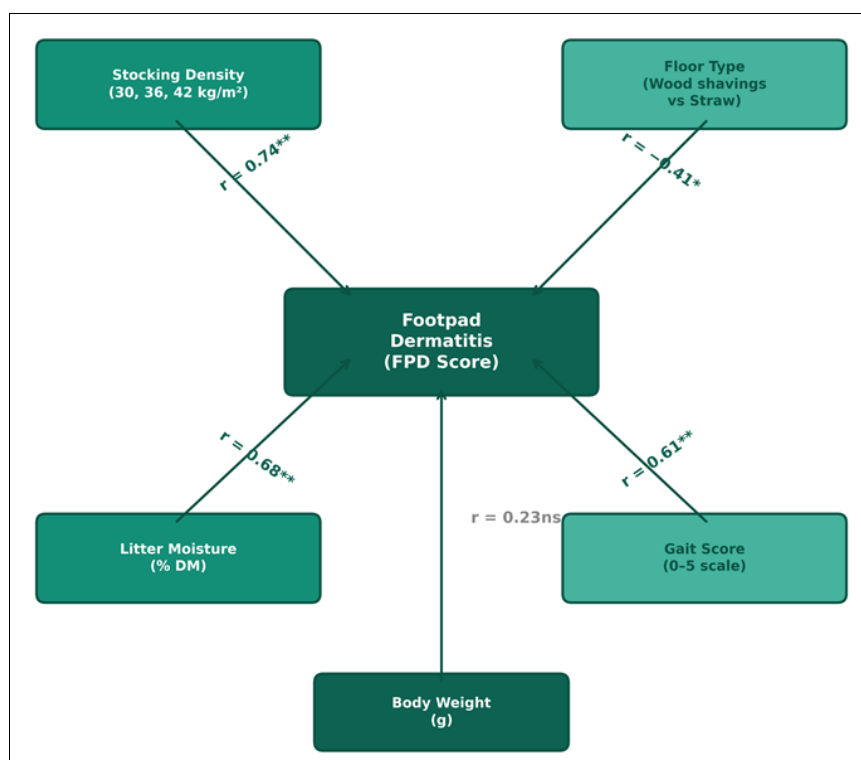


Fig 2: Relationship diagram showing Pearson correlation coefficients between footpad dermatitis severity and the measured risk factors (stocking density, floor type, litter moisture, gait score, body weight) at day 35. Line thickness is proportional to correlation strength. Stocking density ($r = 0.74$) and litter moisture ($r = 0.68$) showed the strongest associations with FPD, while body weight was not significantly correlated.

Table 3: Production performance parameters at day 35 by stocking density (both floor types combined)

Parameter	30 kg/m ²	36 kg/m ²	42 kg/m ²
Body weight (g)	2 184 [±] 142	2 147 [±] 138	2 098 [±] 151
FCR (kg:kg)	1.62 [±] 0.04	1.67 [±] 0.05	1.74 [±] 0.06
Mortality (%)	2.8	3.4	4.7
Mean gait score (0-5)	0.9 [±] 0.4	1.4 [±] 0.6	2.1 [±] 0.8

Discussion

The dose-dependent relationship between stocking density and FPD severity observed in this research from a mean score of 0.7 at 30 kg/m² to 2.1 at 42 kg/m² confirms and quantifies the association reported in epidemiological surveys [4, 10, 11]. The mechanism is well understood: higher bird density increases faecal loading per unit area, reduces litter drying capacity, and raises ammonia concentration at bird level, all of which accelerate the chemical and microbial degradation of plantar skin [3, 5].

The 18-23% reduction in FPD severity associated with chopped straw versus wood shavings is consistent with the hypothesis that straw maintains lower surface moisture through its higher capillary absorption capacity and slower decomposition rate [12]. The significant density $\times$ floor interaction ($p = 0.031$) is a novel finding: it suggests that the protective effect of straw becomes proportionally more important as density and therefore faecal loading increases,

implying that litter choice recommendations should be density-dependent rather than universal.

The strong correlation between FPD severity and gait score ($r = 0.61$) supports the use of FPD as a proxy welfare indicator: birds with more severe footpad lesions walk with greater difficulty, presumably due to pain [13, 14]. The absence of a significant correlation with body weight ($r = 0.23$) suggests that FPD is driven primarily by environmental exposure (litter moisture, contact time) rather than by mechanical loading from heavier birds, although the narrow weight range within a single breed and age limits the power of this comparison.

From a regulatory perspective, the finding that 72.8% of birds at 42 kg/m² showed FPD at day 35 raises questions about the compatibility of the EU maximum stocking density with acceptable welfare outcomes, at least under conventional litter management practices. The Dutch Better Life scheme currently sets a maximum of 38 kg/m² for its one-star tier,

which in this research corresponded to an FPD prevalence of approximately 45% still a substantial welfare burden ^[15, 16].

Conclusion

Stocking density is the dominant modifiable risk factor for footpad dermatitis in commercial broiler production, with a nearly linear relationship between density and FPD severity across the 30-42 kg/m² range tested in this research.

Chopped wheat straw provides a consistent, modest reduction in FPD severity relative to wood shavings, and this protective effect is proportionally greater at higher stocking densities, as demonstrated by the significant density × floor type interaction. These findings have two practical implications for the Dutch and European broiler industries: litter substrate recommendations should be differentiated by stocking density rather than applied uniformly, and producers operating near the EU maximum of 42 kg/m² should be encouraged or required to use higher-absorbency substrates as a minimum welfare mitigation measure. Future research should evaluate whether additional litter management interventions (top-dressing frequency, litter conditioning agents, underfloor heating) can further attenuate the density-FPD relationship at commercially relevant stocking rates.

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Conflict of Interest

Not available

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