Mitigation and management of foot pad dermatitis in Alberta broiler chickens

by

Jesse Marie Hage Hunter

A thesis submitted in partial fulfillment of the requirements for the degree of

Master of Science

in

Animal Science

Department of Agricultural, Food and Nutritional Science

University of Alberta

Thesis Abstract

Foot pad dermatitis was identified as a welfare concern by the Alberta broiler industry. However, there are no published studies benchmarking foot pad dermatitis or methods of foot pad assessment recommended to producers in Alberta. Thus, the objectives of the thesis were to benchmark foot pad dermatitis on Alberta broiler flocks, investigate the correlation between three methods of foot pad assessment and repeatability of the processing line assessment, identify management practices related to foot pad dermatitis on-farm and assess the impact of platforms and peat moss on foot pad quality. Chapter 3 found mean prevalence of foot pad dermatitis for each assessment method was 28.7% (on-farm), 26.2% (processor-line) and 31.8% (processor-sampled) On-farm and processor-sampled scores were highly correlated ($r=0.90$; $P<0.01$), while processor-line scores were not repeatable between measurements ($P<0.01$). The variability in the processor-line influenced correlation scores between processor-line and processor-sampled ($r=0.72$, $P<0.01$) and on-farm ($r=0.77$; $P<0.01$). Foot pad dermatitis prevalence was greater on straw litter (40.6%) compared to other litter types (6.4%). Platform use increased with age, and had no impact on foot pad quality, carcass or body weight (Chapter 4). Wheat Straw had the highest litter moisture and foot pad scores, while Pine Shavings and Pine/Peat had the lowest litter moisture and foot pad scores ($P<0.01$). Peat had an acidifying impact on pH in both Wheat/Peat and Pine/Peat pens, and slightly decreased litter moisture for Wheat/Peat pens. Processors are advised to revise line-scoring. Producers are recommended to use pine shavings litter to reduce foot pad dermatitis and Wheat/Peat to moderately improve litter quality. Platform structures were used and should be increased in size to maximize bird benefit. Producers are strongly encouraged to assess each flock for foot pad dermatitis using the 4-point scale, as it was shown to be accurate and feasible for use on-farm. Legislation mandating use of pine shavings on farm is recommended, but emphasis should be placed on ensuring producers are assessing foot pad dermatitis on-farm.

Preface

All animal protocols and use were approved by the University of Alberta Animal Care and Use Committee (Livestock) in accordance with Canadian Council for Animal Care Requirements (Protocol number: AUP 1235).

Survey questions and participant consent were reviewed and approved by the REB2 Human Ethics Committee of the Research Ethics Office at the University of Alberta (Protocol number: PRO00052391).

Dedication

For Carl: My love, thank you for helping me through these past two years and being the constant positive presence that I needed (even when I complained about it). Thank you for supporting me throughout this degree. I love you, and I look forward to our out-of-school future together!

For my chickens: Spending time with you on-farm and during the trial was the best part of my degree, and kept me motivated during the tough times. Thank you.

Acknowledgements:

This research was completed with funding provided by the Alberta Livestock and Meat Agency, Agriculture and Agri-Food Canada, Agri-Innovation program (Growing Forward 2) and Alberta Chicken Producers. Additional in-kind support was provided by Alberta broiler producers, Sofina Foods, the University of Alberta and the University of Saskatchewan.

Thank you to my supervisor, Dr. Clover Bench, for your support. We have had a bumpy road, but I know it is thanks to your dedication to my success that I have finished this thesis. Thank you for the heartfelt conversations, countless discussions, and always pushing me to achieve the best I could. Thank you for giving me this opportunity.

Thank you to my committee member, Dr. Doug Korver for your dry humour, advice and patience with my many "quick" nutrition questions throughout the research and writing of this thesis. Further, thank you to Dr. Scott Jeffrey for taking the time to review my thesis and participate as my external examiner.

Thank you to Emmanuel Opoku Yeboah for your dedication throughout our work. I truly appreciate the long hours, research, and hard work you contributed to this research.

Thank you to all additional professors who have helped me throughout this thesis. Special thanks to Dr. Sven Anders, who helped me with my survey analysis and offered great perspective on the "big" picture of my research. Also to Dr. Martin Zuidhof for providing many poultry opportunities to help me learn and expand my knowledge of the poultry industry.

Thank you to Teryn Gilmet for the support, laughter, advice and inspiration throughout this degree. You helped me find confidence in myself and my studies, and I am very grateful to have met you.

Thank you to the Ethology lab, past and present for your help and support. Teryn Gilmet, Caitlyn Erickson, Emmanuel Opoku Yeboah, Hector Perez, Mirjam Guesgen, Sarah Nowicki.

Thank you to all of the poultry grad students: Kooney, Bello, Saman, Misaki, Sasha, Sheila and Paulo. Thank you for your help, advice and friendship. All the best for the future!

Thank you to all of the Poultry Research Centre staff: Lyle, Giles, Shawn, Chris, Rachelle, Kerry and Amber. I cannot thank you enough for all the knowledge, help and humour you brought to the barn during this research. I am so glad I got to work with you all.

Thank you to all of the volunteers who participated to make this thesis possible. Special thanks to Matt Oryschak, who helped greatly with the design and implementation of the research trial.

Thank you to all of the producers who participated in my field study. Thank you for being so welcoming and helpful during our farm visits. Thank you to John, for your humour and endless patience during sample collection which allowed this thesis to be completed. I am very grateful to have had the opportunity to work with the Alberta broiler industry.

Thank you to my friends and family, who have been supportive throughout the completion of this thesis. I could not have finished without you.

Table of Contents

Pages

List of Tables

List of Figures

1.0. A review of the development and prevention of foot pad dermatitis in broiler chickens

1.1. Definition and etiology of foot pad dermatitis

1.1.1. Definition

Foot pad dermatitis is a skin condition in broiler chickens characterized by lesions that develop on the underside of the foot which develop as early as 7 days of age (Mayne, 2005; Hashimoto et al., 2011). Lesions range from minor skin irritation to severe ulcerations which can cover the entire underside of the foot (both foot pad and toes; Ventura et al., 2010). Foot pad dermatitis in broilers is associated with necrosis of the foot pad, which presents itself as a crusty lesion (Michel et al., 2012). Foot pad dermatitis is distinct from other dermatitis conditions observed in poultry, such as bumblefoot observed in laying hens. Bumblefoot is characterized by a spherical inflammation as a result of infection, which occurs around the entirety of the foot (Struelens and Tuyttens, 2009). Broiler foot pad dermatitis is not caused by an infection, but occurs after the foot pad has prolonged contact with an irritant in the environment (e.g. moisture), resulting in skin degradation (Sirri et al., 2007). Foot pad dermatitis was considered a contact dermatitis after examination of microbial and fungal communities on both healthy and lesioned foot pads (Martland, 1985). Neither microbial or fungal communities were significantly different, suggesting that neither bacteria nor fungi were the underlying cause of foot pad dermatitis and lesions must result from some other factor (Greene et al., 1985; Martland, 1985).

1.1.2. Relationship of ammonia, water and foot pad dermatitis

Previous research theorized foot pad lesions were due to excess ammonia in the litter (Ekstrand et al., 1997; Haslam et al., 2006). Ammonia is produced from the degradation of fecal uric acid through the interaction of microbes, water and oxygen in the litter (Figure 1.1). Poor litter conditions are often associated with a high concentration of ammonia, as well as severe foot pad dermatitis. As such, excess ammonia became associated with the development of foot pad "ammonia burns" (Kyvsgaard et al., 2013). However, the production of ammonia cannot take place without litter moisture levels of >33%, after which the degradation of uric acid and urea can occur (Figure 1.1; Nahm, 2003; Dunlop et al., 2015).

Litter moisture is accumulated through multiple sources. For example, condensation from heat generation by broilers and barn heating system result in increased litter moisture. Other sources of litter moisture include water during fecal excretion, and leakage from the drinker system in a barn. Constant contact of the foot pad with accumulated litter moisture results in softening and irritation of the skin, which makes the foot pad more susceptible to lesion development (Mayne, 2005). Additionally, wet litter increases the likelihood of fecal and litter debris sticking to the foot pad. Thus, excess litter moisture is currently the leading theoretical cause of foot pad dermatitis (de Jong et al., 2014).

1.1.3. Histology of foot pad dermatitis

The skin which covers the foot pad acts as a protective layer against disease, infection and water loss (Barbut, 2015). Chicken skin is composed of the epidermis (outer layer) and the dermis (inner layer; Barbut, 2015). Keratin cells (keratinocytes) are produced in the dermis and are composed of stiff protein fibres within a cornified matrix (van Hemert et al., 2012; Lees et al., 2014). Keratin is metabolically inactive and resilient to environmental stressors which provides protection and structural support for the skin (Dhouailly, 2009). The epidermis is composed primarily of keratin which is concentrated in the hardened, hydrophobic outer layer called the stratum corneum (Grist, 2006; Lawrence et al., 2012). Irritation of the stratum corneum is the first stage of foot pad dermatitis, resulting in red discolouration of the skin (Ekstrand et al., 1997). Lesion severity increases after prolonged contact between the stratum corneum and water, which prompts migration of heterophilic inflammatory cells from the dermis (Martland, 1985; Greene et al., 1985). Prolonged contact with litter moisture irritates the skin and causes increased numbers of inflammatory cells to migrate to the epidermis. The resulting inflammation forces the stratum corneum to pull apart, reducing the protective keratin layer and exposing the remaining epidermis and dermis to the litter (Greene et al., 1985; Martland, 1985). At this stage, the lesion is now brown/black in colour, but small (1-3mm). As the stratum corneum is forced further apart, blood vessels within the foot pad become constricted from surrounding inflammation (Martland, 1984). Loss of blood flow results in necrosis of the epidermis and the brown/black lesion increases to 5-7 mm in diameter (Greene et al., 1985). The final stage is characterized by necrosis of the skin on either toes and/or foot pad, and severe inflammation of the dermis (Ekstrand et al., 1998). Lesions at this stage tend to collect fecal microorganisms, as well as litter debris and are 7-12 mm in diameter (Greene et al., 1985).

1.2. Welfare and economic implications of foot pad dermatitis

1.2.1. Welfare

The World Organization for Animal Health (2016) defines animal welfare as the state of an animal as it attempts to cope with its environment. A good welfare state is defined as the ability to express natural behaviours and maintain health in a comfortable environment, and the absence of pain or discomfort. Broilers affected by foot pad dermatitis are considered to be in a negative welfare state (Bessei, 2006). Presence of foot pad lesions indicates broilers are having difficulty coping with environmental conditions within the barn, and may be experiencing pain caused by inflamed lesions (Haslam et al., 2006; Buijs et al., 2009; de Jong et al., 2014). Foot pad lesions are associated with tissue damage and inflammation, which can stimulate pain receptors during foot pad lesion development (Haslam et al., 2006; Loeser and Treede, 2008; Gentle, 2011; de Jong et al., 2014). Further evidence to support claims that foot pad dermatitis is painful has come from studies researching dietary preference tests. When broilers are given the choice between food containing analgesic and food without analgesic, broilers affected by foot pad dermatitis were reported to consistently choose the food with analgesic. Further, after consuming food with analgesic, broilers then exhibited improved walking ability (Weeks et al., 2000; Danbury et al., 2000). Thus, foot pad dermatitis is considered a painful condition for broilers and has been deemed a welfare concern.

1.2.2. Prevalence of foot pad dermatitis

Although globally recognized as a welfare issue in broilers, the prevalence of foot pad dermatitis is unavailable for many broiler producing countries (e.g. Brazil, Canada, United States). In Japan, prevalence was assessed over 45 commercial flocks and was 31.8% to 100% (Hashimoto et al., 2011). In Sweden, average prevalence of foot pad dermatitis was measured on 23 flocks and was reported as 34.7%, but ranged from 2% to 82% among flocks (Ekstrand et al., 1997). In the United Kingdom, mean foot pad dermatitis prevalence over 190 flocks was found to be 18.1% (Pagazaurtundua and Warriss, 2006a). However, the range reported for the United Kingdom was also large, with 6.3% of flocks reporting no foot pad lesions, and one flock with 92% lesion prevalence (Pagazaurtundua and Warriss, 2006a). In Portugal, mean prevalence of foot pad dermatitis measured on 765,000 broilers was 74.8% (Gouveia et al., 2009). In France, foot pad dermatitis across 55 flocks was measured at 70% (Allain et al., 2009). Finally, foot pad dermatitis was estimated at 38.4% across 386 broiler flocks in the Netherlands (de Jong et al., 2012). The diversity in range and prevalence between these estimates could be due to the differences in flocks assessed, flock size, or characteristics of the flock. For example, prevalence of foot pad dermatitis in Portugal (74.8%) was larger than the United Kingdom (18.1%). However, broilers in Portuguese flocks were slaughtered at 70-100 days of age, compared to 42 days of age in the United Kingdom (Pagazaurtundua and Warriss, 2006a). Broilers raised to older ages will be kept on the same litter for longer will have prolonged contact with litter material, and thus more time to develop foot pad dermatitis. Another source of variability between estimates could be the diversity in the size of foot pad assessment scales used for each study. Foot pad dermatitis was assessed using a 3-point scale in Portugal and the Netherlands, a 4-point scale in Japan and the United Kingdom, a 6-point scale in Sweden, and a 9-point scale in France which makes it difficult to compare assessments. Another factor which has been reported to affect prevalence of foot pad dermatitis is the type of broiler housing systems. For example, in the United Kingdom, conventional commercial systems (indoor free-run) recorded 14.8% prevalence, while free-range and free-range organic systems (outdoor access) reported 32.8% and 98.1%, respectively (Pagazaurtundua and Warriss, 2006b). The authors speculated that the differences observed between systems due to age at sampling, which ranged between 39 days of age (commercial systems), 56 days of age (free-range) and 70 days of age (free-range organic). Thus, prevalence estimates of foot pad dermatitis can vary between both housing systems and countries depending on age at sampling, method of assessment and number of flocks assessed.

1.2.3. Chicken feet market

Chicken feet have been reported as the third most valuable portion of the broiler carcass as a result of increased demand from Asian markets (Shepherd and Fairchild, 2010; de Jong et al., 2011). In 2015, 683 million broilers were produced in Canada, while 63.7 million broilers were produced in Alberta. Chicken feet are not a major export for Canada, however there are potentially 1.37 billion foot pads (683 million birds*2 foot pads/bird) in Canada and 127 million foot pads (63.7 million birds*2 foot pads/bird) in Alberta (Statistics Canada, 2015) available to be sold. Chicken feet are estimated to be worth $0.04 (CAD)/foot for export to Asian markets (Delmar Group International, 2014), and thus total export market for chicken feet can be estimated at $54.6 million (CAD) in Canada, and $5.1 million (CAD) in Alberta if no foot pads were affected by foot pad dermatitis. Comparably however, production of breast meat is still a much greater market, worth $406 million in Alberta and $3.9 billion in Canada in 2015 (Agriculture and Agri-Food Canada, 2015). However, other countries, such as the United States, with greater poultry production reported the export of chicken feet were worth an estimated $441 million in the United States in 2013, with the majority of chicken feet shipped to China and Hong Kong (United States Department of Agriculture, 2013). China imported a total of 511,000 metric tonnes of chicken feet in 2013 (from all countries; (United States Department of Agriculture, 2013), which represent the majority (61.76%) of all Chinese poultry imports (as reviewed by Carvalho et al., 2014). Smaller poultry suppliers such as Argentina shipped approximately 50,000 metric tonnes of broiler foot pads in 2007 (Guerrero-Legarreta, 2010). However, only blemish-free foot pads are exported, as blemished foot pads are deemed unfit for human consumption and cannot be sold. Thus, foot pad dermatitis is not only a welfare issue, but represents a considerable lost economic opportunity for processors (Pagazaurtundua and Warriss, 2006a). Reducing the prevalence of foot pad dermatitis requires assessment and management during broiler production, however this does not occur in all countries.

1.3. Management of foot pad dermatitis through assessment

1.3.1. Methods of assessment

The European Union Welfare Quality Assessment Protocol (Welfare Quality®, 2009), the Glasgow Foot Pad Score (DEFRA, 2010), and the "Swedish" scoring method (Algers and Berg, 2001) are all on-farm, live-bird measurements used by researchers and industry to assess foot pad dermatitis. Each scale ranges in length, from 2-point (Glasgow; DEFRA Science Research & Development, 2010), 3-point (Swedish; Algers and Berg, 2001) to 5-point (Welfare Quality®, 2009). On-farm foot pad assessment systems allow producers to assess each flock individually and help mitigate foot pad dermatitis through responsive management practices. Standardized assessment systems ensure that all members of the broiler industry (producers, processors, researchers) are familiar with how foot pad dermatitis is being reported, which facilitates knowledge transfer regarding foot pad management techniques. However, while these systems are used in other countries for foot pad assessment, there is currently no standardized system in Canada for foot pad scoring. Further, standardization does not guarantee that a scoring method will be feasible, accurate and/or reliable for producers to implement.

The number of points in a scale can affect feasibility, reliability and accuracy of foot pad lesion measurement. Foot pad assessment scales containing more points (> 5 points) are generally more accurate compared to scales with fewer points, as more points allow greater differentiation between many different degrees of foot pad lesion severity. Scales with more points are often used for investigating the development of foot pad dermatitis, where information regarding lesion severity is required, rather than just the presence of a lesion (Kjaer et al., 2006). However, scales with many points may be too time-consuming for use on-farm as distinguishing between the small differences in lesion categories can be difficult due to dim barn lighting, dust or dirty foot pads. Scales with fewer points provide sufficient information for producers (< 5 points) while allowing for faster scoring and differentiation between categories. Further, scales with fewer points typically allow for greater inter-observer reliability between assessors and consistent scoring of flocks. Foot pad assessment on the processing line is theoretically the most feasible method of scoring, as a large proportion of a flock can be scored in a short amount of time. However, the reliability and accuracy of scores on the processing line is unknown, as assessment methods used at processing plants are not available in the scientific literature. Further, assessment at only the processing plant does not allow mitigation of foot pad dermatitis within a flock prior to processing, while on-farm assessment allows monitoring and management of foot pad dermatitis throughout the production cycle. As such, theoretically on-farm assessment is a feasible and reliable method for industry to adopt. The benefits of on-farm scales with minimal points (2-4 points) include greater feasibility, reduced time required for scoring, and improved reliability between assessors. The consequences of using a scale with fewer points are decreased accuracy for assessment of lesion severity, but producers may not require the detail that a scale with more points would provide.

As technology develops, the future of foot pad assessment at the processing plant may be completely automated. A prototype automated foot pad scoring system for use in processing plants has been investigated (Vanderhasselt et al., 2013). The automated scoring system compares the discolouration from the lesion to the size of the foot pad to estimate severity based on a predefined system. Benefits of an automated system are the ability to score large proportions of a flock and reduce assessment bias during foot pad assessment. However, the prototype still requires further testing, as the most recent report found that the prototype assessed only 43.7% of foot pads scanned and falsely identified dermatitis on 49.4% of foot pads (Vanderhasselt et al., 2013).

1.4. Management factors which influence foot pad dermatitis

1.4.1. Litter

Litter substrates used in broiler production should absorb moisture (e.g. from feces, condensation and humidity) but also allow moisture evaporation, allowing litter to dry which helps prevent development of foot pad dermatitis (Garcia et al., 2012). The ability to absorb and release moisture (absorptive or release capacity) is unique to each litter material, thus influencing moisture content (Grimes et al., 2002; Bilgili et al., 2009). The predominant litter material used in Canada is unknown, however the most common bedding materials used in the United States include pine shavings/chips and chopped straw (Bilgili et al., 1999; Everett et al., 2013). Pine shavings are readily available in some parts of North America and have been considered a benchmark material for comparison between foot pad dermatitis measurements as the majority of foot pad dermatitis studies take place on pine shavings bedding (as reviewed by Grimes et al., 2002 and Bilgili et al., 2009). In Alberta, pine shavings are used by the oil industry and thus pine shavings are not always readily available for producers to use. The volume of pine shavings necessary for broilers will change depending on the size of the barn. However, the cost for bedding a 5400 ft^3 barn at a litter depth of 3 inches with pine shavings is estimated at $3200 CAD, without shipping costs (Mistaya Land & Water Corp, 2014).. A cheaper alternative to pine shavings is wheat straw (Stojčić et al., 2016). Bedding costs for wheat straw bedding in the same 5400 ft^3 barn and litter depth are estimated at $1406 CAD, including shipping (Alberta Agriculture & Forestry, 2016). However, shipping is not usually required as many producers grow wheat on-farm, and can use the straw by-product for broiler bedding. However, wheat straw has a higher initial moisture content (12.2%) and retains more moisture (80.6%) compared to pine shavings (initial moisture: 11.3%, retention: 71.2%; Bilgili et al., 2009). Greater moisture content and retention within straw can result in foot pads being exposed to wet litter which promotes foot pad dermatitis. For example, Bilgili et al. (2009) found the prevalence of foot pad dermatitis was 31% on pine shavings, compared to 50% reported for chopped wheat straw. Other litter materials have been investigated as alternatives to pine shavings and wheat straw to determine if they have improved litter properties or price.

Sphagnum peat moss has been used as a litter material for broiler production previously (Kyvsgaard et al., 2013). Peat has a high absorption capacity, able to absorb twenty times its weight in moisture (Everett et al., 2013) and is naturally acidic with a pH of ~4.5 (Peat Moss Association of Canada, 2016). Microbes function optimally at pH >7, and thus acidic litter helps minimize microbial activity and ammonia production, while maintaining litter quality and reducing irritation of the foot pad (Rothrock et al., 2008; Dunlop et al., 2015). Peat was investigated to determine impact on foot pad lesions in Denmark from 2004 to 2008 (Kyvsgaard et al., 2013). Broiler producers phased out the use of wheat straw, replacing bedding with sphagnum peat and/or pine shavings which resulted in a reduction of 80% to 40% in mean flock foot pad dermatitis (Kyvsgaard et al., 2013). However, litter composed solely of peat moss tends to become very dry, causing dust issues for both birds and farm workers (as reviewed by Everett et al., 2013) which could be mitigated by a blend of peat moss and another litter material. Studies investigating the impact of peat moss litter amendments on foot pad quality have not been completed to date.

Litter depth has been reported to impact prevalence of foot pad dermatitis (Martrenchar et al., 2002). For example, Ekstrand et al. (1997) recorded prevalence of foot pad dermatitis in 101 Swedish broiler flocks. The authors reported the mean prevalence of foot pad dermatitis on litter depths of > 5 cm was much greater (80.7%) compared to depths of < 5 cm (36.4%). Shallower litter depths may allow broilers to turn over the litter more easily compared to deep litter, thus releasing more moisture and reducing foot pad contact with wet litter. However, studies investigating the link between foot pad dermatitis and stocking density are difficult to compare due to the differences in how stocking density is reported. For instance, Meluzzi et al.(2008b) found that deeper litter depths were associated with improved foot pad quality (21.4% prevalence) compared to shallower depths (63.6% prevalence). However, while litter depth is typically reported as the total height of the litter (inches or centimetres), Meluzzi et al. (2008b) reported litter depths as 4.5 kg/m^2 (deep) and 2.3 kg/m^2 (shallow) which are typically used as measures of stocking density within the poultry industry. In addition to differences in litter depth units, results from studies are contradictory, which makes clarifying the relationship between litter depth and foot pad dermatitis difficult. Producers generally use height of litter on-farm in a commercial setting. As such, reporting litter depth in either inches or centimetres would facilitate comparison of research results and on-farm management strategies.

1.4.2. Nutrition

Nutrition has been reported to have a significant impact on foot pad dermatitis. Water excreted with the feces can increase the moisture level in the litter. The concentration of salts (e.g. Na^+, K^+, Cl^-) in broiler diets will require increased water required to maintain homeostasis and effectively metabolize feed during digestion (Francesch and Brufau, 2004). Thus, inclusion levels of salt above required levels (e.g. Sodium requirements: Starter: 0.16-0.23%; Grower: 0.16-0.23%; 0.16-0.20%; Aviagen, 2014) can result in greater moisture excreted with the feces. Hoeven-Hangoor et al. (2013) examined the impact of using dietary Mg and different salts (SO_4, Cl, O) at three different inclusion levels (Control: 0.05%; Treatments: 0.255%, 1.020%, 2.04%) on digesta and fecal moisture in broiler chickens. The authors found that the addition of excess

Mg generally increased excreta moisture by 5%, with differences in moisture observed even between the control and a minimum Mg addition (0.255%) treatment.

The source of crude protein can also impact foot pad dermatitis in broilers. Generally, plant-based proteins (e.g. soy) contain more indigestible protein compared to animal-based proteins (e.g. fish) which can lead to sticky droppings and foot pad dermatitis (Francesch and Brufau, 2004). Broilers fed a grain-based diet with soy protein exhibited a prevalence of 30% foot pad dermatitis compared to 10% dermatitis in male broilers fed a mixture of soy and animal-based protein diets (Nagaraj et al., 2007b). Use of animal-based protein in broiler feeds has significantly decreased, with animal-based proteins banned in the European Union and minimally included (< 3% of all crude protein) in the United States (Eichner et al., 2007). Soybean meal is currently the most widely used protein in poultry feed, with 98% of plant-based diets and 66% of all diets using soybean meal as the primary crude protein (Francesch and Brufau, 2004; Nagaraj et al., 2007a). Soybean meal is the most widely used protein in broiler diets in Canada, with canola meal used as an alternative protein source in Alberta. Increased levels of crude protein in the diet can also negatively impact foot pad score. When broilers consume crude protein beyond recommended intake levels (e.g. CP Starter: 23%; Grower: 21.5%; Finisher: 19.5% for 2.5kg target weight; Aviagen, 2014) birds must increase their water consumption in order to excrete the excess uric acid generated during protein metabolism. (Francesch and Brufau., 2004). High crude protein levels can result in increased excretion of both uric acid and water, resulting in greater microbe activity and reduced litter quality (Nagaraj et al., 2007b). The subsequent increase in litter moisture can lead to more severe foot pad scores. For example, Bench et al. (In Press) investigated the impact of high crude protein (Starter: 25.2 %; Grower: 23.4%, Finisher: 22.5% CP) sourced from two types of canola on foot pad quality in broilers. The authors reported significantly higher litter moisture (36.61%) and foot pad scores (four point scale: 0-3) associated with the high crude protein treatment (foot pad score: 1.36), compared to 31.64% litter moisture and foot pad scores of 0.70 in a standard crude protein treatment (Starter: 22.8%, Grower: 21.2%, Finisher: 22.3%). Indigestible carbohydrates present in cereals, soybean meal, canola meal and other plant based ingredients (non-starch polysaccharides) can result in sticky droppings which decrease the amount of water absorbed in the digestive tract, leading to wet litter (Francesch and Brufau, 2004; Shepherd and Fairchild, 2010).

1.4.3. Stocking density

Studies have reported mixed results regarding the impact of stocking density on prevalence of foot pad dermatitis. For example, Dozier et al., (2005) reported mean foot pad lesion score (three point: 0 to 2) was greater at 42-40 kg/m^2 (mean foot pad score: 1.0) compared to 35 and 30 kg/m^2 (mean foot pad score: 0.5, 0.6 respectively). However, other studies found no impact of stocking densities of 40.1 kg/m^2 and 41.8 kg/m^2 (Martrenchar et al., 2002) or 30-32 kg/m^2 and 38-40 kg/m^2 on foot pad dermatitis (Meluzzi et al., 2008). Further, as stocking density limits vary by country, this also affects which stocking densities will be investigated with foot pad dermatitis. For example, in Canada the allowed stocking density is 31 to 38 kg/m^2 , while maximum stocking density recommendations for the European Union are 42 kg/m^2 (Verspecht et al., 2011). In Sweden, the density recommendations are set at less than 36 kg/m^2 however if a producer's prevalence score is consistently below a specified prevalence (unpublished), a lower stocking density (20 kg/m^2) is enforced through broiler welfare legislation (Haslam et al., 2006). However, no such legislation currently exists in Canada to monitor foot pad dermatitis or enforce different stocking densities based on foot pad dermatitis alone.

1.4.4. Barn environment

Management of the broiler housing environment of a broiler barn is essential for maintaining litter quality and preventing foot pad dermatitis. For example, bell type water drinkers are associated greater foot pad dermatitis (45.2%) due to increased water spilled onto the litter compared to nipple drinkers (34.3%; Ekstrand et al., 1997). Maintaining consistent barn conditions is difficult, and management techniques vary between provinces and countries.

Seasonal changes cause outdoor temperatures to fluctuate, which can make managing litter moisture and relative humidity difficult (Shepherd and Fairchild, 2010). Musilova et al. (2013) reported greater prevalence of foot pad dermatitis in spring (83.2%) and winter (72.4%), and lower prevalence in autumn (62.0%) and summer (29.1%). Further, McIlroy et al. (1987) found that 83% of all severe lesion measurements on-farm occurred during the winter. Recommendations for relative humidity in Canadian broiler facilities from the Animal Care Manual (2009) and Codes of Practice (2016) are 50 to 70% RH, without exceeding 70% RH to maintain litter quality. However, maintaining humidity within that range can be difficult due to the cold temperatures (-20ºC) characteristic of Alberta winters. Cold air entering broiler barns must be heated before being ventilated throughout the barn, increasing operating cost. Decreased ventilation rates result in increased relative humidity throughout the barn, as moisture within the air is no longer removed by the ventilation system. Greater levels of relative humidity cause condensation to accumulate, subsequently increasing litter moisture. As birds stand on the wet litter, foot pads become irritated over time resulting in the development of foot pad lesions. For example, humidity of >75% has been reported to result in greater prevalence of foot pad lesions (54%) compared to <75% relative humidity levels (lesion prevalence = 14%; Weaver and Meijerhof, 1991). Further, when litter moisture was scored on a scale of 0 (very dry) – 10 (very wet), lower ventilation rates of 7.7-9.9 cm/s were associated with significantly higher mean moisture (litter moisture score = 4.63) compared to higher ventilation rates of 17.8-24.5 cm/s (mean litter moisture score= 4.09; Weaver and Meijerhof, 1991).

