ENVIRONMENTAL EFFECTS ON FOOTPAD DERMATITIS

by

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(Under the Direction of Brian D. Fairchild)

ABSTRACT

Paws, the portion of the leg below the spur, have become one of the most profitable parts of the broiler chicken. High demand in export markets for Grade A paws has driven companies to maximize paw recoveries. Footpad dermatitis (FPD) lesions are the cause of 99% of downgraded paws. Histological examination revealed parakeratotic hyperkeratosis in the early stages with keratin shearing. Heterophil infiltration soon followed with the development of lesions. Studies were conducted to evaluate the influence of environmental factors, specifically litter depth, type, and systems on the development of FPD lesions. The data suggest that as litter depth increases, litter moisture decreases, and paw quality improves. Improved paw quality was observed when litter depths were ≥ 3 inches. Better paws were found in houses with used litter than in houses completely cleaned out. Cleaned out houses had 35-45% more Grade C paws than windrowed and caked out houses.

INDEX WORDS: footpad dermatitis, paws, litter depth, litter, broiler, environment

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DEDICATION

I would like to dedicate this thesis to my grandfather Curtis Theo McGee and my good friend David Joseph Williamson who could not be with us today.

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CHAPTER 1

INTRODUCTION

Footpad dermatitis (FPD) is a skin condition that results in the formation of lesions on the plantar surface of the foot pads of broilers and turkeys. This condition is a concern for food safety and animal welfare. It also causes costly downgrades and condemnations of saleable paws. By definition, the chicken paw is the portion below the spur whereas chicken feet include the lower leg as well as the foot (Christensen, 1996). While research in this area dates back to the 1940's, the skin condition being investigated then was the result of nutritional deficiencies (Patrick et al., 1943, 1944; McGinnis and Carver, 1946) and may not be the same FPD that is being observed today.

Research in this area has branched to environmental areas specifically looking at litter moisture and quality when poultry diets became more nutritionally sound and FPD was still present. Factors such as stocking density, drinker systems, litter types, and litter moisture were examined as contributing factors (Ekstrand and Algers, 1997; Ekstrand et al., 1997; Grimes et al., 2002, 2006; Bilgili et al., 2009; Sirri et al., 2007; Meluzzi et al., 2008b; Su et al., 2000, Martland 1984, 1985). Nutritional work continued looking at the relationship between diet densities, protein levels and sources, and enzymes to better understand the relationship between FPD and nutrition (Bilgili et al., 2006; Nagaraj et al., 2007b, c; Eichner et al., 2007). Research has also examined the relationship between strain crosses, gender, and body size with inconsistent results (Harms et al., 1977; Kjaer et al., 2006; Nagaraj et al., 2007a, b; Bilgili et al., 2006; Ask, 2010; Sanotra et al., 2003; Kjaer et al., 2006).

One area where research is lacking and inconsistent in the scientific literature is the relationship between litter depth, litter moisture, and FPD. Some research observed lower incidence of FPD with shallower litter depths (Ekstrand et al., 1997; Martrenchar et al., 2002). Other research noted improvements in FPD with deeper litter depths (Meluzzi et al., 2008b; Haslam et al., 2007). This disagreement in the research findings along with shortages in pine shavings and high demands for Grade A paws for export markets warrants further research into this field. The present studies examined the relationship between litter depths, litter types, and litter systems on the incidence and severity of FPD.

Histological examinations of FPD have been limited in scope and depth. Most work has focused on the lesion after it has already developed (Martland, 1984, 1985; Greene et al., 1985; Harms and Simpson, 1975). Understanding how these lesions begin to develop in the very early stages may be more important from a prevention standpoint. In the following studies, histopathological examinations of broiler paws were conducted to better understand this condition.

CHAPTER 2

LITERATURE REVIEW

FOOTPAD DERMATITIS IN POULTRY[1]

[1] Shepherd, E. M. and B. D. Fairchild. Submitted to *Poultry Science, 3-15-2010*

ABSTRACT

Footpad dermatitis (FPD) is a condition that causes necrotic lesions on the plantar surface of the footpads in growing broilers and turkeys. This condition not only causes downgrades and condemnations of saleable chicken paws, the portion below the spur, but is also an animal welfare concern in both the U.S. and in Europe. Revenue from chicken paws in 2008 alone was worth $280 million (US Poultry & Egg Export Council, 2009). Harvesting large, unblemished paws has become a priority to poultry companies all over the world. Research on this subject has been ongoing since the 1940's and has examined many different areas including nutrition, environment, and genetics. Early research looked at nutritional deficiencies such as riboflavin and biotin mainly in turkey poults. This early research was most likely looking at a separate form of dermatitis than what is being investigated now. Recent findings have suggested that there is a myriad of interacting factors that lead to FPD. Litter moisture appears to be the most likely culprit in the onset of this condition. Research has also shown a possible genetic link in the susceptibility to development of FPD lesions. Chicken paws have become very profitable due to a large export market in Asia. In order to produce unblemished paws for both increased profit and comply with current animal welfare recommendations, further research is needed to understand how the FPD condition develops and what strategies can be utilized to prevent it.

Key Words: Footpad dermatitis, poultry, paw, broiler, pododermatitis

INTRODUCTION

Footpad dermatitis (FPD) was first reported as a skin condition in broilers in the 1980's (McFerran et al., 1983; Greene et al., 1985). A similar condition was reported in turkeys (Mayne, 2005). This condition is usually associated with wet litter in broilers (Greene et al., 1985; Martland, 1985) and turkeys (Martland, 1984; Mayne et al., 2007b). FPD is known by multiple names, such as pododermatitis and contact dermatitis, all of which refer to a condition characterized by inflammation and necrotic lesions ranging from superficial to deep on the plantar surface of the footpads and toes. Deep ulcers may lead to abscesses and thickening of underlying tissues and structures (Greene et al., 1985).

There are several skin conditions that commonly affect broilers and turkeys. Some of these skin conditions are types of dermatitis that are associated with bacterial infections, such as Infectious Process and Gangrenous Dermatitis. Other dermatitis conditions such as hock burns and breast blisters are not usually associated with bacterial infections and are types of contact dermatitis. They are presumed to be manifestations of the same condition that results in FPD (Greene et al., 1985; Martland, 1985; Bruce et al., 1990; Berg, 2004). Hock burns have been shown to be positively correlated with FPD (r=0.76) (Meluzzi et al., 2008a).

Even though FPD was first described in the 1980's, these observations were certainly not the first cases of FPD. Rather, this time period was the beginning of the development of the broiler paw market and greater attention was being given to paw quality. By definition, the chicken paw is the portion of the foot below the spur whereas chicken feet include the lower leg as well as the foot (Christensen, 1996). The terms "paw" and "foot" are interchangeable and both terms will be used in this review. Due to the market value of this product and increasing welfare issues, it is in the best interest of the poultry industry to reduce paw downgrades and condemnations. Therefore, factors associated with increased incidence of FPD and methods to reduce it need to be determined and evaluated.

Economics

Prior to the mid 1980's, chicken paws were of little economic value and were rendered with feathers, blood, and other un-salable portions of the chicken. Footpad dermatitis (FPD) was not considered to be a serious economic issue for companies at that time and little research had been conducted. In 1987, WLR Foods, Inc. was the first US company to enter into the paw market on a large scale selling to southern China and Hong Kong (Christensen, 1996).

Recently, chicken paw prices have escalated due to an almost insatiable demand for high quality paws for export markets. This demand has turned paws into the third most important economic part of the chicken behind the breast and wings, with paws accounting for nearly $280 million in sales a year (US Poultry & Egg Export Council, 2009). The lesions that are caused by FPD are a concern to the poultry industry because of animal welfare, food safety and product downgrade issues.

Animal Welfare

Animal welfare audits in Europe frequently use foot, hock, and breast burns/lesions as an indicator of housing conditions and the general welfare of the birds (Haslam et al., 2007). In fact, the occurrence of FPD is now used as an audit criterion in welfare assessments of poultry production systems in Europe and the United States (Berg, 2004; Berg and Algers, 2004; National Chicken Council, 2010). Birds with severe lesions may also show reduced weight gain perhaps due to pain-induced decreases in feed intake (Martland, 1984, 1985).

Food safety

These lesions can serve as a portal of entry for *Staphylococcus aureus* and other microorganisms (Jensen et al., 1970; Hester, 1994). It was suggested the most important issue with FPD is that it may provide a route of systemic invasion by microorganisms which could gain entrance into the blood stream and settle in the leg joints, causing leg weakness in older turkeys.

Paw Quality

Paw quality refers to the overall health and appearance of the foot, including toes and foot pad. Paw quality has been shown to be affected by a myriad of factors including genetics, environmental factors, nutrition, and bedding materials (Martland, 1984, 1985; Nagaraj et al., 2007b; Sirri et al., 2007; Meluzzi et al., 2008b; Ask, 2010). Paw quality is judged both in the field and in the processing plant. In the field, several scales have been used to determine lesion severity including a 3 point scale that ranges from 0-2 (Bilgili et al., 2006), a 7 point scale that ranges from 0-6 (Ekstrand et al., 1997), and the Modified Ekstrand Score (Ekstrand et al., 1998) which uses a 1-3 scale. The highest number represents the most severe lesion in all 3 scoring systems. Currently, there is no federal grading system for processed paws in the processing plant. Paw scoring depends on consumer specifications. Some plants use an A, B, C, or condemn scale while others use an A, B, or condemn grade. Grading is based on the size of the lesion on the pad from FPD, discoloration, mutilations from processing, and also trauma injuries that may occur during catching/live haul such as broken toes. Roughly 99% of the downgrades come from FPD lesions with the other 1% encompassing both catching and live haul injuries and processing mutilations (Shepherd and Fairchild, 2009, personal observation).

Paws are separated and priced according to quality and size (weight). Paws can be divided into small, medium, and large/jumbo sizes. Jumbo Grade A paws are worth the most money per pound. The incentive to harvest Grade A Jumbo paws is immense but poses challenges to the growers and company. Controlling environmental factors may allow a company to manage FPD problems and ultimately harvest more unblemished paws leading to increased efficiency and subsequent profits.

HISTOPATHOLOGICAL FINDINGS

In turkey poults hyperkeratosis has been observed at 6 weeks of age. This term refers to a rapid turnover of keratinocytes that undergo apoptosis to produce keratin, resulting in a thickened layer of underdeveloped keratin. This is thought to be in response to some external trauma, causing the skin to try and produce protective layers of keratin as quickly as possible. Separation of these keratin layers on the plantar surface of the foot was also seen at 6 weeks of age. Lesions tended to be more superficial at this age but by 16 weeks of age there were more severe ulcerations. Lymphocyte, granulocyte, and lymph follicle populations increased in the dermis adjacent to the lesions (Platt et al., 2001). Mild lesions showed heterophils in the stratum germinativum and also defects in keratin formation (Martland, 1984). Heterophils were also found in the dermis, sub-epidermis, and epidermis along with basophilic cells in the stratum corneum (Greene et al., 1985). Vacuoles containing heterophils have also been found in the epidermis and inside blood vessels of the foot pad (Harms and Simpson, 1975; Martland, 1984, 1985; Greene et al., 1985). Greene et al. (1985) observed complete destruction of the keratin and epidermal layer in the center of the lesion, with necrotic tissue exposed and a mass of heterophils.

