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A Cross-Sectional Study on the Prevalence of Footpad Dermatitis in Canadian Turkeys

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Footpad dermatitis (FPD) can be a prevalent issue in commercial turkey production. This study aimed to identify the bird, housing, and management-related factors associated with the prevalence of FPD in the Canadian turkey flocks. A questionnaire and flock health scoring system were developed and disseminated to ∼500 commercial turkey farmers across Canada. Farmers were asked to score FPD on a subset of 30 birds within their flock using a 0–2 scoring scale based on severity. The prevalence of FPD in the flock was calculated as the percentage of affected birds (score 1 or 2). A multivariate linear regression modeling was used to identify the factors associated with the prevalence of FPD. Four variables were included in the final model and accounted for 26.7% of the variation in FPD prevalence among the flocks. FPD prevalence was higher with increasing bird weight (3.6 ± 1.13), higher in flocks bedded with straw (12.1 ± 7.9), higher in flocks where birds were picked up less frequently during daily inspections (11.6 ± 8.10), and higher in flocks that used feed/water additives to reduce litter moisture (20.5 ± 10.59). These findings are a preliminary exploratory assessment of risk factors related to FPD prevalence on Canadian turkey farms. While these findings emphasize the importance of litter management and the stockperson, estimates and *P*-values from this study should be interpreted with caution. Further, longitudinal studies with the identified variables are required to better determine their influence on FPD.

Keywords: pododermatitis, footpad lesions, risk factors, management, stockmanship, animal well-being and welfare, poultry

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INTRODUCTION

Galliformes are bipedal and when bipedal animals walk, one foot supports the body stance, while the other foot facilitates the forward movement (Muir et al., 1996). This movement pattern stresses the importance of foot health during locomotion. When normal standing and walking are disrupted by a foot health problem, such as a disease (acute or chronic), disorder, trauma, or injury, the body function will suffer (Hawke and Burns, 2009).

Footpad health can decline in commercial (Erasmus, 2017a) and organic (Freihold et al., 2019) turkey production systems. Lesions on the plantar area and the metatarsal footpads start as broken epidermis/skin (Shepherd and Fairchild, 2010). These issues can start

in as early as the first of life and serve as a starting point for local inflammation (dermatitis), which can develop into ulcers, and potentially secondary bacterial infections and lameness (Clark et al., 2002; Erasmus, 2017b) throughout the growing period in male and female turkeys (e.g., ∼11–17 weeks of age in Canada).

A foot health issue of particular importance in turkey production is footpad dermatitis (FPD). The footpads become swollen, discolored, and hard (Sinclair et al., 2015). As early as 6 weeks of age, diagnosable FPD can be common in a flock (Mitterer-Istyagin et al., 2011). At slaughter, it can be common for birds in commercial (Ekstrand and Algers, 1997; Krautwald-Junghanns et al., 2011; Allain et al., 2013; Da Costa et al., 2014) and organic (Hocking and Wu, 2013) flocks to have varying degrees of FPD. As bipedal turkeys need both feet to stand and walk, and FPD tends to affect both feet with the same severity (Ekstrand and Algers, 1997), it is likely, not easy to favor one limb to avoid potential discomfort and pain due to inflammation or alleviate impaired function (Martland, 1984; Ekstrand and Algers, 1997; Hocking and Wu, 2013; Weber Wyneken et al., 2015).

Given the evidence that FPD is painful (Martland, 1984; Hocking and Wu, 2013; Sinclair et al., 2015; Weber Wyneken et al., 2015), it is used as an animal welfare indicator in research, on farms, and in slaughterhouses (Watanabe et al., 2013). To illustrate the importance of FPD, United Kingdom supermarkets have identified FPD as a key welfare indicator in turkeys (Clark et al., 2002), and most animal welfare audits in Europe and the United States consider FPD an indicator of impaired welfare (Berg, 2004; Berg and Algers, 2004). In Canada, producers are provided with background information about FPD as it relates to litter quality and stocking density, but there is no formal assessment or auditing of FPD at this time (Turkey Farmers of Canada, 2018). In addition to the implications for animal well-being, FPD is a key issue for food safety, farm productivity, and financial profitability (Shepherd and Fairchild, 2010). Moreover, to reduce pain, turkeys affected by FPD are less active and exhibit less variation in their behavior patterns (Martland, 1984; Hocking and Wu, 2013; Weber Wyneken et al., 2015). This may result in a lower feed intake, which ultimately reduces growth rate and body weight and increases contact time with the litter, which has implications for further contact dermatitis and increased mortality (Martland, 1984; Mayne et al., 2007).