1.5. Alternative prevention strategies

1.5.1. Behaviour

Up until 21 days of age, broilers are active, walking, running and foraging (Duncan et al., 1992). However, after 21 days of age broilers experience a rapid increase in breast muscle weight, which may alter gait due to the need to support greater body weight (Duncan et al., 1992; Bokkers and Koene, 2002). Standing, walking and foraging result in greater pressure of the foot pad against the litter. If excessive litter moisture is present, contact with wet litter promotes the development of foot pad lesions. After 21 days of age, activity levels decrease, which result in sitting for longer periods of time. While sitting, there is less pressure on the foot pad against the litter. However, broilers sit with both their foot pads and shanks touching the litter and thus the foot pads are always in contact with the litter. As such, existing foot pad lesions which developed prior to 21 days of age can be aggravated by further litter contact and increase in severity. As lesions become more severe, pain from foot pad lesions may act as a deterrent to seek food and water (Gentle and Hill, 1987; Gentle, 2011).

Perching is considered a behavioural need for both wild and domesticated fowl (Estevez et al., 2002). Conventional perches are rounded, horizontal bars raised above the litter and require the bird to fly or jump onto the perch. However, studies have reported broilers stop perching on conventional perches after 21 days of age due to increased breast and body weight, and decreased flying ability (LeVan et al., 2000; Pettit-Riley and Estevez, 2001). Due to the observed decrease in perch use, an alternative method intended to increase activity level in broilers, called barrier perches, was investigated. Barrier perches are not perches, but obstacles placed between resources which force broilers to navigate over or around the barrier to reach food or water (Pettit-Riley et al., 2002). Further, barrier perches are not raised, but rest on the ground and emerge ~5-15 cm above the litter, acting as a hurdle to movement. However, studies investigating barrier perches found that broilers showed interest in perching on the barriers (Bizeray et al., 2002b). Broilers find barrier perches more accessible than conventional perches as they age as breast muscle gain can make flying difficult (Ventura et al., 2010). Moving broilers affected by foot pad dermatitis to dry litter can result in healing of lesions, indicating that preventing contact with litter moisture can mitigate further lesion development (Martland, 1984). As such, perching may help reduce foot pad dermatitis due to the reduced time spent in contact with the litter. Ventura et al. (2010) investigated the impact of simple and complex barrier perches on foot pad dermatitis and found significantly lower prevalence of foot pad dermatitis reported in simple perches (3%) compared to complex perches (17%) and no-perch treatments (21%). The researchers attributed the difference in foot pad quality to reduced litter contact in simple perches and the higher prevalence observed in the complex treatment to the complexity of the barrier perch. If the perch is complex and difficult for broilers to navigate, birds will likely spend more time standing or walking around the perch, resulting in more pressure of the foot pad against the litter and greater chance for development of foot pad lesions. A recent study investigated the impact of different types of perches (X-shaped and I-shaped) on foot pad quality and behaviour (Bench et al., In Press). The authors found no impact of the different perch designs on foot pad quality. However, broilers were observed to sit on perch junctions, which may have been due to the greater body support for broilers at these junctions compared to a narrower perch. Like previous studies (LeVan et al., 2000; Bizeray et al., 2002a), the authors found that use of perches by broilers decreased with time, and concluded structures with an extended area may be more appealing for broilers (Bench et al., In Press).

1.6. Conclusions

Foot pad dermatitis is a welfare concern observed in broiler chickens characterized by ulcerated lesions of the foot pad. The potential market for foot pads is estimated at $54 million (CAD) in Canada and $5.1 million (CAD) in Alberta, and thus foot pad dermatitis has economic implications in addition to welfare concerns. Foot pad dermatitis lesions develop after prolonged contact of the foot pad skin with excess litter moisture as early as 9-12 days of age. However, litter moisture can be affected by multiple factors within a broiler barn, which makes mitigating foot pad dermatitis under commercial conditions difficult. A previous study in Alberta postulated that a potentially alternative management strategy, structures with larger area may improve foot pad quality, but this hypothesis has not been tested. In Alberta, there have been no on-farm studies or recommendations made for producers to manage foot pad dermatitis. Research on Alberta broiler farms is necessary to quantify the issue of foot pad dermatitis within the province and investigate any potential strategies for managing the condition.

1.7. References

Agriculture and Agri-Food Canada. 2015. Weighted average retail poultry and table egg prices report (chicken). Available at http://aimis-simia.agr.gc.ca/rp/index-eng.cfm?report_format_type_code=21&action=gR&signature=5A510CFABB52569B4EBFF9F8486FCD93&pdctc=&r=116&pTpl=1&btnDownload=View (accessed 4 September 2016).

Alberta Agriculture & Forestry. 2016. Hay, Straw and Pasture Listings. Available at https://www.agric.gov.ab.ca/app68/hay?cat=For Sale&cat1=Straw (accessed 8 September 2016).

Algers, B., and C. Berg. 2001. Monitoring animal welfare on commercial broiler farms in Sweden. Animal Science 51:88–92.

Allain, V., L. Mirabito, C. Arnould, M. Colas, S. Le Bouquin, C. Lupo, and V. Michel. 2009. Skin lesions in broiler chickens measured at the slaughterhouse: relationships between lesions and between their prevalence and rearing factors. British Poultry Science 50:407–417.

Aviagen. 2014. Ross 308 broiler: nutrition specifications. :10 pgs.

Barbut, S. 2015. Primary Processing of Poultry.Page 43 in The Science of Poultry and Meat Processing. www.poultryandmeatprocessing.com.

Bench, C. J., M. A. Oryschak, D. R. Korver, and E. Beltranena. In Press. Behaviour, growth performance, foot pad quality, bone density and carcass traits of broiler chickens reared with barrier perches and fed different dietary crude protein levels. Canadian Journal of Animal Science. doi: 10.1139/CJAS-2015-0202.

Bessei, W. 2006. Welfare of broilers: a review. World's Poultry Science Journal 62:455–466.

Bilgili, S. F., J. B. Hess, J. P. Blake, K. S. Macklin, B. Saenmahayak, and J. L. Sibley. 2009. Influence of bedding material on footpad dermatitis in broiler chickens. Journal of Applied Poultry Research 18:583–589.

Bilgili, S. F., G. I. Montenegro, J. B. Hess, and M. K. Eckman. 1999. Live performance, carcass quality and deboning yields of broilers reared on sand as a litter source. Journal of Applied Poultry Research 8:352–361.

Bizeray, D., I. Estevez, C. Leterrier, and J. M. Faure. 2002a. Influence of increased environmental complexity on leg condition, performance, and level of fearfulness in broilers. Poultry Science 81:767–773.

Bizeray, D., I. Estevez, C. Leterrier, and J. M. Faure. 2002b. Effects of increasing environmental complexity on the physical activity of broiler chickens. Applied Animal Behaviour Science 79:27–41.

Bokkers, E. A. M., and P. Koene. 2002. Sex and type of feed effects on motivation and ability to walk for a food reward in fast growing broilers. Applied Animal Behaviour Science 79:247–261.

Buijs, S., L. Keeling, S. Rettenbacher, E. Van Poucke, and F. A. M. Tuyttens. 2009. Stocking density effects on broiler welfare: identifying sensitive ranges for different indicators. Poultry Science 88:1536–1543.

Carvalho, C. M. ., F. H. Litz, E. A. Fernandes, M. M. Silveira, J. M. S. Martins, L. A. Fonseca, and J. A. Zanardo. 2014. Litter characteristics and pododermatitis incidence in broilers fed a sorghum-based diet. Brazilian Journal of Poultry Science 16:291–296.

Chicken Farmers of Canada. 2009. Animal care program manual. :47 pgs.

Danbury, T. C., C. A. Weeks, A. E. Waterman-Pearson, S. C. Kestin, and J. P. Chambers. 2000. Self-selection of the analgesic drug carprofen by lame broiler chickens. Veterinary Record 146:307–311.

DEFRA (Science Research & Development). 2010. Foot pad dermatitis and hock burn in broilers: risk factors, aetiology and welfare consequences-final report. SID 5. Department for Environment, Food and Rural Affairs, Glasgow.

Delmar Group International. 2014. Industry, markets and trade (Canada). Available at https://www.delmarcargo.com/en/links.html#canada (accessed 4 September 2016).

Dhouailly, D. 2009. A new scenario for the evolutionary origin of hair, feather, and avian scales. Journal of Anatomy 214:587–606.

Dozier, W. A., J. P. Thaxton, S. L. Branton, G. W. Morgan, D. M. Miles, W. B. Roush, B. D. Lott, and Y. Vizzier-Thaxton. 2005. Stocking density effects on growth performance and processing yields of heavy broilers. Poultry Science 84:1332–1338.

Duncan, I. J. H., M. C. Appleby, and B. O. Hughes. 1992. Effect of perches in laying cages on welfare and production of hens. British Poultry Science 33:25–35.

Dunlop, M. W., P. J. Blackall, and R. M. Stuetz. 2015. Water addition, evaporation and water holding capacity of poultry litter. Science of the Total Environment 538:979–985.

Eichner, G., S. L. Vieira, C. A. Torres, J. L. B. Coneglian, D. M. Freitas, and O. A. Oyarzabal. 2007. Litter moisture and footpad dermatitis as affected by diets formulated on an all-vegetable basis or having the inclusion of poultry by-product. Journal of Applied Poultry Research 16:344–350.

Ekstrand, C., B. Algers, and J. Svedberg. 1997. Rearing conditions and foot-pad dermatitis in Swedish broiler chickens. Preventive Veterinary Medicine 31:167–174.

Ekstrand, C., T. E. Carpenter, I. Andersson, and B. Algers. 1998. Prevalence and control of footpad dermatitis in broilers in Sweden. British Poultry Science 39:318–324.

Estevez, I., N. Tablante, R. L. Pettit-Riley, and L. Carr. 2002. Use of cool perches by broiler chickens. Poultry Science 81:62–69.

Everett, D. L., C. D. Mcdaniel, and A. S. Kiess. 2013. The impact of peat moss amendments on the microbial load in used pine shaving poultry litter. International Journal of Poultry Science 12:202–205.

Francesch, M., and J. Brufau. 2004. Nutritional factors affecting excreta/litter moisture and quality. World's Poultry Science Journal 60:64–75.

Garcia, R. G., I. C. L. Almeida Paz, F. R. Caldara, I. A. Naas, D. F. Pereira, and V. M. O. S. Ferreira. 2012. Selecting the most adequate bedding material for broiler production in Brazil. Brazilian Journal of Poultry Science 14:121–128.

Gentle, M. J. 2011. Pain issues in poultry. Applied Animal Behaviour Science 135:252–258.

Gentle, M. J., and F. L. Hill. 1987. Oral lesions in the chicken: behavioural responses following nociceptive stimulation. Physiology and Behavior 40:781–783.

Gouveia, K. G., P. Vaz-Pires, and P. Martins da Costa. 2009. Welfare assessment of broilers through examination of haematomas, foot-pad dermatitis, scratches and breast blisters at processing. Animal Welfare 18:43–48.

Greene, J. A., R. M. McCracken, and R. T. Evans. 1985. A contact dermatitis of broilers-clinical and pathological findings. Avian Pathology 14:23–38.

Grimes, J. L., J. Smith, and C. M. Williams. 2002. Some alternative litter materials used for growing broilers and turkeys. World's Poultry Science Journal 58:515–526.

Grist, A. 2006. Poultry inspection: anatomy, physiology and disease conditions. :276 pgs.

Guerrero-Legarreta, I. 2010. Handbook of poultry science and technology: volume 1: primary processing (I Guerrero-Legarreta and YH Hui, Eds.). :611 pgs.

Hashimoto, S., K. Yamazaki, T. Obi, and K. Takase. 2011. Footpad dermatitis in broiler chickens in Japan. J. Vet. Med. Sci. 73:293–297.

Haslam, S. M., S. N. Brown, L. J. Wilkins, S. C. Kestin, P. D. Warriss, and C. J. Nicol. 2006. Preliminary study to examine the utility of using foot burn or hock burn to assess aspects of housing conditions for broiler chicken. British Poultry Science 47:13–18.

van Hemert, C., C. M. Handel, J. E. Blake, R. M. Swor, and T. M. O'Hara. 2012. Microanatomy of passerine hard-cornified tissues: Beak and claw structure of the black-capped chickadee (*Poecile atricapillus*). Journal of Morphology 273:226–240.

van der Hoeven-Hangoor, E., I. B. van de Linde, N. D. Paton, M. W. A. Verstegen, and W. H. Hendriks. 2013. Effect of different magnesium sources on digesta and excreta moisture content and production performance in broiler chickens. Poultry Science 92:382–391.

de Jong, I. C., H. Gunnink, and J. van Harn. 2014. Wet litter not only induces footpad dermatitis but also reduces overall welfare, technical performance, and carcass yield in broiler chickens. Journal of Applied Poultry Research 23:51–58.

de Jong, I. C., J. van Harn, H. Gunnink, A. Lourens, and J. W. van Riel. 2012. Measuring foot-pad lesions in commercial broiler houses. Some aspects of methodology. Animal Welfare 21:325–330.

de Jong, I. C., T. Veldkamp, and J. van Harn. 2011. Management tools to reduce footpad dermatitis in broiler chickens. Aviagen:10 pgs.

Kjaer, J. B., G. Su, B. L. Nielsen, and P. Sørensen. 2006. Foot pad dermatitis and hock burn in broiler chickens and degree of inheritance. Poultry Science 85:1342–1348.

Kyvsgaard, N. C., H. B. Jensen, T. Ambrosen, and N. Toft. 2013. Temporal changes and risk factors for foot-pad dermatitis in Danish broilers. Poultry Science 92:26–32.

Lawrence, J., V. R. Fowler, and J. E. Novakofski. 2012. Growth of farm animals. :352 pgs.

Lees, J. J., L. P. Folkow, R. L. Nudds, and J. R. Codd. 2014. The effects of season and sex upon the morphology and material properties of keratin in the Svalbard rock ptarmigan (*Lagopus muta hyperborea*). Journal of Thermal Biology 44:126–130.

LeVan, N. F., I. Estevez, and W. R. Stricklin. 2000. Use of horizontal and angled perches by broiler chickens. Applied Animal Behaviour Science 65:349–365.

Loeser, J. D., and R. D. Treede. 2008. The Kyoto Protocol of IASP basic pain terminology. Pain 137:473–477.

Martland, M. F. 1984. Wet litter as a cause of plantar pododermatitis, leading to foot ulceration and lameness in fattening turkeys. Avian Pathology 13:241–252.

Martland, M. F. 1985. Ulcerative dermatitis dm broiler chickens: the effects of wet litter. Avian Pathology 14:353–364.

Martrenchar, A., E. Boilletot, D. Huonnic, and F. Pol. 2002. Risk factors for foot-pad dermatitis in chicken and turkey broilers in France. Preventive Veterinary Medicine 52:213–226.

Mayne, R. K. 2005. A review of the aetiology and possible causative factors of foot pad dermatitis in growing turkeys and broilers. World's Poultry Science Journal 61:256–267.

McIlroy, S. G., E. A. Goodall, and C. H. McMurray. 1987. A contact dermatitis of broilers-epidemiological findings. Avian Pathology 16:93–105.

Meluzzi, A., C. Fabbri, E. Folegatti, and F. Sirri. 2008. Effect of less intensive rearing conditions on litter characteristics, growth performance, carcase injuries and meat quality of broilers. British Poultry Science 49:509–515.

Michel, V., E. Prampart, L. Mirabito, V. Allain, C. Arnould, D. Huonnic, S. Le Bouquin, and O. Albaric. 2012. Histologically-validated footpad dermatitis scoring system for use in chicken processing plants. British Poultry Science 53:275–281.

Mistaya Land & Water Corp. 2014. Pine wood shavings. Available at http://www.bestwoodshavings.com/ (accessed 8 September 2016).

Musilova, A., M. Lichovnikova, D. Hampel, and A. Przywarova. 2013. The effect of the season on incidence of footpad dermatitis and its effect on broilers performance. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis 61:1793–1798.

Nagaraj, M., J. B. Hess, and S. F. Bilgili. 2007a. Evaluation of a feed-grade enzyme in broiler diets to reduce pododermatitis. Journal of Applied Poultry Research 16:52–61.

Nagaraj, M., C. A. P. Wilson, J. B. Hess, and S. F. Bilgili. 2007b. Effect of high-protein and all-vegetable diets on the incidence and severity of pododermatitis in broiler chickens. Journal of Applied Poultry Research 16:304–312.

Nahm, K. H. 2003. Evaluation of the nitrogen content in poultry manure. World's Poultry

Science Journal 59:77–88.

National Farm Animal Care Council. 2016. Code of practice for the care and handling of hatching eggs, breeders, chickens and turkeys. :82 pgs.

Pagazaurtundua, A., and P. D. Warriss. 2006a. Measurements of footpad dermatitis in broiler chickens at processing plants. The Veterinary Record 158:679–682.

Pagazaurtundua, A., and P. D. Warriss. 2006b. Levels of foot pad dermatitis in broiler chickens reared in 5 different systems. British Poultry Science 47:529–532.

Peat Moss Association of Canada. 2016. Characteristics of horticultural peat. Available at http://peatmoss.com/peat-in-horticulture/characteristics-of-horticultural-peat/ (accessed 9 September 2016).

Pettit-Riley, R., and I. Estevez. 2001. Effects of density on perching behavior of broiler chickens. Applied Animal Behaviour Science 71:127–140.

Pettit-Riley, R., I. Estevez, and E. Russek-Cohen. 2002. Effects of crowding and access to perches on aggressive behaviour in broilers. Applied Animal Behaviour Science 79:11–25.

Rothrock, M. J., K. L. Cook, J. G. Warren, and K. Sistani. 2008. The effect of alum addition on microbial communities in poultry litter. Poultry Science 87:1493–1503.

Shepherd, E. M., and B. D. Fairchild. 2010. Footpad dermatitis in poultry. Poultry Science 89:2043–2051.

Sirri, F., G. Minelli, E. Folegatti, S. Lolli, and A. Meluzzi. 2007. Foot dermatitis and productive traits in broiler chickens kept with different stocking densities, litter types and light regimen. Italian Journal of Animal Science 6:734–736.

Statistics Canada. 2015. Production of poultry, by province. 2016 Available at http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/prim55a-eng.htm (accessed 4 September 2016).

Stojčić, M. D., S. Bjedov, D. Žikić, L. Perić, and N. Milošević. 2016. Effect of straw size and microbial amendment of litter on certain litter quality parameters, ammonia emission, and footpad dermatitis in broilers. Archives Animal Breeding 59:131–137.

Struelens, E., and F. A. M. Tuyttens. 2009. Effects of perch design on behaviour and health of laying hens. Animal Welfare 18:533–538.

United States Department of Agriculture. 2013. International egg and poultry review. Livestock, Poultry & Grain Market News 16:1–3.

Vanderhasselt, R. F., M. Sprenger, L. Duchateau, and F. A. M. Tuyttens. 2013. Automated assessment of footpad dermatitis in broiler chickens at the slaughter-line: evaluation and correspondence with human expert scores. Poultry Science 92:12–18.

Ventura, B. A., F. Siewerdt, and I. Estevez. 2010. Effects of barrier perches and density on broiler leg health, fear, and performance. Poultry Science 89:1574–1583.

Verspecht, A., F. Vanhonacker, W. Verbeke, J. Zoons, and G. Van Huylenbroeck. 2011. Economic impact of decreasing stocking densities in broiler production in Belgium. Poultry Science 90:1844–1851.

Weaver, W. D., and R. Meijerhof. 1991. The effect of different levels of relative humidity and air movement on litter conditions, ammonia levels, growth, and carcass quality for broiler chickens. Poultry Science 70:746–755.

Weeks, C. A., T. D. Danbury, H. C. Davies, P. Hunt, and S. C. Kestin. 2000. The behaviour of broiler chickens and its modification by lameness. Applied Animal Behaviour Science 67:111–125.

Welfare Quality® Consortium. 2009. Welfare Quality ® assessment protocol for poultry (broilers, laying hens). :111 pgs.

World Organisation for Animal Health (OIE). 2016. Introduction to the recommendations for animal welfare.Pages 1–2 in Terrestrial Code. 25th ed. OIE, Online Publication.

1. Uric acid + O_2 + 4 H_2O $\xrightarrow{\text{Uricase (from microbes)}}$ 2 Urea + Glycoxylic acid + CO_2 + Hydrogen Peroxide

2. Urea + H_2O $\xrightarrow{\text{Urease (from microbes)}}$ 2 NH_3 + CO_2

3. **Net Equation**: Uric Acid $\longrightarrow$ 2 Urea $\longrightarrow$ 4 NH_3 + 3 CO_2

Figure 1.1. Conversion of uric acid to ammonia after excretion by chicken (Nahm, 2003).

2.0. Thesis objectives

Research benchmarking foot pad dermatitis on commercial broiler farms in Alberta has not been previously completed. However, foot pad dermatitis has been identified as a welfare and economic concern by the Alberta broiler industry. The primary objective of this thesis research was to benchmark and identify practical strategies to improve foot pad quality and broiler welfare in Alberta. Within this larger overarching objective, the first objective was to benchmark foot pad dermatitis in commercial broiler flocks throughout Alberta. Chapter 3 reviews information collected from Alberta broiler flocks to assess prevalence of foot pad dermatitis and management practices on-farm to mitigate foot pad dermatitis.

Currently, no method of foot pad assessment is standardized for use throughout the Canadian broiler and processing industries. Further, although foot pad dermatitis was identified as an issue of concern in Alberta, there is no information provided to Alberta broiler producers which instructs the assessment of foot pad dermatitis. The lack of standardized assessment for producers makes foot pad dermatitis difficult to manage on-farm. Thus, the second objective was to compare the correlations between three foot pad assessment methods for commercial broiler flocks sampled, as well as the repeatability of the foot pad assessment method currently used at an Alberta processing facility (Chapter 3).

Management factors reviewed in Chapter 1, such as litter characteristics, nutrition, stocking density, barn age and equipment have been reported to influence foot pad dermatitis. However, no on-farm studies have been completed in Alberta to determine which management strategies used in Alberta help to prevent or reduce foot pad dermatitis are currently used on-farm. Thus, the third objective was to investigate the relationship between foot pad dermatitis and management practices on commercial broiler farms in Alberta, specifically with regards to litter moisture management using a management practices survey (Chapter 3; Appendix A).

Previous literature has reported that excess litter moisture is associated with the development of foot pad dermatitis. Reducing the amount of litter moisture or the time foot pads are in contact with litter are potential strategies to mitigate foot pad dermatitis. Litter material can have an impact on foot pad dermatitis, as each litter material will have different moisture retention and release properties. The impact on foot pad dermatitis after changing litter properties through the addition of sphagnum peat moss has not been investigated. Thus, the first part of the fourth objective was to determine the impact of litter material (wheat straw, pine shavings, sphagnum peat moss) on foot pad dermatitis (Chapter 4). Bench et al (In Press) found that broilers preferred the junctions of perches and may prefer structures which have a large, supportive surface area. Further, if the structure is slatted, broilers could then avoid contact with litter, potentially mitigating foot pad dermatitis. Thus, the second part of the fourth objective was to determine the impact of raised slatted platforms on foot pad dermatitis (Chapter 4).

The results of this thesis will provide the Alberta broiler industry with a benchmark for the current prevalence of foot pad dermatitis in Alberta, in addition to management strategies currently used by producers to mitigate foot pad dermatitis on-farm. Further, the results from this thesis will recommend an assessment method for broiler producers and evaluate the current processor-line scoring method. The results from this thesis will also potentially provide producers with new management strategies (e.g. alternative litter supplements, broiler perch structures) for mitigating foot pad dermatitis on-farm, and help to improve overall broiler welfare in Alberta broiler flocks. The recommendations from this thesis can also provide information for revision of future codes of practice for broilers.

3.0. Practical assessment and management of foot pad dermatitis in commercial broiler chickens[1]

3.1. Introduction

Foot pad dermatitis in broiler chickens is characterized by ulcerated lesions on the underside of the foot (Mayne, 2005). Severe lesions are associated with inflammation and pain, and thus foot pad dermatitis is considered a welfare concern (Danbury et al., 2000; Gentle, 2011; de Jong et al., 2012a). Research in both broilers and turkeys has shown that litter moisture is associated with development of foot pad lesions (Eichner et al., 2007; Mayne et al., 2007). Prolonged contact of the skin with litter moisture results in irritation and degradation of the foot pad and formation of a lesion (Greene et al., 1985; Martland, 1985). However, litter moisture can be affected by a multitude of factors including litter material and depth, barn environment and moisture management, nutrition, and season. The multi-factorial aspects of foot pad dermatitis makes the condition difficult to manage on-farm. Foot pad dermatitis is prevalent worldwide and flock prevalence has been estimated at 74.8% (Portugal), 70% (France), 38.4% (Netherlands), 34.7% (Sweden), 18.1% (UK) and has also been observed in free-run, outdoor and organic housing systems (Pagazaurtundua and Warriss, 2006; de Jong et al., 2014).

In Canada, chicken feet are not as economically valuable as the breast, the value of which was estimated at $3.9 billion (CAD) in Canada and $406 million (CAD) in Alberta (Agriculture and Agri-Food Canada, 2015). Chicken feet for export to Asian markets from Canada have been reported as $0.04/foot pad (Delmar Group International, 2014). If all chicken feet were sold, the

[1] This chapter will be submitted for publication to JAPR as a Research Note and is formatted in accordance with its conventions and instructions to authors.

export value is estimated at $54.6 million (CAD) for Canada and $5.1 million (CAD) for Alberta Statistics Canada, 2015). Blemished chicken feet cannot be sold, and thus foot pad dermatitis can have economic consequences for the processing plant.

Foot pad dermatitis can be assessed on-farm, at the processing plant or after the feet have been removed during processing. However, within research and industry, scoring systems can range from 2-point (DEFRA, 2010) to 9-point scales (Kjaer et al., 2006). The range in points between assessment scales is due to different objectives prioritized for these two different settings. Scales with many points (e.g. 9-point) are usually used in research, where accurate differentiation between lesions may be necessary. However, these scales can be associated with lower inter-observer reliability scores compared to scales with fewer points. Conversely, scales with fewer points (e.g. 2-point) are used in more commercial settings where feasibility is a priority, but do not provide the same detailed information regarding lesions. Canada currently has no standardized foot pad scoring system and no published benchmark of foot pad dermatitis prevalence (National Farm Animal Care Council, 2016). Although producers are encouraged to monitor flock foot pad health, no particular method is recommended to producers.

Foot pad scoring on-farm is important for management of foot pad dermatitis as it allows producers to determine current foot pad dermatitis prevalence within a flock. If prevalence is high (e.g. 90%), proactive management strategies can be implemented, which can deter further lesion development or potentially heal existing lesions (Martland, 1984). Despite the benefits of on-farm foot pad assessment, there is minimal scoring by producers recorded at the farm level in both Canada and Europe (Butterworth et al., 2016). In Alberta, only one processing plant currently assesses foot pad dermatitis on the production line, but the methods used for foot pad scoring methods are proprietary and unpublished. In contrast, the majority of foot pad assessments in the

European Union are carried out instead using an unpublished method at the processing plant and enforced through welfare legislation (Butterworth et al., 2016). Although foot pad dermatitis was noted by the Alberta broiler industry as an issue of specific concern, there have been no published benchmarks regarding foot pad dermatitis prevalence in the province. Further, as an issue of concern to Alberta, there may be management practices unique to the province which could help mitigate foot pad dermatitis. Thus, it is important to quantify current prevalence of foot pad dermatitis in Alberta, investigate current foot pad assessment methods within the province and evaluate on-farm management practices to determine which practices reduce foot pad dermatitis.

The objectives of the study were to: 1) benchmark foot pad dermatitis prevalence in Alberta broiler flocks, 2) compare correlations between three foot pad assessment methods and the repeatability of a current foot pad assessment method used at a processing plant and 3) determine on-farm management practices which influence foot pad quality. We hypothesized that the same assessment method used to score the same flock at multiple points would be strongly correlated, while the current processor scoring method would not be strongly correlated with other assessment methods. We predicted that management practices related to litter moisture would impact the prevalence of foot pad dermatitis on-farm.

3.2. Materials and methods

3.2.1. Animal care

The animal care protocols for the study were approved by the University of Alberta Animal Care and Use Committee for Livestock and followed principles established by the Canadian Council for Animal Care Guidelines and Policies (Canadian Council on Animal Care, 2009). The survey developed for the study was reviewed and approved by the REB2 Human Ethics Committee of the Research Ethics Office at the University of Alberta.

3.2.2. Experimental design

Eight Alberta broiler producers located throughout the province of Alberta affiliated with the same processing plant participated in the study. Producers were located throughout Alberta, equally representing both southern and northern Alberta. Producers were chosen based on history of foot pad dermatitis prevalence provided by the processing plant. To ensure adequate representation of foot pad dermatitis within the province, producers with both consistently high and low prevalence were selected. Producers with high and low prevalence were equally distributed throughout Alberta. Producers were given anonymous identifiers (A to H). Each producer was visited four times throughout the study for a total of 32 flock visits during January – September, 2015. Two farm visits were completed during flock cycles during January-June, and two additional visits completed during flock cycles from June-September. Flock visits were spread over January-September to capture potential differences in management practices between winter and summer months. Each flock was also assessed at the processing plant, where foot pad scores and samples were collected. Two trained research staff conducted all on-farm visits when broilers were 35 to 39 days of age. Each of the 32 on-farm visits were randomly assigned to one member of the research team (~16 visits/research team member). An inter-observer reliability test between the two trained researchers was performed once midway through the study to ensure consistent scoring occurred during foot pad scoring. Researchers each scored the same batch of foot pads (N=600) during post-mortem scoring. A Pearson correlation analysis was run between the scores, and correlation of 97% was confirmed between researchers ($P<0.01$). Two on-farm flock visits were missed, reducing total visits to N=30 flocks. The first was due to poor road conditions which prevented the researcher from travelling. The second was due to unusually hot outdoor temperatures (~35ºC), combined with high mortalities noted by the producer. The producer was concerned that birds were stressed and sampling may further agitate the flock and thus and requested to skip the on-farm sampling. However, the survey was completed by phone, and processor samples were still collected for missed on-farm visits (N=32). Broilers of flocks visited represented Ross 308 (~90%), Cobb and Hubbard (~10%) strains.