In severe lesions, there was acute inflammation with a more dense cellular infiltration and a thickening of the stratum corneum which were referred to as “horned pegs” (Martland, 1984; Whitehead, 1990). The epidermis was more eroded and the dermis was filled with fluid. There was congestion and dilation of blood vessels that were sometimes found to be necrotic (Whitehead, 1990).

ENVIRONMENTAL FACTORS ASSOCIATED WITH FPD

Litter Material

Litter management is an important aspect in rearing broilers to market age. It serves several functions that include thermal insulation, moisture absorption, protective barrier from the ground, and allows for natural scratching behavior. Bedding material must not only be a good absorber of moisture but also have a reasonable drying time (Grimes et al., 2002; Bilgili et al., 2009). While litter refers to the mixture of bedding material, fecal droppings and moisture, the term is used interchangeably with bedding materials. In this paper litter will refer to both fresh bedding material and that which has fecal material and moisture. Litter material and depth is an important area of research for the understanding and prevention of FPD. Litter materials vary by geographical region with regards to cost and availability. The most commonly used litter material is pine shavings in the US but sawdust is being used regularly also. Rice hulls, peanut hulls, and sand are other materials used regularly as bedding materials where it is economically feasible (Grimes et al., 2002).

Various materials have been examined for use as broiler litter and are generally tested for moisture absorption, caking and bird performance. Caking refers to the compression of litter layers into a single wet layer on the very top of the bedding material. This thick dense layer usually holds most of the moisture and fecal material in the litter. Therefore a common management practice is to remove this caked litter between flocks providing drier floors and better air quality for the next flock. The best performing material was pine shavings, and was followed by: rice hulls, ground corncobs, stump chips, pine sawdust, bark and chips, pine bark, and clay (Grimes et al., 2002). No differences in paw quality or performance were observed between hay, bark and wood chip litter as long as the particle size was less than 1 inch. Lower FPD scores have been observed in pine shavings when compared to straw in broilers (Su et al., 2000; Sirri et al., 2007; Meluzzi et al., 2008b) and in turkeys (Mayne et al., 2007b). One explanation of this observation may be that straw tends to have higher moisture content initially when compared to other materials such as pine shavings, rice hulls and peanut hulls (Andrews and McPherson, 1963; Grimes et al., 2002).

Recycled paper products have been found (with proper management practices) to be as effective as pine shavings (Grimes et al., 2002). More recently Grimes et al. (2006) looked at litter materials made from cotton waste, gypsum, and newspaper as a comparison to pine shavings. There was no significant difference in the occurrence of FPD lesions among the different materials used, however there was more caking with the cotton waste products.

Particle size of some litter materials has been examined as a possible contributing factor in the development of FPD. Used particleboard, a by-product of secondary wood products, has been evaluated in turkeys as a possible litter material. Large litter particles were between 0.32-1.27cm and the fine particles were similar to fine sawdust or powder. Turkeys raised on fine particleboard had significantly lower incidence of leg abnormalities than those raised on the coarse size. The highest incidence of FPD was found with the coarse particleboard treatment (Hester et al., 1997). However, increased poult mortality was observed due to gizzard compaction from consumption of fine particles. Better performance was seen in broilers raised on particles of newspaper and sawdust that are 0.64cm when compared to broilers raised on the same materials with particle sizes of 0.64-1.27cm and also 1.27-2.54cm (Malone and Chaloupka, 1983). Sand has been found to be an acceptable litter alternative to pine shavings, consistently showing a lower incidence of foot pad lesions compared to broilers raised on shavings (Bilgili et al., 1999a, b). Particle size is significantly different between these two materials and may explain why sand performed better as a litter material for broilers in that study. A more recent study looked at pine shavings, pine bark, chipped pine, mortar sand, chopped wheat straw, ground hardwood pallets, ground door filler, and cotton-gin trash. It was found that mortar sand and the ground door filler had significantly lower incidence of FPD than did the other treatments. It was theorized that the ground door filler performed well because of its moisture holding capacity and the mortar sand performed well because of its ability to release moisture (Bilgili et al., 2009).

Litter Moisture

Several factors can affect litter moisture which include but are not limited to stocking density, ventilation, and drinker design. One thing that is common among most previous research is that litter moisture is a significant factor in the onset of FPD. Martland (1985) found that wet litter appeared to be the only factor resulting in ulceration of broiler feet. Similar to findings with broilers, turkeys raised on wet litter have higher rates of FPD than those raised on dry litter (Martland, 1984). Mayne (2005) suggested that continually standing on wet litter will cause the footpad to soften and become more prone to damage, predisposing the bird to developing FPD. Drying out the litter and moving birds from wet litter to dry litter was observed to reverse the severity of FPD (Greene et al., 1985; Martland, 1985). FPD lesions have been found to be more severe as litter moisture increases, especially when the litter contains high moisture with sticky fecal droppings (Abbott et al., 1969; Harms et al., 1977; Greene et al., 1985; McIlroy et al., 1987; Ekstrand et al., 1997; Wang et al., 1998; Sorensen et al., 2000; Dozier et al., 2005, 2006; Meluzzi et al., 2008a, b; and Allain et al., 2009). While most of the literature suggests that litter moisture is a critical component in the development of contact dermatitis, other studies have found no significant correlation between litter moisture and the incidence and severity of FPD (Eichner et al., 2007; Nagaraj et al., 2007b).

Drinker Design and Management. Drinker design can play an important role in the overall moisture of the litter and thus the occurrence of FPD. Ekstrand et al. (1997) found that flocks reared with small drinker cups had a higher prevalence of FPD than did those reared on nipple drinkers. Nipple drinkers, however, have been shown to result in more scratches on the legs, breast, and backs than other drinkers (Allain et al., 2009). In turkeys, small water cups have been shown to have a lower occurrence of FPD than bell drinkers (Ekstrand and Algers, 1997). Bray and Lynn (1986) found that nipple drinkers with drip cups were most efficient and resulted in better litter conditions than nipple drinkers alone and bell drinkers. Drinkers that are too low or have the water pressure set too high tend to result in wetter floors. Water lines that may have a biofilm or other particulates can result in leaky drinkers, which will result in increased litter moisture. Regular flushing and sanitizing of the water lines will reduce water leakage. This will keep litter drier and improve its quality, subsequently resulting in better paw and hock quality (Mayne et al., 2007b; Tucker and Walker 1999).

Stocking Density. Stocking density in general is a significant factor in broiler performance (Bilgili and Hess, 1995; Sorensen et al., 2000; Feddes et al., 2002; Heckert et al., 2002; Tablante et al., 2003). A survey of broiler production in Ireland over a 2 year period reported that flocks stocked at a higher density (≤0.48ft²/bird) had 10% more hock lesions and 20% more breast lesions when compared to flocks at a lower stocking density (≥0.49ft²/bird). While no FPD data were recorded in this study, it was stated that when litter quality suddenly deteriorated, the level of hock lesions doubled when compared to flocks where litter quality did not suddenly deteriorate (Bruce et al., 1990). Some studies have reported that higher stocking densities are associated with a greater incidence of FPD than lower stocking densities (McIlroy et al., 1987; Ekstrand et al., 1997; Sorensen et al., 2000; Dozier et al., 2005, 2006; Haslam et al., 2007; and Meluzzi et al., 2008b), while other studies have suggested that stocking density plays little or no role in the formation of footpad lesions (Martrenchar et al., 2002; Sirri et al., 2007; and Meluzzi et al., 2008a). Buijs et al. (2009) found that FPD was only negatively affected when density reached 56kg/m² while Dawkins et al. (2004) reported that some leg health issues are compromised at or above a stocking density of 42kg/m^2. The sudden onset of poor litter conditions associated with higher stocking densities is considered to be the biggest influence on the development of FPD. Litter conditions deteriorate rapidly and litter moisture increases as stocking density increases (Bessei, 2006). Feddes et al. (2002) found that as stocking density increased, water consumption increased per bird. As birds drink more water, their feces may become more watery and thus increase overall litter moisture. Nevertheless, while more birds in a house makes litter quality difficult to maintain, it has been concluded that stocking density has little effect as long as appropriate environmental conditions are maintained (Dawkins et al., 2004).

Seasonal Effect. The time of year flocks are raised has been suggested as contributing factor associated with the incidence of FPD. Dermatitis has been found more frequently during winter months compared to summer, and footpad condition has a high correlation with relative humidity (RH) inside and outside the broiler house. When outdoor RH levels increased in winter months, there was an increase in paw lesions (Ekstrand and Carpenter, 1998). A 28% increase in the incidence of hock lesions has been observed in winter when compared to summer flocks (Bruce et al., 1990). Similar results were reported in other studies in which the incidence of paw lesions was greater in cold weather (Greene et al., 1985; McIlroy et al., 1987; Martrenchar et al., 2002; Dawkins et al., 2004; Haslam et al., 2007; and Meluzzi et al., 2008a). While outside RH is important, it is related to temperature so it is difficult to ascertain whether the main effect is RH or increased RH due to low outside temperatures. These seasonal effects are most likely caused by an increase in broiler house RH which is due to decreases in ventilation rates typically observed in cold weather as operations try to avoid reducing house temperature and save on heating costs. Similar seasonal trends have been observed with higher incidences of hock and breast lesions occurring during the winter months when compared to summer months (Mayne, 2005). Not all research has found the incidence of FPD elevated in the winter months. Wang et al. (1998) observed no cases of FPD in White Leghorn chickens when outside temperatures were between 48-59 °F (9-15 °C), but more birds with FPD were found when the temperature was warmer, between 68-79 °F (20-26 °C). White leghorns are genetically different than the modern broilers used today, with leghorns being much smaller in size. It was suggested by the authors that a certain temperature may be required for FPD to develop regardless of litter moisture.

Litter Depth

Most research agrees that litter quality and type are important predisposing factors in the onset of FPD. Less focus has been given to the actual depth of the litter being used. Ekstrand et al. (1997) found that litter material had little influence on the prevalence of FPD in broilers; rather litter depth appeared to have more of an effect. Flocks reared on a thin layer (< 5cm) of litter had a lower prevalence of FPD than those raised on deeper layers (> 5cm). A similar study in France reported that high quality flocks were raised on thin layers of litter and adding large amounts of litter may be a risk factor for FPD but whether that was caused by litter conditions degrading was not determined (Martrenchar et al., 2002). In contrast to these results, Meluzzi et al. (2008b) found that broilers raised on deeper litter had a lower occurrence of FPD than those raised on a thin layer. This suggests that litter depth may be an important factor in foot health. An increase in final litter depth was found to have an overall lower hock burn score, with every centimeter increase in final depth there was a corresponding decrease in hock burn score of 0.015 points (Haslam et al., 2007). Tucker and Walker (1999) noticed lower hock burn scores when shavings were at a depth of 10cm when compared to 2.5cm and 5cm. No data was recorded on FPD lesions in this study.

The studies that involved litter depth and its relationship with incidence of FPD were conducted in Europe where poultry houses have concrete floors, an aspect that differs from the packed dirt floors commonly found in the US. Meluzzi et al. (2008b) gave a weight per volume measurement (kg/m^2) for the amount of bedding material used. The initial depth could normally be explained by this measurement, but in this case initial litter moisture was not taken into account, making it difficult to compare to other studies. In this paper, the authors suggested that the experimental design confounded the actual effect of the litter depth because stocking density and photoperiod varied among treatments.