The etiology of FPD is known to be multifactorial (Shepherd and Fairchild, 2010). Predisposing factors, such as genetics, bird age and body weight, diet and excreta composition, bedding material, and management have been identified as the main contributing factors as birds stand, rest, and walk-in floor barns at stocking densities that allow the floor (and any bedding on it) to quickly accrue with feathers, waste feed, and excreta (Monckton et al., 2020). However, reported on-farm FPD assessments of turkeys are typically from Europe, where genetic line, housing, and management practices can differ compared with North America (Martrenchar et al., 2002; Krautwald-Junghanns et al., 2013). Currently, investigations of risk factors associated with the prevalence of FPD in North American turkey production systems are lacking. Therefore, this study aimed to identify the bird, housing, and management characteristics associated with the prevalence and severity of FPD on Canadian turkey farms.

MATERIALS AND METHODS

This study was part of a larger cross-sectional study to describe the housing and management practices of commercial turkeys in Canada (van Staaveren et al., 2020), and identify housing and management risk factors for FPD and pecking injuries. In brief, farmers were asked to 1) complete a questionnaire about their housing and management practices for a turkey flock on their farm and 2) perform simplified health scoring on a random subset of 30 turkeys in their flock. The data from both the questionnaire and health scoring were then used to identify the practices associated with FPD using regression modeling. The present study reports the prevalence of FPD and related risk factors on Canadian farms.

TABLE 1 | A summary of the housing and management information on Canadian turkey flocks obtained from the survey questionnaire.

Background information	Farmer demographics Farmer experience Farm size and production Veterinary relationship
Flock characteristics	Flock sex, strain, age, average weight Physical alterations Stocking density Flock certifications (i.e., RWA[a])
Flock housing	Housing system Flooring Enrichment
Lighting	Lighting type, intensity, evenness Dark period (length, intermittent lighting)
Air quality	Ventilation type Ventilation rate Target temperature and humidity Ammonia and dust
Litter management	Litter type, depth, condition Practices for maintaining litter quality Reuse of litter Litter products
Feeding	Feed structure Diet changes Feed source Feed supplements Animal by-products
Watering	Drinker type Water source Water sanitizing products Water supplements Water quality Flock water consumption
Flock health	Barn cleaning Biosecurity practices Flock inspections Vaccines and medications Flock diseases Mortality and culling

[a] *Raised without antibiotics.*

Survey Design

The survey to identify risk factors for FPD contained two main components such as a questionnaire and an FPD scoring guide. The questionnaire consisted mainly of (semi-) closed questions and covered sections on general farm information and experience, housing (i.e., lighting, air quality), litter management, feed and water management, flock health and biosecurity, and farmer perceptions. The farmers were asked to fill in the questionnaire for a flock of birds currently on their farm. A more detailed breakdown of the questionnaire sections and subsections can be found in **Table 1**. The questionnaire was tested by industry collaborators and was estimated to take ∼1–1.5 h to complete. The questionnaire was further reviewed by the members of the national organization representing turkey farmers of Canada, the Turkey Farmers of Canada (TFC), poultry veterinarians, feed sales representatives, and turkey farmers to ensure the questions and wording were understandable and accurately reflected the commercial settings.

The FPD scoring guide was designed in collaboration with the industry stakeholders to ensure that it was feasible to complete in a commercial turkey production setting. The scoring guide was used by farmers to assess FPD in the flock corresponding with the information from the questionnaire. FPD was scored by each farmer on a random subset of 30 birds in their flock on a 3-point scale according to the severity of the condition based on visual (**Figure 1**) and written (**Table 2**) descriptions, adapted from Knierim et al. (2016). The proportion of the footpad affected by FPD was used to differentiate between lesion scores (i.e., in the most severe category, more than half of the footpad is affected; Knierim et al., 2016). The footpad images used in the visual aid were obtained from cleaned turkey feet at slaughter. To try and account for the cleanliness of the scoring images, farmers were asked to lightly brush any loose litter that might obscure FPD lesions from the footpad before scoring. If the two footpads of a bird differed in severity, the farmers were instructed to record the more severe of the two scores. Farmers did not receive any formal training on the scoring system, but they were given visual and written instructions for selecting a random sample of birds and conducting the scoring of the footpads.