3.2.3. Data Collection: Survey

A survey composed of 46 questions regarding producer knowledge of foot pad dermatitis, management and prevention of foot pad dermatitis was completed during each flock visit (Appendix A). All responses recorded for the survey were given by the producer and not verified by researchers (e.g. protein content in feed was not tested). Survey questions were chosen based on a thorough review of the scientific literature that identified risk factors which contribute to the development of foot pad dermatitis (Meluzzi et al., 2008a; Shepherd and Fairchild, 2010; de Jong et al., 2012b). Prior to use on-farm, survey questions were reviewed by members of the Alberta broiler industry and poultry researchers at the University of Alberta and University of Saskatchewan to ensure comprehensiveness of foot pad dermatitis related risk factors identified previously in the scientific literature. The survey attempted to capture litter moisture and environment mitigation strategies and philosophies of Alberta broiler producers with regards to foot pad dermatitis management and prevention.

3.2.4. Data collection: on-farm foot pad and litter assessment

A sub-sample of two hundred broilers were assessed for foot pad dermatitis during each on-farm visit (N=30 visits). Broilers were randomly selected from all areas of the barn (e.g. near doors, walls, drinkers, feeders). Left and right foot pads were scored independently using a 4-point assessment system modified from the Welfare Quality Assessment Protocol for Poultry (Welfare Quality®, 2009; Table 3.1). Welfare Quality® (2009) is a 5 point photographic point scale used throughout the European Union for welfare enforcement, and was chosen because it is used on-farm and went through extensive review prior to implementation. The Welfare Quality® scale was modified to a 4 point scale in the current study to ensure feasibility for use on-farm while still providing information regarding different levels of lesion severity. Written descriptions describing percentage of foot pad affected by lesion were created based on photographs provided by the Welfare Quality® (2009; Table 3.1). A previous study (Bench et al., In Press) used a similar 4-point scale. On-farm scoring was designated to be the 'standard' of comparison for both processor-line and processor-sampled scores. On-farm scoring is the only way that allows producers to assess prevalence within a flock and potentially mitigate foot pad dermatitis prior to processing, compared to assessments which take place at the processing plant.

Following foot pad assessment, litter was assessed for moisture content using a 5-point scale (Table 3.1). The litter assessment scale was modified for use using hand sampling instead of boot sampling from the Welfare Quality Assessment Protocol (Welfare Quality®, 2009). Eighteen locations were sampled throughout the barn including areas near walls, feeders, drinkers. Litter was first disturbed by foot to mix the top and bottom layers, which allowed researchers to assess if a compacted crust was present (Score 4, Table 3.1), and to assess litter quality throughout litter layers. A handful of litter was picked up, compressed, assessed and given a score from 0 (dry, friable litter) to 4 (remains in a ball after compacted crust is broken; Table 3.1). Hand sampling of litter is easy to complete on-farm, and allows moisture to be assessed quickly which helps inform foot pad dermatitis management. Odour (intensity of ammonia smell) is an indicator of poor air and litter conditions and was assessed using a 3-point scale modified from a 5-point scale (Zhang et al., 2002; Table 3.1). Odour assessment scale was simplified to 3 points for added on-farm feasibility. Odour was assessed upon first entering the barn by inhaling and assessing according to a 3-point scale, 0 (no ammonia smell) to 2 (overwhelming ammonia smell).

3.2.5. Data collection: processing line

Within 24-48 hours of on-farm sampling, each flock was shipped to the processing plant. Processor-line foot pad scores were collected by counting the number of blemished foot pad pairs over one minute. Blemishes were defined as a foot pad pair with at least one blemished foot, regardless of lesion severity. The processor then divided the number of blemished feet by 100 foot pad pairs, with the assumption that one-minute always represents 100 foot pad pairs passing by on the line. Foot pad dermatitis prevalence is then expressed as a percentage (number of blemished pairs/100 pairs). Line scores were recorded during three distinct 1-minute periods to assess repeatability of the measurement (N=3 scores/flock).

3.2.6. Data collection: processor foot pad samples

Subsamples of 300 pairs of washed foot pads were collected off the production line in two batches of ~150 pairs each (range: 77 to 153 foot pad pairs/batch; mean: 148 foot pad pairs/batch) to assess reliability between samples with variable intervals (~one-minute) between subsamples for all flocks (N=2). Following collection, batches were separately placed in sealed Rubbermaid containers on ice and subsequently scored at the University of Alberta using the on-farm assessment system previously described in Table 3.1. Sampled foot pads enabled comparison to both on-farm scores and processor line scores.

3.2.7. Statistical analysis: survey

To facilitate survey data analysis, a thorough literature search was completed to investigate factors which contribute to the development of foot pad dermatitis. Factors included: foot pad dermatitis management, barn environment, flock information, water management, nutrition program, flock health, litter management, lighting program. Questions from each category were chosen by the research team if the factor was identified as significantly contributing to foot pad dermatitis prevalence, or was related to the objectives of the study.

Descriptive survey data was calculated for questions listed in Table 3.2 and 3.3. Frequency of responses for all flock surveys was calculated by:

$$\text{Response Frequency (\%)} = \left[\frac{\text{(number of specific responses)}}{\text{total flocks assessed}}\right] * 100$$

Scores are reported as proportion (%) of respondents out of all 32 flocks surveyed.

The relationship between on-farm management practices and on-farm prevalence of foot pad dermatitis was analyzed using a two-sample Student's t-test or one-way ANOVA. The arithmetic mean on-farm foot pad dermatitis prevalence score was generated for each flock (N=30). The prevalence estimate for each flock was compared to the survey response for each flock. Questions with >2 responses were analyzed using ANOVA, while binomial survey responses were analyzed using Student's two-sample t-test.

Using the survey data, the authors attempted to create a performance index for each flock using management practices identified through a literature review as contributing factors for foot pad dermatitis. The performance index (Appendix B) was a score from 23 to 64 created for each flock, after which the correlation between the performance index score and the mean on-farm flock foot pad dermatitis prevalence was assessed. Each score represented the number of "best management practices" related to mitigating foot pad dermatitis used during that flock cycle. Scores near 64 were considered high, and ideally associated with low prevalence of foot pad dermatitis. Scores closer to 23 were considered low, and associated with high prevalence of foot pad dermatitis. The range in scores for each question was determined by assigning scores to all possible responses to selected survey questions (Appendix B). Low scores (e.g. Response point=1) were assigned when management practices were previously reported in the literature found to promote foot pad dermatitis development (e.g. cup/bell water drinkers), while high scores (Response point=3) were assigned when management practices were previously reported in the literature to prevent foot pad dermatitis development (e.g. nipple water drinkers; Ekstrand et al., 1997; Shepherd and Fairchild, 2010; de Jong et al., 2011). Questions where the producer did not respond were given a value of zero. After rankings were assigned to all selected survey questions, the values were summed to create a performance index score for each flock (N=32; Appendix C). Correlations were analyzed using the Corr procedure of SAS® (SAS® Institute University Edition, 2016, Cary, NC).

3.2.8. Statistical analysis: foot pad, litter and odour scores

As the processor-line scores were only available as prevalence of foot pad dermatitis (%), foot pad scores for both on-farm and processor-sampled foot pads were converted to prevalence (%) to facilitate statistical analysis. Prevalence for on-farm scores was calculated by counting lesion presence for each pair of foot pads (200 birds/flock). In order to simulate processor-line scores, if either right or left foot exhibited foot pad dermatitis, the bird was given a score of '1'. If there was no foot pad dermatitis, the bird was given a score of '0'. The number of birds exhibiting foot pad lesions were summed and divided by 200 (i.e. total assessed birds) to give flock prevalence of foot pad dermatitis (%). Processor-sampled foot pad dermatitis prevalence was calculated after running a correlation analysis using the Corr procedure of SAS® University Edition (2016). Batch 1 and Batch 2 were highly correlated ($r=0.85$, $P<0.01$), so both Batch 1 and 2 were combined during prevalence calculations for foot pad dermatitis within each flock. Left and right foot pads sampled during processing were highly correlated ($r=0.93$, $P<0.01$), so data from only right feet was chosen to represent the foot pad score of the bird. Prevalence was then calculated using the same method described for on-farm scoring, by summing the number of birds exhibiting foot pad lesions and expressed as a percentage for each of the 32 sampled flocks. Flock prevalence for processor-line scores were calculated by averaging the three line scores taken during sampling for each of the 32 sampled flocks. Average prevalence for each of on-farm, processor-sampled and processor-line scores is reported as the arithmetic mean.

On-farm, processor-sampled and processor-line prevalence scores, and litter and odour scores for each flock were analyzed as a generalized linear mixed model using the Glimmix procedure of SAS® University Edition (2016). The repeatability of the processor-line score was analyzed using a repeated measures ANOVA with the Glimmix procedure of SAS® University Edition (2016). The Univariate procedure of SAS® and Kolmogorov-Smirnov test specified a Poisson distribution. Type III tests were requested with the log-link function and the inverse link (ilink) option specified. The fixed effects included Producer and Visit. The random term in all models was Flock. A Bonferroni means separation test was used and results considered significant at $P<0.05$. A tendency was defined at $0.05<P<0.10$, and $P>0.10$ was not considered significant. Results from the Glimmix analysis are reported as lsmeans ± SEM. Correlation between on-farm foot pad and litter scores were assessed using the Corr procedure of SAS® University Edition (2016).

3.3. Results and discussion

3.3.1. Foot pad dermatitis prevalence and assessment methods

The first objective of the current study was to benchmark the prevalence of foot pad dermatitis on commercial broiler farms in Alberta. Results are reported as the arithmetic mean prevalence of the 32 flocks sampled. Mean foot pad dermatitis prevalence for each assessment method was 28.65% (on-farm), 26.17% (processor-line) and 31.83 % (processor-sampled). However, variability in prevalence of foot pad dermatitis for each flock ranged from 0.5% to 76% (on-farm), 0.0% to 99% (processor-line) and 0.83% to 84.4% (processor-sampled). Results indicate that foot pad dermatitis is a prevalent issue within Alberta, and prevalence varies depending on assessment method. The second objective of the study was to investigate the correlation between three assessment methods for foot pad dermatitis, and the repeatability of the processor-line score. Despite having the lowest mean prevalence (26.17%), the processor-line score exhibited the largest range of foot pad dermatitis prevalence compared to both processor-sampled and on-farm. In addition, processor-line scores were significantly different from each other between scoring events, and were not repeatable ($P<0.01$). For example, one flock had processor-line scores of 1%, 2% and 99% prevalence, while on-farm and processor-sampled prevalence estimates for that same flock were 78.0% and 78.1%, respectively. The unreliability between the three processor-line scores affected the correlation with the other assessment methods. The on-farm assessment and processor-sampled assessment were highly correlated ($r = 0.90$; $P<0.001$; Figure 3.1). However, the correlation was weaker between processor-line and processor-sampled ($r = 0.72$; $P<0.001$; Figure 3.1), as well as processor-line and on-farm ($r = 0.77$; $P<0.001$; Figure 3.1) scores. The weaker correlation is likely due to the variability introduced by the processor-line measurements. In Alberta, foot pads are assessed once per flock at only one processing plant in the province. However, our results indicate that this assessment is not providing an accurate estimate of foot pad dermatitis within flocks. Further, increasing the number of flock scores does not improve repeatability, or correlation with other assessment methods. The variability in the measurement is likely twofold. First, the assumption at the processing plant that there are always one hundred birds passing on the line every minute. Line speed at the processing plant changes frequently and is not accounted for, as assessors are trained to always divide the number of blemished foot pads by one hundred. The prevalence estimate could be over or underestimating the prevalence of foot pad dermatitis in the flock. Second, the assessment at the processing plant is not always conducted by the same person, and inter-observer reliability is not monitored. Assessors are trained to identify any dark spot on the foot as a blemish, however due to the busy environment and changing line speed, small blemishes may be noted by one assessor but missed by another. Thus, unaccounted differences between assessment personnel may affect the consistency of foot pad assessments between flocks. Our results indicate that the current foot pad assessment system used at the Alberta processing plant should be revised. Currently, resources at the processing plant are not being used effectively for foot pad scoring, and could be directed towards resources to help producers assess foot pad dermatitis on-farm.

Dim lighting and dirty foot pads potentially make on-farm foot pad scoring difficult compared with the processor-sampled method as they have been washed and removed from the bird (de Jong et al., 2012b; Marchewka et al., 2013). Despite this, correlation between on-farm and processor-sampled scores was high (r=0.90). We hypothesized that the on-farm and processor-sampled assessment would be strongly correlated because they both use the same methodology. These results confirm our hypothesis that there is a strong correlation between the two methods, and indicates that on-farm and processor-sampled scoring consistently and accurately assessed flock foot pad dermatitis. Results from the current study indicate that an on-farm foot pad scoring system could be used by producers to assess each flock for foot pad dermatitis. Producers who score a flock throughout the production cycle can immediately identify foot pad dermatitis as a problem and manage the flock to mitigate further lesion development.

The best scoring method for use on-farm identified in the current study was the 4-point on-farm assessment scale. However, one disadvantage associated with the 4-point scale is that it may be too lengthy for use by producers on-farm. Generally, scales with more points are less repeatable and have poorer inter-observer reliability compared to scales with fewer points. However, for foot pad assessment systems used in Alberta, the current study found the opposite. The correlation between the two research personnel using the 4-point assessment system was 97%, while the processor-line score did not demonstrate repeatability even when scored by the same person. The- 4-point system was used successfully on-farm, and able to be used at two different times with a high degree of accuracy. The processor-line binary system tested in the current study was not found to be repeatable, and did not accurately assess prevalence of foot pad dermatitis within the flocks. However, as the environments at the processing plant and the barn are very different, the binary scale may have more success on-farm. The authors feel an emphasis should be placed on promoting assessment of foot pad dermatitis on-farm, rather than the assessment system itself. The current study recommends the 4-point scale, as it was tested, but acknowledges that other scales may also be practical for producers in Alberta.

3.3.2. Management practices

The final objective of the current study was to determine on-farm management practices which influence foot pad quality. Foot pad scores for each assessment method were significantly different between producers ($P<0.01$; Figure 3.2). Further, there were also significant differences in mean prevalence scores between producers (P<0.01, Figure 3.2). For example, Producer D had mean prevalence estimates (lsmeans ± SEM) of 0.73% ± 0.93 (on-farm), 2.7% ± 2.6 (processor-line), and 2.6% ± 1.7 (processor-sampled), while Producer F had prevalence estimates of 86.9% ± 32.5 (on-farm), 54.3% ± 33.2 (processor-line) and 66.4% ± 16.9 (processor-sampled). There were distinct differences in management practices between these producers. For example, Producer D had a litter depth of <10 cm and used pine shavings litter, while Producer F used wheat straw bedding and had litter depths of >10 cm. As such, prevalence of foot pad dermatitis was affected by the method of assessment, but also by the management practices used on-farm for each producer. The results for management practices and survey data are reported as the arithmetic mean foot pad dermatitis on-farm prevalence score for each survey response (Tables 3.2, 3.3, and 3.4).

Current assessment methods for foot pad dermatitis varied between survey respondents, with 40.6% of respondents assessing foot pads of dead birds only, 25% of respondents assessing the foot pads of live birds, and 21.8% who did not assess foot pad dermatitis at all (Table 3.2). The assessment of dead or live birds was not based on a scale, and respondents noted that foot pads were only examined briefly to determine if lesions were present. Only 6.25% of respondents used a scientific method of assessment, and only began after the respondent requested that the research team teach them how to score using the 4-point on-farm method. These results indicate that the majority of respondents (71.85%) currently assess foot pad dermatitis on-farm in Alberta, which may facilitate the introduction of a defined foot pad assessment system such as the 4-point on-farm method used in the current study.

Management practices such as ventilation, barn age, lighting system and intensity, stocking density and drinker system were not associated with significantly different foot pad dermatitis estimates (Tables 3.3 and 3.4, P >0.10). For example, ventilation system was identified in the literature review as an important factor in the development of foot pad dermatitis. If ventilation rates are not high enough, moisture in the air is retained and increases relative humidity within the barn (Spindler and Hartung, 2009). High relative humidity can create condensation which results in increased litter moisture and the development of foot pad lesions (Weaver and Meijerhof, 1991). However, as survey respondents had multiple types of ventilation systems within their barns, we were unable to discern if there was a significant impact of ventilation system on foot pad dermatitis (Table 3.3). Further, ventilation rate is typically decreased in winter when temperatures drop below -20ºC (Environment Canada, 2016) as heating the cold incoming air increases operating costs. Winter has been associated with greater prevalence of foot pad dermatitis, as the subsequent increase in relative humidity results in poor litter quality and foot pad lesions (Musilova et al., 2013). However, we found no significant difference in prevalence of foot pad dermatitis between winter and summer visits (data not shown; P >0.10). This indicates that there may be other factors in the summer which were not accounted for in the survey, such as misting, which may have resulted in wet litter conditions to that which is seen in the winter. However, visits for each producer were every eight weeks, which may not have been long enough to see the distinction between winter and summer months. Additional examples of management factors expected to influence foot pad dermatitis were stocking density and type of drinker system used. High stocking density can result in a greater prevalence of foot pad lesions because more birds present on the litter produce more moisture, which may result in a reduction of litter quality (Haslam et al., 2007). Bell drinker systems are associated with leakage and increased litter moisture compared to nipple drinkers (Ekstrand et al., 1997). However, there were no differences between survey respondents for these factors, as all respondents used nipple drinkers and stocking densities of 38 kg/m^2. A trend was identified for the number of dietary phases used by producers (3 phases: 34.7%; >3 phases: 18.3%; P=0.08; Table 3.4). Nutritional requirements of broilers change with age, so more dietary phases allow more accurate fulfillment of those requirements compared to only three phases (as reviewed by Shariatmadari, 2012). However, we did not test feed for any of the respondents, as respondents used different feed companies or mixed feed on-farm, and there could have been other confounding factors which influenced this trend. As such, we are unable to make recommendations based solely on these data.

The majority of producers (62.5%) used wheat straw as litter material, compared to pine shavings (21.9%) and newspaper (12.5%; Table 3.3). The majority of pine shavings used as litter by Alberta broiler producers are shipped from British Columbia, due to high demand for pine shavings from the oil industry. A supplier in Alberta sells pine shavings bales which expand to 8 ft^3 bedding for $4.50/ bale (Mistaya Land & Water Corp, 2014). One barn in the current study was estimated to require 5400 ft^3 of shavings per broiler flock, which would cost $3200 CAD, plus shipping. In comparison, wheat straw is much easier to obtain, as wheat is commonly grown by Alberta poultry producers for feed. Wheat straw is then readily available on-farm for use as litter. Even if producers do not grow straw on-farm, purchasing wheat straw is cheaper compared to pine shavings, as straw is usually available locally. For the same 5400 ft^3 of required litter, purchasing wheat straw would cost approximately $1406 ($25 per 96 ft^3 bushel) including shipping (Alberta Agriculture & Forestry, 2016). The current study found that respondents reported choosing bedding based on local availability (71.9%) and low cost (40.6%; Table 3.3). The majority of producers sourced bedding on-farm (65.6%) compared to elsewhere in the province (31.3%; Table 3.3). However, flocks raised on straw litter had significantly higher on-farm prevalence of foot pad dermatitis (40.6%) compared to flocks raised on alternative materials (6.4%; P<0.001; Table 3.4).

Wheat straw has been previously associated with higher prevalence of foot pad dermatitis compared to pine shavings (Meluzzi et al., 2008b; Bilgili et al., 2009). However, results from the current study indicate that Alberta producers are more likely to choose wheat straw litter due to the lower cost despite an increased prevalence of foot pad dermatitis, due to the high cost of alternative materials like pine shavings. The average flock size in the current study was 30,000 birds, and there are approximately 7 flock cycles in a year for producers. As such, there are approximately 420,000 foot pads produced by each producer per year. If the prevalence estimates found for wheat straw (40.%) and pine shavings (6.4%) are applied to that one producer, then the number of chicken feet unaffected by foot pad dermatitis and able to be sold each year are 393,120 feet/year from pine shavings litter and 248,640 feet/year from wheat straw litter. Chicken feet have been estimated at $0.04/foot (Delmar Group International, 2014) and chicken feet from pine shavings would generate $15,725/year compared to $9,946/year for wheat straw for one producer. However, the cost of implementing pine shavings over one year for 5400 ft^3 of litter is $22,400/year, compared to $9,842/year for wheat straw. Further, processors receive all income associated with sale of chicken feet, which means that producers using pine shavings would be in deficit of $6,675/year even if compensated for chicken foot sales. It is important to remember that broilers with blemish free feet often grow better and have higher market weights, which is results in greater financial benefit to the producer. However, this was not calculated. Legislation mandating pine shavings bedding for Alberta broilers should be considered for welfare improvement. It is unlikely producers would switch otherwise unless superior litter materials are made locally available at a lower cost. It is also recommended that if a change to pine shavings is mandated, an incentive program for producers for excellent foot pad quality should be considered to negate the increased costs of production associated with pine shavings.

No significant differences in odour score (lsmeans ± SEM) were observed between producers (A: 0.12 ± 0.14; B: 1.43 ± 0.50; C: 0.60 ± 0.31; D: 0.71 ± 0.35; E: 0.71 ± 0.35; F: 0.71 ± 0.35; G: 0.01 ± 0.01; H: 0.33 ±0.28; P>0.10). However, significant differences in litter scores (lsmeans ± SEM) were found between producers (A: 1.398 ± 0.20; B: 1.396 ± 0.14; C: 1.519 ± 0.21; D: 0.801 ± 0.12; E: 0.913 ± 0.13; F: 2.020 ± 0.26; G: 0.558 ± 0.10; H: 1.708 ± 0.23; P<0.01). Flocks with mean litter scores of '2' or greater (litter formed a ball upon compaction) resulted in significantly more birds affected by foot pad dermatitis (40.1%) compared to litter scores of 1 (friable litter) or less (7.4%; P<0.01; Table 3.4). Further, on-farm foot pad scores and litter moisture scores were significantly, positively correlated (r =0.65; P<0.01). Multiple studies have reported higher prevalence of foot pad dermatitis associated with excess litter moisture (Martland, 1985; Dozier et al., 2006; Mayne et al., 2007; Bassler et al., 2013). Excess litter moisture irritates the skin of the foot pad over time, resulting in the development of foot pad lesions (as reviewed by Shepherd and Fairchild, 2010). Results from the current study agree with these previous reports and indicate litter moisture is a major contributing factor to the development of foot pad dermatitis in Alberta. Litter moisture can be affected by multiple management factors within the barn. Some factors discussed previously, such as ventilation rate, stocking density and season were not found to be significant in the current study. However, previous studies have reported that broilers raised on straw depths of >10 cm had 47% foot pad dermatitis prevalence (Ekstrand et al., 1997) compared to 20% prevalence on depths <10 cm (Martrenchar et al., 2002). Ekstrand et al. (1997) hypothesized that shallower litter is more easily overturned by broilers and dried by the ventilation system. Increased litter movement allows greater moisture release and reduced foot pad dermatitis compared to deeper litter which may trap moisture (Ekstrand et al., 1997). The current study observed flocks raised on litter depths >12.7 cm had a higher prevalence of foot pad dermatitis

(46.4%) compared to flocks raised on depths <12.7cm (23.9%; P>0.05; Table 3.4). As researchers did not measure litter depth for each flock, more in-depth research is required before shallow litter depths are recommended to Alberta broiler producers. However, given that 75% of producers indicate that they use litter depths of <12.7 cm, it would take minimal effort for most producers to meet the recommendation.

The performance index score for each flock was compiled after collection of all survey data was complete (Appendix C). The intention behind the performance index was to assign a score to each producer that reflected both management practices and prevalence of foot pad dermatitis for each of their flocks, which would have then been a useful tool for the industry to monitor and manage foot pad dermatitis. For example, after taking a short survey, producers could identify areas where they could improve management of foot pad dermatitis, and areas that they already excelled in. However, the correlation between the performance index and on-farm foot pad score was not significant (r =0.19; P >0.10; Appendix C). One of the difficulties in the creation of the performance index was the many different ways producers can manage a barn. It was difficult to identify which management practices were "best" and "worst" for each question as the answer varied between the literature, experts and/or producers. Another possible explanation for the weak relationship is that selected survey questions used in the performance index were not weighted by degree of influence on foot pad dermatitis prevalence due to the limitations of the data. Weighting questions is effective for large (N= >200) numbers of respondents as it helps account for potential confounding factors within the ranking system. However, after consultation with an expert in economics, it was determined that weighting questions would be impractical due to the limitations in survey sample size and the time required to create a such a weighting system. Survey results showed that litter management practices (e.g. litter depth, material, moisture) had the greatest influence on foot pad dermatitis prevalence compared to all other parameters (Table 3.4). As such, if a producer had a high prevalence of foot pad dermatitis and scored poorly in litter management (e.g. used wheat straw, had high litter moisture, used litter depths of >12.7 cm), but excelled in other, less influential categories (e.g. lighting, barn age), the performance index scores may be inflated. Thus, as our questions were not weighted, performance index scores of producer may have been inflated which influenced the correlation of the performance index score with foot pad dermatitis. However, the authors encourage the creation of a performance index for foot pad dermatitis which would be useful for management throughout the industry, and should be considered for future studies with larger sample sizes.

3.4. Conclusions and applications

The objectives of the current study were to benchmark prevalence of foot pad dermatitis in Alberta, compare the correlations of three foot pad assessment methods and assess the reliability of current foot pad assessment at an Alberta processing plant. The final objective was to determine any management practices in Alberta which may contribute to the development of foot pad dermatitis. Mean foot pad dermatitis prevalence for each assessment method was 28.65% (on-farm), 26.17% (processor-line) and 31.83 % (processor-sampled). On-farm and processing-sampled assessment methods were more strongly correlated to one another compared to correlation with the processing-line assessment. One reason for this is that processing-line assessment was not repeatable between measurements on the same flock, which resulted in greater variability compared to either on-farm or processor-sampled assessment. As such, the current processing-line methodology needs to be reassessed as current procedures may be wasting resources by not accurately assessing foot pad dermatitis. On-farm foot pad scoring was determined to be the most accurate and feasible method of foot pad assessment, as producers can assess foot pad dermatitis throughout the production cycle and actively manage the condition. Management practices associated with litter moisture were found to influence the prevalence of foot pad dermatitis. For example, use of pine shavings bedding material, litter depths of <12.7cm and litter scores of ≤ 1 were all associated with an increase in foot pad quality. Requiring producers in Alberta to use pine shavings should be considered to improve broiler welfare in Alberta. However, legislation should consider that producers be compensated or rewarded for improved foot pad quality due to the increased cost of production associated with pine shavings litter.

3.5. Acknowledgments

Funding for the current project was provided by Agriculture and Agri-Food Canada through the Agri-Innovation Program (Growing Forward 2), Alberta Livestock and Meat Agency, Alberta Chicken Producers, with in-kind support from Sofina Foods, the University of Alberta and the University of Saskatchewan.

The authors would like to acknowledge all of the participating producers who allowed us to visit their farms throughout this experiment. Additionally, the authors would like to acknowledge Emmanuel Opoku Yeboah for his technical assistance throughout the current research. The authors would also like to thank the staff at the Sofina (Lilydale) Processing Plant specifically John Mah (Calgary, AB), as well as Dr. Rob Renema and Trevor Prout from the Alberta Chicken Producers.

3.6. References

Agriculture and Agri-Food Canada. 2015. Weighted average retail poultry and table egg prices report (chicken). Available at http://aimis-simia.agr.gc.ca/rp/index-eng.cfm?report_format_type_code=21&action=gR&signature=5A510CFABB52569B4EBF

F9F8486FCD93&pdctc=&r=116&pTpl=1&btnDownload=View (accessed 4 September 2016).

Alberta Agriculture & Forestry. 2016. Hay, Straw and Pasture Listings. Available at https://www.agric.gov.ab.ca/app68/hay?cat=For Sale&cat1=Straw (accessed 8 September 2016).

Bassler, A. W., C. Arnould, A. Butterworth, L. Colin, I. C. De Jong, V. Ferrante, P. Ferrari, S. Haslam, F. Wemelsfelder, and H. J. Blokhuis. 2013. Potential risk factors associated with contact dermatitis, lameness, negative emotional state, and fear of humans in broiler chicken flocks. Poultry Science 92:2811–2826.

Bilgili, S. F., J. B. Hess, J. P. Blake, K. S. Macklin, B. Saenmahayak, and J. L. Sibley. 2009. Influence of bedding material on footpad dermatitis in broiler chickens. Journal of Applied Poultry Research 18:583–589.

Butterworth, A., I. C. de Jong, C. Keppler, U. Knierim, L. Stadig, and S. Lambton. 2016. What is being measured, and by whom? Facilitation of communication on technical measures amongst competent authorities in the implementation of the European Union Broiler Directive (2007/43/EC). Animal 10:302–308.

Canadian Council on Animal Care. 2009. Guidelines on the care and use of farm animals in research, teaching and testing. Canadian Council on Animal Care, Ottawa, Canada.

Danbury, T. C., C. A. Weeks, A. E. Waterman-Pearson, S. C. Kestin, and J. P. Chambers. 2000. Self-selection of the analgesic drug carprofen by lame broiler chickens. Veterinary Record 146:307–311.

DEFRA (Science Research & Development). 2010. Foot pad dermatitis and hock burn in broilers: risk factors, aetiology and welfare consequences-final report. SID 5. Department for Environment, Food and Rural Affairs, Glasgow.

Delmar Group International. 2014. Industry, markets and trade (Canada). Available at https://www.delmarcargo.com/en/links.html#canada (accessed 4 September 2016).

Dozier, W. A., J. P. Thaxton, J. L. Purswell, H. A. Olanrewaju, S. L. Branton, and W. B. Roush. 2006. Stocking density effects on male broilers grown to 1.8 kilograms of body weight. Poultry Science 708:344–351.

Eichner, G., S. L. Vieira, C. A. Torres, J. L. B. Coneglian, D. M. Freitas, and O. A. Oyarzabal. 2007. Litter moisture and footpad dermatitis as affected by diets formulated on an all-vegetable basis or having the inclusion of poultry by-product. Journal of Applied Poultry Research 16:344–350.

Ekstrand, C., B. Algers, and J. Svedberg. 1997. Rearing conditions and foot-pad dermatitis in Swedish broiler chickens. Preventive Veterinary Medicine 31:167–174.