Litter Amendments

Litter amendments are often used in poultry production to reduce litter pH to control ammonia and as an intervention method in houses with a recurring disease issue such as gangrenous dermatitis. The most common type of litter amendments are litter acidifiers. These compounds lower the pH of the litter, inhibiting bacterial growth which produces ammonia as a by-product of their metabolism. Some common litter amendments include: aluminum sulfate, sodium bisulfate, ferrous sulfate, and phosphoric acid. Sodium bisulfate's, $NaHSO_4$, influence on the incidence and severity of FPD in broilers has been evaluated. Application rates of sodium bisulfate were 0.22kg/m² or 0.44kg/m² at chick placement while a third treatment had 0.22 kg/m² at both 0 and 21 d. There were no significant differences in FPD lesions noted between the treatments. The researchers stated there was a trend of decreasing incidence and severity of FPD with the use of $NaHSO_4$ (Nagaraj et al., 2007a).

NUTRITIONAL FACTORS ASSOCIATED WITH FPD

Nutrition is considered to be a major factor in the onset of FPD along with poor litter conditions. Early FPD research took place with turkey poults and focused on soybean meal inclusion in diets and nutritional deficiencies such as biotin and riboflavin (Abbott et al., 1969; Jensen et al., 1970; Murillo and Jensen, 1976; Patrick et al., 1943, 1944; McGinnis and Carver, 1947). This dermatitis may not be the same as FPD which is believed to be more of a contact dermatitis rather than a dermatitis caused by a deficiency. Biotin serves many roles in avian species, one of which is skin integrity, as reviewed by Mayne (2005). Research has branched from earlier work focused mainly on deficiencies and has looked different protein sources and levels, different diet densities, mineral and vitamin supplementation, and also the use of enzymes.

Nutritional Deficiencies

Deficiencies of vitamins and amino acids such as biotin, riboflavin, methionine, and cystine in the diets of growing birds have been reported to affect the incidence of FPD. Diets deficient in biotin have produced FPD lesions in turkeys (Patrick et al., 1942). When turkey poults were fed diets deficient in riboflavin and biotin, FPD was prevented by biotin supplementation but not with riboflavin supplementation (Patrick et al., 1944). Later, McGinnis and Carver (1947) found riboflavin supplementation of turkey diets prevented dermatitis in poults. Jensen and Martinson (1969) observed severe dermatitis of the feet and around the head in poults that were fed a diet deficient in biotin. Additional supplementation of biotin was not found to alleviate FPD in several poults. Additional research has also shown that supplementation of biotin does not reduce the occurrence or severity of FPD lesions (Atuahene et al., 1984; Mayne et al., 2007a). An interaction between biotin supplementation and litter quality may exist. In a study by Harms and Simpson (1977), supplemental biotin resulted in significantly reduced foot pad scores when given to poults grown on dry litter, but was not observed when given to poults grown on wet litter. This finding either suggests that biotin alone is not responsible for the occurrence of these lesions or that it is not effective in conditions that are known to directly increase the incidence and severity of FPD.

Grain Sources

Soybean meal has been examined as a possible cause of FPD. There are some indications that sticky indigestible carbohydrates from plant sources (primarily soybean meal) may be caustic and contribute to FPD (Hess et al., 2004). These carbohydrates are referred to as non-starch polysaccharides (NSP) and are found in higher concentrations in wheat, barley, and other grains when compared to soybean meal. As the diet NSP concentrations increase, gut viscosity increases resulting in manure that adheres more readily to the foot pads of the birds. Diets containing wheat that have increased levels of viscous NSP tend to have lower metabolizable energy values and higher digesta viscosity than normal wheat diets. These diets can be improved with addition of NSP-degrading enzymes, showing significantly lower digesta viscosity than the wheat diet alone (Choct et al., 1995). The viscosity of gut contents can affect fecal dropping adhesion to the foot, and over time may deteriorate the epidermis and keratin layers. When diets contain high levels of soybean meal, the incidence of dermatitis is very high with turkey poults, and it appears that the dermatitis is caused by manure sticking to the feet of the birds (Jensen et al., 1970).

Abbott et al. (1969) found that lesions were the result of wet, crusty litter and not dietary treatments differing in the amount of soybean meal fed to poults. These contradicting results suggest that dermatitis may be associated with independent and combined effects of soybean meal content in feed and litter moisture.

Vitamin, Mineral, and Amino Acid supplementation

Nutrients such as biotin, riboflavin, pantothenic acid, and sulfur amino acids have been shown to affect the structural components of the skin. The addition of vitamins and trace minerals did not significantly reduce FPD, and it was concluded that factors other than nutrition might be involved (Burger et al., 1984). In young poults, FPD has been associated with methionine deficiency, but the supplementation of sulfate and cystine to the diet yielded no improvement in FPD (Chavez and Kratzer, 1974; Murillo and Jensen, 1975). Foot pad condition never fully corrected with the addition of the methionine either but contact of the bird’s feet with the excreta was suggested to play a major role in FPD (Jensen et al., 1970; Abbott et al., 1969). Hess et al. (2001) supplemented broiler diets with a zinc amino acid complex and observed no significant difference in FPD scores in males but did detect a decrease in lesions when given to females.

Protein Level and Source

The incidence and severity of FPD is significantly affected by protein level and source (Nagaraj et al., 2007b). Birds reared on a low protein diet and fed a diet based on vegetable and animal proteins showed the lowest incidence of FPD compared with other treatments. The most severe cases were associated with birds fed a high protein diet consisting of only plant based proteins (Nagaraj et al., 2007b). Eichner et al. (2007) observed similar results, but found the addition of corn gluten meal to an all-vegetable diet reduced the incidence of FPD when compared to a vegetable and animal based diet. Birds raised on an all-vegetable diet had a higher incidence of FPD than did birds raised on a mixed animal and plant diet. Studies on protein level and source have provided inconsistent results. For example, a second study by Nagaraj et al. (2007c) evaluating the effect feed grade enzymes may have on protein digestion and paw quality observed no differences between the high and low protein diets. However, it was noted the litter moisture was greater in this study possibly due to increased water consumption in response to high environmental temperatures experienced during that trial.

Diet Density

In a study that examined the effects of diet density, 2 density levels were tested while keeping the feed formulation iso-caloric and iso-nitrogenous. Diet density is related to the level of fat in the diet, with low density diets having less fat than a high density diet. Broilers raised on the low density diet had significantly less incidence of paw lesions compared to the high density diet due to reduced fecal viscosity from lower soybean meal content in the ration (Bilgili et al., 2006).

Enzymes

Nagaraj et al. (2007c) evaluated a feed-grade enzyme in diets with or without animal protein on the subsequent incidence of FPD. The incidence of lesions were lower with the addition of the enzyme to the all vegetable diet with no differences noted when enzyme was added to the vegetable and animal protein diet. The improvement in foot pad condition was noted in the later stages of the flock and could be confounded with healing of the lesions. It is unclear whether the rate of healing is affected by the dietary treatments or if it was a direct effect on fecal composition that would influence foot pad condition. Additional research on feed enzymes to enhance feed utilization and reduce nitrogen in the litter is needed to better understand the impact of these feed additives on foot pad condition.

Electrolyte Imbalances

Harms and Simpson (1982) found that dietary salt content had a direct influence on the severity of foot pad lesions and that dermatitis was more severe with higher levels of salt. Birds with diets containing high salt content had fecal droppings containing more moisture resulting in poor litter conditions. They observed a reduction in both body weight and FPD with the supplementation of salt suggesting that body size is a predisposing factor in the development of lesions.

GENDER, BODY SIZE, AND STRAIN-CROSS

Gender and Body Size

The gender and size of broilers has been investigated as possible factors for the onset of FPD. It has been shown that male broilers tend to have higher incidence and severity of FPD than females (Harms and Simpson, 1975; Greene et al., 1985; McIlroy et al., 1987; Bilgili et al., 2006; Nagaraj et al., 2007b). The increased incidence of FPD in male broilers could be related to body size, as males are typically heavier than females and thus more weight is placed on their foot pads. This leads to increased surface area contact with the litter possibly causing an increase in the incidence of burns and lesions. Body weight has been shown to be positively correlated with hock burns (r=.353) (Broom and Reefman, 2005). Bruce et al. (1989) found that the prevalence of both hock and breast lesions was significantly higher in male broiler flocks than female broiler flocks.

Some research alternatively suggests that females have a higher incidence of foot pad lesions than males (Harms et al., 1977; Kjaer et al., 2006). In contrast to their earlier findings (Nagaraj et al., 2007b) in which males had a higher incidence than females, Nagaraj et al. (2007a) observed a higher incidence of FPD in females. Other studies such as Martland (1985) and Nagaraj et al. (2007c) reported no relationship between body size and gender in the incidence of FPD. Because of the inconsistent results reported from research that has evaluated body size and gender on the incidence and severity of FPD, it is currently believed that these factors are not significant contributors in the occurrence of FPD. Ask (2010) stated that continued selection for increased body weights without considering FPD in the breeding goal is likely to result in increased cases of FPD in broilers in the future.

Strain-Cross

Bilgili et al. (2006) looked at the effect of strain-cross (SC) on the development of FPD along with diet densities. They found a significant SC x diet density interaction at 42 d of age which suggested that the susceptibility to FPD may vary by SC. Similar results have been reported by Kestin et al. (1999) where FPD scores varied between 4 different crosses which suggested that FPD was not merely the product of poor management, but that there may be a difference between various strains in susceptibility to FPD. Sanotra et al. (2003) found a lower prevalence of FPD in Swedish Cobb chicks when compared to Swedish or Danish Ross chicks. The authors mentioned however that differences in housing conditions may have confounded their findings. Later, Kjaer et al. (2006) reported that Ross 308 broilers had higher rates of FPD and hock burns than did a slow-growing dual purpose strain. It was stated that it should be possible to decrease the incidence of FPD through genetic selection. Similar conclusions were made by Allain et al. (2009) when looking at a fast growing strain vs. a slow growing strain, with the fast growing strain having higher rates of FPD but fewer breast blisters. Genetic variation between and within 10 commercial broiler lines was present for both FPD and hock burns (Ask, 2010). The authors stated it may be possible to select against both FPD and hock burns without negatively impacting body weight. Chavez and Kratzer (1972) found Large White turkey poults had more severe FPD lesions than did Broad Breasted Bronze poults when reared in the same conditions on wire floors.

OTHER FACTORS

Feed Manufacturers

Bruce et al. (1990) examined feed manufacturers in Northern Ireland as a possible factor in the development of FPD, hock burns and breast blisters. It was found that between 1984 and 1985, flocks supplied by one feed manufacturer had a significantly lower level of hock burns and breast lesions than flocks supplied by 2 other feed manufacturers. However, it was found that between 1986 and 1987 flocks did not differ significantly with respect to hock burns and breast lesions in relation to feed manufacturer. These contradicting results may suggest that there is some variation between feed producers. Ekstrand et al. (1998) and McIlroy et al. (1987) reported significant differences in paw quality between feed manufacturers, with no obvious deficiencies or imbalances between the feed products. Feed quality variations between suppliers were hypothesized to have an effect by adding moisture to the litter through droppings or by an effect on skin integrity from insufficient levels of vitamins such as biotin (Haslam et al., 2007) as reviewed by Mayne (2005). The effect of feed source in the US is probably minimal due to the vertical integration of feed mills within a company that produce the same feed for all contract farms.