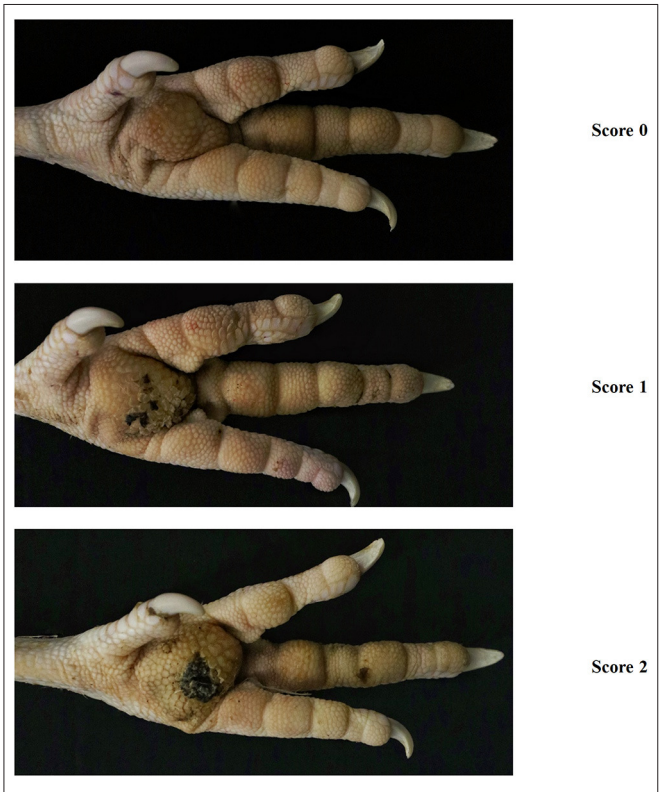

FIGURE 1 | Photographs of foot lesions from turkeys at slaughter used as visual descriptions in the footpad dermatitis (FPD) scoring system.

Survey Distribution

The turkey farmers across Canada were invited to participate in the survey through the TFC in April 2019. Each farmer received a package containing a cover letter, questionnaire, health scoring guide with instructions, and return envelope with a unique code to collect all responses anonymously. All documents were made available in English and French. Additionally, farmers were provided the opportunity to fill in the questionnaire online *via* Qualtrics® (Qualtrics, Provo, UT, USA). The reminders were sent out through the TFC until the end of data collection in December 2019. As an incentive and thanks for participating, farmers received a $10 CAD gift card for a popular Canadian coffee franchise. This study was approved by the University of Guelph Research Ethics Board (REB 19-02-015) and the University of Guelph Animal Care Committee (AUP 3782), Ontario, Canada.

Statistical Methods

Due to the lower number of birds with an FPD score of 2 (most severe) (**Table 3**), the flock-level prevalence of FPD for analysis was estimated as the percentage of birds in a flock with a score >0. Data obtained from the questionnaires were used to determine potential factors associated with FPD prevalence in a flock. The statistical analyses were performed in RStudio (version 3.5.3., R Core Team, Vienna, Austria, 2019).

TABLE 2 | Simplified scoring system for farmers to score footpad dermatitis (FPD) on a subset of 30 turkeys in their flock.

Score	Footpad condition
0	No signs of footpad dermatitis Intact, soft skin without swelling or necrotic areas Litter can be brushed off footpad easily
1	Hard or dense skin Small necrotic areas on <25% of the footpad Litter cannot be removed easily from footpad
2	Large necrotic areas and/or swelling on >25% of the footpad Litter adhered to footpad and cannot be removed easily

TABLE 3 | Descriptive characteristics of 63 commercial turkey flocks were used in this analysis.