Environment Canada. 2016. Historical climate data. Government of Canada Available at http://climate.weather.gc.ca/index_e.html (accessed 1 May 2016).

Gentle, M. J. 2011. Pain issues in poultry. Applied Animal Behaviour Science 135:252–258.

Greene, J. A., R. M. McCracken, and R. T. Evans. 1985. A contact dermatitis of broilers-clinical and pathological findings. Avian Pathology 14:23–38.

Haslam, S. M., T. G. Knowles, S. N. Brown, L. J. Wilkins, S. C. Kestin, P. D. Warriss, and C. J. Nicol. 2007. Factors affecting the prevalence of foot pad dermatitis, hock burn and breast burn in broiler chicken. British Poultry Science 48:264–275.

de Jong, I. C., H. Gunnink, and J. van Harn. 2014. Wet litter not only induces footpad dermatitis but also reduces overall welfare, technical performance, and carcass yield in broiler chickens. Journal of Applied Poultry Research 23:51–58.

de Jong, I. C., J. van Harn, H. Gunnink, V. A. Hindle, and A. Lourens. 2012a. Footpad dermatitis in Dutch broiler flocks: prevalence and factors of influence. Poultry Science 91:1569–1574.

de Jong, I. C., J. van Harn, H. Gunnink, A. Lourens, and J. W. van Riel. 2012b. Measuring foot-pad lesions in commercial broiler houses. Some aspects of methodology. Animal Welfare 21:325–330.

de Jong, I. C., T. Veldkamp, and J. van Harn. 2011. Management tools to reduce footpad dermatitis in broiler chickens. Aviagen:10 pgs.

Kjaer, J. B., G. Su, B. L. Nielsen, and P. Sørensen. 2006. Foot pad dermatitis and hock burn in broiler chickens and degree of inheritance. Poultry Science 85:1342–1348.

Marchewka, J., T. T. N. Watanabe, V. Ferrante, and I. Estevez. 2013. Welfare assessment in broiler farms : Transect walks versus individual scoring. Poultry Science 92:2588–2599.

Martland, M. F. 1984. Wet litter as a cause of plantar pododermatitis, leading to foot ulceration and lameness in fattening turkeys. Avian Pathology 13:241–252.

Martland, M. F. 1985. Ulcerative dermatitis dm broiler chickens: the effects of wet litter. Avian Pathology 14:353–364.

Martrenchar, A., E. Boilletot, D. Huonnic, and F. Pol. 2002. Risk factors for foot-pad dermatitis in chicken and turkey broilers in France. Preventive Veterinary Medicine 52:213–226.

Mayne, R. K. 2005. A review of the aetiology and possible causative factors of foot pad dermatitis in growing turkeys and broilers. World's Poultry Science Journal 61:256–267.

Mayne, R. K., R. W. Else, and P. M. Hocking. 2007. High litter moisture alone is sufficient to cause footpad dermatitis in growing turkeys. British Poultry Science 48:538–545.

Meluzzi, A., C. Fabbri, E. Folegatti, and F. Sirri. 2008a. Survey of chicken rearing conditions in Italy: effects of litter quality and stocking density on productivity, foot dermatitis and carcase injuries. British Poultry Science 49:257–264.

Meluzzi, A., C. Fabbri, E. Folegatti, and F. Sirri. 2008b. Effect of less intensive rearing conditions on litter characteristics, growth performance, carcase injuries and meat quality of broilers. British Poultry Science 49:509–515.

Mistaya Land & Water Corp. 2014. Pine wood shavings. Available at http://www.bestwoodshavings.com/ (accessed 8 September 2016).

Musilova, A., M. Lichovnikova, D. Hampel, and A. Przywarova. 2013. The effect of the season on incidence of footpad dermatitis and its effect on broilers performance. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis 61:1793–1798.

National Farm Animal Care Council. 2016. Code of practice for the care and handling of hatching eggs, breeders, chickens and turkeys. :82 pgs.

Pagazaurtundua, A., and P. D. Warriss. 2006. Levels of foot pad dermatitis in broiler chickens reared in 5 different systems. British Poultry Science 47:529–532.

SAS Institute Inc. 2016. SAS University Edition. SAS Institute Inc, Cary, NC, USA.

Shariatmadari, F. 2012. Plans of feeding broiler chickens. World's Poultry Science Journal 68:21–30.

Shepherd, E. M., and B. D. Fairchild. 2010. Footpad dermatitis in poultry. Poultry Science 89:2043–2051.

Spindler, B., and J. Hartung. 2009. Assessment of litter quality in broiler houses. Sustainable animal husbandry: prevention is better than cure. Proceedings of the 14th International Congress of the International Society for Animal Hygiene (ISAH).:489–492.

Statistics Canada. 2015. Production of poultry, by province. 2016 Available at http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/prim55a-eng.htm (accessed 4 September 2016).

Weaver Jr, W. D., and R. Meijerhof. 1991. The Effect of Different Levels of Relative Humidity and Air Movement on Litter Conditions, Ammonia Levels, Growth, and Carcass Quality for Broiler Chickens. Poultry Science 70:746–755.

Welfare Quality® Consortium. 2009. Welfare Quality ® assessment protocol for poultry (broilers, laying hens). :111 pgs.

Table 3.1. Foot pad, litter and odour assessment systems used during on-farm and processor-sample assessment.

Assessment	Score	Definition
Foot Pads[1]	0	No blemish or discolouration of foot pad
	1	Small black lesion (<25% of foot pad) or keratosis of foot pad
	2	Moderate lesion (25-50% of foot pad) with black colouration
	3	Severe lesion (>50% of foot pad). Black colouration, may extend to toes.
Litter[2]	0	Litter is dry, moves easily when touched in the hand
	1	Litter moves less easily in the hand, but does not form a ball
	2	Litter forms a ball when compressed, but it easily falls apart
	3	Litter stays in a ball when compressed, wet litter
	4	Litter stays in a ball when compressed, after compacted surface crust is broken
Odour[3]	0	No ammonia smell
	1	Mild ammonia smell
	2	Intense ammonia smell

[1]Scale modified from 5 to 4 point scale from the Welfare Quality Assessment Protocol (Welfare Quality® Consortium, 2009).

[2]Modified from the Welfare Quality Assessment Protocol (Welfare Quality® Consortium, 2009).

[3]Scale modified from 5 to 3 point scale from Zhang et al. (2002).

Table 3.2. Frequency of responses for selected survey questions. Survey was completed during every flock visit (N=32). Values[1] are expressed in proportion of flocks which employed the management practice in "Responses".

Category	Question	Responses	Flocks (%)
Foot Pad Dermatitis Management	Foot Pad Prevention On-Farm	Keep Floor/Litter Dry	56.3
		Maintain Air Quality	56.3
		In-Floor Heating	12.5
		Other	15.6
	Foot Pad Assessment On-Farm	Standardized Assessment System Used	6.25
		Assess Live Birds	25.0
		Assess Dead Birds	40.6
		No Assessment/Did Not Answer	21.8
	Time Managing Farm	≤5 years	3.1
		>5 years	96.9
Flock Information	Age at Processing	≤ 39 days	78.1
		> 39 days	21.9
	Stocking Density	38 kg/m^2	100
	Thin Flock	Yes	9.4
		No	90.1
Water Management	Drinker System	Nipple	100
	Drinker Height Change	Head Angle	46.9
		Visual Bird Assessment	37.5
		Weekly/Guidelines	25.0
	Date of Last Water Test	≤ 6 months	37.5
		≥ 1 year	62.5
Nutrition Program	Starter	≤ 21% CP	18.8
		> 21% CP	46.9
	Grower	≤ 19% CP	25.0
		> 19% CP	40.6
	Finisher	≤ 18% CP	59.37
		> 18% CP	12.5
	Number of Diet Phases	3 phases	75.0
		>3 phases	25.0

[1]Value calculated by counting number of responses for each category / (32 total flocks assessed)*100

Table 3.3. Frequency of responses for selected survey questions. Survey was completed during every flock visit (N=32). Values[1] are expressed in proportion of flocks which employed the management practice in "Responses".

Category	Question	Responses	Flocks (%)
Barn Environment	Barn Age	≥10 years old	62.5
		<10 years old	37.2
	Ventilation System	Tunnel	31.3
		Stack/Chimney	25.0
		Side Vent (side or ceiling)	90.6
		Other	31.3
	Heating System	Floor	12.5
		Forced Air	46.9
		Radiators	46.9
		Other	31.3
Flock Health	Mortality Rate	≤ 5%	28.1
		5-10 %	50.0
		>10%	6.25
	Disease Occurrences	None	75.0
		Disease(s) occurred	25.0
Lighting	Lightbulb Type	LED or Fluorescent	52.5
		Incandescent	38.4
	Light Intensity	Lux changes (20: chicks, 5-10: rearing)	3.1
		Lux unchanged	46.8
		Lux unknown	50
Litter Properties	Litter Material	Wheat Straw	62.5
		Canola Straw	3.1
		Pine Shavings	21.9
		Shredded Newspaper	12.5
	Reason for Litter Choice	Inexpensive	40.6
		Locally Available	71.9
		Industry Standard	6.3
		Other	28.1
	Source of Litter	On-Farm	65.6
		Off-Farm	31.3
	Litter Depth	≤12.7 cm	75.0
		>12.7 cm	25.0

[1]Value calculated by counting number of responses for each category / (32 total flocks assessed)*100

Table 3.4. Statistics from selected survey questions. Questions were chosen from selected categories which relate to foot pad dermatitis development (Table 3.3). Survey responses were compared with arithmetic mean foot pad score recorded during on-farm sampling.

Question	Responses	Mean FPD Prevalence (%)	Test Used	P-value[1]
On-Farm Foot Pad Assessment	Live & dead birds assessed	36.5	ANOVA	0.203
	Dead birds only assessed	29.7		
	No birds assessed	10.8		
On-Farm FPD Prevention	Maintain litter & ventilate	47.3	ANOVA	0.323
	Ventilate & other	42.7		
	Ventilate alone	30.5		
	In-floor heating	23.8		
Barn Age	<10 years old	30.3	t-test	0.836
	≥10 years old	28.4		
Age at Processing	≤ 39 days	31.9	t-test	0.219
	> 39 days	18.3		
Change of Drinker Height	Weekly/guidelines	34.6	ANOVA	0.518
	Visual/behaviour	32.8		
	Head angle	23.4		
Date of Last Water Test	< 6 months	28.1	t-test	0.514
	1 year	36.6		
Number of Diet Phases	3	34.7	t-test	0.076
	>3	18.3		
Litter Material	Straw	40.6	t-test	<0.001
	Not Straw	6.40		
Litter Moisture	Moist	40.1	t-test	<0.001
	Dry	7.40		
Litter Depth	≤12.7 cm	24.0	t-test	0.027
	> 12.7 cm	46.4		
Lightbulb Type	Incandescent	38.4	ANOVA	0.363
	LED	27.0		
	Fluorescent	25.2		
	Other	55.5		
Light Intensity (lux)	Lux changes during rearing	40.3	ANOVA	0.617
	Lux does not change	28.2		
	Lux is unknown	26.7		

[1]Differences considered significant at P<0.05, a trend at P=0.05-0.10 and insignificant at P >0.10

Table 3.5. Distribution of foot pad scores by severity for each producer (lsmeans ± SEM). On-farm and processor-sampled scores used the same assessment method (Table 3.2). Scores of 0 were considered blemish-free, while scores of 3 indicated a severe foot pad lesion.

Producer[2]	On-Farm Score[1] (%)				
	0	1	2	3	P-value[3]
A	76.0^a ± 8.1	11.9^b ± 2.9	6.4^b ± 1.6	5.7^b ± 2.5	<0.01
B	67.5^a ± 7.7	10.3^b ± 2.7	10.4^b ± 2.2	11.8^b ± 3.6	<0.01
C	87.4^a ± 8.7	5.6^b ± 2.0	3.8^b ± 1.4	3.3^b ± 1.9	<0.01
D	99.1^a ± 9.3	0.7^b ± 0.7	0.0^b ± 0.1	0.2^b ± 0.5	<0.01
E	62.4^a ± 7.4	17.4^b ± 3.5	9.3^b ± 2.1	10.9^b ± 3.4	<0.01
F	54.6^a ± 6.9	15.0^b ± 3.2	16.3^b ± 2.1	14.1^b ± 3.9	<0.01
G	97.2^a ± 10.6	2.17^b ± 1.4	0.3^b ± 0.5	0.3^b ± 0.7	<0.01
H	44.5^a ± 7.2	13.3^b ± 3.5	14.9^b ± 3.9	27.3^a ± 6.2	<0.01
	Processor-Sampled Score[1] (%)				
	0	1	2	3	P-value
A	71.5^a ± 7.8	17.3^b ± 3.7	7.3^c ± 2.1	3.9^c ± 1.8	<0.05
B	54.2^a ± 6.8	23.0^b ± 4.3	13.8^{bc} ± 2.8	9.1^c ± 2.7	<0.01
C	90.8^a ± 8.8	4.9^b ± 2.0	2.6^b ± 1.2	1.7^b ± 1.2	<0.01
D	96.9^a ± 9.1	1.7^b ± 1.2	0.9^b ± 0.7	0.5^b ± 0.6	<0.01
E	59.5^a ± 7.1	25.6^b ± 4.6	9.9^c ± 2.4	5.0^c ± 2.0	<0.01
F	46.8^a ± 6.3	22.5^b ± 4.3	17.5^b ± 3.2	13.2^b ± 3.3	<0.01
G	89.7^a ± 8.8	8.4^b ± 2.6	1.3^c ± 0.9	0.6^c ± 0.7	<0.01
H	36.9^a ± 5.6	21.2^b ± 4.1	21.4^b ± 3.5	20.5^b ± 4.1	<0.05

[1]Calculated by taking number of foot pads scored per category (0-3) and dividing by total number of feet scored

[2]Each producer score is the percentage of feet per scoring category over four flocks

[3] Different subscripts indicate a difference in treatment means

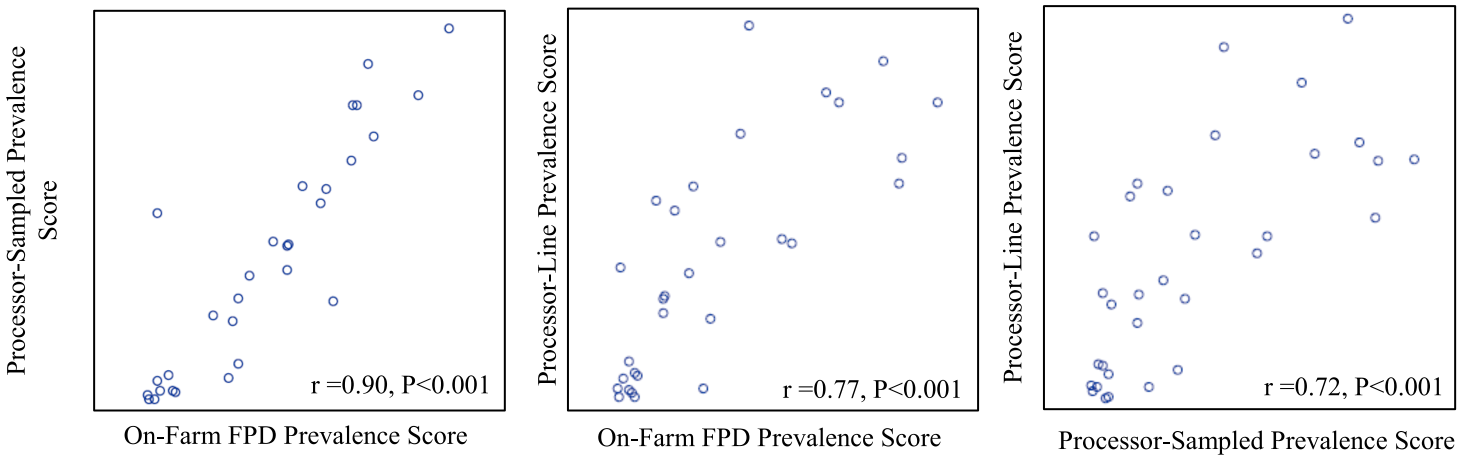


Figure 3.1. Correlation matrix of three foot pad assessment methods. Correlation was tested using Pearson's rank correlation test using the Corr procedure of SAS. Significance was defined as P<0.05.

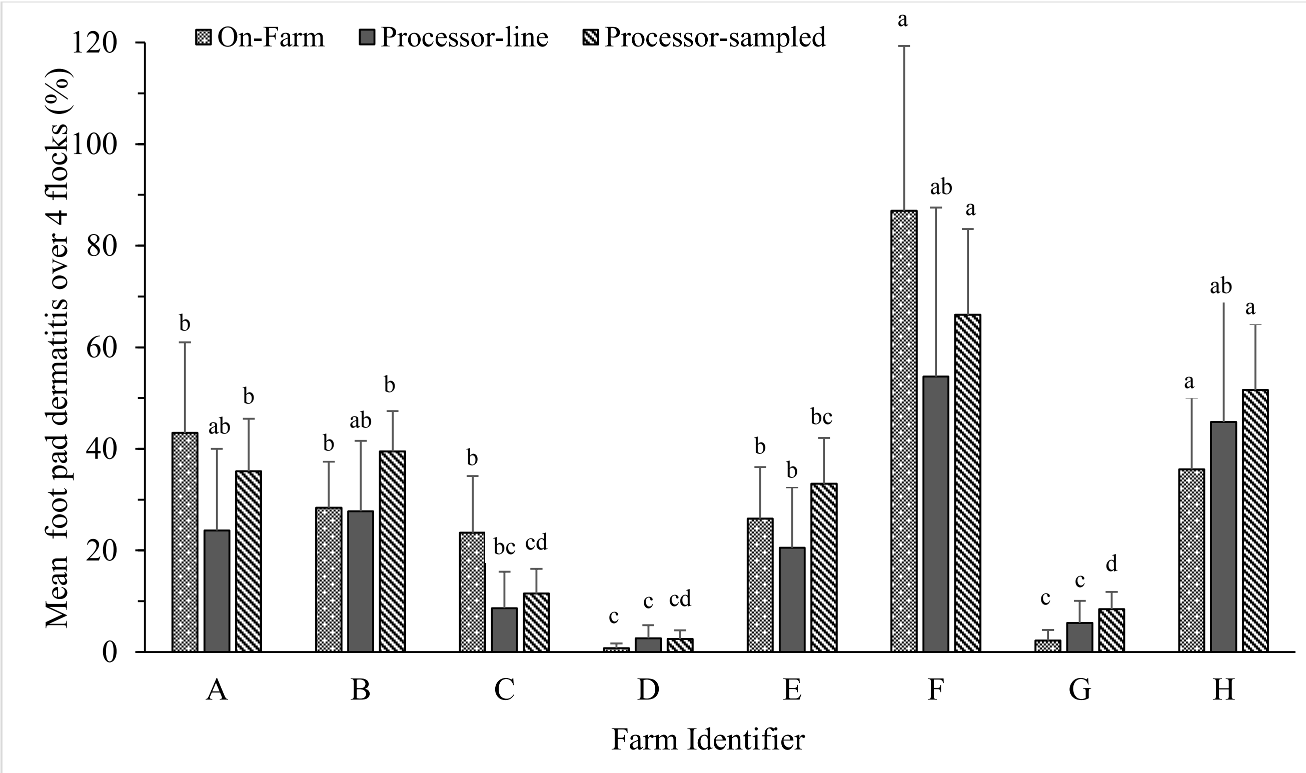


Figure 3.2. Mean foot pad scores for on-farm, processor-line and processor-sampled assessment methods by producer (lsmeans ±SEM[1]). On-farm assessment completed on 200 birds using scoring system detailed in Table 3.1 for each of 30 flocks. Processor-line scores taken 3 times on processing line. Line scores estimated by: number of blemished feet/100 counted feet* 100%. Processor-sampled assessment completed on 300 foot pad pairs off processing line for each of 32 flocks using scoring system (Table 3.1). Scores represent the average prevalence score for all flocks assessed for each producer and each assessment method.

4.0. Impact of raised slatted platforms and litter material on broiler chicken foot pad quality[2].

4.1. Introduction

Foot pad dermatitis is a skin condition in broiler chickens characterized by lesions that develop primarily after prolonged contact with excessive litter moisture (Greene et al., 1985; Eichner et al., 2007; de Jong et al., 2012). Foot pad dermatitis is a welfare concern for broilers as lesions are associated with inflammation and considered painful (de Jong et al., 2014). Although the export market for chicken feet is worth considerably less than the $3.9 billion (CAD) breast meat market (Agriculture and Agri-Food Canada, 2015), loss from foot pad dermatitis is estimated at $15.8 million (CAD) in Canada and $1.5 million (CAD) in Alberta (Delmar Group International, 2014; Statistics Canada, 2015) as blemished feet cannot be sold.

Litter moisture is influenced by litter depth, litter quality and litter material (Chapter 3). Specifically, litter depths of ≤12.7 cm, friable litter and pine shavings litter material have been associated with reduced prevalence of foot pad dermatitis in Alberta (Chapter 3). The majority of producers (62.5%) have been reported to use wheat straw as litter, compared to pine shavings (21.9%; Chapter 3). Wheat straw is a by-product of wheat, which is commonly grown on-farm in Alberta for use in poultry feed. Further, as pine shavings are used by the Alberta oil industry producers must ship pine shavings from British Columbia. Pine shavings are expensive at $4.50 CAD/8 ft^3 bale plus shipping (Mistaya Land & Water Corp, 2014), compared to wheat straw, priced at $25 CAD/96 ft^3 bushel (Alberta Agriculture & Forestry, 2016). However, wheat straw

[2]This chapter will be submitted for publication to Poultry Science and is formatted in accordance with its conventions and instructions to authors.

has been reported to have higher initial moisture (12.2%) and retains more moisture (80.6%) compared to pine shavings (initial:11.3%, retention: 71.2%) which may lead to greater litter moisture and development of foot pad dermatitis (Bilgili et al., 2009).

Many alternative bedding materials with varying moisture retention capacities have been investigated for use in broiler production. For example, peat moss can absorb approximately 20 times its weight in moisture and has been used as a litter material in Scandinavian countries (Everett et al., 2013). However, litter comprised of peat alone can become very dusty, as peat readily releases moisture. As such, a combination of peat moss and pine shavings or wheat straw may be more effective to avoid excessively dry and dusty litter (Everett et al., 2013). From 2004 to 2008, Danish broiler producers transitioned from using primarily straw to pine shavings and/or sphagnum peat moss, which was effective in reducing foot pad dermatitis prevalence by 40% (Kyvsgaard et al., 2013). Peat moss is naturally acidic with a pH of 4.5 (Peat Moss Association of Canada, 2016) and has also been found to be effective at reducing the microbial population in the litter (Everett et al., 2013). With litter moisture, microbes facilitate the conversion of fecal uric acid to ammonia (Nahm, 2003). Peat moss was reported to reduce the populations of bacteria, yeast and mold when added as an amendment to pine shavings which could decrease production of ammonia and maintain acidity (Everett et al., 2013). However, the impact of peat moss litter amendments in wheat straw and/or on foot pad dermatitis has not been investigated.

Foot pad dermatitis development is influenced by the amount of time birds are in contact with litter. Broilers are most active until about 21 days of age when breast muscle development and body weight rapidly increase (Duncan et al., 1992). Standing and walking presses the foot pad into the litter, which results in the development of foot pad lesions if litter is excessively wet. After 21 days of age, broilers become more inactive, spending up to 60 to 90% of their daily activity time budget sitting or resting, (Bizeray et al., 2002a; Kristensen and Cornou, 2011), which further increases contact with wet litter and exacerbates any existing foot pad lesions (Bessei, 2006). Whether standing or sitting, the foot pads of broiler chickens are constantly in contact with litter, which increases the risk of developing foot pad lesions. As such, any means of getting birds off the litter (e.g. perches) could potentially decrease time that foot pads are in contact with litter and reduce prevalence of foot pad dermatitis. However, perching in broilers has been found to decrease with age due to the large gain in breast muscle mass which deters birds from perching (LeVan et al., 2000; Pettit-Riley and Estevez, 2001; Bizeray et al., 2002a). Barrier perches are obstacles placed on the ground between resources which require broilers to navigate barriers to access food and water, however broilers have been observed to perch on barrier perches (Ventura et al., 2010). Bench et al. (In Press) investigated the impact of two designs of ground perches (I and X shaped) on foot pad dermatitis. The authors found no impact of perch design on foot pad dermatitis and reported that perching decreased with age. However, broilers were observed to prefer perching on the junctions of both I and X perches. The authors speculated that the greater surface area of the junctions provided more support for broilers, and that a wider surface might encourage perch use and decrease time foot pads were in contact with litter. Previous research has shown that foot pad dermatitis lesions can heal when broilers were transferred to new, dry bedding (Martland, 1985; Taira et al., 2014). As such, raised slatted platforms are potentially more attractive for broilers to sit on while reducing contact with litter, potentially maintaining litter quality and allowing existing foot pad lesions to heal. Further, if platforms were placed in an environment where pine shavings or wheat straw litter is amended with an absorbent material like peat moss, the combination of reduced litter contact and improved moisture properties has the potential to minimize prevalence of foot pad dermatitis in a broiler flock.

The objectives of the current study were to 1) investigate the use of raised, slatted platforms on the behaviour and foot pad quality of broiler chickens, and 2) assess the impact of litter material (e.g. pine shavings, wheat straw, layered pine shavings/peat and layered wheat straw/peat) on foot pad quality of broiler chickens. We hypothesized that platforms would have an impact on foot pad quality, and that litter treatments containing peat moss would have an impact on foot pad quality.

4.2. Materials and methods

4.2.1. Animals and facilities

All research procedures were approved by the Animal Care and Use Committee for Livestock at the University of Alberta (AUP 1235). Broilers were raised according to Canadian Council for Animal Care Guidelines (Canadian Council on Animal Care, 2009; Chicken Farmers of Canada, 2009) and the Ross 308 Broiler Management Handbook (2014). Research took place from October – November, 2015 at the Poultry Research Centre at the University of Alberta in Edmonton, AB, Canada.

4.2.2. Experimental design

A randomized complete block design was used, with four blocks each containing two complete sets of treatments (16 pens) and a treatment factorial arrangement of 2 (platform) x 4 (litter), with an interaction of N =8 platform by litter treatment. Experimental units (N =64 floor pens) measured 2.1 m x 1.7 m with 45 birds, and final stocking density of 38 kg/m^2. Day-old Ross 308 mixed-sex broiler chickens (N =2880) were obtained from the Sofina Foods Hatchery (Edmonton, Alberta, Canada). Sampling units (N=10 focal birds/pen; 22% of experimental unit population) were randomly selected and individually identified using livestock spray and wing bands. Food and water were provided ad libitium using hanging tube feeders and nipple drinkers. Mortality was recorded twice daily.

4.2.3. Litter treatments

Litter treatments consisted of 100% pine shavings (**Pine**), 100% wheat straw (**Wheat)**, 75% wheat straw/25% peat moss (**Wheat/Peat**), and 75% pine shavings/25% peat moss (**Pine/Peat**). The inclusion level of 25% was chosen based on similar levels used by a previous study investigating the impact of peat moss amendment on microbial populations (20%; Everett et al., 2013) Litter was spread to a depth of 6.35 cm in all treatments. The peat component of Wheat/Peat and Pine/Peat treatments was determined by volume (25% of total litter volume). Pine shavings or wheat straw was then layered on top and measured to ensure a consistent litter depth of 6.35 cm.

4.2.4. Platform treatments

Platform treatments were: pens with platforms (**Platform**) and pens without platforms (**NoPlatform**). Platforms (B.C.M. Manufacturing Ltd., Canada) were made of hard plastic with 6.45 cm^2 holes (Figure 4.1). Platforms were raised to 10.16 cm using 1½” x 3½” pine lumber planks and placed opposite the drinker (Figure 4.2).

4.2.5. Behaviour observations

Instantaneous scan sampling was conducted at day 12, 19, 26 and 33 of the experiment (2 to 5 weeks of age) using 10 focal birds/pen. Eight mutually exclusive categories of behavior were sampled: Stand, Walk, Sit, Forage, Eat, Drink, Platform and Other (Table 4.1). Platform was recorded if birds were sitting, standing, walking or performing any other behaviours on the platform. Standing, Walking, Foraging and Sitting are all associated with litter contact, which leads to the development of foot pad dermatitis. Eating and Drinking were recorded as broilers had to walk and stand at the feeder and drinker which are also associated with litter contact. Circadian rhythms occur in broiler behaviour (Shields et al., 2005), thus observations occurred weekly during morning (8:30 to 12:00) and afternoon (13:00 to 16:30). A 15 minute acclimation period was used prior to observations to allow birds to adjust to observers. Prior to the start of observations, observers were trained to properly identify all behaviors in the ethogram by a senior research team member. During training, the observer and trainer assessed the same pen to ensure agreement in behaviour coding. Reliability between observers was assessed weekly by comparing behaviour counts (lsmeans ± SEM) between observers to maintain 90% reliability. During data collection, four observers were spaced equidistance apart in front of pens. Three cycles of observations were completed within each sampling period using a one-minute sampling interval. Each pen was observed 12 times/morning or afternoon session, for a total of 24 times per pen per behaviour observation day.

4.2.6. Foot pad and gait assessment

Foot pad dermatitis can develop as early as 7 days of age (Hashimoto et al., 2011). To ensure measurement of foot pad health prior to the development of foot pad lesions, foot pad scoring was performed at 6, 13, 20, 27 and 34 days of age (1 to 5 weeks of age). Foot pads were also assessed post-mortem directly from the processing line at 41 days of age. Left and right feet of focal birds (N=10 focal birds/pen) were scored using the assessment method described in Table 4.2, modified from the Welfare Quality® Assessment Protocol (2009) . A score of '1' was recorded to a pair of foot pads if either left or right foot had any severity of foot pad lesions, while a score of '0' was given to each blemish-free pair of foot pads. The number of blemished foot pad pairs were summed and divided by the total number of birds scored. If foot pad lesions are severe, pain may result in an alteration of gait. Thus, focal bird gait was assessed at 28 and 35 days of age, as broilers are expected to become increasingly lame with age due to foot pad lesions (Baéza et al., 2012). Gait was assessed using the method described in Garner et al. (2002). Individual birds were placed into a sampling arena with 2.54 cm depth of pine shavings. Birds were gently encouraged to walk, and observed from the back and side for a minimum of 30 seconds then assigned a gait score of 0 (no impairment of gait), 1 (moderate impairment) or 2 (severe impairment; Table 4.2).