Alternative Production Systems

Recently, companies have considered alternative production systems to supply niche markets. Organic and free-range raised chickens have become more popular. The type of environment these birds are raised in has been compared with relation to paw quality. In a study by Pagazaurtundua and Warriss (2006) confined, organic, and free-range systems were compared. It was found that birds with the highest prevalence of footpad dermatitis were those raised with access to the outside (free-range and organic). The researchers hypothesized this could be due to sharp objects such as stones cutting the bird's feet and initiating the onset of the lesions or that they must be grown longer giving them more time for lesions to develop. Alternatively, Broom and Reefman (2005) found that organic raised chickens had half as many hock burns as did commercially reared broilers. It was suggested these results were due to drier litter conditions and greater leg strength in the organic birds. This may mean that birds with better leg strength spend less time sitting thus reducing the contact time between the hocks and litter.

While there has been considerable attention given to FPD in broilers and turkeys, the condition is still a welfare and economic problem as demand for high quality paws increases. While there is some understanding of the factors that affect the incidence and severity of foot pad lesions, the exact multifaceted process that results in FPD is not clearly understood. While of concern a few decades ago, nutritional deficiencies are not the issue behind FPD today. Nutrition directly influences both fecal dropping and litter moisture which are significant predisposing factors in the development of foot pad lesions. The literature demonstrates that litter type and management is a critical component in maintaining optimum foot pad and bird health. There is still a need to understand the histological changes that occur during the early stages of lesion formation in response to the factors discussed in this paper. Understanding these interactions between the footpad and the poultry house bedding material may lead to methods to manage this condition in the future.

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CHAPTER 3

USING LITTER DEPTH TO MANAGE FOOTPAD DERMATITIS IN BROILERS[1]

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SUMMARY

Litter is an often overlooked component in broiler production, even though birds are in direct contact with it throughout their life. Wet litter has been shown to be a major contributing factor in the development of footpad dermatitis (FPD). Litter depth has a direct influence on litter moisture by providing for moisture dissipation into the base and minimizing direct contact on the litter surface with the birds. In 2 trials, litter depth was evaluated in side-by-side experimental floor pens with mixed sex birds. In addition to bird performance and litter moisture data, foot pads were scored weekly to monitor the development of FPD.

Litter depth had little effect on bird performance in both trials. In trial one, the thinnest layer of litter (1 inch) had significantly higher moisture ($p<0.05$) than all other treatments at day 21, 28, and 35. The thickest depth of litter (5 inches) had significantly better paw scores of 0 and 1 at day 21 than the 1 inch fresh and 2 inch used treatment ($p<0.05$), but not different than the fresh 3 inch. At day 35 the 5 inch fresh treatment had less paw scores of 2 than the 1 inch fresh treatment ($p<0.05$), but not different than the 3 inch fresh and 2 inch used treatments. In trial 2, the 5 inch treatment had significantly lower litter moisture than the 1 inch treatment at day 28 and 35, but not different than the 3 inch treatment. At day 42 the 5 inch treatment had significantly lower litter moisture than both the 1 and 3 inch treatment. The 5 inch treatment had significantly better paw scores in all 3 categories at day 35 and 42 than the 1 inch treatment ($p<0.05$), but not different than 3 inches. As litter depth increases, litter moisture decreases and paw quality improves.

Key words: Footpad dermatitis, paws, litter depth, broiler

DESCRIPTION OF PROBLEM

Chicken paws have become an increasingly profitable export item over the last two decades, from being rendered at cents per pound to now bringing in approximately $280 million a year (1). With such high profits coming from paws, increased pressure has been put on growers to produce large, unblemished paws to bring maximum value in overseas markets. Approximately 99% of all paw downgrades and condemnations are due to footpad dermatitis (FPD) lesions (2). These lesions range from superficial to deep within the plantar surface of the footpads and toes, at times becoming inflamed and necrotic. Deep ulcers may lead to abscesses and thickening of underlying tissues and structures (3). Birds with severe lesions may also show reduced weight gain due to pain-induced decreases in feed intake (4, 5).

These lesions are not only a problem from product loss and downgrades, but also from food safety and animal welfare standpoints. These lesions can serve as a portal of entry for *Staphylococcus aureus* and other microorganisms (6, 7). These lesions are not associated with bacterial infections usually, but may become infected with bacteria found in the litter when lesions are severe. This may pose a potential problem for processing plants with cross contamination of carcasses. Animal welfare audits in Europe and the US often use foot, hock, and breast burns/lesions as an indicator of housing conditions and the general welfare of the birds (8). The occurrence of FPD is now used as an objective audit criterion in welfare assessments of poultry production systems (9). With animal welfare becoming more mainstream here in the US, paw quality is as important as ever.

The environment in which the birds live is an important contributing factor for the development of FPD. Bedding material type and litter moisture have been shown to be major predisposing factors. Litter materials vary by region with regards to cost and availability. The most commonly used litter material in the US is pine shavings while straw is commonly used in Europe. Other materials such as sawdust, peanut shells, rice hulls, and sand are used where it is economically feasible (10). Lower FPD scores have been observed in pine shavings when compared to straw in broilers (11, 12, 13) and in turkeys (14). Bedding material particle size has been proposed to be the most important factor with regards to choice of bedding material (15). Turkeys raised on fine particleboard had significantly lower incidence of leg abnormalities and FPD lesions than those raised on a larger particle size (16). The most important contributing factor to FPD is thought to be litter moisture. Wet litter has been theorized to be the main factor resulting in ulceration of broiler feet (5). Similar to findings with broilers, turkeys raised on wet litter have higher rates of FPD than those raised on dry litter (4). Drying out the litter and moving birds from wet litter to dry litter was observed to reverse the severity of FPD (3, 5).

Litter depth has a direct influence on litter moisture in broiler houses. Litter acts as a sponge, absorbing moisture and dispersing it throughout the base of litter. The thicker the sponge, the more moisture it can hold before it becomes saturated. Few studies have focused on litter depth and the results obtained have been contradictory. Flocks reared on a thin layer (< 5 cm) of litter have been reported to have a lower prevalence of FPD than those raised on deeper layers (> 5 cm) (17). A similar study in France reported that high quality flocks were raised on thin layers of litter and adding large amounts of litter may be a risk factor for FPD (18). In contrast to these results it has been reported that broilers raised on deeper litter had a lower occurrence of FPD than those raised on a thin layer (12). An increase in final litter depth was found to have an overall lower hock burn score, with every centimeter increase in final depth there was a corresponding decrease in hock burn score of 0.015 points (8). Hock burns have been shown to be positively correlated with FPD (r=0.76) (19). Recent communication with industry representatives have indicated that paw quality is better on used litter than with fresh shavings. It is assumed litter material is influencing the incidence of FPD, but it could be litter depth. Houses that have fresh shavings tend to have litter at a more shallow depth than houses with used litter due to high costs of fresh shavings (20). The contradicting results from previous research and a high demand for unblemished paws from both a product loss and animal welfare standpoint warrant further research in this field. The objective of this study was to evaluate the effect that litter depth had on paw quality.

MATERIALS AND METHODS

Study 1: <u>Fresh Shavings</u>

Four hundred ninety-six straight run broilers were placed within 16 pens (1.9 m^2) at a bird density of 0.7 ft^2/bird (0.07m^2/bird). Fresh pine shavings were used as the bedding material. There were a total of 4 treatments with 4 reps per treatment. Treatments included 1, 3, and 5 inches (2.5 cm, 7.6 cm, and 12.7 cm) of fresh pine shavings and one treatment with 2 inches (5.1 cm) of used litter. The used litter served as an “industry control” simulating what is commonly seen in the field. Birds were fed standard diets, including a crumbled starter (0-21 d) and a pelleted grower (21-40 d). Birds had unrestricted access to food and water via a hanging tube feeder and nipple drinker. All birds were weighed on a per pen basis up through 6 weeks of age. The paws of all birds in each pen were scored on a weekly basis. A 3-point scale was used to score paws for lesion incidence and severity (21, 22, Figure 3.1). Performance data (body weight and feed conversion) were taken weekly as were litter samples for moisture analysis (23). Mortality was recorded daily.

Study 2: Used Litter

Three hundred twelve broilers were placed within 12 pens (26 birds/pen) at a bird density of 0.76 ft^2/bird (0.71 m^2/bird). Used pine shavings were used as the bedding material. There were a total of 3 treatments with 4 reps per treatment. Treatments included 1, 3, and 5 inches of used litter (2.5 cm, 7.6 cm, and 12.7 cm). Birds were fed standard industry type diets, including a crumbled starter (0-21 d) and a pelleted grower (21-42 d). Birds had unrestricted access to food and water via a hanging tube feeder and nipple drinker. All birds were weighed on a per pen basis up through 6 weeks of age. The paws of all the birds in each pen were scored on a weekly basis using the same 3 point scale used in study one. Performance data, including body weights and feed weights, were measured weekly as were litter samples for moisture analysis. Mortality was recorded daily.

Paws were scored by the same researchers in both studies. Performance and litter moisture data were analyzed using the General Linear Model (GLM) procedure of SAS with p values ≤ 0.05 being considered significant (24, 25).

RESULTS AND DISCUSSION

Study 1: Fresh Shavings

There were no treatment effects on livability or performance, including body weights and feed conversion ($p>0.05$) (Table 3.1). Litter moisture was significantly different from d 21 through the end of the study with the 1 inch treatment having significantly higher litter moisture than all other treatments ($p<0.05$) (Table 3.2). Paw scores were significantly better as litter depth increased from 1 to 5 inches at d 21, with the 5 inch treatment having significantly better paw scores of 0 and 1 than the fresh 1 inch and used 2 inch treatments (Table 3.2). The 5 inch treatment had 86.1% of birds with no lesions, compared to 56.6% in the used 2 inch treatment and 66.2% in the fresh 1 inch. At d 35 the 1 inch treatment had a significantly higher percentage of birds with severe lesions than did the fresh 5 inch treatment (Table 3.2). The 5 inch treatment had 1.8% of birds with severe lesions, with the used 2 inch treatment having 5.4% and 8.9% in the fresh 1 inch. Paw scores at d 42 were not significantly different at any score category. Although not significant, the deeper litter treatments had better paw quality at d 42.

Study 2: <u>Used Litter</u>

In the second study the 1 inch treatment had significantly higher body weights than the 3 and 5 inch treatments ($p<0.05$), but there were no differences in livability or feed conversion (Table 3.3). The reason behind these early differences in body weight is not clearly understood and there were no differences seen by d 42. Litter moisture was significantly different from d 28 through the end of the study with the 1 inch treatment having significantly higher litter moisture than the 5 inch pens (Table 3.4). Paw scores were significantly better for all score categories in the 5 inch treatment versus the 1 inch treatment at d 35 and 42. At d 35 the 5 inch treatment had 89.7% of birds with no lesions, compared to 58.5% in the 1 inch treatment. At d 42 the 5 inch treatment had 92.8% of birds with no lesions, with the 1 inch treatment having only 55.2% (Table 3.4). At d 35 and 42 the 1 inch pens had 25.3% and 19.5% of birds with mild lesions respectively, with the 5 inch pen having only 7.2% and 4.1% respectively. At d 35 and 42 the 1 inch pens had 16.1% and 25.2% of birds with severe lesions respectively, with the 5 inch pen having only 3.1% at both time periods.