	N[a]	Mean (SD)	Median (IQR)
Flock age (wks)[b]	63		
Toms	24	11 (3)	12 (IQR: 10 – 14)
Hens	39	11 (7)	9 (IQR: 7 – 12)
Average bird weight (kg)[c]	63		
Toms	24	9 (3)	9 (IQR: 7 – 11)
Hens	39	6 (3)	5 (IQR: 4 – 8)
Flock size[d]	63		
Toms	24	5,885 (4,282)	4,350 (IQR: 2,198 – 10,450)
Hens	39	8,030 (5,063)	7,380 (IQR: 4,560 – 11,284)
FPD prevalence (%)[e]			
Score 0	1,175	62 (34)	73 (IQR: 33 – 90)
Score 1	539	29 (25)	20 (IQR: 7 – 47)
Score 2	176	9 (20)	0 (IQR: 0 – 10)
Score 1 + Score 2	715	38 (34)	27 (IQR: 10 – 67)

Data are presented as the mean ± SD and the median with associated interquartile range (IQR).
[a]Number of flocks (age, weight, and flock size) or the number of birds (FPD prevalence only).
[b]Age of the flock in weeks at the time of survey completion.
[c]Average weight of an individual bird in the flock in kilogram at the time of survey completion.
[d]Size of the flock in the number of birds at the time of survey completion.
[e]Flock level prevalence of the different FPD severity scores from the 63 surveyed flocks.

Model Building

Data collected from the questionnaire were entered into Excel using manual double entry and checked for errors. The variables with many missing values or insufficient variation (e.g., a binary variable with a proportion of responses approximately >0.85 in one category) were excluded from the further investigation (Decina et al., 2019). Some variables underwent retrospective collapsing of categories to remove the unused or infrequent categories. After this screening, a total of 19 variables remained and progressed to the univariate analysis.

In the univariate analysis, variables that had a $p \leq 0.25$ or were considered biologically relevant were retained for further analysis. This *P*-value was chosen based on similar poultry risk factor analysis for feather damage (Decina et al., 2019) and FPD (Martrenchar et al., 2002). The variables were tested for collinearity using Pearson correlations. Strong correlations ($r > 0.5$) were considered to indicate redundant variables, and only one of these variables was retained in the multivariate analysis. To illustrate, the flock age was highly correlated with flock weight, stocking density, and target temperature. We chose flock weight to be retained in the multivariate analysis because bird weight has important biological implications for FPD development (Tullo et al., 2017). After assessing collinearity, 16 predictor variables were included in the multivariate analysis using a mixed linear regression model with a forward selection approach. The variables that were significant ($P \leq 0.05$) and/or contributed to a higher adjusted R^2 were included in the final model. Relevant interactions among the included predictor variables were also tested.

Model diagnostics to assess the normality of the residuals were conducted using a QQ-plot. The homogeneity of variance was graphically evaluated using a scatterplot of the studentized residuals against the predicted values. Collinearity was assessed using the variance inflation factor (VIF). The outliers were identified using a boxplot of the model residuals, and Cook's distance was used to investigate the influential data points.

RESULTS

Response Rate

In this study, 500 surveys were sent to turkey farmers across the country. The response rate was ∼20% (101 responses). Of the 101 responses, 66 were completed surveys with scoring (13.2%), and 35 were incomplete (7.0%) where the respondents indicated that they are not currently producing turkeys or did not complete the scoring portion of the survey. Three surveys were excluded from the analysis due to incorrect interpretation of the instructions, which left 63 surveys to be used in the risk factor analysis.

General Flock Information

Of the flocks included in the risk factor analysis, 39 were hen flocks (61.9%), and 24 flocks were tom flocks (38.1%). The FPD prevalence (score > 0) for the surveyed flocks is shown in **Figure 2**.

The information on flock age, bird weight, flock size, and FPD prevalence can be found in **Table 3**. A detailed description of the flocks included in this study and their housing and management practices can be found in van Staaveren et al. (2020).

Univariate Analysis of Factors Associated With FPD

The variables associated at a liberal significance level ($\alpha = 0.25$) or biologically relevant to FPD at the univariate analysis level are presented in **Table 4**. These variables were related to the

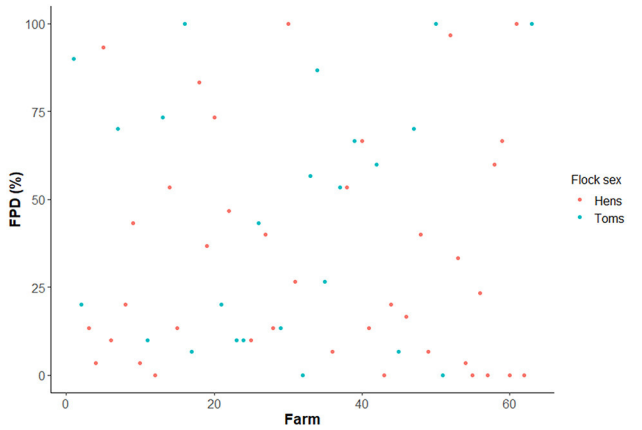

FIGURE 2 | Percentage of birds affected with FPD (score > 0) in the scored subsets of the surveyed flocks ($N_{Flocks} = 63$).

bird characteristics, such as sex, physical alterations, age, and weight. There were also several variables related to litter and litter management (e.g., litter type, litter tilling, and adding dry bedding) and housing (e.g., housing system and drinker type).