4.2.7. Moisture retention test and litter sampling

Prior to placing litter in pens, a litter moisture retention test was performed on 30g of clean bedding materials (Wheat Straw, Wheat/Peat, Pine/Peat, Pine Shavings, Peat) to determine how adding a peat moss amendment changed litter characteristics. Moisture retention and release was tested using method described in Garcês et al. (2013). Moisture parameters were calculated using equations in Appendix B.

Litter moisture during the trial was determined by sampling litter in front, middle and back (relative to the door) for each pen on day 5, 18 and 32 of the experiment (weeks 1, 3, 5) as litter moisture tends to increase as broilers age (Shepherd and Fairchild, 2010). Litter moisture was determined using methods detailed by AOAC International, (1990) and litter moisture calculations are described in Appendix D. Litter pH was analyzed after adding distilled water to ground litter samples and pH determined using an electronic pH meter (Fisher-Scientific Accumet© Basic Model AB15).

4.2.8. Production parameter measurements

Body weight was intended to be measured at each feed phase change. However, due to personnel and time constraints body weight was measured at 0 and 39 days of age. As the primary focus of the current study was foot pad dermatitis, emphasis was placed on obtaining measurements related to foot pad quality over nutrition and production parameters. All birds in each pen (~ 45 birds) were weighed on day 0 prior to placement. Focal birds (N =10/pen) were weighed on day 39. Individual focal bird weights were averaged and multiplied by the number of birds per pen to estimate total pen weight.

Broilers were fed according to a standard 3-phase commercial feeding program. Birds were switched from Starter (21% CP, 0.4988% aP, 1.2607% Lys, 0.5309% Meth, 0.9861% Met/Cys) to Grower (19% CP, 0.5198% aP, 1.1938% Lys, 0.5309% Meth, 0.9713% Met/Cys) at 10 days, and switched to Finisher rations (18% CP, 0.4810% aP, 1.0788% Lys, 0.4611% Meth, 0.8844% Met/Cys) at 25 days of age. Remaining feed was weighed after each phase change to calculate feed disappearance. Body weight and feed intake data were corrected for mortality, then used to calculate average daily gain (ADG), average daily feed intake (ADFI) and feed conversion ratio (FCR; g feed /g body weight).

A total of 640 focal birds were processed at 41 days of age at the Poultry Research Centre processing facility at the University of Alberta to determine if platform or litter treatments had an effect on production variables. Post-processing, carcass components weighed were *Pectoralis major*, *Pectoralis minor*, wings, drumsticks, thighs and total carcass. Yield of individual carcass components as a percentage of total carcass was calculated by taking the weight of each carcass component and dividing by total carcass weight, then expressing as percent yield (Appendix D).

4.2.9. Statistical analysis

The experimental unit was defined as the pen, while the sampling units were focal birds. Data were analyzed as a generalized linear mixed model using the Glimmix procedure in SAS®

(University Edition, Cary NC, 2016). Behaviour, foot pad, gait, litter moisture, pH, and carcass data specified a Poisson distribution for count data, while body weight and feed data were analyzed using a Gaussian distribution. Both distributions were determined using the Univariate procedure of SAS (University Edition, 2016) and the Kolmogorov-Smirnov test. Type III tests were requested and the inverse link (ilink) option specified. Fixed effects of the model included Bedding, Platform and Bedding by Platform interaction. The random effects for behaviour were Block and Observer. The random effect for all other variables was Block. A Bonferroni means separation test was used and differences considered significant at $P < 0.05$. A tendency was defined at $0.05 < P < 0.10$, and differences with $P > 0.10$ was considered non-significant. All values are reported as lsmeans ± SEM).

4.3. Results

4.3.1. Behaviour

Behaviour results are reported as the least square means ± SEM counts of the number of focal birds performing each behaviour per pen. Block and Observer were not significant. Broilers performed significantly more Standing (0.49 ± 0.02), Walking (0.24 ± 0.01), Sitting (7.81 ± 0.01) and Other (0.15 ± 0.01) behaviours in NoPlatform pens, compared to Platform (Stand: 0.37 ± 0.02; Walk: 0.17 ± 0.01; Sit: 5.85 ± 0.08; Other: 0.21 ± 0.01) treatment pens ($P < 0.01$; Table 4.3). Differences between Platform and NoPlatform treatments were not significant for Foraging, Eating or Drinking behaviours observed ($P > 0.10$; Table 4.3). Effects of bedding treatment did not significantly differ for Stand, Walk, Sit, Eat, Drink, Platform or Other behaviours ($P > 0.10$; Table 4.4). Foraging had a strong tendency to be performed most in Wheat/Peat pens (0.18 ± 0.02) compared to Pine Shavings pens (0.11 ± 0.01; $P=0.06$; Table 4.4).

Walking, Standing and Foraging were observed most at 2 weeks of age and gradually decreased with age, with 50% less Standing, 84% less Walking, and 88% less Foraging observed by 5 weeks of age ($P < 0.01$; Table 4.5). Platform behaviour was observed least at 2 weeks of age (1.53 ± 0.03), and most at 4 weeks of age (2.55 ± 0.04; $P < 0.01$; Table 4.5). Sitting behaviour was observed 10% less at 3 weeks of age (6.38 ± 0.08) compared to 5 weeks of age, when Sitting behaviour was observed most (7.35 ± 0.09; $P < 0.05$; Table 4.5). Eating, Drinking and Other behaviours were observed most at 3 weeks of age, and observed 31% less (Eating), 24% (Drinking) and 37% less (Other) at 5 weeks of age ($P < 0.05$; Table 4.5).

4.3.2. Body weight, feed and carcass

Body weights for Pine Shavings (1433.5g ± 18.1), Pine/Peat (1419.2g ± 17.0), Wheat Straw (1414.0g ± 17.5) and Wheat/Peat (1410.0g ± 17.6) were not significantly different ($P > 0.10$; Table 4.6). Further, body weight in Platform pens (1417.2g ± 12.4) and NoPlatform pens (1421.5g ± 12.4) were not significantly different ($P > 0.05$; Table 4.6). Differences between Bedding and Platform treatments were not significant for average daily gain, average daily feed intake or feed conversion ratio ($P > 0.10$; Table 4.6). Pectoralis minor tended to be heaviest in Wheat Straw pens (102.3g ± 0.3) and lightest in Wheat/Peat pens (97.7 ± 1.3; $P = 0.06$; Table 4.7). Wings tended to be heaviest in Wheat Straw pens (307.9g ± 5.8) and lightest in Pine/Peat pens (288.5 ± 5.5; $P = 0.07$; Table 4.7). Treatment effects for both Platform and Bedding were not significant between all other carcass component weights and carcass component yields ($P > 0.10$; Table 4.7; Table 4.8).

4.3.3. Litter moisture, pH and moisture retention

Moisture retention results for the clean litter material prior to the start of the trial showed that Pine/Peat (394.18% ± 10.1) absorbed 19% more water compared to Pine Shavings and Wheat Straw, 29% more than Wheat/Peat and 38% more than Peat (P <0.01; Table 4.9). However, results of the moisture release test showed that Peat (86.7% ± 1.3) released 30% more moisture than Wheat/Peat and Pine Shavings, 25% more than Pine/Peat and 20% more than Wheat Straw (P<0.01; Table 4.9). Peat also had the lowest final litter moisture, which was ~17% - 26% less than all other treatments (P<0.001; Table 4.9). Final litter moisture was highest in Pine Shavings (39.7%) which was 66% higher than Peat, 23% higher than Wheat Straw, and 11% higher than Pine/Peat (P <0.01; Table 4.9).

Final litter moisture results for litter samples taken during the trial found that Wheat Straw had the highest litter moisture (18.65% ± 0.01) and was 3% greater than Wheat/Peat (18.03% ± 0.01), 12% greater than Pine/Peat (16.40% ± 0.01) and 16% greater than Pine Shavings (15.65% ± 0.01; P <0.01; Table 4.10). However, final litter moisture was significantly different between weeks (P <0.01). Mean final litter moisture for all treatments gradually increased from Week 1 (9.11% ± 0.01) to Week 3 (16.48% ± 0.01) to Week 5 (25.71% ± 0.01; P< 0.01). Differences in final litter moisture between Platform treatments were not significant (P >0.10, Table 4.10).

Litter pH of bedding treatments was significantly acidified by the addition of peat moss (P <0.01; Table 4.10). The pH of Wheat/Peat (5.67 ± 0.05) treatment was significantly more acidic compared to Wheat Straw (6.20 ± 0.045) treatment (P< 0.01; Table 4.10). Further, pH of Pine/Peat (5.43 ± 0.04) was significantly more acidic than pH of Pine Shavings (5.69 ± 0.05) treatment (P <0.01; Table 4.10). However, differences in litter pH for Platform treatment were not significant (P >0.10; Table 4.10).

4.3.4. Foot pad score

Wheat Straw (0.10 ± 0.03) and Wheat/Peat (0.08 ± 0.02) pens had significantly greater mean counts of foot pads with lesions compared to Pine Shavings (0.003 ± 0.01) and Pine/Peat (0.005 ± 0.01) treatments ($P < 0.01$, Table 4.10). Foot pad scores were not significant between Platform (0.020 ± 0.01) and NoPlatform (0.018 ± 0.01) treatments ($P > 0.10$; Table 4.10). Prevalence of foot pad dermatitis across all treatments at 41 days of age was 4%. Due to the low occurrence of foot pad lesions throughout the trial, we observed higher counts of score '0' than expected, which skewed the distribution of foot pad scores. Thus, lsmeans reported for foot pad score are small, representing the adjusted mean and accounting for the high number of '0' scores observed.

4.3.5. Gait score

There was a significant interaction between Platform and Bedding on gait score ($P < 0.01$; Figure 4.3). In the Platform treatment, peat moss improved gait score (lsmeans ± SEM) in both Wheat/Peat (0.09 ± 0.02) and Pine/Peat (0.11 ± 0.03) pens ($P < 0.01$; Figure 4.3). However in the NoPlatform treatment, peat moss impaired gait score in Wheat/Peat pens (0.23 ± 0.04) and improved gait score in Pine/Peat (0.10 ± 0.02). In NoPlatform treatment, the pens without added peat moss (Wheat Straw 0.21 ± 0.04 and Pine Shavings 0.20 ± 0.04) impaired gait score ($P < 0.01$; Figure 4.3).

4.4. Discussion

4.4.1. Platform treatment

The first objective was to determine the effect of raised, slatted platforms on foot pad quality. We hypothesized that platforms would result in improved foot pad scores due to decreased contact with litter material and increased air exposure, allowing foot pads to remain dry (Ventura et al., 2010; Karcher et al., 2013). There were no significant differences in foot pad quality between Platform (0.020 ± 0.01) and NoPlatform (0.018 ± 0.01) treatment ($P>0.10$; Table 4.9). A recent study investigating foot pad quality in ducks raised on slatted plastic flooring also found no impact on foot pad quality from slatted flooring (Fraley et al., 2013). However, foot pad dermatitis prevalence across all treatments at the conclusion of the current study was low (4%) compared to other foot pad dermatitis studies where prevalence ranged from 20% to 50% (Ventura et al., 2010; de Jong et al., 2014; Skrbic et al., 2015). As such, effects from platforms may have been minimized due to an overall lack of severity and prevalence of foot pad dermatitis. Design can affect perch use by broilers and subsequent foot pad quality due to less time spent in contact with litter (Ventura et al., 2010). For example, perches located high above the ground are not preferred by broilers and often result in severe foot pad scores, while platform-type structures or perches close to the ground are used more often (Faure and Jones, 1982; Pettit-Riley and Estevez, 2001; Ventura et al., 2010). Platforms in the current study were raised 10.6 cm above the litter, which resulted in broilers using platforms for 15% (2 weeks), 22% (3 weeks), 26% (4 weeks) and 21% (5 weeks) of sample intervals, which suggests that platforms were neither too high nor complex for broilers (Table 4.5). Despite consistent platform use, there was no impact on foot pad score. This indicates that platforms could be a viable means of decreasing time broilers spend in contact with litter. However, structures may need to be enlarged to increase the number of birds able to occupy the platform simultaneously.

While there was no effect of platforms on foot pad quality, there were significant differences in behaviour between Platform and NoPlatform treatments. Broilers performed 24% fewer Standing behaviours, 29% fewer Walking behaviours, 25% fewer Sitting behaviours and 29% fewer Other behaviours in Platform pens compared to NoPlatform pens (Table 4.3). A study investigating barrier perches and activity found that broilers in pens containing barrier perches spent significantly less time Lying, which the authors attributed to greater time spent perching (Bizeray et al., 2002b). The current study found that Platform behaviours were observed in 21% of all sample intervals. As such, it is likely that results for Standing, Walking, Sitting and Other behaviours between Platform and NoPlatform treatments were due to broilers using the platforms. If behaviours performed on the platform were measured, it is unlikely there would be differences in Standing, Walking, Sitting and Other behaviours between Platform treatments, as platforms did not reduce the amount of space available in the pen. Further, Eating, Drinking and Foraging behaviours required broilers to get off platforms and as a result, no differences were observed in these behaviours between Platform treatments. Thus, the differences in behaviours between Platform and NoPlatform treatments can be attributed to broilers using the platforms instead of performing Standing, Walking, Sitting and Other behaviours on the litter.

Age had a significant effect on all observed behaviours. At 12 days of age, proportion of birds performing Platform behaviours was lowest, while Standing, Walking and Foraging behaviours was highest (Table 4.5). Number of birds performing Standing, Walking and Foraging behaviours all decreased with age, while the number of birds using platforms was highest at 26 days of age (Table 4.5). Our platforms were not placed as barriers, however previous studies reported the same trend for perching on barrier perches (Pettit-Riley and Estevez, 2001; Estevez et al., 2002; Bench et al., In Press), with lowest perch use at 7 days of age, highest perch use at 28 days of age, which then declined at 35 days of age (Bizeray et al., 2002b). Although there were slight variations in the study, the current study found that use of the platforms increased with age, which indicates that platforms were appealing throughout the production cycle. The current study also demonstrates that broilers will get up onto a platform structure provided it is wide enough to support their weight.

There were no effects of Platform treatment on body weight, feed conversion ratio, average daily feed intake, average daily gain or carcass parameters. We did not expect platforms to affect production parameters, as previous studies did not observe significant effects on production parameters from barrier perches (Pettit-Riley and Estevez, 2001) or slatted plastic flooring (Fraley et al., 2013). These results indicate that there was no negative impact of adding platform structures on broiler production parameters.

4.4.2. Bedding treatment

The second objective was to assess the impact of litter material (pine shavings, wheat straw, layered pine shavings/peat and layered wheat straw/peat) on foot pad quality of broiler chickens. We hypothesized that pens with peat would have an impact on foot pad dermatitis. However, adding peat moss to wheat straw resulted in only a slight reduction in foot pad score (Table 4.10). Further, there were no significant differences between Pine Shavings and Pine/Peat treatments. Thus, we cannot accept the hypothesis that peat had a significant impact on foot pad dermatitis. However, results from the current study found that foot pad score was lower in pens with Pine Shavings compared to Wheat Straw pens (Table 4.10). Despite the prevalence of 4% foot pad dermatitis, we found that 21.7% of foot pad lesions were in pens with pine shavings, while 78.3% were in pens with wheat straw. Our results agree with previous studies which reported prevalences of foot pad dermatitis of 51% on wheat straw versus 33% on pine shavings (Meluzzi et al., 2008b) 80% on wheat straw versus 8% on pine shavings (Mihai et al., 2013). Thus, our results support previous studies and indicate that pine shavings is the best litter material for reducing prevalence of foot pad dermatitis.

We found that final litter moisture was highest in wheat straw and wheat/peat pens, which corresponded with the highest foot pad scores (Table 4.9). Mean litter moisture significantly increased with age in all bedding treatments (e.g. Week 1: 9.11% ± 0.01 to Week 3 16.48% ± 0.01). For example at 32 days of age, mean litter moisture was 25.71% ± 0.01 which is lower compared to previous reports of 30% (dry litter) and 48% (wet litter) at 35 days of age (Taira et al., 2014). The low litter moisture throughout the study likely contributed to the low prevalence (4%) of foot pad dermatitis observed throughout the study. One potential explanation for overall low litter moisture in the current study may be the time of year. Environmental conditions during the current study (October to November) ranged from 0.9 ºC to 8.5ºC to with average precipitation of 3 mm to 9.6 mm (Environment Canada, 2016). This is much warmer and drier compared to historical data from 1981 to 2010, where mean temperature ranged from -4.4 ºC to 4.2 ºC with average precipitation of 16.8 mm to 20.4 mm (Environment Canada, 2016). Previous studies have found that summer and fall conditions are associated with decreased prevalence of foot pad dermatitis, but have not reported the temperatures associated with each season (Meluzzi et al., 2008a; Musilova et al., 2013). However, minimal precipitation and temperatures between 0-10 ºC could potentially reduce condensation and moisture within the barn, and make ventilation of moisture more effective. Thus, the minimal litter moisture scores observed may have been partially influenced by the weather and dry climate of the Alberta autumn season.

Litter pH ranged from 5.43 (Pine Shavings/Peat) to 6.42 (Wheat Straw) at 35 days of age (Table 4.9). Previous studies have reported the range of litter pH for pine shavings as 7.97 to 8.9 (Carvalho et al., 2014; Teixeira et al., 2015) and a pH of 9.0 for wheat straw (Tercic et al., 2015). The current study found that wheat straw was significantly more basic (6.20) compared to all other treatments, despite pH of 6.20 being significantly more acidic compared to a wheat straw pH previously reported as 9.0 (Table 4.9). However, the acidic pH found in the current study is consistent with our low litter moisture results, as a litter moisture threshold of >33% must be achieved before pH increases in alkalinity (Garcês et al., 2013; Dunlop et al., 2015). The current study observed a significant acidifying effect by the addition of peat moss to the litter. The pH of Wheat Straw was 6.20 while Wheat/Peat was 5.69, and pH of Pine Shavings was 5.69, significantly more basic compared to Pine Shavings/Peat pens, with a pH of 5.43 (Table 4.9). Ammonia is produced through the degradation of uric acid by litter microbes and moisture (Chapter 1). Although litter moisture is the primary cause of foot pad dermatitis, the skin of the foot pad is composed primarily of keratin which is a structural protein that is sensitive to reducing agents like ammonia (Grist, 2006). However, the microbes necessary for the production of ammonia do not function optimally at pH values of <7 (Dunlop et al., 2015) and thus litter quality can be maintained by keeping litter moisture <33% and pH <7. The addition of peat moss to both pine shavings and wheat straw resulted in a decrease in pH. Peat moss previously been shown to be an effective means of decreasing the microbial population within poultry litter (Everett et al., 2013) and the current study further indicates that peat also has potential as an acidifying litter amendment.

The authors anticipated the addition of peat would increase the water holding and release capacity of pine shavings and wheat straw litter materials. Results from the clean litter moisture retention test showed that the moisture retention capacity of wheat straw was increased only slightly by the addition of peat. Wheat/Peat had the lowest moisture absorption capacity (278.33%) compared to Wheat Straw (317.84%) and Pine/Peat (394.18%) when measured on clean, unused litter prior to trial commencement (Table 4.9). However, Wheat/Peat had the highest final litter moisture (39.31%) compared to Pine/Peat (35.20%) and Wheat Straw (30.50%; Table 4.9). These results may be explained in part by the methodology used. First, the litter was not pre-conditioned or dried prior to the beginning of the retention test, which may have confounded results as initial moisture content may have been different between litter materials. Second, the methodology from Garcês et al. (2013) recommending a fibreglass mesh was not intended for a peat moss substrate. Peat moss has a much smaller particle size compared to wheat straw and pine shavings. As such, a greater amount of peat moss material escaped through the mesh when immersed in water compared to other litter materials tested, which could have confounded moisture retention and release results.

4.4.3. Gait scores

There was a significant interaction between bedding and platform treatment on gait score (Figure 4.3). The addition of a platform resulted in an improvement in gait score for Pine Shavings, Pine/Peat and Wheat/Peat treatments (Figure 4.3). Pine Shavings and Pine/Peat pens had the lowest litter moisture and foot pad scores, while Wheat straw had the highest. Wheat straw resulted in the highest gait scores in Platform pens. The poor qualities (e.g. higher litter moisture and promotion of foot pad lesions) of Wheat Straw as a litter material were not improved by the addition of platforms, despite the positive influence of the platforms on gait score in other litter treatments. In the NoPlatform treatment, the lack of platforms resulted in higher gait scores for Pine Shavings, Wheat/Peat and Wheat Straw treatments. However, despite the negative effects on gait score in pens without platforms, Pine/Peat pens were able to maintain the low gait score observed in Platform pens. However, the mechanism behind the impact of platforms and peat on gait score is not clear.

The impact of platforms and litter on gait score was surprising due to the minimal prevalence of foot pad dermatitis observed. Severe foot pad dermatitis has been reported to hinder gait due to pain from foot pad lesions while walking (Da Costa et al., 2014). However, mean prevalence of foot pad dermatitis was 4% with minimal incidence of severe lesions (i.e. 96% of all foot pads were blemish-free). Further, the current study did not observe a significant correlation between gait and foot pad scores ($r = -0.01$, $P > 0.10$). Thus, due to the lack of severity of foot pad dermatitis in the current study, it is unlikely that pain from foot pad dermatitis affected gait score. As such, future studies should investigate the mechanism of the relationship between gait score, litter and platforms identified in the current study.

4.5. Conclusion

The objective of the current study was to assess the impact of raised, slatted platforms and four different litter treatments on foot pad quality of broiler chickens. Foot pad scores were improved in pine shavings pens compared to wheat straw pens. The addition of peat moss did not have a significant impact on foot pad quality, but acidified pH in both Wheat/Peat and Pine/Peat pens. Litter moisture was highest in Wheat Straw pens, which was slightly lowered by the addition of peat moss. Wheat Straw also resulted in the majority (78%) of all foot pad lesions, despite the low prevalence of 4%. If possible, producers are recommended to use pine shavings litter to maintain foot pad and litter quality. However, if changing to pine shavings is not economically feasible, the addition of 25% peat moss to wheat straw showed a moderate decrease in litter moisture and significant decrease in litter pH, which may help maintain litter quality. Platform treatment had no negative impact on foot pad quality or carcass parameters. Platform use increased with age and was observed in 15% (Week 2) to 21% (Week 5) of sample intervals, which has not been reported in previous perching studies. Standing, Walking, Sitting and Other behaviours were performed significantly less in Platform pens. However, Eating, Drinking and Foraging behaviours required broilers to get off platforms, and were not significantly different between Platform and NoPlatform pens. Broilers in Platform pens were likely performing similar Sitting, Standing, Walking and other behaviours on the platforms. Platforms represent a means for broilers to get off the litter, and our results indicate that if the platform/perch structure is large enough to support the body, broilers will use it consistently. Future studies should investigate the use of larger platform structures to maximize the number of birds able to use the platform.

4.6. Acknowledgements

Funding for this project was provided by Alberta Livestock and Meat Agency, Agriculture and Agri-Food Canada through the Agri-Innovation Program (Growing Forward 2), Alberta Chicken Producers, and in-kind support from the University of Alberta. We would like to acknowledge the technical assistance of Emmanuel Opoku Yeboah, the Poultry Research Centre and staff, all volunteers who helped with data collection (e.g. processing, weighing, foot pad scoring) and behaviour observations (Lazar Cvijanovic, Lauren Engelking, Abiodun Bello, Felipe Silva, Hector Perez, Brenna Clark, Nicole Zukiwsky, Madison Ricard, Emmanuel Opoku Yeboah, Antha Dietrich-Henderson).

4.7. References

Agriculture and Agri-Food Canada. 2015. Weighted average retail poultry and table egg prices report (chicken). Available at http://aimis-simia.agr.gc.ca/rp/index-eng.cfm?report_format_type_code=21&action=gR&signature=5A510CFABB52569B4EBFF9F8486FCD93&pdctc=&r=116&pTpl=1&btnDownload=View (accessed 4 September 2016).

Alberta Agriculture & Forestry. 2016. Hay, Straw and Pasture Listings. Available at https://www.agric.gov.ab.ca/app68/hay?cat=For Sale&cat1=Straw (accessed 8 September 2016).

AOAC International. 1990. Official methods of analysis of the association of official analytical chemists (K Helrich, Ed.). 1:771 pgs.

Baéza, E., C. Arnould, M. Jlali, P. Chartrin, V. Gigaud, F. Mercerand, C. Durand, E. Le Bihan-Duval, and C. Berri. 2012. Influence of increasing slaughter age of chickens on meat quality, welfare, and technical and economic results. Journal of Animal Science 90:2003–2013.

Bench, C. J., M. A. Oryschak, D. R. Korver, and E. Beltranena. In Press. Behaviour, growth performance, foot pad quality, bone density and carcass traits of broiler chickens reared with barrier perches and fed different dietary crude protein levels. Canadian Journal of Animal Science. doi: 10.1139/CJAS-2015-0202.

Bessei, W. 2006. Welfare of broilers: a review. World's Poultry Science Journal 62:455–466.

Bilgili, S. F., J. B. Hess, J. P. Blake, K. S. Macklin, B. Saenmahayak, and J. L. Sibley. 2009. Influence of bedding material on footpad dermatitis in broiler chickens. Journal of Applied

Poultry Research 18:583–589.

Bizeray, D., I. Estevez, C. Leterrier, and J. M. Faure. 2002a. Influence of increased environmental complexity on leg condition, performance, and level of fearfulness in broilers. Poultry Science 81:767–773.

Bizeray, D., I. Estevez, C. Leterrier, and J. M. Faure. 2002b. Effects of increasing environmental complexity on the physical activity of broiler chickens. Applied Animal Behaviour Science 79:27–41.

Canadian Council on Animal Care. 2009. Guidelines on the care and use of farm animals in research, teaching and testing. Canadian Council on Animal Care, Ottawa, Canada.

Carvalho, C. M. ., F. H. Litz, E. A. Fernandes, M. M. Silveira, J. M. S. Martins, L. A. Fonseca, and J. A. Zanardo. 2014. Litter characteristics and pododermatitis incidence in broilers fed a sorghum-based diet. Brazilian Journal of Poultry Science 16:291–296.

Chicken Farmers of Canada. 2009. Animal care program manual. :47 pgs.

Da Costa, M. J., J. L. Grimes, E. O. Oviedo-Rondón, I. Barasch, C. Evans, M. Dalmagro, and J. Nixon. 2014. Footpad dermatitis severity on turkey flocks and correlations with locomotion, litter conditions, and body weight at market age. Journal of Applied Poultry Research 23:268–279.

Delmar Group International. 2014. Industry, markets and trade (Canada). Available at https://www.delmarcargo.com/en/links.html#canada (accessed 4 September 2016).

Duncan, I. J. H., M. C. Appleby, and B. O. Hughes. 1992. Effect of perches in laying cages on welfare and production of hens. British Poultry Science 33:25–35.

Dunlop, M. W., P. J. Blackall, and R. M. Stuetz. 2015. Water addition, evaporation and water holding capacity of poultry litter. Science of the Total Environment 538:979–985.

Eichner, G., S. L. Vieira, C. A. Torres, J. L. B. Coneglian, D. M. Freitas, and O. A. Oyarzabal. 2007. Litter moisture and footpad dermatitis as affected by diets formulated on an all-vegetable basis or having the inclusion of poultry by-product. Journal of Applied Poultry Research 16:344–350.

Environment Canada. 2016. Historical climate data. Government of Canada Available at http://climate.weather.gc.ca/index_e.html (accessed 1 May 2016).

Estevez, I., N. Tablante, R. L. Pettit-Riley, and L. Carr. 2002. Use of cool perches by broiler chickens. Poultry Science 81:62–69.

Everett, D. L., C. D. Mcdaniel, and A. S. Kiess. 2013. The impact of peat moss amendments on the microbial load in used pine shaving poultry litter. International Journal of Poultry Science 12:202–205.

Faure, J. M., and R. B. Jones. 1982. Effects of sex, strain, and type of perching behaviour in the domestic fowl. Applied Animal Ethology 8:281–293.

Fraley, G. S., S. M. Fraley, D. M. Karcher, M. M. Makagon, and M. S. Lilburn. 2013. Influence of raised plastic floors compared with pine shaving litter on environment and Pekin duck condition. Poultry Science 92:583–590.

Garcês, A., S. M. S. Afonso, A. Chilundo, and C. T. S. Jairoce. 2013. Evaluation of different litter materials for broiler production in a hot and humid environment: 1. Litter characteristics and quality. Journal of Applied Poultry Research 22:168–176.

Garner, J. P., C. Falcone, P. Wakenell, M. Martin, and J. A. Mench. 2002. Reliability and validity of a modified gait scoring system and its use in assessing tibial dyschondroplasia in broilers. British Poultry Science 43:355–363.

Greene, J. A., R. M. McCracken, and R. T. Evans. 1985. A contact dermatitis of broilers-clinical and pathological findings. Avian Pathology 14:23–38.

Grist, A. 2006. Poultry inspection: anatomy, physiology and disease conditions. :276 pgs.

Hashimoto, S., K. Yamazaki, T. Obi, and K. Takase. 2011. Footpad dermatitis in broiler chickens in Japan. J. Vet. Med. Sci. 73:293–297.

de Jong, I. C., H. Gunnink, and J. van Harn. 2014. Wet litter not only induces footpad dermatitis but also reduces overall welfare, technical performance, and carcass yield in broiler chickens. Journal of Applied Poultry Research 23:51–58.

de Jong, I. C., J. van Harn, H. Gunnink, V. A. Hindle, and A. Lourens. 2012. Footpad dermatitis in Dutch broiler flocks: prevalence and factors of influence. Poultry Science 91:1569–1574.

Karcher, D. M., M. M. Makagon, G. S. Fraley, S. M. Fraley, and M. S. Lilburn. 2013. Influence of raised plastic floors compared with pine shaving litter on environment and Pekin duck condition. Poultry Science 92:583–590.

Kristensen, H. H., and C. Cornou. 2011. Automatic detection of deviations in activity levels in groups of broiler chickens - A pilot study. Biosystems Engineering 109:369–376.