The effect of litter depth on paw quality was more pronounced in the second study. As mentioned earlier, environmental temperature was not uniform in the first study. High litter moisture alone has been shown to cause FPD (5). This can explain why paw quality was so poor in all treatments in the first study in which the highest percentage of score 0 paws at d 42 was only 10.7% as compared to 92.8% in the second study. The second study had litter moisture levels that were 10-15% lower by d 28 than the first study. The second study was conducted in a more climate controlled building and during warmer weather. The increased incidence and severity of FPD with cooler weather is supported by previous research (26, 3, 19, 8, 18). The current findings of lower FPD scores on broilers raised on deeper litter depths is in concurrence with previous research (12).

The current studies found better paw quality with used litter compared to fresh but research needs to be done comparing depths of both at the same time. As poultry companies look to save money by switching to used litter programs and delay cleaning out houses between flocks, the effect of built up litter programs will need to be determined to understand if a thicker base of built up litter is a major contributing factor to better paw quality.

CONCLUSIONS AND APPLICATIONS

1. Increasing litter depth from 1 to 5 inches led to decreased moisture levels and improved paw quality in both trials ($p < 0.05$).
2. Litter depth had little effect on bird performance and livability in both trials.
3. A litter depth of at least 3 inches should be used to accommodate moisture added throughout the flock.

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22. A 3 point scale that ranges from 0-2 was used to score paws, with 0 being a paw with no lesion (none), 1 moderate lesion (mild), and 2 severe lesions (severe).

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Table 3.1. (Trial 1) Influence of litter depth on broiler performance[1]

	1 to 21d of age			1 to 42d of age		
Treatment	Weight (g)	FC[2]	Livability	Weight (g)	FC	Livability
Used Litter (2 inch)	844.9±15.8	0.82±0.02	96.8	2384.4±19.6	1.84±0.02	89.5
Fresh Litter (1 inch)	882.2±12.1	0.83±0.03	98.4	2348.5±28.1	1.91±0.02	87.1
Fresh Litter (3 inch)	904.9±10.3	0.80±0.01	98.4	2370.1±20.3	1.94±0.03	90.3
Fresh Litter (5 inch)	884.1±16.4	0.82±0.02	98.4	2352.7±67.5	1.93±0.02	89.5

[1] Means ± Standard Error of the Mean

[2]FC= Feed Conversion adjusted for mortality

[a-b]Means within a column without a common superscript are different ($P \leq 0.05$)

Table 3.2. (Trial 1) Influence of litter depth on litter moisture (%) and incidence of footpad lesions (%) [1, 2]

Treatment	21 d of age				28 d of age				35 d of age				42 d of age		
	Moisture	None	Mild	Severe	Moisture	None	Mild	Severe	Moisture	None	Mild	Severe	None	Mild	Severe
Used Litter (2 inch)	30.8^{b}±1.5	56.6^{b}±3.4	42.6^{a}±3.4	0.8±0.8	39.7^{B}±1.9	36.9±1.7	62.3±1.0	0.8±0.8	39.9^{B}±1.9	15.2±1.7	79.5±3.0	5.4^{ab}±3.1	5.0±2.9	77.5±2.5	17.5±4.8
Fresh Litter (1 inch)	38.9^{a}±1.1	66.2^{b}±7.6	33.8^{a}±7.6	0	46.2^{A}±0.9	24.9±4.6	70.1±1.9	5.0±3.1	48.9^{A}±1.1	7.15±4.4	83.9±4.7	8.9^{a}±1.0	4.5±3.4	64.0±7.5	31.5±9.3
Fresh Litter (3 inch)	29.7^{b}±2.8	73.7^{ab}±8.3	26.4^{ab}±8.3	0	37.0^{BC}±0.9	35.2±8.2	62.3±6.1	2.5±2.5	37.9^{BC}±0.8	15.2±4.0	83.9±3.4	0.9^{b}±0.9	10.7±3.9	72.3±5.9	16.9±6.7
Fresh Litter (5 inch)	29.9^{b}±2.1	86.1^{a}±5.3	13.9^{b}±5.3	0	34.1^{C}±2.4	46.9±7.9	53.1±7.9	0	34.7^{C}±1.4	17.9±4.8	80.4±5.9	1.8^{b}±1.8	8.2±1.8	79.0±3.6	12.8±3.2

[1] Means ± Standard Error of the Mean
[2]None = no lesions present, Mild = lesions ≤ 7.5mm, Severe = ≥ 7.5mm
[a-b]Means within a column without a common superscript are different (P ≤ 0.05)
[A-C]Means within a column without a common superscript are different (P ≤ 0.01)

Table 3.3. (Trial 2) Influence of litter depth on broiler performance[1]

	1 to 21d of age			1 to 42d of age		
Treatment	Weight (g)	FC[2]	Livability	Weight (g)	FC	Livability
1 inch	922.5[a]±13.7	0.92±0.01	99.0	2497.7±97.3	1.75±0.03	95.2
3 inch	874.7[b]±9.0	0.99±0.03	98.1	2429.9±97.7	1.85±0.07	94.2
5 inch	877.0[b]±3.0	0.96±0.02	97.1	2522.0±42.6	1.98±0.11	91.3

[1] Means ± Standard Error of the Mean
[2]FC= Feed Conversion adjusted for mortality
[a-b]Means within a column without a common superscript are different ($P \leq 0.05$)

Table 3.4. (Trial 2) Influence of litter depth on litter moisture (%) and incidence of footpad lesions (%) [1, 2]

	21 d of age				28 d of age				35 d of age				42 d of age			
Treatment	Moisture	None	Mild	Severe	Moisture	None	Mild	Severe	Moisture	None	Mild	Severe	Moisture	None	Mild	Severe
1 inch	31.1±4.6	54.6±11.6	25.1±7.7	20.2±5.7	27.8^{a}±2.1	54.5±11.2	15.5±3.5	29.9±8.3	37.5^{a}±2.3	58.5^{b}±9.7	25.3^{a}±5.8	16.1^{a}±5.4	34.4^{a}±2.8	55.2^{B}±10.7	19.5^{a}±3.8	25.2^{a}±8.5
3 inch	24.2±2.5	65.1±9.7	19.2±5.8	15.6±9.2	24.0^{ab}±0.9	63.0±9.7	20.7±7.1	16.1±5.1	33.9^{ab}±1.1	76.3^{ab}±2.6	15.6^{ab}±3.4	8.1^{ab}±3.0	32.1^{a}±1.2	76.6^{AB}±4.1	12.1^{ab}±3.1	11.2^{ab}±3.6
5 inch	20.4±0.8	77.1±6.6	12.8±3.6	10.1±4.3	21.3^{b}±1.1	74.6±5.8	16.2±5.2	9.1±3.3	29.1^{b}±0.8	89.7^{a}±4.3	7.2^{b}±3.6	3.1^{b}±1.0	25.3^{b}±1.8	92.8^{A}±3.0	4.1^{b}±2.8	3.1^{b}±2.0

[1] Means ± Standard Error of the Mean
[2]None = no lesions present, Mild = lesions ≤ 7.5mm, Severe = ≥ 7.5mm
[a-b]Means within a column without a common superscript are different (P ≤ 0.05)
[A-B]Means within a column without a common superscript are different (P ≤ 0.01)

Figure 3.1. Paw scoring system (From left to right: score of 2, score of 1, score of 0)

CHAPTER 4

ALTERNATIVE BEDDING MATERIALS, MOISTURE, AND PAWS[1]

[1] Shepherd, E. M. and B. D. Fairchild. To be submitted to Journal of Applied Poultry Research

SUMMARY

The ability of bedding materials to absorb and remove moisture effectively from the surface of the material is particularly important in poultry production, due to the fact that the birds are in contact with the material throughout their life. Bedding materials including fresh pine shavings (FS), used pine shavings (US), peat moss (PM), rice hulls (RH), peanut hulls (PH), gypsum with paper (GP), gypsum without paper (GYP), sawdust (SD), and chopped wheat straw (CS) were examined for moisture absorption ability and relative drying times. PM and CS absorbed nearly 8x and 7x their own weight respectively in water. RH and PH showed the best ability for drying with each losing 75.6% and 78.7% of their moisture respectively at 60 minutes. At 120 minutes RH and PH had 2.2% and 1.3% of their saturated moisture left.

From the moisture retention analysis, one of the products with the highest moisture retention values, PM, was tested as an alternative bedding material and compared to materials commonly used in poultry housing, FS and US, in pens with mixed sex broilers for 6 weeks. No differences in ammonia generation or pH were observed. Litter moisture was significantly higher for PM on day 0, 7, and 14 with no differences for the remainder of the study. The percentage of paws with score 0 and 1 were significantly greater with the FS and PM compared to US at both day 21 and 42.

The ability to retain and lose moisture differs among materials and can affect litter and air quality during the production period. In this study, birds performed well on PM indicating that it may be an acceptable alternative bedding material and should be evaluated on a commercial scale in areas where it can be obtained economically.

Key words: Broiler, bedding material, moisture holding capacity, peat moss

DESCRIPTION OF PROBLEM

The bedding material used in broiler houses is often given little thought as producers utilize locally available supplies. Most growers do not realize the importance of a good quality bedding material. Bedding materials are often referred to as "litter" which is a combination of bedding and fecal material. Both terms, bedding material and litter, will be used interchangeably in this paper. Litter serves many important functions for poultry. The primary function of litter is to absorb moisture and dilute fecal material throughout the base, keeping the top layer of litter that comes into contact with the birds dry. Bedding provides cushion and insulation for the birds from the cooler packed dirt or concrete floors and provides the opportunity for natural scratching behaviors. Wet sticky litter has been shown to be a predisposing factor in the development of footpad dermatitis (FPD) (1) which is a concern from product loss, food safety (2, 3) and animal welfare (4, 5, 6, 7).

The ability of bedding materials to absorb moisture is important but perhaps not as important as the ability to release the moisture via evaporation. Better paw scores have been reported with ground door filler which had a high absorption capability, and with mortar sand which released moisture well, when compared to various other common and alternative bedding materials (8). Litter that absorbs twice its weight in water but remains soggy throughout the duration of the flock is not desirable. Bedding material particle size has been proposed to be an important factor with regards to choice of bedding material (8). Turkeys raised on fine particleboard had significantly lower incidence of leg abnormalities and FPD lesions than those raised on larger particle sizes (9).

The most commonly used litter material is pine shavings in the US but straw is commonly used in Europe. Local availability in the quantities needed and cost of the material are common problems associated with potential alternative bedding materials. Rice hulls, peanut hulls, and straw are some alternative materials which are commonly used in the southern states where those crops are locally produced (10). Lower FPD scores have been observed in pine shavings when compared to straw in broilers (11, 12, 13) and in turkeys (14). Research has examined the absorption of moisture over periods of time and calculated its absorption capacity (8) but none has looked at the rate of moisture release from these materials. In this paper the following materials were examined for the rate of moisture release: fresh shavings (FS), used shavings (US), peat moss (PM), rice hulls (RH), peanut hulls (PH), gypsum with paper (GP), gypsum without paper (GYP), sawdust (SD), and chopped wheat straw (CS).

PM has several characteristics that make it a potential suitable bedding material for poultry producers. It readily absorbs water and naturally has a low pH of 4.5-6.4. The ability of PM to absorb vast quantities of moisture and quickly release that moisture could allow for exceptional moisture control within broiler houses. The natural acidity of PM could be useful in the control of ammonia (NH_3) volatilization from litter by decreasing bacterial populations. Bacteria naturally found in the litter break down uric acid in the bird's feces, producing NH_3 as a by-product. Controlling moisture while possibly decreasing NH_3 levels makes PM a very attractive choice as an alternative bedding material.