Multivariate Analysis of Factors Associated With FPD

Average bird weight, litter type, picking up birds during inspections, and feed/water additives were included in the final model and accounted for 26.7% of the variation in FPD prevalence among flocks (**Table 5**). Increasing average weight was associated with an increased prevalence of FPD. Additionally, the use of straw (vs. wood shavings) and not picking up birds during routine inspections tended to be associated with a higher prevalence of FPD. Interestingly, in flocks where feed/water additives were used to reduce litter moisture, the prevalence of FPD tended to be higher than those that did not use additives.

DISCUSSION

Footpad dermatitis is a well-known health and welfare issue of turkey (Shepherd and Fairchild, 2010). WWhen not treated through appropriate management, it can lead to FPD affecting almost 100% of birds to some degree on one or both feet, (Allain et al., 2013; Krautwald-Junghanns et al., 2013; Da Costa et al., 2014), making movement potentially uncomfortable, irritating, or even painful (Sinclair et al., 2015; Weber Wyneken et al., 2015). However, there is relatively little published information on the severity and prevalence of FPD in turkeys in North America (Da Costa et al., 2014; Erasmus, 2017b) even though North America is a major contributor to the global turkey industry (Windhorst, 2006). To add information to the North American prevalence of FPD in turkeys, we conducted a survey on housing and management factors associated with FPD in turkey flocks in Canada using farmer self-reported FPD scores.

The median prevalence of FPD across both tom and hen flocks was 27% [interquartile range (IQR): 10–67%] across 63 flocks. This is lower than the prevalence of FPD reported in other studies, however, this could be due to the reason that these studies are typically being conducted at slaughter (Ekstrand et al., 1997; Krautwald-Junghanns et al., 2011; Allain et al., 2013; Da Costa et al., 2014). The factors most strongly associated with FPD were increasing bird weight, using straw litter, infrequently picking up birds during inspections, and using feed or water additives to reduce litter moisture.

The current study involved both hen and tom flocks reared for different median target weights (hens: 6.5 kg, toms: 16.0 kg, van Staaveren et al., 2020). It is well-established that the prevalence and severity of FPD increase with both bird age and weight. This is understandable as birds gain weight as they get older ($r = 0.92$ in the current study), and so to avoid issues with collinearity, weight was included in the model as a biological consequence of both flock sex and age. Using bird weight instead of age also improved the adjusted R^2 of the model, which reinforced our choice.

Flock sex passed the univariate stage ($p = 0.15$) but was not included in the final multivariate model. At the univariate level, tom flocks were found to have a higher FPD prevalence than hen flocks (estimate: $+12.5 \pm 8.66\%$). This can be expected in North America since toms are grown at a higher per weight density (National Farm Animal Care Council, 2016), and so these larger birds consume more feed and water. This results in more excreta (and more watery) potentially leading to worse litter quality which is a factor in the development of FPD (Youssef et al., 2011). It is also possible that we found a higher prevalence in tom flocks due to the cross-sectional nature of this study and the lack of restriction placed on the flock age to make the study as inclusive as possible. The hen flocks that were surveyed had a younger median age (9 weeks) and a lighter median weight (5 kg) than tom flocks (12 weeks and 9 kg, respectively). The pressure exerted by heavier birds on the footpads increases contact with excreta-soiled litter (Shepherd and Fairchild, 2010). Since our surveyed tom flocks were older and heavier, this may have contributed to the higher observed prevalence.