Kyvsgaard, N. C., H. B. Jensen, T. Ambrosen, and N. Toft. 2013. Temporal changes and risk factors for foot-pad dermatitis in Danish broilers. Poultry Science 92:26–32.

LeVan, N. F., I. Estevez, and W. R. Stricklin. 2000. Use of horizontal and angled perches by broiler chickens. Applied Animal Behaviour Science 65:349–365.

Martland, M. F. 1985. Ulcerative dermatitis dm broiler chickens: the effects of wet litter. Avian Pathology 14:353–364.

Meluzzi, A., C. Fabbri, E. Folegatti, and F. Sirri. 2008a. Survey of chicken rearing conditions in Italy: effects of litter quality and stocking density on productivity, foot dermatitis and carcase injuries. British Poultry Science 49:257–264.

Meluzzi, A., C. Fabbri, E. Folegatti, and F. Sirri. 2008b. Effect of less intensive rearing conditions on litter characteristics, growth performance, carcase injuries and meat quality of broilers. British Poultry Science 49:509–515.

Mihai, C. S., I. Van, and G. Ciurescu. 2013. Influence of litter on footpad dermatitis and body weight in broilers. Lucrari Stiintifice 56:145–148.

Mistaya Land & Water Corp. 2014. Pine wood shavings. Available at http://www.bestwoodshavings.com/ (accessed 8 September 2016).

Musilova, A., M. Lichovnikova, D. Hampel, and A. Przywarova. 2013. The effect of the season on incidence of footpad dermatitis and its effect on broilers performance. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis 61:1793–1798.

Nahm, K. H. 2003. Evaluation of the nitrogen content in poultry manure. World’s Poultry Science Journal 59:77–88.

Peat Moss Association of Canada. 2016. Characteristics of horticultural peat. Available at http://peatmoss.com/peat-in-horticulture/characteristics-of-horticultural-peat/ (accessed 9

September 2016).

Pettit-Riley, R., and I. Estevez. 2001. Effects of density on perching behavior of broiler chickens. Applied Animal Behaviour Science 71:127–140.

Ross. 2014. Ross 308 managment handbook. :132 pgs.

SAS Institute Inc. 2016. SAS University Edition. SAS Institute Inc, Cary, NC, USA.

Shepherd, E. M., and B. D. Fairchild. 2010. Footpad dermatitis in poultry. Poultry Science 89:2043–2051.

Shields, S. J., J. P. Garner, and J. A. Mench. 2005. Effect of sand and wood-shavings bedding on the behavior of broiler chickens. Poultry Science 84:1816–1824.

Skrbic, Z., Z. Pavlovski, M. Lukic, and V. Petricevic. 2015. Incidence of footpad dermatitis and hock burns in broilers as affected by genotype, lighting program and litter type. Annals of Animal Science 15:433–445.

Statistics Canada. 2015. Production of poultry, by province. 2016 Available at http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/prim55a-eng.htm (accessed 4 September 2016).

Taira, K., T. Nagai, T. Obi, and K. Takase. 2014. Effect of litter moisture on the development of footpad dermatitis in broiler chickens. Journal of Veterinary Medical Science 76:583–586.

Teixeira, A., M. Oliveira, J. Menezes, B. Gouvea, S. Teixeira, and A. Gomes. 2015. Poultry litter of wood shavings and/or sugarcane bagasse: animal performance and bed quality. Revista Colombiana de Ciencias Pecuarias 28:238–246.

Tercic, D., M. Žolger, and M. Pestotnik. 2015. Effect of different litter materials on foot pad dermatitis, hock burn and feather coverage in broiler chickens. Acta Agriculturae Slovenica 106:97–101.

Ventura, B. A., F. Siewerdt, and I. Estevez. 2010. Effects of barrier perches and density on broiler leg health, fear, and performance. Poultry Science 89:1574–1583.

Table 4.1. Ethogram of mutually-exclusive behaviours observed during instantaneous scan sampling of broiler chickens.

Behaviour:	Definition:
Walking	Moving from one location to another location within the pen, using either legs or by flapping its wings, regardless of speed (i.e. includes running).
Standing	Bird has both feet on the ground but is not moving. Feet and shank are visible and breast is not in contact with the ground.
Sitting	Bird has breast, keel-bone and feet visibly in contact with the ground. Bird is still.
Foraging	Bird alternately kicks legs in a backwards motion with the head directed forward, so as to disturb the litter and kick substrate backwards. Bird may then look down at the litter.
Eating	Bird moves head in a forward motion towards the feeder and places head in feeder
Drinking	Bird moves head in a forward motion towards the drinker and pecks at the nipple to release water. The bird's head tips back to swallow water
Platform	Bird is on platform. Bird was recorded as Platform regardless of any other behaviours being performed (e.g. walking, sitting, standing)
Other	Behaviours not previously described in ethogram which were observed during behaviour observations (e.g. dustbathing, preening, etc.).

Table 4.2. Scoring scales for foot pad dermatitis and gait assessment in broiler chickens.

Measurement	Score	Definition
Foot Pad[1]	0	No blemish or discolouration of foot pad
	1	Small black lesion (<25% of foot pad) or keratosis of foot pad
	2	Moderate lesion (25-50% of foot pad) with black colouration
	3	Severe lesion (>50% of foot pad). Black colouration, may extend to toes.
Gait[2]	0	No impairment of walking ability
	1	Having obvious impairment but still ambulatory
	2	Having severe impairment, not able to walk without great encouragement

[1]Modified from Welfare Quality Assessment Protocol (Welfare Quality®, 2009).

[2]Modified from Garner et al. (2002).

Table 4.3. Effect of Platform treatment on number of observed behaviours reported (lsmeans ± SEM). Behaviour observations occurred weekly on 10 focal birds per pen[1] from 12 to 33 days of age in both the morning and afternoon[2,3].

Behaviour	Platform[3]		NoPlatform		P-value[5]
Stand	0.37[b] ± 0.02	[0.04][4]	0.49[a] ± 0.02	[0.05][4]	<0.001
Walk	0.17[b] ± 0.01	[0.02][4]	0.24[a] ± 0.01	[0.02][4]	<0.001
Sit	5.85[b] ± 0.08	[0.59][4]	7.81[a] ± 0.01	[0.78][4]	<0.001
Forage	0.14 ± 0.01	[0.01][4]	0.15 ± 0.01	[0.02][4]	0.264
Eat	0.45 ± 0.03	[0.04][4]	0.50 ± 0.03	[0.05][4]	0.144
Drink	0.41 ± 0.01	[0.04][4]	0.39 ± 0.01	[0.04][4]	0.394
Platform	2.12 ± 0.22	[0.21][4]	N/A	N/A	
Other	0.15[b] ± 0.01	[0.02][4]	0.21[a] ± 0.01	[0.02][4]	0.008

[1] Lsmeans represent number of birds performing each behaviour at time observed (count data). 640 focal birds total; 24 observations/pen per week; 96 observations/pen total; 6144 observations total for all 64 pens throughout the 39-day study. Interaction was not significant.

[2] Morning observations occurred from 8:00-11:30 am, afternoon observations occurred from 13:00-15:30 pm.

[3] Different subscripts indicate a difference in treatment means. Platform treatment was comprised of Platform (32 pens with platform) and NoPlatform (32 pens without platform).

[4] Average proportion of birds performing behaviour in any given sample interval was calculated by dividing lsmeans for each behaviour by number of focal birds in each pen and contained in [ ].

[5]Significance was defined at P<0.05, and considered non-significant at P>0.10.

Table 4.4. Lsmeans[1] ± SEM for all mutually-exclusive observed behaviours using instantaneous scan sampling on 10 focal birds[2,3] behaviours and litter treatment effects[4].

Behaviour	Pine Shavings		Pine/Peat		Wheat Straw		Wheat/Peat		P-value
Stand	0.41 ± 0.03	[0.04][5]	0.43 ± 0.03	[0.04][5]	0.45 ± 0.03	[0.05][5]	0.42 ± 0.03	[0.04][5]	0.75
Walk	0.18 ± 0.02	[0.02][5]	0.21 ± 0.01	[0.02][5]	0.19 ± 0.01	[0.02][5]	0.21 ± 0.02	[0.02][5]	0.33
Sit	6.82 ± 0.13	[0.68][5]	6.75 ± 0.12	[0.68][5]	6.72 ± 0.12	[0.67][5]	6.75 ± 0.12	[0.68][5]	0.95
Forage	0.11 ± 0.01	[0.01][5]	0.14 ± 0.02	[0.01][5]	0.16 ± 0.02	[0.02][5]	0.18 ± 0.02	[0.02][5]	0.06
Eat	0.50 ± 0.04	[0.05][5]	0.53 ± 0.04	[0.05][5]	0.46 ± 0.04	[0.05][5]	0.42 ± 0.03	[0.04][5]	0.19
Drink	0.39 ± 0.02	[0.04][5]	0.39 ± 0.02	[0.04][5]	0.42 ± 0.02	[0.04][5]	0.40 ± 0.02	[0.04][5]	0.75
Platform	2.31 ± 0.49	[0.23][5]	1.58 ± 0.34	[0.16][5]	2.25 ± 0.46	[0.23][5]	2.45 ± 0.47	[0.25][5]	0.90
Other	0.23 ± 0.02	[0.02][5]	0.23 ± 0.01	[0.02][5]	0.23 ± 0.02	[0.02][5]	0.28 ± 0.01	[0.03][5]	0.99

[1] Lsmeans represent number of birds performing each behaviour at time observed (count data). Interaction was not significant.

[2] 640 focal birds total; 24 observations/pen per week; 96 observations/pen total; 6144 observations total for all 64 pens throughout the 39-day study. Ethogram found in Table 4.1.

[3] Morning observations occurred from 8:00-11:30 am, afternoon observations occurred from 13:00-15:30 pm.

[4] Differences were considered significant at $P<0.05$, a trend at $P=0.5-0.10$, and non-significant at $P>0.10$. Bedding treatment was determined by volume in pens with 6.35 cm litter depth comprised of Pine Shavings (100%), Pine/Peat (75% Pine; 25% Peat), Wheat Straw (100%), Wheat/Peat (75% Wheat Straw/25% Peat).

[5] Average proportion of birds performing behaviour in any sample interval was calculated by dividing lsmeans for each behaviour by number of focal birds in each pen and contained in [ ].

Table 4.5. Number of birds performing behaviours at 2 to 5 weeks of age (lsmeans ± SEM)[1]. Mutually exclusive behaviours were recorded on 10 focal birds[2] using instantaneous scan sampling and differences were analyzed using the Glimmix procedure of SAS[3,4].

Behaviour	Week 2		Week 3		Week 4		Week 5		P-value
Stand	$0.56^{a} \pm 0.02$	[0.06][5]	$0.53^{b} \pm 0.02$	[0.05][5]	$0.34^{c} \pm 0.02$	[0.03][5]	$0.28^{d} \pm 0.02$	[0.03][5]	<0.01
Walk	$0.38^{a} \pm 0.02$	[0.04][5]	$0.26^{b} \pm 0.01$	[0.03][5]	$0.12^{c} \pm 0.01$	[0.01][5]	$0.06^{d} \pm 0.01$	[0.01][5]	<0.01
Sit	$6.60^{b} \pm 0.08$	[0.66][5]	$6.38^{c} \pm 0.08$	[0.64][5]	$6.71^{b} \pm 0.08$	[0.67][5]	$7.35^{a} \pm 0.09$	[0.74][5]	<0.01
Forage	$0.25^{a} \pm 0.02$	[0.03][5]	$0.17^{b} \pm 0.01$	[0.02][5]	$0.01^{d} \pm 0.01$	[0.00][5]	$0.03^{c} \pm 0.01$	[0.00][5]	<0.01
Eat	$0.47^{b} \pm 0.02$	[0.05][5]	$0.58^{a} \pm 0.02$	[0.06][5]	$0.44^{b} \pm 0.02$	[0.04][5]	$0.40^{c} \pm 0.02$	[0.04][5]	<0.01
Drink	$0.41^{a,b} \pm 0.02$	[0.04][5]	$0.45^{a} \pm 0.02$	[0.05][5]	$0.39^{b} \pm 0.02$	[0.04][5]	$0.34^{c} \pm 0.02$	[0.03][5]	<0.01
Platform	$1.53^{c} \pm 0.03$	[0.15][5]	$2.20^{b} \pm 0.04$	[0.22][5]	$2.55^{a} \pm 0.04$	[0.26][5]	$2.14^{b} \pm 0.04$	[0.21][5]	<0.01
Other	$0.25^{b} \pm 0.02$	[0.03][5]	$0.29^{a} \pm 0.02$	[0.03][5]	$0.23^{b} \pm 0.01$	[0.02][5]	$0.18^{c} \pm 0.01$	[0.02][5]	<0.01

[1] Lsmeans represent number of birds performing each behaviour at time observed (count data).

[2] 640 focal birds total; 24 observations/pen per week; 96 observations/pen total; 6144 observations total for all 64 pens throughout the 39-day study. Ethogram found in Table 4.1.

[3] Different subscripts indicate a difference in treatment means. Platform treatment was comprised of Platform (32 pens with platform) and NoPlatform (32 pens without platform). Bedding treatment was determined by volume in pens with 6.35 cm litter depth comprised of Pine Shavings (100%), Pine/Peat (75% Pine; 25% Peat), Wheat Straw (100%), Wheat/Peat (75% Wheat Straw/25% Peat).

[4] Differences were considered significant at P<0.05, a trend at P=0.5-0.10, and non-significant at P>0.10. Main effects shown. Interaction was not significant.

[5] Average proportion of birds performing behaviour in any sample interval was calculated by dividing lsmeans for each behaviour by number of focal birds in each pen and contained in [ ].

Table 4.6. Differences for Bedding and Platform treatments of production parameters for broilers raised to 39 days of age (lsmeans ± SEM)[4,5].

	Bedding Treatment					**Platform Treatment**		
	Pine Shavings	Pine/Peat	Wheat Straw	Wheat/Peat	P-value[5]	Platform	NoPlatform	P-value
BW[1]	1433.5 ± 18.1	1419.2 ± 17.0	1414.0 ± 17.5	1410.0 ± 17.6	0.82	1417.2 ± 12.4	1421.5 ± 12.4	0.81
ADG[2]	124.9 ± 2.4	126.7 ± 2.3	128.7 ± 2.3	124.1 ± 2.3	0.70	126.3 ± 1.6	125.4 ± 1.6	0.52
ADFI[2]	313.4 ± 7.7	316.1 ± 7.2	327.3 ± 7.4	314.8 ± 7.5	0.44	320.8 ± 5.3	314.9 ± 5.3	0.54
FCR[3]	2.51 ± 0.04	2.51 ± 0.03	2.54 ± 0.04	2.54 ± 0.04	0.40	2.54 ± 0.03	2.51 ± 0.03	0.89

[1]Body weight taken at 39 days of age, averaged per pen, expressed in grams.

[2]Average daily gain and average daily feed intake expressed in grams/day. Feed consumption was measured at phase change (10 and 25 days of age).

[3]Feed conversion ratio expressed in feed consumed (g): gain (g).

[4] Platform treatment was comprised of Platform (32 pens with platform) and NoPlatform (32 pens without platform). Bedding treatment was determined by volume in pens with 6.35 cm litter depth comprised of Pine Shavings (100%), Pine/Peat (75% Pine; 25% Peat), Wheat Straw (100%), Wheat/Peat (75% Wheat Straw/25% Peat).

[5] Main effects shown. Interaction was not significant.

[6] Differences were considered significant at $P<0.05$, a trend at P=0.5-0.10, and non-significant at $P>0.10$.

Table 4.7. Mean weight of carcass components[1] by Bedding and Platform treatments for broilers processed at 41 days of age (lsmeans ± SEM)[2,3,4].

	Bedding Treatment					Platform Treatment		
Weight (g)	Pine Shavings	Pine/Peat	Wheat Straw	Wheat/Peat	P-value	Platform	NoPlatform	P-value
Total Carcass	1979.4 ± 22.9	1989.5 ± 21.5	2036.5 ± 22.3	1995.3 ± 22.3	0.29	2006.7 ± 15.8	1993.9 ± 15.7	0.58
Pectoralis major	493.0 ± 7.7	492.4 ± 7.3	507.8 ± 7.5	492.8 ± 7.5	0.39	500.6 ± 5.3	492.3 ±5.3	0.27
Pectoralis minor	99.9 ± 1.3	98.3 ± 1.2	102.3 ± 0.3	97.7 ± 1.3	0.06	99.3 ± 0.8	99.8 ±0.9	0.70
Wings	294.6 ± 5.9	288.5 ± 5.5	307.9 ± 5.8	289.3 ± 5.9	0.07	292.1 ± 4.1	297.8 ±4.1	0.32
Thighs	277.3 ± 4.2	282.6 ± 3.9	282.3 ± 4.1	281.8 ± 4.2	0.78	283.6 ± 2.9	278.4 ±2.9	0.21
Drums	222.2 ± 3.6	226.3 ± 3.4	225.2 ± 3.5	228.2 ± 3.6	0.69	227.5 ± 2.5	223.4 ±2.5	0.24
Remaining	597.5 ± 7.0	601.5 ± 6.6	614.0 ± 6.9	607.1 ± 7.0	0.37	604.7 ± 4.9	605.3 ±4.8	0.93

[1]Broilers processed at Poultry Research Centre processing facility at the University of Alberta. Broiler carcasses were cut into individual components and weighed.

[2] Differences were considered significant at P<0.05, a trend at P=0.5-0.10, and non-significant at P>0.10.

[3] Platform treatment was comprised of Platform (32 pens with platform) and NoPlatform (32 pens without platform). Bedding treatment was determined by volume in pens with 6.35 cm litter depth comprised of Pine Shavings (100%), Pine/Peat (75% Pine; 25% Peat), Wheat Straw (100%), Wheat/Peat (75% Wheat Straw/25% Peat).

[4] Main effects shown. Interaction was not significant.

Table 4.8. Mean carcass component yield[1] by Bedding and Platform treatments for broilers processed at 41 days of age[2] (lsmeans ± SEM)[3,4].

	Bedding Treatment					Platform Treatment		
Yield (%)	Pine Shavings	Pine/Peat	Wheat Straw	Wheat/Peat	P-value	Platform	NoPlatform	P-value
Pectoralis major	24.9^{a} ± 0.01	24.6^{a} ± 0.01	24.9^{a} ± 0.01	24.6^{a} ± 0.01	0.68	24.9^{a} ± 0.01	24.6^{a} ± 0.01	0.23
Pectoralis minor	5.1^{a} ± 0.01	5.0^{ab} ± 0.01	5.0^{ab} ± 0.01	4.9^{b} ± 0.01	0.11	5.0^{a} ± 0.01	5.0^{a} ± 0.01	0.31
Wings	14.9^{a} ± 0.02	14.5^{a} ± 0.01	15.1^{a} ± 0.01	14.6^{a} ± 0.01	0.18	14.6^{a} ± 0.01	15.0^{a} ± 0.01	0.11
Thighs	14.0^{a} ± 0.01	14.2^{a} ± 0.01	13.9^{a} ± 0.01	14.1^{a} ± 0.01	0.25	14.2^{a} ± 0.01	14.0^{a} ± 0.01	0.14
Drums	11.2^{a} ± 0.01	11.4^{a} ± 0.01	11.0^{a} ± 0.01	11.4^{a} ± 0.01	0.15	11.4^{a} ± 0.01	11.2^{a} ± 0.01	0.19
Remaining	30.3^{a} ± 0.02	30.3^{a} ± 0.01	30.2^{a} ± 0.01	30.5^{a} ± 0.01	0.69	30.2^{a} ± 0.01	30.4^{a} ± 0.01	0.12

[1]Yield calculated by taking (component part weight/total carcass weight)*100%

[2]Broilers processed at Poultry Research Centre processing facility at the University of Alberta. Broiler carcasses were cut into individual components and weighed.

[3]Differences were considered significant at $P<0.05$, a trend at P=0.5-0.10, and non-significant at $P>0.10$.

[4] Main effects shown. Interaction was not significant.

Table 4.9. Moisture absorbed, released and final moisture content of clean, unused bedding materials analyzed (lsmeans ± SEM)[1, 2,3].

	Pine Shavings	Pine/Peat	Wheat Straw	Wheat/Peat	Peat	P-value
Moisture absorbed (%)	$319.4^{b} \pm 9.1$	$394.2^{a} \pm 10.1$	$317.8^{b} \pm 9.0$	$278.3^{c} \pm 8.5$	$243.4^{d} \pm 7.9$	P<0.001
Moisture released (%)	$60.3^{d} \pm 1.1$	$64.8^{c} \pm 1.1$	$69.5^{b} \pm 1.1$	$60.7^{d} \pm 1.1$	$86.7^{a} \pm 1.3$	P<0.001
Final litter moisture (%)	$39.7^{a} \pm 1.2$	$35.2^{b} \pm 1.1$	$30.5^{c} \pm 1.1$	$39.3^{a} \pm 1.2$	$13.4^{d} \pm 0.7$	P<0.001

[1] Differences were considered significant at P<0.05, a trend at P=0.5-0.10, and non-significant at P>0.10.

[2] Methods followed as detailed in Grimes et al. (2006) and Garces et al. (2013).

[3] Different subscripts indicate a difference in treatment means. Platform treatment was comprised of Platform (32 pens with platform) and NoPlatform (32 pens without platform). Bedding treatment was determined by volume in pens with 6.35 cm litter depth comprised of Pine Shavings (100%), Pine/Peat (75% Pine; 25% Peat), Wheat Straw (100%), Wheat/Peat (75% Wheat Straw/25% Peat).

Table 4.10. Mean litter moisture (%), pH and foot pad scores for both bedding and platform treatments (lsmeans ± SEM).

	Bedding Treatment					Platform Treatment		
	Pine Shavings	Pine/Peat	Wheat Straw	Wheat/Peat	P-value	Platform	NoPlatform	P-value[4]
Foot Pad Dermatitis[3]	$0.003^{b} \pm 0.01$	$0.005^{b} \pm 0.01$	$0.08^{a} \pm 0.02$	$0.10^{a} \pm 0.03$	<0.001	$0.020^{a} \pm 0.01$	$0.018^{a} \pm 0.01$	0.77
Litter Moisture[1] (%)	$15.65^{d} \pm 0.01$	$16.40^{cd} \pm 0.01$	$18.65^{a} \pm 0.01$	$18.03^{bc} \pm 0.01$	<0.01	$17.67^{a} \pm 0.01$	$16.63^{a} \pm 0.01$	0.13
pH[2]	$5.69^{b} \pm 0.05$	$5.43^{c} \pm 0.04$	$6.20^{a} \pm 0.05$	$5.69^{b} \pm 0.05$	<0.001	$5.77^{a} \pm 0.03$	$5.72^{a} \pm 0.03$	0.32

[1]Foot pads were scored at 6, 13, 20, 27, 34 days of age and post-processing using scoring system detailed in Table 4.2. Lsmeans values for each treatment represent the mean foot pad score.

[2]pH was determined after litter was dried and ground using an electronic pH meter.

[3]Litter was sampled on 5, 18 and 32 days of age. Litter moisture was determined after drying in convection oven after conclusion of the trial.

[4] Differences were considered significant at P<0.05, a trend at P=0.5-0.10, and non-significant at P>0.10.

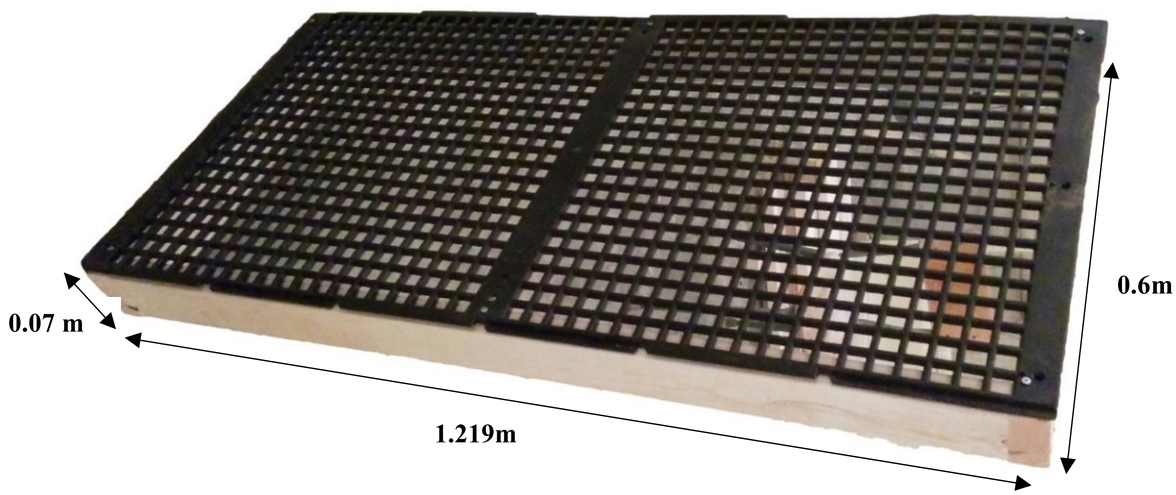


Figure 4. 1. Photograph of raised slatted platform. Holes were 2.54 cm^2. Manufactured by B.C.M. Manufacturing Ltd., Canada.

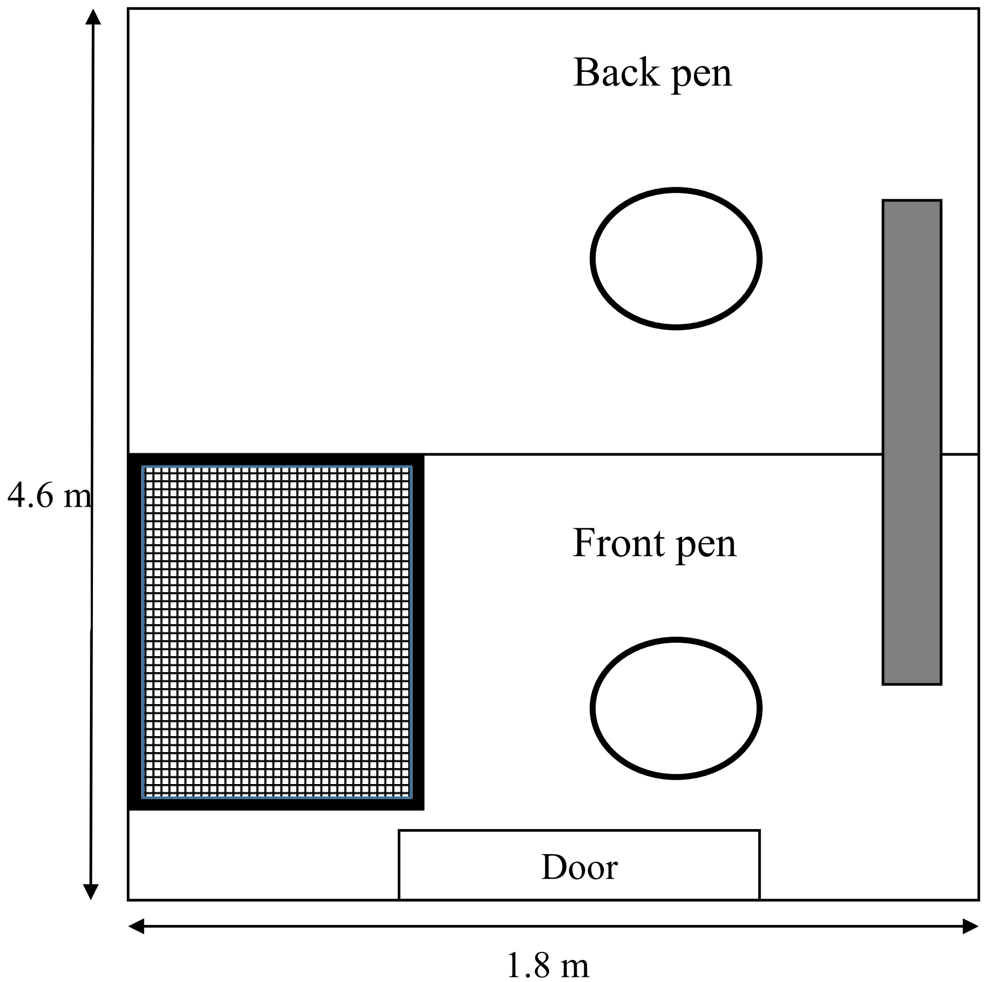


Figure 4.2. Pen diagram. Front and back pens were divided by PVC pipe and netting. Circles represent feeders, and gray bar represents water lines. There were 3 nipple drinkers per pen. Platforms were located in the same location in each pen, always opposite the drinker.