Previous work has been conducted on PM as a bedding material, in fact, research dates back to the 1950's where it was first tested with poultry and found to have exceptional absorptive capacity but with dust issues (15). These results with broilers were later confirmed and PM was found to be an acceptable bedding material when it is locally available and economical to be used (16, 17). While performance (body weight gain, feed conversion and livability) has not been negatively impacted by PM litter, turkeys raised on large particles of PM have been observed to have swollen foot pads (18).

None of the previous research has evaluated the effect of PM on NH_3 reduction from the naturally acidic nature of the material. The objective of the current study was to examine the possibility of using PM to control NH_3 and evaluate broiler performance compared to both fresh and used pine shavings.

MATERIALS AND METHODS

Bedding materials (Study 1). Materials were evaluated for moisture absorption capacity along with the ability to release moisture using the following procedure with minor revisions: (Bilgili et al., 2009) (19).

Peat moss (Study 2). Three hundred Cobb 500 straight run broilers were placed within 12 pens (20ft^2 or 1.9 m^2) at a bird density of 0.7 ft^2/bird (0.07m^2/bird) (Figure 4.1). Based on the results from Study 1, PM was selected as the third treatment in this study to be compared to FS and US. Each treatment had 4 replicate pens and with bedding materials 4 in (10cm) deep. The US and FS served as “industry standards” simulating what is commonly used in U.S. broiler houses. Birds were fed standard broiler diets, including a crumbled starter (d 0-21) and a pelleted grower (d 21-40). Birds had unrestricted access to food and water via a hanging tube feeder and nipple drinker. Birds were managed according to primary breeder guidelines.

Litter moisture was sampled weekly and analyzed for moisture throughout the study for each pen starting at chick placement (20). Litter pH was measured at the end of the study on d 42 (21). Ammonia is not typically in sufficient quantities to be detected until d 28, therefore readings were taken at d 28, 35, and 42 (22). Bird and feed weights were recorded on d 0, 7, 21, and 42. Mortality was recorded daily. Feed conversion was adjusted for mortality at the end of the study. Paws were scored on d 21 & 42 using a 3 point scale (23, 24) (Figure 4.2).

Paws were scored by the same researcher throughout the study. Performance and litter moisture data were analyzed using the General Linear Model (GLM) procedure of SAS. P values ≤ 0.05 were considered significant (25, 26).

RESULTS AND DISCUSSION

Bedding materials (Study 1). Several bedding materials exhibited exceptional moisture absorption and releasing capabilities (Table 4.1). Peat moss, CS, SD, and FS all had outstanding moisture absorption capabilities. Peat moss absorbed nearly 8x its own weight in water (317.5%) and CS absorbed roughly 7x its own weight (297.6%). This ability to absorb water is critical to prevent excessive moisture build up in broiler houses. This characteristic of straw, along with availability and low cost is probably the reason it is so commonly used in Europe. Straw however has been reported to cause excessive caking when pieces are larger than 1 in (10). In this study, the straw was chopped into 1 in pieces. Peat moss is not commonly used in poultry production, but more commonly in horticulture as a soil aerator, acidifier, and for moisture retention.

Moisture release is probably as important as absorption. The amount of moisture left after 60 and 120 min was used to determine which bedding materials had the best release ability. Rice hulls and PH showed the best ability for moisture removal with each losing 75.6% and 78.7% of their moisture respectively at 60 min. At 120 min RH had 2.2% and PH had 1.3% of its moisture left. Particle size probably plays a critical role in moisture release, with smaller sizes having a greater surface area to mass ratio and thus a higher evaporation rate than larger particles. Some materials may also display adsorption properties, with moisture adhering to the surface rather than being absorbed into the material. This allows for excellent evaporative capabilities.

Built up litter programs are commonly used in poultry production in which fresh shavings may only be used as a top dress or when houses are completely cleaned out. It is not uncommon for houses to reuse litter for multiple flocks, sometimes even years. Used shavings have better moisture releasing capabilities than FS and tend to result in drier floors than houses that are completely cleaned out. Gypsum is not commonly used in poultry production but sometimes is used where there is a local supply and shavings aren't readily available. Several studies have examined GYP as an acceptable litter material (27, 28, 29, 30).

Moisture results from the current study indicate that gypsum with and without paper may be acceptable bedding materials, as long as product containing paper particles that are 1 inch or less to prevent excessive caking. Rice hulls and PH showed a great ability to remove moisture but did not absorb nearly as much moisture as PM and CS. The ability of PM to readily absorb and release moisture makes it an acceptable alternative bedding material and thus was used in the Study 2.

Peat moss (Study 2). There were no differences in body weights, feed conversion, or livability at d 21 or 42 (Table 4.2). Litter moisture was significantly higher for the PM treatment on d 0, 7, and 14 (Table 4.3). There were no differences in NH_3 and pH at any sampling period (Table 4.4). Paw scores of 0 and 1 were significantly better with the FS and PM compared to US at both d 21 and 42 (Tables 4.5).

The PM treatment had significantly higher moisture content until d 21 when it dried out sufficiently. The PM used in commercial operations will have to be placed in the houses as soon as possible and preheated longer to dry the material out before bird arrival. While not a detriment in the current study, floors with high moisture have been associated with reduce chick performance in the first week (31). While PM had numerically lower NH_3 production rates than any of the other treatments, it was not statistically significant (Table 4.4). It should be noted that the NH_3 concentration was 50% lower than that observed in the US treatment and 85% lower than FS. It is unknown why the fresh shavings had such high NH_3 concentrations.

Current findings support previous research that PM is an acceptable bedding material. While these initial results show that PM had no significant effect on bird performance and resulted in better paw quality than US, it would be of interest to evaluate PM that had been used for multiple flocks. The increase in paw quality seen in broilers raised on peat moss in this study is interesting. Litter moisture levels stayed low throughout the entire study, with the highest levels being 25% at d 42. There were no differences in litter moisture after d 21 so there may be some other factor that is responsible for the increase in paw quality in the peat moss pens. The top layer of peat moss was dry and fluffy, unlike the used and fresh shavings which sometimes have sharp edges. Possibly the less abrasive particle sizes of peat moss was a factor in better paw quality seen in this study.

Dust was an issue in this study, especially in the early weeks when ventilation rates were minimal, however no respiratory issues were observed. These findings agree with the observations of a previous study where dust levels were noticeably higher than shavings (15). While no respiratory issues were noted in this study, this may pose a problem in commercial situations where ventilation is marginal, especially in cold weather. In the current study, workers found the need to wear dust masks due to respiratory irritations noted in the first couple of weeks due to dust levels in the room. It would be of interest to determine whether the dust levels subside with additional flocks as the material is used in built up litter systems. While there were no statistical differences in NH_3 depression, the acidic nature and low moisture content of PM later in the flock may be responsible for lower levels when compared to US and FS. This warrants further research into the use of PM as a natural litter amendment.

CONCLUSIONS AND APPLICATIONS

1. Several bedding materials showed an affinity for high moisture absorption (PM, CS, SD, and FS).
2. RH and PH showed an exceptional ability to release moisture, with nearly all moisture removed after 120 min of drying.
3. Birds raised on PM had significantly better paws at both d 21 and 42.
4. PM is an acceptable bedding material, with no significant affects on broiler performance.
5. Dust may be an issue with use of PM, especially in minimum ventilation situations.

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19. Moisture absorption protocol:

Place 80g of each material into separate pans and place in a drying oven at 71°C for 24hrs. Subtract original weight from dried weight to obtain initial moisture content.
Ex: Initial weight 80g. After 24hr drying, weight= 60g.
Initial moisture content = 80-60=20g. Initial % moisture = (20/80)*100= 25%
Place 40g of dried material in each of 5 nylon socks (5 reps per material).
Tie socks and submerge in 1000ml of deionized water in a 1000ml beaker for 24 and 48hrs.
At the end of 24 hrs, the socks are removed from the water and hung to air-dry to remove any excess water for 30 min.
Socks are gently massaged to remove water while hanging.
Material is removed from socks after the air drying period and weighed in a pan to obtain saturated weight.

Moisture release protocol:

Material in the pan is then placed in a drying oven at 75°C and taken out and re-weighed every 30 min during the first 4 hrs then dried for the next 24 hrs.
Moisture retention calculation
% Moisture retained= ((Soaked weight – Dried weight)/Dried weight)*100
Ex: Initial dried weight = 60g. 24 hr soak weight = 100g (40g moisture).
24 hr % Moisture = (40/60)*100= 66.67% moisture
The % moisture that is left after each weighing period is calculated by dividing the drying period % moisture by the 24hr soaking moisture % and multiplied by 100.
Ex: 24hr soak weight 100g (40g moisture, 66.67% moisture). 60 min drying weight = 80g. (Initial dried weight = 60g). 80-60 = 20g moisture left at 60 min period. 60 min % moisture = (20/60)*100= 33.33%. % moisture left from saturated weight (100g) at 60 min= (33.33/66.67)*100=49.99

20. Litter moisture was measured by placing 100 g of litter into a pan and placing into a drying oven at 75°C for 24hrs. The samples were then reweighed after 24hrs. The initial weight was subtracted from the 24hr weight to yield grams of moisture.

21. The litter pH procedure involved diluting 50g litter samples 1:2 with deionized water followed by a one hour incubation period at room temperature. The samples were then measured using a Beckman 32 pH meter.

22. Ammonia readings were taken using a Draeger CMS Ammonia Analyzer (Draeger Safety Inc., 101 Technology Dr., Pittsburgh, PA).

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24. A 3 point scale that ranges from 0-2 was used to score paws, with 0 being a paw with no lesion (none), 1 moderate lesion (mild), and 2 severe lesions (severe).