In poultry studies, the influence of sex on FPD is largely inconclusive because of the inconsistent results which may suggest that sex is not an important contributor to FPD prevalence (Shepherd and Fairchild, 2010). Several European studies of turkey FPD prevalence demonstrate that hens are typically more severely affected than toms (Martrenchar et al., 2002; Krautwald-Junghanns et al., 2011; Bergmann et al., 2013). However, the rearing conditions (e.g., mixed-sex flocks) and other management decisions (e.g., diet and strain) are different in European systems compared to North America. For example, wheat-based diets are more commonly used in Europe compared with North America which is dominated by corn-soybean based diets (Wood and Willems, 2014). Wheat-based diets have a larger non-starch polysaccharide component that decreases digestibility and increases water intake, and consequently excretion which may influence the development of FPD (Patterson et al., 1989; Wood and Willems, 2014). So, there may be other underlying

TABLE 4 | Explanatory variables ($p \leq 0.25$ or biologically relevant) associated with FDP in turkeys at the univariate analysis level.

Variable	*N* (%)	Estimate (SE)	*P*-value
Flock sex			0.1548
Hens	39 (61.9)	Referent	
Toms	24 (38.1)	12.479 (8.662)	
Toe trimming			0.09163
No	29 (47.5)	Referent	
Yes	32 (52.5)	−14.705 (8.576)	
Dew claw removal			0.02859
No	47 (76.7)	Referent	
Yes	14 (23.3)	−22.477 (10.016)	
Growing system			0.6214
Brood and move	45 (75.0)	Referent	
Brood to finish	15 (25.0)	5.037 (10.145)	
Flock age (weeks)	63 (100.0)	1.1271 (0.7706)	0.1487
Stocking density (kg/m^2)	63 (100.0)	0.7585 (0.2855)	0.01011
Flock weight (kg)	63 (100.0)	3.680 (1.136)	0.001941
Housing system			0.2796
Power	41 (66.1)	Referent	
Natural	21 (33.9)	−9.752 (8.938)	
Target temperature (°C)	63 (100.0)	−1.9320 (0.7705)	0.01493
Litter type			0.1717
Wood shavings	34 (54.0)	Referent	
Straw	29 (46.0)	11.687 (8.451)	
Number of methods to check litter quality	63 (100.0)	−7.444 (4.834)	0.1288
Adding dry bedding			0.1641
No	10 (16.4)	Referent	
Yes	51 (83.6)	16.33 (11.590)	
Adding heat			0.7888
No	40 (65.0)	Referent	
Yes	21 (35.0)	−2.468 (9.173)	
Litter tilling			0.2945
No	52 (85.2)	Referent	
Yes	9 (14.8)	−12.885 (12.182)	
Feed/water additives to reduce litter moisture			0.02585
Yes	10 (16.4)	Referent	
No	51 (83.6)	−25.82 (11.300)	
Feed supplements (e.g., vitamins, grit)			0.1988
Yes	30 (52.6)	Referent	
No	27 (47.4)	−11.64 (8.95)	
Drinker type			0.9130
Closed	44 (71.0)	Referent	
Open	18 (29.0)	1.044 (9.510)	
Picking up birds during inspections			0.1075
Half the time or more	28 (45.2)	Referent	
Never/sometimes	34 (54.8)	13.936 (8.528)	
Cumulative mortality rate (%)	63 (100.0)	3.836 (1.574)	0.01795

N represents the number of flocks where a response was provided.

factors that make comparisons difficult between North America and Europe.

In tom flocks, a positive correlation (0.22) between body weight gain and severity of FPD has been reported (Da Costa et al., 2014). Similarly, we found that a 1 kg increase in average body weight was associated with a 3.6% higher prevalence of FPD, regardless of the sex of the flock. The heavier birds are typically older and have spent more time on the litter which can

TABLE 5 | Final multivariate linear regression model for FPD prevalence in turkey flocks in Canada (alpha = 0.05, adjusted $R^2 = 0.2148$, $p = 0.003347$, $N_{Flock} = 60$).

Variable	Estimate	Standard Error	*P*-value
Intercept	18.881	14.839	0.20851
Flock weight (kg)	3.584	1.133	0.002239
Litter type			0.075398
Wood shavings	Referent		
Straw	12.136	7.924	
Picking up birds during inspection			0.082570
Half the time or more	Referent		
Never/sometimes	11.590	8.099	
Feed/water additives to reduce litter moisture			0.058101
Yes	Referent		
No	−20.488	10.591	

play a large role in the development of FPD (Tullo et al., 2017). However, FPD lesions can heal over time in the appropriate environmental conditions (15 days for complete healing; Mayne et al., 2007), which may lead to a reduced prevalence/severity of FPD in birds with longer growing periods. Toms have a longer growing period than hens so they may have more time for lesions to heal which may explain some of the inconsistencies with regards to the effect of sex on FPD as it is confounded with other productions factors. The interconnections between flock sex, age, and weight are difficult to disentangle and have further connections to important management aspects, such as growing period, feed composition, geographic area, and litter quality.