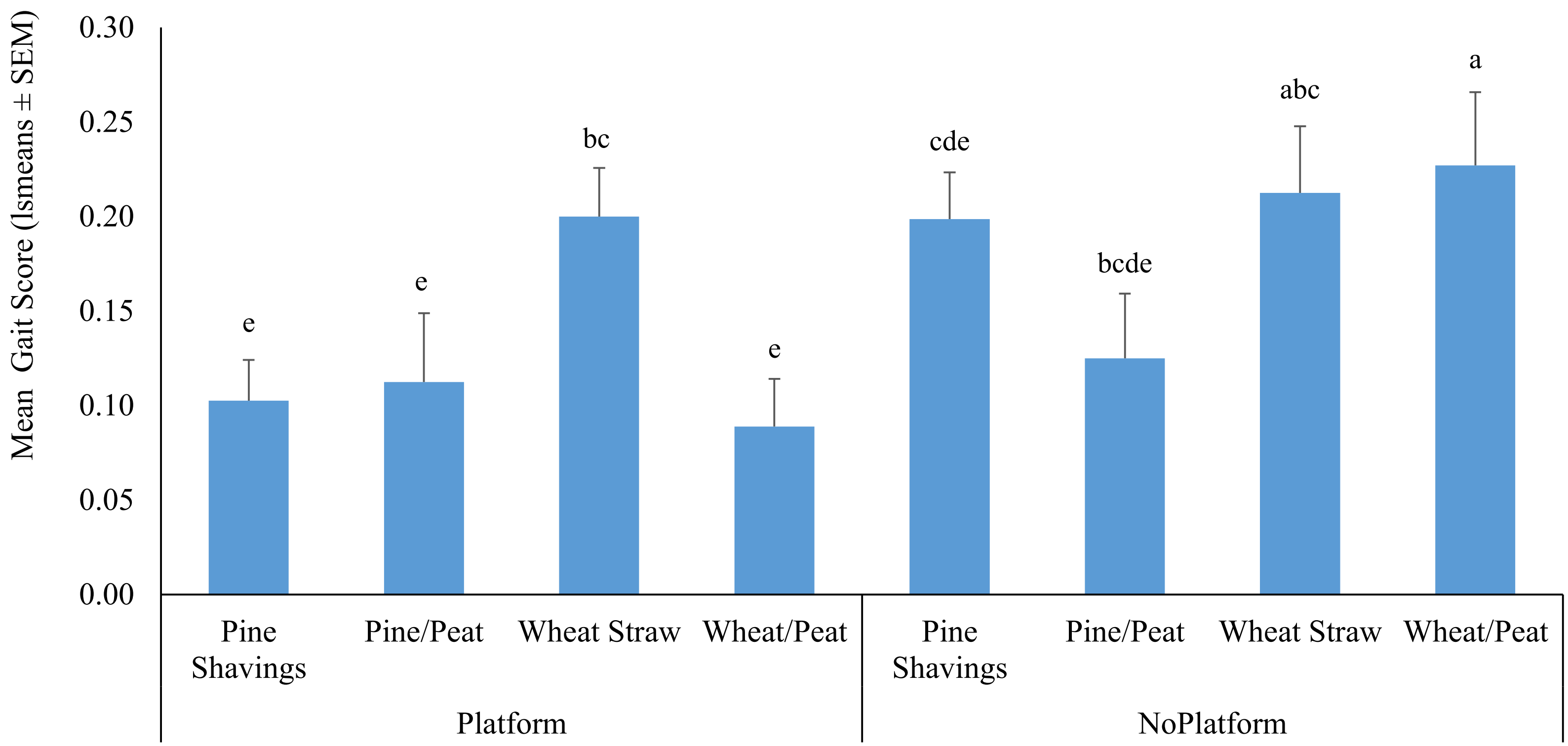


Figure 4.3. Gait score treatment differences for Bedding and Platform Interaction (lsmeans ± SEM)[1]. Gait scoring was performed on 28 and 35 days of age. Gait was assessed using scoring system described in Table 4.2 (ranged from 0: no gait impairment to 2: severe gait impairment). Platform treatment was comprised of Platform (32 pens with platform) and NoPlatform (32 pens without platform). Bedding treatment was determined by volume in pens with 6.35 cm litter depth comprised of Pine Shavings (100%), Pine/Peat (75% Pine; 25% Peat), Wheat Straw (100%), Wheat/Peat (75% Wheat Straw/25% Peat).

5.0. Synthesis

5.1. Review of thesis objectives

The primary objective of the thesis research was to identify practical strategies to improve foot pad quality on commercial broiler farms in Alberta, Canada. Within this overarching objective, the goals of this research were to 1) benchmark foot pad dermatitis across broiler flocks in Alberta, 2) investigate three methods of foot pad dermatitis assessment 3) investigate litter management strategies on-farm which influence foot pad dermatitis, and 4) investigate litter material and raised slatted platforms for the prevention of foot pad dermatitis.

5.2. Prevalence of foot pad dermatitis in Alberta

Chapter 1 estimated the potential market for chicken feet in Canada would be worth $54.6 million (CAD) and $5.1 million (CAD) annually in Alberta if no broilers were affected by foot pad dermatitis. On-farm prevalence of foot pad dermatitis was found to be 28.7% in Alberta (Chapter 3). If the prevalence estimate from Chapter 3 is applied to number of broilers produced, foot pad dermatitis results in an annual loss of $15.8 million (CAD) in Canada and $1.5 million (CAD) in Alberta.

Previous foot pad dermatitis prevalence estimates found 78% (Portugal), 38.4% (Netherlands), 14.8% (United Kingdom) and 70% (France; de Jong et al., 2014). The results from Chapter 3 regarding prevalence of foot pad dermatitis in Alberta were measured as 28.7% (on-farm), 26.2% (processor-line) and 31.8 % (processor-sampled). These findings are lower than many estimates in other countries, which is likely due to the differences in assessment method, climate and broiler management practices (e.g. age at processing, stocking density, litter material) between countries. Similar variability in foot pad dermatitis prevalence noted between countries was also observed between flocks sampled in Chapter 3 and were likely due to management practices related to litter (litter depth, material and moisture) found to be significantly different between producers (Chapter 3). Prevalence of foot pad dermatitis in Alberta flocks ranged from 1% to 99% (Chapter 3). However, the range in prevalence of foot pad dermatitis for Alberta broiler flocks was also affected by method of assessment. Results from Chapter 3 indicate the processor-line scoring method was not repeatable, and did not accurately assess prevalence of foot pad dermatitis within a flock compared to both on-farm and processor-sampled assessments. Thus, the difference in prevalence estimates between countries is likely due to both variation in local management practices and assessment methods.

In contrast, prevalence of foot pad dermatitis reported in the 39-day trial was 4% across all treatments at 39 days of age (Chapter 4). This estimate is 86% lower than the mean foot pad dermatitis prevalence estimated on-farm, which was 28.7% (Chapter 3). One explanation for the differences observed between prevalence estimates is the scale at which each experiment took place. The average sampled flock size during on-farm visits was 30,000 birds housed in a large commercial facility (Chapter 3) where comparatively, the pens in the 39-day trial housed only 45 birds (Chapter 4). Further, the 39-day trial took place from October to November when temperatures ranged from 5º to 20ºC, and precipitation was <10 mm over the two months, compared to the historical >20 mm in October and November (Environment Canada, 2016; Chapter 4). The minimal precipitation and favourable outdoor temperatures may have contributed to the lower reported prevalence of 4% (Chapter 4). The experimental facility where Chapter 4 took place is much smaller than a commercial facility, and can maintain a faster ventilation rate throughout production which could have resulted in improved litter conditions and foot pad quality. Further, due to the moderate outdoor temperatures, the air did not require excessive heating prior to ventilation, which minimized the risk of condensation accumulation within the research barn. In contrast, on-farm visits were completed during January to September, when temperatures ranged from -30 to 30ºC, with >25 mm precipitation over the duration of the study. Winter conditions (January to April) are characterized by cold temperatures and producers typically reduce ventilation rates to save on costs associated with heating the incoming air (Chapter 1). Decreased ventilation rates, especially with flock sizes of 30,000 broilers in large commercial facilities can result in increased condensation accumulation, litter moisture and prevalence of foot pad dermatitis. In the warmer spring/summer months (June to September), hot outdoor temperatures do not require air to be heated prior to barn entry. However, large flock sizes can result in overheating, which prompted some producers to mist the birds (Chapter 3). Misting allows birds to cool off, however broilers become wet which may subsequently decrease litter quality and increase the risk of foot pad dermatitis. The differences observed in foot pad dermatitis prevalence estimates between Chapter 3 and Chapter 4 is likely due to differences in facility size, flock size and the seasonality during each experiment.

The discrepancy in foot pad dermatitis prevalence observed between field (Chapter 3) and controlled (Chapter 4) settings emphasizes the benefit of completing research under both on-farm and experimental conditions. In particular, the research conducted at commercial facilities in Alberta in Chapter 3 allowed for identification of several management practices which were incorporated into the design of Chapter 4. For example, prior to conducting this thesis research, no published data was available regarding the predominant litter material used at commercial broiler facilities in Alberta. Chapter 3 reported 62.5% of producers surveyed use wheat straw, which was included as a litter treatment in Chapter 4 to ensure applicability to the Alberta broiler industry with regards to foot pad dermatitis management strategies. Additionally, litter material was found to have a significant impact on the prevalence of foot pad dermatitis on-farm (Chapter 3). To reduce the time foot pads are in contact with litter material, raised slatted platforms were investigated in Chapter 4. Testing specific on-farm management practices in an experimental setting increased control over confounding variables found on-farm and increased statistical confidence due to the ability to increase replication.

5.3. Assessment of foot pad dermatitis

On-farm foot pad scoring is the only assessment method which allows foot pad dermatitis to be mitigated before birds are sent for processing, and gives producers the ability to determine which management practices specific to their farm need to be altered to reduce the prevalence of foot pad dermatitis. Live bird assessment also provides information regarding the development of foot pad dermatitis throughout the production cycle, which is not captured by a single measurement post-processing. Further, live-bird sampling allows birds to be scored from multiple areas within a barn, while sampling at the processor does not guarantee sampling from all areas of the barn. Just as prevalence of foot pad dermatitis can vary between broilers in different locations within a barn (de Jong et al., 2012), sampling at only one point on the processing line per flock may result in an incorrect estimation of foot pad dermatitis prevalence. Further, pulling foot pads from the processing line and scoring as used in processor-sampled assessment is time-consuming and requires additional processing personnel to be trained (Chapter 3). Thus, the on-farm method of foot pad assessment was designated as the standard of comparison for both processor-line and processor-sampled scores (Chapter 3). While processor-line scoring can be performed quickly, poor reliability was observed between measurements (Chapter 3). Variability in line speed and personnel assessing foot pad dermatitis for each flock was likely responsible for the poor repeatability of the processor line score (Chapter 3).

However, scoring at the processing plant may still be valuable, as it provides an additional prevalence measurement of a flock, which can be compared to on-farm assessment completed by producers. In the European Union, foot pad dermatitis is monitored primarily at the processing plant (Butterworth et al., 2016). If prevalence meets a set standard, lower stocking densities for the producer can be enforced via welfare legislation. In Alberta, one processing plant currently conducts foot pad assessment on the line, and producers are not trained, nor required, to foot pad score on-farm. The results from Chapter 3 show that assessment only at the processing plant is not currently feasible in Alberta, as processor-line scoring does not provide an accurate estimate of foot pad dermatitis prevalence in a flock compared to on-farm and processor-sampled scoring. The recommendation to the processing plant is to revise the current foot pad assessment method in order to improve the use of resources which are not currently being used effectively to assess foot pad dermatitis. Until the processor-line scoring method is revised, the authors recommend the emphasis be placed on educating producers on assessment of foot pad dermatitis during broiler production.

Currently, the processing plant uses a binary scale of 0 (no foot pad dermatitis) and 1 (any presence of foot pad dermatitis; Chapter 3). Producers are given a percentage score from the processor which represents the prevalence of foot pad dermatitis recorded for the flock (Chapter 3). However, because the foot pad assessment system used during processing is proprietary, and there is no recommended foot pad scoring method in animal care guidelines given to producers, the final processor score is not understood by many producers. Further, the lack of information regarding the development foot pad dermatitis or how it is defined makes understanding foot pad assessment scales difficult for producers. Foot pad assessment scales comprised of multiple points (e.g. >5), can be more challenging to train due to small differences which characterize each scoring category. This deters producers from conducting foot pad assessment on-farm. The standardized 4-point scale used in Chapter 3 was found to be the most feasible, reliable and accurate method of foot pad assessment method compared to both processor-line and processor-sampled. We found that using the 4-point scoring system resulted in highly correlated prevalence estimates, even when a flock was scored at two different points, both on-farm and when foot pad samples were collected from the processing line. Qualitatively, the 4-point scale used in this thesis was found by researchers to be easy to learn and use on-farm (Chapter 3). We recommend that producers should begin assessment of foot pad dermatitis on-farm, regardless of the scale chosen. However, recommendations to industry are to provide the 4-point scale tested in Chapter 3 for producers, with information on foot pad assessment to ensure that all producers in Alberta are properly informed on how to score their flocks.

5.4. Management practices on-farm

Chapter 3 reported 62.5% of Alberta broiler producers use wheat straw, which differs from litter used in other countries. For example, the primary litter material used throughout the United States is pine shavings (Fraley et al., 2013). As litter materials differ between countries, foot pad dermatitis management methods may not automatically apply when used in Canada.

In Chapter 3, foot pad dermatitis prevalence on straw was 40%, compared to 6% on pine shavings and/or newspaper. Despite a low prevalence of 4% observed in Chapter 4, 78.3% of foot pad lesions, regardless of severity, occurred in pens with wheat straw compared to 21.7% in pine shavings pens. Further, wheat straw pens had a significantly higher final litter moisture content (18.65 % ± 0.01) compared to pine shavings pens (15.65 % ± 0.01; Chapter 4). Chapter 3 found producers with litter scores >2 were associated with higher mean prevalence of foot pad dermatitis on-farm (40.1%) compared to dry litter scores (7.4%; Chapter 3).

The majority of producers stated their primary reason for choosing a particular litter material was that it was locally available (79.1%) and inexpensive (40.6%; Chapter 3). Wheat is grown on-farm by many Alberta broiler producers for use in poultry feed and the straw by-product is then used as litter. Even if wheat straw is not grown by a producer, it can be purchased locally and inexpensively at \$25/96 ft^3 bushel, including shipping (Alberta Agriculture & Forestry, 2016). Purchasing straw for a broiler flock at this price, for a depth of 7.62 cm and volume of 5,400 ft^3 would cost \$1,406 CAD per flock. In contrast, pine shavings is used by the Alberta oil industry which reduces availability for broiler producers, resulting in the majority of farmers shipping pine shavings from British Columbia for \$4.50/8 ft^3 bale (Mistaya Land & Water Corp, 2014). For the same litter depth and volume, a producer would pay \$3,200 CAD plus shipping to use pine shavings for one broiler flock. Further, producers do not receive any income from foot pad sales, or consequences for poor foot pad scores. As such, there is little incentive for producers to switch from wheat straw to pine shavings. If pine shavings bedding cost a producer \$1,750 more per flock, it is unlikely that producers will change litter material without financial compensation or legal requirement. However, the results of both Chapter 3 and Chapter 4 indicate that pine shavings bedding is associated with lower prevalence of foot pad scores compared to wheat straw and is strongly recommended to reduce prevalence of foot pad dermatitis. Legislation requiring the use of pine shavings on-farm should be considered, but only if producers will be compensated for the increased cost of switching litter materials. Further, promoting assessment of foot pad dermatitis in Alberta is of greater importance initially before legislating a change to pine shavings. If producers are assessing their flocks and aware that there is a consistent issue with foot pad dermatitis on their farm, they may be more willing to consider switching to pine shavings litter.

Litter blends have been proposed as an alternative option for decreasing prevalence of foot pad dermatitis (Grimes et al., 2002). Peat is an unexplored potential bedding material in Alberta with a moisture absorption capacity of twenty-times its weight, and release capacity of 89% (Chapter 4; Everett et al., 2013). Chapter 4 investigated the impact on foot pad quality after adding peat moss to wheat straw or pine shavings. There was no significant improvement in litter moisture observed in Pine/Peat treatments (Chapter 4). However, the addition of peat moss in Wheat/Peat pens was associated with a small decrease in litter moisture compared to Wheat Straw pens (Chapter 4). One reason for the small decrease may have been that the peat inclusion level tested (25%) may have been too low to see an impact on foot pad quality in the Wheat/Peat treatment. Future studies should investigate higher inclusion levels of peat in wheat straw to determine if a higher inclusion level might improve both litter and foot pad quality (Chapter 4). There was also a significant acidifying effect of the addition of peat moss to both pine shavings and wheat straw pens (Chapter 4). Acidic litter pH (<6) is associated with better litter conditions as it helps reduce microbial activity and ammonia production (Rothrock et al., 2008). Thus, if it is not economically feasible for producers to change from wheat straw to pine shavings, use of peat moss as a litter amendment is recommended to moderately improve litter quality.

5.5. Additional management strategies

Foot pad lesions can heal when broilers are removed from wet litter and placed on new litter (Martland, 1985; Taira et al., 2014). However, moving broilers to different litter midway through the production cycle under commercial conditions is infeasible due flock sizes of

>30,000 birds. Perching has the potential to reduce development of foot pad lesions, as perches reduce the time that broiler foot pads are in contact with litter. However, perching in broilers has been reported to decrease with age, due to the large increase in breast muscle mass which increases pressure on the keel (Pettit-Riley and Estevez, 2001; Bench et al., In Press). A previous Alberta study by Bench et al. (In Press), investigated the impact of two different perch designs (I and X shaped) on foot pad quality. The authors found no impact of perch design on foot pad quality, but observed that broilers preferred to perch on the junctions of both I and X perches. They recommended that structures with large surface areas might be more appealing to broilers throughout the production cycle. In Chapter 4, we investigated the impact of raised, slatted platforms on foot pad quality. We observed no effect of platforms on foot pad quality (Chapter 4). One reason may have been because the prevalence of foot pad dermatitis was too low to result in observation of significant treatment effects. Prevalence of foot pad dermatitis in the trial (4%) conducted in Chapter 4 was low compared to mean on-farm prevalence in Chapter 3 (28.7%), and another study where prevalence was measured at 39% (Skrbic et al., 2015). Chapter 4 is the first study which has investigated the impact of platform structures on foot pad quality in broiler chickens. Chapter 4 found that the platforms had no negative impact on foot pad, litter or carcass measurements, indicating that slats did not irritate foot pads and result in lesions. Further, in all litter treatments except Wheat Straw, platforms had an improving effect on mean gait score (Chapter 4). Contrary to previous studies which showed that perching behaviour decreases with age (Pettit-Riley and Estevez, 2001; Bench et al., In Press), Chapter 4 found that use of platforms by broilers increased with age, indicating that the platforms did not result in discomfort nor compromised growth performance. Platform behaviour was observed throughout the trial, least at Week 2 (15% of sample intervals) and most at 4 weeks of age (26% of sample intervals;

Chapter 4). Our results indicate that the larger structure provided enough support for broilers throughout the production cycle. Platforms have potential for implication on commercial facilities as an area where broilers can get off of the litter, as current facilities do not provide any space where broilers are not sitting or standing on litter. Larger platform structures which can fit a large number of broilers would maximize the benefits within a flock, and should be investigated to maintain foot pad quality.

5.6. Recommendations

On-farm assessment of foot pad dermatitis is recommended for every flock by producers as this is the only means available to mitigate foot pad dermatitis during the production cycle. However, due to the limited amount of information provided in terms of assessment programs in Alberta, workshops or pamphlets should be provided to producers to aid in scoring foot pad dermatitis. The assessment method and scale for use by producers should be standardized, and we recommend the 4-point scale utilized throughout this thesis for use by producers on-farm as it was shown to be accurate, feasible and reliable for estimating prevalence of foot pad dermatitis. Processors are recommended to revise the current method of foot pad assessment at the processing plant. Results from Chapter 3 indicate that processor-line scoring does not accurately assess foot pad dermatitis within a flock. Pine shavings bedding material is strongly recommended for use on-farm to reduce prevalence of foot pad dermatitis. Legislation mandating pine shavings litter is feasible, but support for producers should be provided due to the increased costs of production associated with pine shavings. Producers unable to switch to pine shavings are advised to use peat moss litter amendments to moderately improve litter quality of wheat straw. Producers are recommended to provide a raised slatted area in barns to reduce amount of time that foot pads are in contact with litter. Future studies should investigate larger platform structures on-farm, to maximize the benefits to the birds, and investigate the impact of platforms on foot pad quality in a commercial setting. Further studies investigating the impact of shallower litter depths on foot pad dermatitis and the impact of >25% peat inclusion in wheat straw on foot pad quality would also be beneficial for further management strategies for Alberta broilers producers.

5.7. Conclusions

Foot pad dermatitis is a prevalent welfare concern for broilers and has economic implications for processors who export chicken feet to Asian markets. The primary cause of foot pad dermatitis is litter moisture, however there are multiple factors within the production environment which affect moisture and make managing foot pad health difficult. Mitigation and management of foot pad dermatitis can be made easier through vigilant on-farm foot pad assessment by producers. However, the only foot pad assessment method currently used in Alberta occurs on the processing line. Results from this thesis indicate that processor-line scoring is not repeatable, and does not provide an accurate assessment of foot pad dermatitis within a flock. The variability in the processor-line assessment also affected the strength of the correlation with the other tested foot pad assessment methods. The on-farm 4-point assessment scale was highly correlated with the processor-sampled method, which was the same scale performed post-processing on the same flock. The on-farm 4-point scale is recommended to producers, as this thesis found that it was reliable, accurate and the most feasible for use by producers on-farm out of the assessment methods tested. However, the authors feel that the promotion of assessment is more important that the assessment system recommended by the industry. As such, the industry is advised to provide information regarding development and prevention of foot pad dermatitis to producers, to improve the number of producers completing foot pad assessment on-farm. Litter management practices were identified in this thesis as significantly contributing to prevalence of foot pad dermatitis. Specifically, pine shavings bedding was shown to be associated with reduced prevalence of foot pad dermatitis in both Chapter 3 and Chapter 4. Pine shavings is strongly recommended for use as litter on-farm to reduce the prevalence of foot pad dermatitis and broiler welfare in Alberta. Widespread use of wheat straw on Alberta broiler facilities will be difficult to change due to increased operations costs associated with pine shavings. However, practices such as providing platforms which allow broilers to reduce foot pad contact with litter, and addition of peat moss litter amendments were identified as potential strategies in this thesis to improve foot pad quality. In the long term, legislation mandating the use of pine shavings in Alberta is recommended. However, as there is a lack of knowledge throughout Alberta in terms of foot pad dermatitis assessment and management, it is more important to provide producers with the tools to self-assess their flocks prior to legislation of pine shavings. Consistent assessment of each flock may reveal to a producer that there is an issue with foot pad dermatitis within the flock, and switching to pine shavings may help reduce the condition. Further, if legislation mandates pine shavings, it is in the interest of the processor to help producers transition to the more expensive litter material, as processors receive all increased income associated with improved foot pad quality. In conclusion, this thesis has made a significant contribution to our understanding of foot pad dermatitis in Alberta. The recommendations provided can be used to improve the welfare of the broiler industry throughout the province.

5.8. References

Alberta Agriculture & Forestry. 2016. Hay, Straw and Pasture Listings. Available at https://www.agric.gov.ab.ca/app68/hay?cat=For Sale&cat1=Straw (accessed 8 September 2016).

Bench, C. J., M. A. Oryschak, D. R. Korver, and E. Beltranena. In Press. Behaviour, growth performance, foot pad quality, bone density and carcass traits of broiler chickens reared with barrier perches and fed different dietary crude protein levels. Canadian Journal of Animal Science. doi: 10.1139/CJAS-2015-0202.

Butterworth, A., I. C. de Jong, C. Keppler, U. Knierim, L. Stadig, and S. Lambton. 2016. What is being measured, and by whom? Facilitation of communication on technical measures amongst competent authorities in the implementation of the European Union Broiler Directive (2007/43/EC). Animal 10:302–308.

Environment Canada. 2016. Historical climate data. Government of Canada Available at http://climate.weather.gc.ca/index_e.html (accessed 1 May 2016).

Everett, D. L., C. D. Mcdaniel, and A. S. Kiess. 2013. The impact of peat moss amendments on the microbial load in used pine shaving poultry litter. International Journal of Poultry Science 12:202–205.

Fraley, G. S., S. M. Fraley, D. M. Karcher, M. M. Makagon, and M. S. Lilburn. 2013. Influence of raised plastic floors compared with pine shaving litter on environment and Pekin duck condition. Poultry Science 92:583–590.

Grimes, J. L., J. Smith, and C. M. Williams. 2002. Some alternative litter materials used for growing broilers and turkeys. World's Poultry Science Journal 58:515–526.

de Jong, I. C., H. Gunnink, and J. van Harn. 2014. Wet litter not only induces footpad dermatitis but also reduces overall welfare, technical performance, and carcass yield in broiler chickens. Journal of Applied Poultry Research 23:51–58.

de Jong, I. C., J. van Harn, H. Gunnink, A. Lourens, and J. W. van Riel. 2012. Measuring foot-pad lesions in commercial broiler houses. Some aspects of methodology. Animal Welfare 21:325–330.

Martland, M. F. 1985. Ulcerative dermatitis dm broiler chickens: the effects of wet litter. Avian Pathology 14:353–364.

Mistaya Land & Water Corp. 2014. Pine wood shavings. Available at http://www.bestwoodshavings.com/ (accessed 8 September 2016).

Pettit-Riley, R., and I. Estevez. 2001. Effects of density on perching behavior of broiler chickens. Applied Animal Behaviour Science 71:127–140.

Rothrock, M. J., K. L. Cook, J. G. Warren, and K. Sistani. 2008. The effect of alum addition on microbial communities in poultry litter. Poultry Science 87:1493–1503.

Skrbic, Z., Z. Pavlovski, M. Lukic, and V. Petricevic. 2015. Incidence of footpad dermatitis and hock burns in broilers as affected by genotype, lighting program and litter type. Annals of Animal Science 15:433–445.

Taira, K., T. Nagai, T. Obi, and K. Takase. 2014. Effect of litter moisture on the development of footpad dermatitis in broiler chickens. Journal of Veterinary Medical Science 76:583–586.

References

Agriculture and Agri-Food Canada. 2015. Weighted average retail poultry and table egg prices report (chicken). Available at http://aimis-simia.agr.gc.ca/rp/index-eng.cfm?report_format_type_code=21&action=gR&signature=5A510CFABB52569B4EBFF9F8486FCD93&pdctc=&r=116&pTpl=1&btnDownload=View (accessed 4 September 2016).

Alberta Agriculture & Forestry. 2016. Hay, Straw and Pasture Listings. Available at https://www.agric.gov.ab.ca/app68/hay?cat=For Sale&cat1=Straw (accessed 8 September 2016).

Algers, B., and C. Berg. 2001. Monitoring animal welfare on commercial broiler farms in Sweden. Animal Science 51:88–92.

Allain, V., L. Mirabito, C. Arnould, M. Colas, S. Le Bouquin, C. Lupo, and V. Michel. 2009. Skin lesions in broiler chickens measured at the slaughterhouse: relationships between lesions and between their prevalence and rearing factors. British Poultry Science 50:407–417.

AOAC International. 1990. Official methods of analysis of the association of official analytical chemists (K Helrich, Ed.). 1:771 pgs.

Aviagen. 2014. Ross 308 broiler: nutrition specifications. :10 pgs.

Baéza, E., C. Arnould, M. Jlali, P. Chartrin, V. Gigaud, F. Mercerand, C. Durand, E. Le Bihan-Duval, and C. Berri. 2012. Influence of increasing slaughter age of chickens on meat quality, welfare, and technical and economic results. Journal of Animal Science 90:2003–

2013.

Barbut, S. 2015. Primary Processing of Poultry.Page 43 in The Science of Poultry and Meat Processing. www.poultryandmeatprocessing.com.

Bassler, A. W., C. Arnould, A. Butterworth, L. Colin, I. C. De Jong, V. Ferrante, P. Ferrari, S. Haslam, F. Wemelsfelder, and H. J. Blokhuis. 2013. Potential risk factors associated with contact dermatitis, lameness, negative emotional state, and fear of humans in broiler chicken flocks. Poultry Science 92:2811–2826.

Bench, C. J., M. A. Oryschak, D. R. Korver, and E. Beltranena. In Press. Behaviour, growth performance, foot pad quality, bone density and carcass traits of broiler chickens reared with barrier perches and fed different dietary crude protein levels. Canadian Journal of Animal Science. doi: 10.1139/CJAS-2015-0202.

Bessei, W. 2006. Welfare of broilers: a review. World's Poultry Science Journal 62:455–466.

Bilgili, S. F., J. B. Hess, J. P. Blake, K. S. Macklin, B. Saenmahayak, and J. L. Sibley. 2009. Influence of bedding material on footpad dermatitis in broiler chickens. Journal of Applied Poultry Research 18:583–589.

Bilgili, S. F., G. I. Montenegro, J. B. Hess, and M. K. Eckman. 1999. Live performance, carcass quality and deboning yields of broilers reared on sand as a litter source. Journal of Applied Poultry Research 8:352–361.

Bizeray, D., I. Estevez, C. Leterrier, and J. M. Faure. 2002a. Influence of increased environmental complexity on leg condition, performance, and level of fearfulness in broilers. Poultry Science 81:767–773.

Bizeray, D., I. Estevez, C. Leterrier, and J. M. Faure. 2002b. Effects of increasing environmental complexity on the physical activity of broiler chickens. Applied Animal Behaviour Science 79:27–41.

Bokkers, E. A. M., and P. Koene. 2002. Sex and type of feed effects on motivation and ability to walk for a food reward in fast growing broilers. Applied Animal Behaviour Science 79:247–261.

Buijs, S., L. Keeling, S. Rettenbacher, E. Van Poucke, and F. A. M. Tuyttens. 2009. Stocking density effects on broiler welfare: identifying sensitive ranges for different indicators. Poultry Science 88:1536–1543.

Butterworth, A., I. C. de Jong, C. Keppler, U. Knierim, L. Stadig, and S. Lambton. 2016. What is being measured, and by whom? Facilitation of communication on technical measures amongst competent authorities in the implementation of the European Union Broiler Directive (2007/43/EC). Animal 10:302–308.

Canadian Council on Animal Care. 2009. Guidelines on the care and use of farm animals in research, teaching and testing. Canadian Council on Animal Care, Ottawa, Canada.

Carvalho, C. M. ., F. H. Litz, E. A. Fernandes, M. M. Silveira, J. M. S. Martins, L. A. Fonseca, and J. A. Zanardo. 2014. Litter characteristics and pododermatitis incidence in broilers fed a sorghum-based diet. Brazilian Journal of Poultry Science 16:291–296.

Chicken Farmers of Canada. 2009. Animal care program manual. :47 pgs.

Da Costa, M. J., J. L. Grimes, E. O. Oviedo-Rondón, I. Barasch, C. Evans, M. Dalmagro, and J. Nixon. 2014. Footpad dermatitis severity on turkey flocks and correlations with locomotion, litter conditions, and body weight at market age. Journal of Applied Poultry Research 23:268–279.

Danbury, T. C., C. A. Weeks, A. E. Waterman-Pearson, S. C. Kestin, and J. P. Chambers. 2000. Self-selection of the analgesic drug carprofen by lame broiler chickens. Veterinary Record 146:307–311.

DEFRA (Science Research & Development). 2010. Foot pad dermatitis and hock burn in broilers: risk factors, aetiology and welfare consequences-final report. SID 5. Department for Environment, Food and Rural Affairs, Glasgow.

Delmar Group International. 2014. Industry, markets and trade (Canada). Available at https://www.delmarcargo.com/en/links.html#canada (accessed 4 September 2016).