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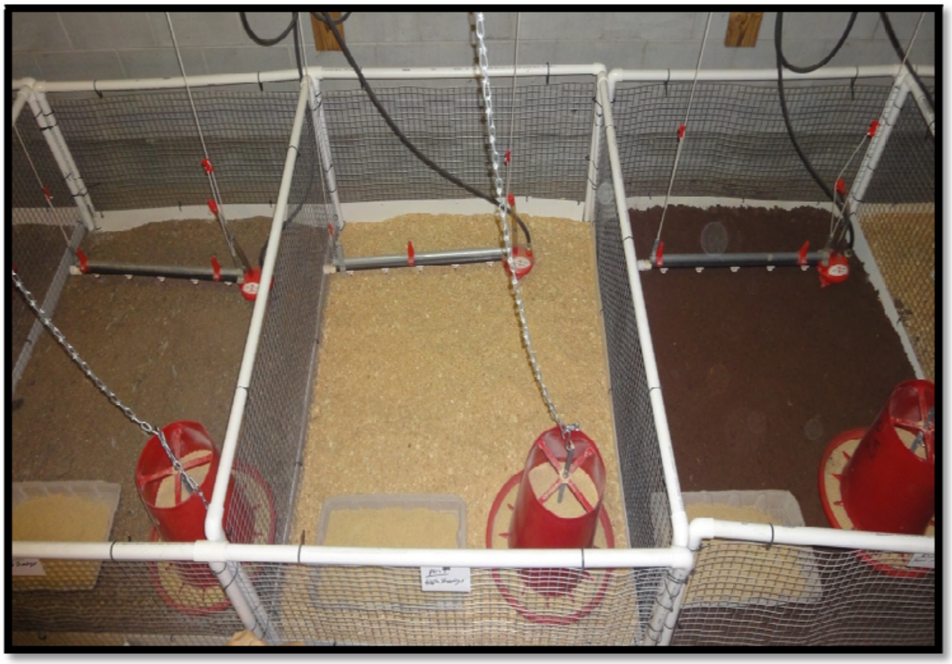

Used Litter Fresh Shavings Peat Moss

Figure 4.1. Pen setup of the 3 bedding materials used in the study

Figure 4.2. Paw scoring system (From left to right: score of 2, score of 1, score of 0)

Table 4.1. Moisture absorption and drying rates of several alternative bedding materials (%)

Type[1]	Initial %	24hr soak %	30m % left	60m % left	90m % left	120m % left	150m % left	180m % left	210m % left	240m % left	24hr % left
PM	41.7	317.5	84.8	61.2	44.7	28.6	17.3	10.0	4.5	1.3	0.0
FS	15.3	193.8	66.6	38.4	22.8	13.8	8.3	2.8	0.6	0.1	0.0
US	21.4	167.5	72.7	46.1	25.1	8.8	2.7	0.7	0.3	0.1	0.0
RH	9.9	104.5	53.6	24.4	8.4	2.2	0.7	0.5	0.5	0.5	0.0
PH	14.3	174.9	52.9	21.3	5.4	1.3	0.6	0.3	0.1	0.1	0.0
GP	11.2	121.4	86.5	26.8	16.5	9.7	5.6	5.1	4.5	4.5	0.0
GYP	9.3	40.2	56.0	41.7	24.3	12.4	6.8	2.5	2.5	2.5	0.0
SD	5.0	196.9	92.8	52.3	33.6	24.8	14.1	6.2	0.8	0.1	0.0
CS	9.9	297.6	57.1	56.3	46.1	28.6	28.2	14.5	7.3	1.3	0.0

[1]Fresh shavings (FS), Used shavings (US), Peat moss (PM), Rice hulls (RH), Peanut hulls (PH), Gypsum with paper (GP), Gypsum without paper (GYP), Sawdust (SD), and Chopped wheat straw (CS).

Table 4.2. Influence of bedding material type on broiler performance[1]

	1 to 21d of age			1 to 42d of age		
Treatment	Weight (g)	FC[2]	Livability	Weight (g)	FC	Livability
Fresh Shavings	923.4±29.6	2.08±0.03	97.0	2895.6±30.8	1.66±0.01	96.0
Peat Moss	858.7±17.9	2.19±0.02	99.0	2826.3±34.1	1.70±0.04	95.0
Used Shavings	860.8±9.8	2.19±0.01	97.0	2903.2±32.9	1.66±0.02	96.0

[1] Means ± Standard Error of the Mean
[2]FC= Feed Conversion adjusted for mortality
[a-b]Means within a column without a common superscript are different ($P \leq 0.05$)

Table 4.3. Litter moisture levels (%), litter NH_3 (ppm), and litter pH throughout the study[1]

Treatment	Day 0	Day 7	Day 14	Day 21	Day 28	Day 35	Day 42
Fresh Shavings	5.7^{B}±0.4	6.3^{B}±0.3	10.3^{B}±0.9	20.5±2.1	29.5±3.8	27.0±2.7	25.3±3.1
Peat Moss	47.7^{A}±1.3	36.9^{A}±3.4	28.5^{A}±1.2	25.9±1.8	25.8±0.8	25.1±3.7	21.8±1.4
Used Shavings	10.1^{C}±0.7	9.8^{B}±0.4	13.4^{B}±1.4	21.6±3.1	29.3±3.4	26.4±2.3	22.1±3.0
-------------------- Litter NH_3 concentrations (ppm) and pH readings------------------							
Treatment				NH_3 D28	NH_3 D35	NH_3 D42	pH D42
Fresh Shavings				6.28±0.91	16.33±5.46	45.70±34.25	7.88±0.37
Peat Moss				4.08±1.48	10.50±5.64	6.78±1.7	7.34±0.29
Used Shavings				7.20±2.98	12.03±4.58	12.95±6.53	7.52±0.41

[1] Means ± Standard Error of the Mean
[A-C]Means within a column without a common superscript are different ($P \leq 0.01$)

Table 4.4. Influence of bedding material type on incidence of footpad lesions (%) [1, 2]

	21d of age			42 d of age		
Treatment	None	Mild	Severe	None	Mild	Severe
Fresh Shavings	97.9^{A}±1.2	2.1^{B}±0.03	0	91.8^{A}±3.9	5.1^{B}±2.5	3.1±1.9
Peat Moss	100^{A}	0^{B}±0.02	0	97.9^{A}±1.2	$1. 0^{B}$±1.0	1.1±1.1
Used Shavings	85.7^{B}±2.7	14.3^{A}±0.01	0	75.8^{B}±5.6	13.7^{A}±2.2	10.5±4.3

[1] Means ± Standard Error of the Mean
[2]None = no lesions present, Mild = lesions ≤ 7.5mm, Severe = ≥ 7.5mm
[A-B]Means within a column without a common superscript are different (P ≤ 0.01)

CHAPTER 5

EVALUATION OF A FOOT COATING TO PREVENT FOOTPAD DERMATITIS IN BROILERS[1]

[1] Shepherd, E. M. and B. D. Fairchild. To be submitted to Journal of Applied Poultry Research as a research note.

SUMMARY

Footpad dermatitis (FPD) is a costly skin condition that affects the feet of broilers and is responsible for roughly 99% of paw downgrades and condemnations. Wet litter, especially when sticky, has been shown to be a major contributing factor in the development of FPD. While birds are young, they may have underdeveloped skin layers which make them susceptible to FPD lesion formation. A protective coating, such as glue, may allow time for better skin development and prevent the formation of these lesions.

A foot coating consisting of super glue and quaternary ammonia was applied to mixed sex day old broilers housed on fresh shavings in floor pens. In addition to bird performance data and litter moisture samples, foot pads were scored weekly to monitor the development of FPD. Body weights, feed conversion, and livability were unaffected by the treatment. No differences were observed in paw scores between birds that had the coating applied and those that did not. The incidence of FPD was very low throughout the study possibly due to low relative humidity and litter moisture in the room.

Key words: Footpad dermatitis, paws, coating, broiler, foot

DESCRIPTION OF PROBLEM

The poultry industry makes an estimated $280 million dollars every year from chicken paw exports (1). Many paws are condemned or downgraded due to footpad dermatitis (FPD) lesions, resulting in extensive financial losses. FPD lesions have been shown to be associated with high litter moisture and/or prolonged contact with sticky fecal material (2, 3). Research has focused on environmental and nutritional areas to control this condition, but with limited success. One method to actually prevent this condition from developing is to create a barrier between the litter and feet of the birds. As the birds grow older they develop thicker keratin layers on the bottom of their feet, providing more protection from litter conditions and physical injury that are conducive to the formation of FPD. Applying a protective coating on the feet of young broilers may allow time for the epidermis and keratin layers to thicken and reduce or prevent the incidence of FPD.

No previous research has looked at the possibility of applying a coating on the feet of broilers to prevent FPD. This process comes with several challenges. Firstly, the only time when this product could be applied successfully and economically would be in the hatchery. This would allow for only one coating during the life of the flock. The time at placement is the most vulnerable time for chicks and may actually be the best time to apply the coating. The feet of broilers, as well as their entire body, develops very rapidly the first few weeks of life. The skin constantly sheds and will only allow for the product to be useful for a week at the most as bird mass usually quadruples during this time. The idea of a preventative measure such as a glue/wax spray or dip could alleviate paw quality issues later in the flock and is the basis of the current study. The objectives are to evaluate the effects of a foot coating on the development of FPD.

MATERIALS AND METHODS

There were 2 treatments in this study, a coating treatment and a non-coated treatment to serve as the control. Twenty-five birds were placed in each of 12 4x5 ft (1.9 m^2) pens with 4 in of fresh pine shavings spread evenly at a stocking density of 0.7 ft^2/bird (0.07m^2/bird).. There were 6 pens per treatment. All birds had ad libitum access to food and water, via a hanging tube feeder and enclosed drinker systems. Birds were managed according to primary breeder guidelines.

The product used, Maxxspray, is a combination of cyanoacrylate and quaternary ammonia. The product is commonly used as an anti-microbial agent to coat floors, Astroturf, and walls. A primer is first applied to clean the surface of the feet and then the coating is applied and allowed to dry. The product dries clear in about 30 sec. Individual birds are dipped first in the primer then in the coating (Figure 5.2). An indicator dye that preferentially stained the coating was applied periodically with a spray bottle after the coating had dried and then rinsed with deionized water (Figure 5.3). This dye stained material on which the coating is fixed but will wash off if the coating has not been properly fixed (Figure 5.4). This staining method was used to ensure that the feet had the coating properly applied and to estimate the time frame over which the coating remained on the growing chicks' feet.

Birds and feed were weighed on a pen basis weekly until the end of the study. Litter moisture was sampled weekly and analyzed for moisture throughout the study for each pen starting at chick placement (4). Paws were evaluated using a 3 point visual scoring system (5, 6, Figure 5.1). Paws were scored by the same researchers throughout the entire study. Performance data were analyzed using the General Linear Model (GLM) procedure of SAS. P values ≤ 0.05 were considered significant (7, 8).

RESULTS AND DISCUSSION

Body weights, feed conversion, and livability were not significantly affected by treatment at any time period (Table 5.1). Litter moisture was not significantly different between treatments at any sampling period indicating the birds consumed similar amounts of feed and water and that the drinker systems were managed the same among the different floor pens. Litter moisture was low in the beginning of the study with fresh shavings having around 7% moisture (Table 5.2). Normal initial litter moisture for fresh pine shavings has been found to be between 11-15% (9, 10). Litter moisture never exceeded 30-35%, which is the level of moisture that begins to cause FPD problems (2, 11, 12). Since the litter moisture was so low, paw quality was exceptionally good in this study with roughly 96% of birds having lesion free paws by the end of the study (Table 5.2). There were only 4% of birds with mild lesions and no birds had severe lesions at d 42.

In this study litter moisture stayed very low at every sampling period in both treatments. This resulted in very good paw quality with > 90% of birds showing no sign of FPD lesions. The recommendation of litter having no greater than 30% moisture is supported by these findings. Due to such low FPD levels, it was difficult to distinguish the possible effects of the foot coating. The litter in this trial was approximately 4 in deep, and is in the range that is suggested to prevent excessive moisture build up (13). If this study was repeated, a shallower layer of litter would be used to elevate litter moisture in order to increase the incidence of FPD. This would enhance the ability to detect differences between the coated treatment and control. Due to the low incidence of FPD in both the treatment and control, it is not possible to discern the possible benefits of a foot coating on the prevention of FPD. Further research is needed to determine how long the coating stays on the foot and if it is beneficial in environments with higher litter moisture.

CONCLUSIONS AND APPLICATIONS

1. The foot coating had no effect on bird performance and livability in both trials.

2. No differences were seen in paw quality between the treatments.

3. Litter moisture remained below 30% which resulted in a high percentage of bird with no incidence of FPD.

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4. Litter moisture was measured by placing 100 g of litter into a pan and placing into a drying oven at 75°C for 24hrs. The samples were then reweighed after 24hrs. The initial weight was subtracted from the 24hr weight to yield grams of moisture.