The quality of stockmanship has an undeniable connection with animal welfare (Rushen and Passillé, 1992), but this aspect has received little attention in poultry farming. We found that the farmers who picked up their birds more frequently during inspections have a lower prevalence of FPD compared with the farmers who pick up birds less frequently. The effort put into picking up birds during most or all inspections can speak to the stockmanship of the farmer and indicate a conscious effort on the part of the farmer to address the FPD issues. Good stockmanship has been shown to be crucial for broiler welfare and can be even more influential than the factors, such as stocking density (Dawkins et al., 2004). This could explain why De Jong et al. (2012) found that the farmers had a relatively significant contribution in explaining FPD in broilers compared with e.g., hatchery, veterinary practice, or feed manufacturer. Furthermore, it is essential to realize that farmers as primary caretakers are responsible for the main decisions that influence the aspects of production, such as stocking density, litter management, and nutrition that all can influence FPD. This is especially important because of the seasonal changes in North America. Drying out the litter is more difficult during the winter seasons because of reduced ventilation but this problem can be reduced with good management. Further research should identify and quantify which specific attributes of stockmanship can positively impact turkey welfare to improve the conditions for both farm staff and birds.

Management of litter quality is one of the most frequently mentioned aspects to control FPD (Shepherd and Fairchild, 2010). Due to the nature of the study, it was not possible to take detailed litter quality measures; however, it should be noted that the majority of farmers indicated that, at the time of the survey, the litter was in good condition (i.e., not very dry/dusty nor damp/wet). There have also been many investigations into different litter types and textures and how they influence the development of FPD (Mayne, 2005; Shepherd and Fairchild, 2010). We found that the flocks housed in barns that were bedded with straw had a higher prevalence of FPD compared with those that did not use a straw. In the literature, straw bedding is associated with more severe FPD than wood shavings (Ekstrand and Algers, 1997; Mayne et al., 2007; Terčič et al., 2015). As suggested by Mayne et al. (2007), straw may perform worse than materials like wood shavings due to its higher moisture content. This effect was also demonstrated by Terčič et al. (2015), who found that straw litter had the highest moisture content (22%) compared with wood shavings (8%) and shredded paper (9%). It should be noted that the litter materials will vary between the regions depending on cost and availability. In North America, straw bedding is still popular because it is more cost-effective than wood shavings and is typically readily available, depending on the region (Hybrid Turkeys, 2020). The most common litter material reported in this study was wood shavings (54%), which also is the most commonly used litter substrate in the United States, but can be subject to shortages, is more expensive, and produces more dust compared to some bedding types (Grimes et al., 2002; Hybrid Turkeys, 2020).

It is also worth considering the textural difference between straw and wood shavings. The particle size has been implicated as a contributing factor for FPD (Grimes et al., 2002). Large particle sizes make the litter more susceptible to caking, which can be a contributing factor for poultry dermatitis conditions (Grimes et al., 2002). Straw is typically a coarser material compared with wood shavings (Ward et al., 2000). Adding further evidence to the particle size argument, studies of broiler chickens have found that chopped straw results in significantly better leg health and FPD severity compared with unchopped straw (Đuki et al., 2016). A variety of questions related to litter management were included in the survey, but aspects, such as adding dry litter, adding heat, or tilling the litter did not contribute to the final model. We should

note that these factors can still play a role in the prevalence of FPD and warrant further investigation.