Dhouailly, D. 2009. A new scenario for the evolutionary origin of hair, feather, and avian scales. Journal of Anatomy 214:587–606.

Dozier, W. A., J. P. Thaxton, S. L. Branton, G. W. Morgan, D. M. Miles, W. B. Roush, B. D. Lott, and Y. Vizzier-Thaxton. 2005. Stocking density effects on growth performance and processing yields of heavy broilers. Poultry Science 84:1332–1338.

Dozier, W. A., J. P. Thaxton, J. L. Purswell, H. A. Olanrewaju, S. L. Branton, and W. B. Roush. 2006. Stocking density effects on male broilers grown to 1.8 kilograms of body weight. Poultry Science 708:344–351.

Duncan, I. J. H., M. C. Appleby, and B. O. Hughes. 1992. Effect of perches in laying cages on welfare and production of hens. British Poultry Science 33:25–35.

Dunlop, M. W., P. J. Blackall, and R. M. Stuetz. 2015. Water addition, evaporation and water holding capacity of poultry litter. Science of the Total Environment 538:979–985.

Eichner, G., S. L. Vieira, C. A. Torres, J. L. B. Coneglian, D. M. Freitas, and O. A. Oyarzabal. 2007. Litter moisture and footpad dermatitis as affected by diets formulated on an all-vegetable basis or having the inclusion of poultry by-product. Journal of Applied Poultry Research 16:344–350.

Ekstrand, C., B. Algers, and J. Svedberg. 1997. Rearing conditions and foot-pad dermatitis in Swedish broiler chickens. Preventive Veterinary Medicine 31:167–174.

Ekstrand, C., T. E. Carpenter, I. Andersson, and B. Algers. 1998. Prevalence and control of foot-pad dermatitis in broilers in Sweden. British Poultry Science 39:318–324.

Environment Canada. 2016. Historical climate data. Government of Canada Available at http://climate.weather.gc.ca/index_e.html (accessed 1 May 2016).

Estevez, I., N. Tablante, R. L. Pettit-Riley, and L. Carr. 2002. Use of cool perches by broiler chickens. Poultry Science 81:62–69.

Everett, D. L., C. D. Mcdaniel, and A. S. Kiess. 2013. The impact of peat moss amendments on the microbial load in used pine shaving poultry litter. International Journal of Poultry Science 12:202–205.

Faure, J. M., and R. B. Jones. 1982. Effects of sex, strain, and type of perching behaviour in the domestic fowl. Applied Animal Ethology 8:281–293.

Fraley, G. S., S. M. Fraley, D. M. Karcher, M. M. Makagon, and M. S. Lilburn. 2013. Influence of raised plastic floors compared with pine shaving litter on environment and Pekin duck condition. Poultry Science 92:583–590.

Francesch, M., and J. Brufau. 2004. Nutritional factors affecting excreta/litter moisture and quality. World's Poultry Science Journal 60:64–75.

Garcês, A., S. M. S. Afonso, A. Chilundo, and C. T. S. Jairoce. 2013. Evaluation of different litter materials for broiler production in a hot and humid environment: 1. Litter characteristics and quality. Journal of Applied Poultry Research 22:168–176.

Garcia, R. G., I. C. L. Almeida Paz, F. R. Caldara, I. A. Naas, D. F. Pereira, and V. M. O. S. Ferreira. 2012. Selecting the most adequate bedding material for broiler production in Brazil. Brazilian Journal of Poultry Science 14:121–128.

Garner, J. P., C. Falcone, P. Wakenell, M. Martin, and J. A. Mench. 2002. Reliability and validity of a modified gait scoring system and its use in assessing tibial dyschondroplasia in broilers. British Poultry Science 43:355–363.

Gentle, M. J. 2011. Pain issues in poultry. Applied Animal Behaviour Science 135:252–258.

Gentle, M. J., and F. L. Hill. 1987. Oral lesions in the chicken: behavioural responses following nociceptive stimulation. Physiology and Behavior 40:781–783.

Gouveia, K. G., P. Vaz-Pires, and P. Martins da Costa. 2009. Welfare assessment of broilers through examination of haematomas, foot-pad dermatitis, scratches and breast blisters at processing. Animal Welfare 18:43–48.

Greene, J. A., R. M. McCracken, and R. T. Evans. 1985. A contact dermatitis of broilers-clinical and pathological findings. Avian Pathology 14:23–38.

Grimes, J. L., J. Smith, and C. M. Williams. 2002. Some alternative litter materials used for growing broilers and turkeys. World's Poultry Science Journal 58:515–526.

Grist, A. 2006. Poultry inspection: anatomy, physiology and disease conditions. :276 pgs.

Guerrero-Legarreta, I. 2010. Handbook of poultry science and technology: volume 1: primary processing (I Guerrero-Legarreta and YH Hui, Eds.). :611 pgs.

Hashimoto, S., K. Yamazaki, T. Obi, and K. Takase. 2011. Footpad dermatitis in broiler chickens in Japan. J. Vet. Med. Sci. 73:293–297.

Haslam, S. M., S. N. Brown, L. J. Wilkins, S. C. Kestin, P. D. Warriss, and C. J. Nicol. 2006. Preliminary study to examine the utility of using foot burn or hock burn to assess aspects of housing conditions for broiler chicken. British Poultry Science 47:13–18.

Haslam, S. M., T. G. Knowles, S. N. Brown, L. J. Wilkins, S. C. Kestin, P. D. Warriss, and C. J. Nicol. 2007. Factors affecting the prevalence of foot pad dermatitis, hock burn and breast burn in broiler chicken. British Poultry Science 48:264–275.

van Hemert, C., C. M. Handel, J. E. Blake, R. M. Swor, and T. M. O'Hara. 2012. Microanatomy of passerine hard-cornified tissues: Beak and claw structure of the black-capped chickadee (*Poecile atricapillus*). Journal of Morphology 273:226–240.

van der Hoeven-Hangoor, E., I. B. van de Linde, N. D. Paton, M. W. A. Verstegen, and W. H. Hendriks. 2013. Effect of different magnesium sources on digesta and excreta moisture content and production performance in broiler chickens. Poultry Science 92:382–391.

de Jong, I. C., H. Gunnink, and J. van Harn. 2014. Wet litter not only induces footpad dermatitis but also reduces overall welfare, technical performance, and carcass yield in broiler chickens. Journal of Applied Poultry Research 23:51–58.

de Jong, I. C., J. van Harn, H. Gunnink, V. A. Hindle, and A. Lourens. 2012a. Footpad dermatitis in Dutch broiler flocks: prevalence and factors of influence. Poultry Science 91:1569–1574.

de Jong, I. C., J. van Harn, H. Gunnink, A. Lourens, and J. W. van Riel. 2012b. Measuring foot-pad lesions in commercial broiler houses. Some aspects of methodology. Animal Welfare 21:325–330.

de Jong, I. C., T. Veldkamp, and J. van Harn. 2011. Management tools to reduce footpad dermatitis in broiler chickens. Aviagen:10 pgs.

Karcher, D. M., M. M. Makagon, G. S. Fraley, S. M. Fraley, and M. S. Lilburn. 2013. Influence of raised plastic floors compared with pine shaving litter on environment and Pekin duck condition. Poultry Science 92:583–590.

Kjaer, J. B., G. Su, B. L. Nielsen, and P. Sørensen. 2006. Foot pad dermatitis and hock burn in broiler chickens and degree of inheritance. Poultry Science 85:1342–1348.

Kristensen, H. H., and C. Cornou. 2011. Automatic detection of deviations in activity levels in groups of broiler chickens - A pilot study. Biosystems Engineering 109:369–376.

Kyvsgaard, N. C., H. B. Jensen, T. Ambrosen, and N. Toft. 2013. Temporal changes and risk factors for foot-pad dermatitis in Danish broilers. Poultry Science 92:26–32.

Lawrence, J., V. R. Fowler, and J. E. Novakofski. 2012. Growth of farm animals. :352 pgs.

Lees, J. J., L. P. Folkow, R. L. Nudds, and J. R. Codd. 2014. The effects of season and sex upon the morphology and material properties of keratin in the Svalbard rock ptarmigan (*Lagopus muta hyperborea*). Journal of Thermal Biology 44:126–130.

LeVan, N. F., I. Estevez, and W. R. Stricklin. 2000. Use of horizontal and angled perches by broiler chickens. Applied Animal Behaviour Science 65:349–365.

Loeser, J. D., and R. D. Treede. 2008. The Kyoto Protocol of IASP basic pain terminology. Pain 137:473–477.

Marchewka, J., T. T. N. Watanabe, V. Ferrante, and I. Estevez. 2013. Welfare assessment in broiler farms : Transect walks versus individual scoring. Poultry Science 92:2588–2599.

Martland, M. F. 1984. Wet litter as a cause of plantar pododermatitis, leading to foot ulceration and lameness in fattening turkeys. Avian Pathology 13:241–252.

Martland, M. F. 1985. Ulcerative dermatitis dm broiler chickens: the effects of wet litter. Avian Pathology 14:353–364.

Martrenchar, A., E. Boilletot, D. Huonnic, and F. Pol. 2002. Risk factors for foot-pad dermatitis in chicken and turkey broilers in France. Preventive Veterinary Medicine 52:213–226.

Mayne, R. K. 2005. A review of the aetiology and possible causative factors of foot pad dermatitis in growing turkeys and broilers. World's Poultry Science Journal 61:256–267.

Mayne, R. K., R. W. Else, and P. M. Hocking. 2007. High litter moisture alone is sufficient to cause footpad dermatitis in growing turkeys. British Poultry Science 48:538–545.

McIlroy, S. G., E. A. Goodall, and C. H. McMurray. 1987. A contact dermatitis of broilers-epidemiological findings. Avian Pathology 16:93–105.

Meluzzi, A., C. Fabbri, E. Folegatti, and F. Sirri. 2008a. Survey of chicken rearing conditions in Italy: effects of litter quality and stocking density on productivity, foot dermatitis and carcase injuries. British Poultry Science 49:257–264.

Meluzzi, A., C. Fabbri, E. Folegatti, and F. Sirri. 2008b. Effect of less intensive rearing conditions on litter characteristics, growth performance, carcase injuries and meat quality of broilers. British Poultry Science 49:509–515.

Michel, V., E. Prampart, L. Mirabito, V. Allain, C. Arnould, D. Huonnic, S. Le Bouquin, and O. Albaric. 2012. Histologically-validated footpad dermatitis scoring system for use in chicken processing plants. British Poultry Science 53:275–281.

Mihai, C. S., I. Van, and G. Ciurescu. 2013. Influence of litter on footpad dermatitis and body weight in broilers. Lucrari Stiintifice 56:145–148.

Mistaya Land & Water Corp. 2014. Pine wood shavings. Available at http://www.bestwoodshavings.com/ (accessed 8 September 2016).

Musilova, A., M. Lichovnikova, D. Hampel, and A. Przywarova. 2013. The effect of the season on incidence of footpad dermatitis and its effect on broilers performance. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis 61:1793–1798.

Nagaraj, M., J. B. Hess, and S. F. Bilgili. 2007a. Evaluation of a feed-grade enzyme in broiler diets to reduce pododermatitis. Journal of Applied Poultry Research 16:52–61.

Nagaraj, M., C. A. P. Wilson, J. B. Hess, and S. F. Bilgili. 2007b. Effect of high-protein and all-vegetable diets on the incidence and severity of pododermatitis in broiler chickens. Journal of Applied Poultry Research 16:304–312.

Nahm, K. H. 2003. Evaluation of the nitrogen content in poultry manure. World's Poultry Science Journal 59:77–88.

National Farm Animal Care Council. 2016. Code of practice for the care and handling of hatching eggs, breeders, chickens and turkeys. :82 pgs.

Pagazaurtundua, A., and P. D. Warriss. 2006a. Measurements of footpad dermatitis in broiler chickens at processing plants. The Veterinary Record 158:679–682.

Pagazaurtundua, A., and P. D. Warriss. 2006b. Levels of foot pad dermatitis in broiler chickens reared in 5 different systems. British Poultry Science 47:529–532.

Peat Moss Association of Canada. 2016. Characteristics of horticultural peat. Available at http://peatmoss.com/peat-in-horticulture/characteristics-of-horticultural-peat/ (accessed 9 September 2016).

Pettit-Riley, R., and I. Estevez. 2001. Effects of density on perching behavior of broiler chickens. Applied Animal Behaviour Science 71:127–140.

Pettit-Riley, R., I. Estevez, and E. Russek-Cohen. 2002. Effects of crowding and access to perches on aggressive behaviour in broilers. Applied Animal Behaviour Science 79:11–25.

Ross. 2014. Ross 308 managment handbook. :132 pgs.

Rothrock, M. J., K. L. Cook, J. G. Warren, and K. Sistani. 2008. The effect of alum addition on microbial communities in poultry litter. Poultry Science 87:1493–1503.

SAS Institute Inc. 2016. SAS University Edition. SAS Institute Inc, Cary, NC, USA.

Shariatmadari, F. 2012. Plans of feeding broiler chickens. World's Poultry Science Journal 68:21–30.

Shepherd, E. M., and B. D. Fairchild. 2010. Footpad dermatitis in poultry. Poultry Science 89:2043–2051.

Shields, S. J., J. P. Garner, and J. A. Mench. 2005. Effect of sand and wood-shavings bedding on the behavior of broiler chickens. Poultry Science 84:1816–1824.

Sirri, F., G. Minelli, E. Folegatti, S. Lolli, and A. Meluzzi. 2007. Foot dermatitis and productive traits in broiler chickens kept with different stocking densities, litter types and light regimen. Italian Journal of Animal Science 6:734–736.

Skrbic, Z., Z. Pavlovski, M. Lukic, and V. Petricevic. 2015. Incidence of footpad dermatitis and hock burns in broilers as affected by genotype, lighting program and litter type. Annals of Animal Science 15:433–445.

Spindler, B., and J. Hartung. 2009. Assessment of litter quality in broiler houses. Sustainable animal husbandry: prevention is better than cure. Proceedings of the 14th International Congress of the International Society for Animal Hygiene (ISAH).:489–492.

Statistics Canada. 2015. Production of poultry, by province. 2016 Available at http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/prim55a-eng.htm (accessed 4 September 2016).

Stojčić, M. D., S. Bjedov, D. Žikić, L. Perić, and N. Milošević. 2016. Effect of straw size and microbial amendment of litter on certain litter quality parameters, ammonia emission, and footpad dermatitis in broilers. Archives Animal Breeding 59:131–137.

Struelens, E., and F. A. M. Tuyttens. 2009. Effects of perch design on behaviour and health of laying hens. Animal Welfare 18:533–538.

Taira, K., T. Nagai, T. Obi, and K. Takase. 2014. Effect of litter moisture on the development of footpad dermatitis in broiler chickens. Journal of Veterinary Medical Science 76:583–586.

Teixeira, A., M. Oliveira, J. Menezes, B. Gouvea, S. Teixeira, and A. Gomes. 2015. Poultry litter of wood shavings and/or sugarcane bagasse: animal performance and bed quality. Revista Colombiana de Ciencias Pecuarias 28:238–246.

Tercic, D., M. Žolger, and M. Pestotnik. 2015. Effect of different litter materials on foot pad dermatitis, hock burn and feather coverage in broiler chickens. Acta Agriculturae Slovenica 106:97–101.

United States Department of Agriculture. 2013. International egg and poultry review. Livestock, Poultry & Grain Market News 16:1–3.

Vanderhasselt, R. F., M. Sprenger, L. Duchateau, and F. A. M. Tuyttens. 2013. Automated assessment of footpad dermatitis in broiler chickens at the slaughter-line: evaluation and correspondence with human expert scores. Poultry Science 92:12–18.

Ventura, B. A., F. Siewerdt, and I. Estevez. 2010. Effects of barrier perches and density on broiler leg health, fear, and performance. Poultry Science 89:1574–1583.

Verspecht, A., F. Vanhonacker, W. Verbeke, J. Zoons, and G. Van Huylenbroeck. 2011. Economic impact of decreasing stocking densities in broiler production in Belgium. Poultry Science 90:1844–1851.

Weaver Jr, W. D., and R. Meijerhof. 1991. The Effect of Different Levels of Relative Humidity and Air Movement on Litter Conditions, Ammonia Levels, Growth, and Carcass Quality for Broiler Chickens. Poultry Science 70:746–755.

Weaver, W. D., and R. Meijerhof. 1991. The effect of different levels of relative humidity and air movement on litter conditions, ammonia levels, growth, and carcass quality for broiler chickens. Poultry Science 70:746–755.

Weeks, C. A., T. D. Danbury, H. C. Davies, P. Hunt, and S. C. Kestin. 2000. The behaviour of broiler chickens and its modification by lameness. Applied Animal Behaviour Science 67:111–125.

Welfare Quality® Consortium. 2009. Welfare Quality ® assessment protocol for poultry (broilers, laying hens). :111 pgs.

World Organisation for Animal Health (OIE). 2016. Introduction to the recommendations for animal welfare.Pages 1–2 in Terrestrial Code. 25th ed. OIE, Online Publication.

Appendix A.

On-farm Management Practices Survey

This survey is part of an ongoing University of Alberta study examining factors that affect the occurrence and severity of footpad dermatitis in Alberta. Alberta appears to have a higher incidence of footpad dermatitis; however it is unclear if any management factors could be contributing to this. The confidential and anonymous information collected in this survey will be grouped with other producer data, and will not be individually identified in any manner in any subsequent journalistic and scientific media publications. This study aims to act as a starting point for future studies concerning foot pad dermatitis. The results from this study will be published in both scientific and journalistic media, and made available to producers. Recommendations for management practices will be provided to industry with the goal of improving footpad quality and welfare of broilers in Alberta.

(Fill in or circle answer that applies)

1. Farm identifier:
2. Date of visit:
3. Flock ID code: Barn ID:

4. How long have you managed this farm? <6mo   6-12 mo   1-5 yrs   >5 yrs
   a. Are you: Farm Owner   Farm Manager

5. How often do you or your staff receive extra training or attend seminars for on-farm management and skills?
   Twice a year or more   Once per year   Once per 5 years   Never

6. Which of the following answers best describes your understanding of foot pad dermatitis? Pick all that apply:
   a. A skin condition resulting from contact with poor litter
   b. An infection on the foot caused by bacteria
   c. A burn caused by ammonia in the litter
   d. An open wound caused by an injury to the foot

7. Do you think that foot pad dermatitis an issue for the Alberta broiler industry?
   a. If yes, what % of AB broilers are affected?

8. Do you receive information from the processor about your flock's foot pad quality? Y / N
    a. If Yes, is the information related to foot pad quality understandable? Y/N
    b. If No, why not? Select all that apply: Confusing Lack of Information Excess Information

9. Does this feedback from the processor change how you manage your flock? Y / N
    a. If yes, please describe:
10. Do you assess foot pad dermatitis on farm? Y / N
    a. If Yes, please describe method:
    b. If Yes, what is current foot pad dermatitis prevalence in your flock? <25% 25-50% 50-75% >75%

11. Do you do anything to try to prevent foot pad dermatitis? Y / N
    a. If Yes, please describe:

Barn Environment

12. Describe interior dimensions of barn:
    a. Length: b. Width:

13. Describe:
    a. Age: <1 yr 1-5 yr 5-10 yrs >10 yrs
    b. Construction material: Concrete Metal Wood Other
    c. Insulation material (walls): Thickness:
    d. Insulation material (ceiling): Depth:
    e. Roofing material:

14. Ventilation system: Tunnel Stack/Chimney Side Vent-side inlets Side Vent-ceiling inlets Other

15. Heating system: Floor Forced Air Radiators Other

16. How do you know when to change the barn temperature?

17. Number of chicks placed in barn and date placed:
    a. Number of birds to be marketed from flock:
    b. Stocking density:
    c. Length of production cycle (days):
    d. Date shipped
    e. Average weight of previous flock (kg):
    f. Was flock thinned? Y / N If yes, what age? %Flock removed:

Drinkers

18. Drinker system type: Nipple Bell Other

19. How would you describe the effectiveness of your drinkers?

    Excellent (no leakage, litter unaffected)

    Good (minimal leakage, litter becomes wet under drinkers)

    Poor (constant leakage, litter is wet throughout barn)

20. What is the average water consumption of a bird over the course of production?

21. How do you know when to change drinker height?

22. Water system pressure:

23. Have you tested your water? Y / N
    a. Date of last test? <1 mo <6 mo <1 yr >1 yr Don't know/NA

24. Did you treat your water for this flock? Y / N if yes, with what?

25. When was water system last cleaned? <1 mo <6 m <1 yr >1 yr Don't know/NA

26. Have you ever experienced a "flood" (large leakage of water) when the drinker system malfunctions? Y / N
    a. If yes, how often does this occur?
       Multiple times per flock Once per flock Once per year Other/Never

Feed/Feeding Systems

27. Name of feed supplier:

28. What is the source of feed? Mix own feed Complete ration (commercial supplier)

29. Do you supplement wheat to the diet on-farm? Y / N
    a. If yes, proportion of wheat added in each dietary phase, S / G / F (%)

30. Do you have the calculated nutrient composition of your rations? Y / N
    a. If yes, protein level in each diet phase, S / G / F (%)
    b. At what age do you switch rations (days)?

31. When was the date of your last feed test? <1 mo <6 mo <1 yr >1 yr Don't know
    a. Crude protein level: Undisclosed

32. Do you add anything to the feed to help maintain litter quality? Y / N
    a. If yes, what?

33. What was the average mortality rate of your previous flock?
    a. Birds culled from this flock?

34. Did you use antibiotics for disease treatment on this flock? Y / N

35. Did you use antibiotics for growth promotion on this flock? Y / N

36. If antibiotics were used, what were the drugs?

37. Were there disease occurrences in this flock? Y / N

38. Have you experienced pest issues in the last: Month 6 mo 1 yr 5 yrs Never
    a. Which? Northern Fowl Mite Vermin Other

Litter

39. What is your litter material?
    a. Why do you use that litter? Inexpensive Local Industry Standard Other
    b. Where do you source your litter?

40. Litter replacement occurs: During production After every flock Longer
    a. Was litter turned over (mixed) for this flock? Y / N if yes, frequency?

41. Did you use litter additives for this flock? Y / N if yes, additive:

42. If you were to go into the barn today, how would you describe your litter?

Dry and Loose Clumpy/wet patches, mostly dry Wet/damp throughout barn

Lighting

43. Do you have a lighting program in your barn? Y / N
    a. If yes, hours of light: dark:

44. What type of lightbulb is used in the barns? Fluorescent Incandescent LED Other
    a. What is light intensity (lux)? Don't know

Do you have any further questions?

Appendix B: Ranked Survey Questions

Ranked Survey Questions. Questions were taken from the management practices survey (Appendix A) which was used for response collection in Chapter 3. Each potential response for each question was given a score. Smaller values (e.g. 1) were associated with responses found in the literature to be linked to higher prevalence of foot pad dermatitis. Higher values (e.g. 4) were associated with responses found in the literature to be linked to lower prevalence of foot pad dermatitis. Each question had a variable number of possible responses, and thus the number of categories for responses was different between questions. For each farm visit, responses were noted on the survey. For each question included in the ranked survey, the response was graded according to the scale detailed for that question (below). After each question on the ranked survey was graded, all of the responses were summed for each flock (N=32).

Question	Categories for Responses				Min	Max
What do you do to try to prevent foot pad dermatitis	1: No prevention	2: Mentions either ventilation rate increase OR maintaining litter conditions	3: Mentions ventilation or litter conditions		1	3
How do you assess foot pad dermatitis on farm?	1: No assessment	2: Assessment of dead birds	3: Assessment of live birds	4: Assessment with science basis (e.g.WQAP)	1	4
How long have you managed this farm?	1: <1 year	2: 1-5 years	3: 5+ years		1	3
What is the age of your barn?	1: 10+ years	2: 5-10 years	3: 1-5 years		1	3
What is your ventilation system?	1: one system	2: Multiple systems			1	2
What is your heating system?	1: Other options	2: Floor heating	3: Floor heating and something else		1	3
Age at processing?	1: 40+ days	2: 38-39			1	2
Stocking density?	1: 38 kg/m2	2: 31 kg/m2			1	2
Did you thin flock?	1: no	2: yes			1	2
Drinker system?	1: bell drinkers	2: nipple			1	2
When/Why do you change drinker height?	1: no idea/unclear	2: Same time/always done it	3: computerized/specified	4: bird behaviour/head angle/physical	1	4
When was the date of the last water test?	1: 5+ years/Don't Know	2: 1-5 years	3: <1 year	4: < 6 mo	1	4
What is the protein content for each dietary phase?	1: Doesn't know	2: Knows, but does not decrease with age/fluctuates	3: Decreases with age		1	3

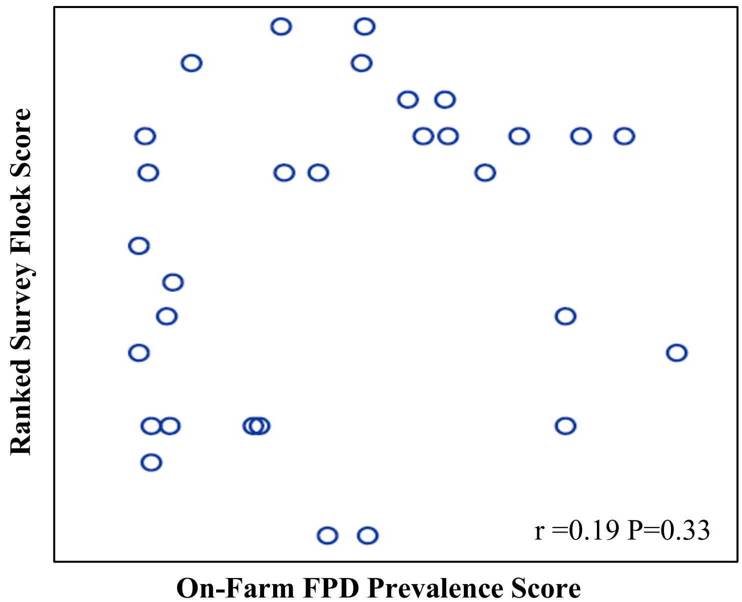
What is the wheat % in each dietary phase of the diet?	1: Doesn't know	2: Knows, but does not increase with age/starts high	3: Increases with age	1	3
Age at ration switch/number of phases	1: 3 phase	2: Prestarter, std 3 phases	3: >4 phases	1	3
What was the average mortality rate of your previous flock?	1: 10+ %	2: 5-9%	3: <5%	1	3
Were there disease occurrences in this flock?	1: yes	2: no		1	2
What is your litter material?	1: straw	2: shavings/other		1	2
What depth is your litter?	1: >10 inches	2: 5-10 inches	3: <5 inches	1	3
When do you replace the litter?	1: After multiple flocks	2: after each flock		1	2
What is the lighting program in your barn?	1: Less than 1 hrs darkness for day 1-3; Less than 4 hrs darkness for age 4-30; less than 3 hrs darkness for last 3 days	2: follows most of guidelines	3: follows all guidelines (1 hr D for age 1-3; min 4 hrs D for age 4-30; min 3 hrs darkness for last few days)	1	3
What type of lightbulbs do you have in the barn?	1: LED, Fluor, Other	2: Incandescent		1	2
What is your light intensity?	1: lux is unknown	2: Lux is known, but not changed during rearing	3: min 20 lux for chicks, 5-10 lux for rearing	1	3
				23	63
				Min	Max

Appendix C: Ranked Survey Flock Scores and Correlations

Max potential score: 63

Producer	Visit	Flock	Ranked Survey Score	Mean foot pad prevalence		
				On-Farm Score	Processor-line	Processor-sampled
A	1	1	36	27.5	1.67	36.55
A	2	2	46	26.5	19.00	27.00
A	3	3	39	18	12.67	17.56
A	4	4	36	33.5	42.33	32.89
B	1	5	50	21	12.67	48.25
B	2	6	47	41.5	10.67	45.18
B	3	7	46	50.5	72.33	53.17
B	4	8	49	32.5	44.67	36.67
C	1	9	49	8	4.00	24.17
C	2	10	48	39.5	15.33	3.327
C	3	11	43	5.5	5.33	6.167
C	4	12	42	4.5	2.67	3.327
D	1	13	41	0.5	1.33	2.493
D	2	14	44	0.5	5.33	1.167
D	3	15	46	2	4.00	8.000
D	4	16	47	1.5	4.67	0.833
E	1	17	48	44.5	20.00	46.50
E	2	18	46	21.5	13.00	23.89
E	3	19	42	62	56.67	54.67
E	4	20	50	33	27.00	37.00
F	1	21	41	78	34.00	78.06
F	2	22	47	55.5	32.00	58.67
F	3	23	39	62	81.33	53.33
F	4	24	39	17	24.33	22.79
G	1	25	39	5	6.00	21.70
G	2	26	39	2.5	22.67	7.139
G	3	27	40	.	3.00	8.466
G	4	28	38	2.5	1.00	3.833
H	1	29	47	64	53.33	70.28
H	2	30	45	.	65.00	84.42
H	3	31	47	45	71.67	40.50
H	4	32	47	70.5	67.67	57.33

Appendix C: Ranked Survey Flock Scores and Correlations



Appendix D. Equations used for litter moisture retention calculations

Litter Moisture Absorption: $$\% \text{ Moisture Absorbed} = \left[\frac{\text{Absorbed} - \text{Initial}}{\text{Initial}}\right] * 100$$

Final Litter Moisture (%): $$\% \text{ Final Moisture} = \left[\frac{\text{Absorbed} - \text{Released}}{\text{Absorbed}}\right] * 100$$

Moisture Released by Litter (%): $$\% \text{ Moisture Released} = \left[\frac{\text{Released}}{\text{Absorbed}}\right] * 100$$

Moisture in Unground Litter (%): $$\% \text{ Unground Moisture} = \left[\frac{(\text{Inital UG} - \text{Final UG})}{\text{Initial UG}}\right] * 100$$

Moisture in Ground Litter (%): $$\% \text{ Ground Moisture} = \left[\frac{\text{Initial G} - \text{Final G}}{\text{Initial G}}\right] * 100$$

Carcass Yield (%): $$\text{Proportion of Carcass}(\%) = \left[\frac{\text{Carcass component}}{\text{Total carcass weight}}\right] * \ 100$$