One factor that did, however, contribute to the final model was the use of feed or water additives to reduce litter moisture. This question in the survey asked farmers specifically if they used additives to reduce litter moisture, as opposed to using additives for, e.g., performance, growth, or gut health, which was covered in a separate question. Surprisingly, using feed or water additives to reduce litter moisture tended to be associated with increased FPD prevalence. Using additives was associated with a 20% higher FPD prevalence compared with flocks where additives were not used. This finding is contrary to the previously reported effects where feed or water additives reduce litter moisture in poultry production, and so reduce the development of FPD (Mayne et al., 2007). Some limitations within our study could potentially explain this contradictory finding. First, we were unable to analyze the effect of specific additives or additives delivery methods (e.g., *via* feed or water) due to the small number of respondents who supplied this information ($N = 11$). The most frequently mentioned products included betaine, copper, citric acid, and essential oils (van Staaveren et al., 2020). Products, such as betaine and copper have been shown to impact water and ion balance (Saeed et al., 2017) or tissue integrity of the birds (Rucker et al., 1998). Consequently, these products can reduce litter moisture (Ferket, 1995) and positively impact the FPD scores when supplemented with poultry (Zhao et al., 2010; Manangi et al., 2012). Therefore, it was expected that the farmers who used these products in their flock would have lower levels of FPD due to benefits for litter quality and integument health. However, due to the cross-sectional nature of the study, we were unable to determine at what point the additives were introduced to the flock. It is possible that the additives to reduce litter moisture were applied to the flock as a response to FPD instead of a preventative technique—which also positively illustrates that the farmers are aware of the relationship between litter quality and footpad health. Furthermore, it may be due to the farms that have regular issues with FPD use these products, and so there may be other underlying characteristics of these farms influencing the prevalence that were not captured in this study. Additionally, the level of variation for this variable was close to our cut-off value (84% of respondents indicated they do not use additives), and so we may also be lacking some variation to make a proper assessment about this relationship.

This study was the first attempt to assess the factors associated with FPD on Canadian turkey farms. The main limitation that should be acknowledged is that, due to the exploratory nature of this study and the desire to include farms from the entire country, we relied on self-reported FPD scores from individual farmers. While the scoring system was simplified and based on the previous literature (Knierim et al., 2016), it was developed and pilot-tested with industry stakeholders. Each farmer received the same informational packet and scoring instructions; we cannot, however, completely rule out that there may have been differences among the farmers in how they scored their birds. Considering the variety in prevalence reported by the farmers, we believe that the instructions allowed farmers to capture the extent of FPD in their flocks. However, with the cross-sectional study design, this can only be considered as a snapshot of that specific flock in time, and the estimates and *P*-values presented in this study are exploratory. To truly determine the impact of the factors identified in this study, further longitudinal studies are required. This would also allow further investigation on FPD development over time and the potential management strategies in the future.

CONCLUSION

This study provided an exploratory assessment of FPD prevalence and risk factors using a survey of Canadian turkey flocks. The majority of FPD cases in the surveyed flocks were mild (score 1, mean flock prevalence = 29%), with a lesser percentage of birds severely affected (score 2, mean flock prevalence = 9%). The age of the flocks ranged from 10 to 14 weeks for toms and 7–12 weeks for hens. Overall, there was a median FPD prevalence (score > 0) of 48 and 20% for tom and hen flocks, respectively. However, the range in prevalence was large for both tom (IQR: 10–72%) and hen (IQR: 7–53%) flocks suggesting a need for FPD management strategies to mitigate FPD. The analysis of factors related to FPD indicates that good stockmanship (picking up birds during inspections) and using wood shavings over straw bedding are associated with lower levels of FPD. The use of feed/water additives to reduce litter moisture and birds with heavier body weights was associated with the higher prevalence of FPD. However, in the case of cross-sectional studies, it is not possible to determine the cause and effect, and associations can be difficult to disentangle, so the results presented in this study should be interpreted with caution. The variables identified in this study would benefit from further longitudinal studies to investigate their impact on FPD in turkeys in more detail and develop management strategies to reduce FPD from an economic, societal, and animal welfare point of view.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the University of Guelph Research Ethics Board REB#:19-02-015. The patients/participants provided their written informed consent to participate in this study. The animal study was reviewed and approved by the University of Guelph Animal Care Committee (AUP 3782). Written informed consent was obtained from the owners for the participation of their animals in this study.

AUTHOR CONTRIBUTIONS

EL, NvS, VO, BW, AH-M, and CB conceived and designed the study, provided substantive input, and contributions to manuscript revision. EL and NvS conducted the study.

EL analyzed the data and wrote the main manuscript. All the authors reviewed and approved the final manuscript.

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Conflict of Interest: BW was an employee of Hybrid Turkeys at the time of the study. Hybrid turkeys disseminated an invitation to voluntarily participate in the study among its farm managers. The funders had no further role in the design of the study and collection, analysis, and interpretation of data and in writing the manuscript.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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