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6. A 3 point scale that ranges from 0-2 was used to score paws, with 0 being a paw with no lesion (none), 1 moderate lesion (mild), and 2 severe lesions (severe).

7. SAS Institute Inc., 2009. SAS/STAT(R) 9.2 User's Guide, 2nd ed., Cary, NC.

8. Paw scores percentage data were subjected to arc sin transformation and then analyzed via the GLM procedure. P values ≤ 0.05 were considered significant and means were separated out using least squared (LS) means procedure of SAS.

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Figure 5.1. Paw scoring system (From left to right: score of 2, score of 1, score of 0)

Figure 5.2. Application of primer and coating to broiler feet via dip

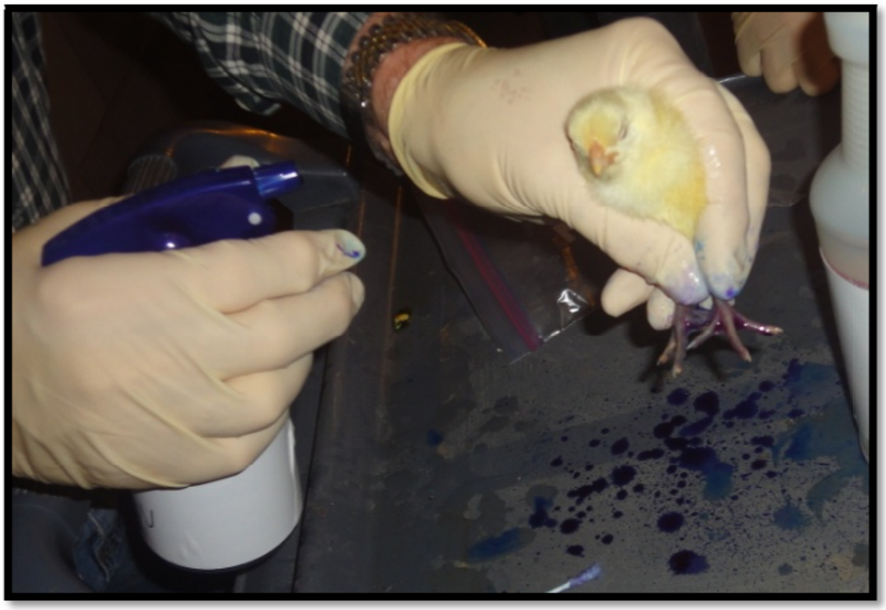

Figure 5.3. Dye applied to broiler feet via spray bottle

Figure 5.4. Broiler feet not coated, resulting in no staining effect (left) and feet that have been coated and successfully stained (right)

Table 5.1. Effect of foot coating on broiler performance[1]

	1 to 21 d of age			1 to 42 d of age		
Treatment	Weight (g)	FC[1]	Livability	Weight (g)	FC	Livability
No spray	911.0±16.4	0.73±0.02	96.8	2876.1±38.5	1.77±0.11	89.5
Spray	921.5±11.4	0.71±0.01	98.4	2998.6±112.6	1.59±0.06	87.1

[1] Means ± Standard Error of the Mean
[a-b]Means within a column without a common superscript are different ($P \leq 0.05$)

Table 5.2. Effect of foot coating on litter moisture (%) and incidence of footpad lesions (%) [1, 2]

	28 d of age				35 d of age				42 d of age			
Treatment	Moisture	None	Mild	Severe	Moisture	None	Mild	Severe	Moisture	None	Mild	Severe
No spray	28.7±1.3	98.3±1.1	1.7±1.1	0	25.8±1.3	94.3±2.3	2.6±0.5	3.1±2.0	28.2±1.4	97.9±1.3	2.1±1.3	0
Spray	26.8±3.4	98.6±0.7	1.4±0.7	0	26.1±3.1	94.2±3.5	2.4±1.1	3.4±2.9	26.6±3.1	95.1±3.7	4.9±3.7	0

[1] Means ± Standard Error of the Mean
[2]None = no lesions present, Mild = lesions ≤ 7.5mm, Severe = ≥ 7.5mm
[a-b]Means within a column without a common superscript are different ($P \leq 0.05$)

CHAPTER 6

LITTER SYSTEM AND ITS RELATION TO FOOTPAD DERMATITIS IN BROILERS[1]

[1] Shepherd, E.M., C. W. Ritz, and B. D. Fairchild. Accepted by WATT POULTRY USA. Reprinted here with permission of publisher 7-8-2010

SUMMARY

As pine shavings become increasingly expensive and hard to find, growers are forced to reuse litter for multiple flocks. There are several systems that are commonly used to reuse litter between flocks, such as: cake out, complete clean out, and windrowing. Six, 40x500ft commercial broiler houses, all on the same farm, were tested to determine which litter system produced the best paw quality. Two houses each were caked out and top dressed, windrowed, or completely cleaned out. The cleaned out houses had 0% Grade A and 75% Grade C or Condemn paws at d 56 in the processing plant. The windrowed and caked out houses had 5% and 4.5% Grade A paws respectively at the plant. They same houses had 30% and 40% Grade C or Condemn paws. These results show that built up litter programs, such as cake out and windrowing, produced the best paw quality. Controlling moisture early in the flock is critical to producing high quality paws. Management factors are likely as important as the litter type and system being used when trying to control relative humidity and preventing footpad dermatitis.

Key words: Footpad dermatitis, paws, litter system, broiler

DESCRIPTION OF PROBLEM

Pine shavings have historically been the bedding material of choice for poultry producers in the United States. This is due to the relative low cost and ample availability of pine shavings for growers. In recent times, however, the supply of dry pine shavings has dwindled due to competition from other markets and more efficient sawmills which produce less by-product shavings. Increased cost has forced poultry companies to evaluate their litter programs to try and utilize economical alternative materials. A common practice is to delay clean-out of houses as long as possible and reuse the existing litter. Some companies will clean out once a year while others allow growers to clean out only when disease issues make it necessary for a complete clean out.

To reuse litter between flocks, some growers will simply remove the top layer of caked litter (the top portion of litter that is compacted into a mass with high moisture content), and top-dress with fresh shavings. Other growers will till up and break the cake into small pieces to prevent having to purchase fresh litter. Recently, built up litter programs have gained more attention by looking at a procedure known as "windrowing". This process involves piling the litter in the house into 2 piles running the length of the house which results in a partial heating of the litter in the house to create a thermal kill of potentially pathogenic bacteria (1). This process is accomplished by windrowing all the litter inside the house and turning it once or twice to allow for air exchange and uniform heating throughout the piles. Once the windrows have heated for about 10 days, it is spread out in the houses and allowed to cool down and dry out before chicks arrive.

This method has become an increasingly popular litter system management choice for poultry producers in the last 5 yrs. As more companies look to utilize this litter system, the effects on moisture control and thus paw quality should be evaluated. In this study, the litter systems of windrowing, cake out, and complete clean out were evaluated on the effects they have on the incidence and severity of foodpad dermatitis (FPD).

MATERIALS AND METHODS

Six, 40x500ft commercial broiler houses were evaluated for the effects of different litter systems and their effect on foot pad quality. Two houses were windrowed, 2 houses were caked out, and 2 houses were cleaned out. One-hundred birds per house were scored for FPD lesion incidence and severity using a 3-point scale (2, 3, Figure 6.1). Paw scores were conducted at d 14, 28, and 42 by the researchers in the broiler houses and by the company in the processing plant at d 56. Grading of paws at the processing plant followed an A, B, C or Condemn ranking (4).

Litter samples were taken on each sampling day for moisture analysis via a trench method in which litter was taken in a single line from the middle of the house to the sidewall (5, 6). This litter mixed thoroughly and a representative sample was taken for analysis (7). Three replicate samples were taken from each of the 6 houses. In the beginning of the study when the houses were partial house brooded, all 3 samples were taken in the brood end. After the birds were released to the whole house, the trenches were evenly spaced out with the first sample in the brood end, the second sample in the middle, and the third sample near the back of the house in the non-brood end.

RESULTS AND DISCUSSION

At d 14 there were very few birds with FPD lesions. A high percentage of the birds had no FPD lesions. The caked out houses had the highest number of birds with mild FPD lesions, at 18% (Figure 6.2). There were no severe FPD lesions until d 28 when litter moisture levels were approaching 40%. FPD began to appear more frequently, especially in the cleaned out houses where it was noticed that the litter was becoming noticeably wetter. In these houses nearly 40% of the birds had mild FPD lesions. The caked out and windrowed houses had nearly 75% of birds with no FPD lesions (Figure 6.3). At d 42, paw quality rapidly deteriorated in all treatments. The windrowed houses had the highest percentage of birds with no FPD lesions, with 20% being lesion free. The cleaned out houses had nearly 65% of the birds with severe FPD lesions and only 5% of birds were lesion free (Figure 6.4). At the processing plant on d 56, there were no birds with Grade A paws from the cleaned out houses. The highest percentage of birds with Grade A paws came from the caked out and windrowed houses, with only 4.8 and 5% respectively, having no lesions. The majority of birds were observed to have mild lesions. Data indicates that the windrowed houses produced more Grade A and B paws in the processing plant than did caked and cleaned out houses (Figure 6.5). Litter moisture may have had a larger impact on paw quality than the type of litter system being used. Houses being cleaned out between flocks have been observed to be lacking in the amount of bedding material that is put back in before birds are placed. Shallow litter depths have been shown to have a direct negative impact on paw quality (8, 9, 10).

As litter moisture levels increased, paw quality decreased. The biggest impact on paw quality may be the sudden increase in litter moisture, as observed in the cleaned out houses (Figure 6.6). The litter moisture tripled from the time of chick placement to d 28. This climb in litter moisture led to a dramatic reduction in litter quality and subsequent paw quality. Deeper bases of litter act as a sponge, allowing moisture to be absorbed and dissipated throughout the base of litter. If broiler houses are completely cleaned out in between flocks, a minimum of 3-4 in of litter is needed to handle the moisture throughout the flock (10). If a used litter program is being utilized between flocks, remove the caked litter to reduce ammonia (NH_3) volatilization. Running half the tunnel fans during the day will remove moisture from the litter more rapidly in moderate or warm weather. During cold weather houses should be preheated and circulation fans should be used to mix the warm air at the ceiling with the cooler air at the floor to promote floor drying. Exhaust fans will need to be operated during this time to keep the relative humidity (RH) between 50 and 60% (11).

In times of minimum ventilation, it is important to ventilate adequately to bring in fresh air and lower RH. Ventilating in cooler weather may seem a daunting task to some growers when fuel costs are high, but the gain in performance far outweighs the cost of bringing in fresh air. Attic inlets are one management option available to producers to increase ventilation rates without increasing heating costs (12). Ventilating more is not always better. Ventilating too little can cause wetter litter, paw quality issues, and poorer performance, while ventilating too much can cause heating costs to increase and lead to a dusty, cold house. Ventilating to keep NH_3 levels <30ppm and RH between 50-60% is the best rule of thumb. It is possible to remove moisture from houses even when RH outdoors in high. Placing humidity sensors inside the house can help monitor RH and help control dust and NH_3 issues (13).

Proper drinker line management according to manufacturer's guidelines can prevent excessive moisture from being added to the litter. Drinkers that are too low or have the water pressure set too high tend to result in wetter floors. Water lines that may have a biofilm or other particulates can result in leaky nipples, which will also increase litter moisture. Regularly flushing and sanitizing the drinker system will reduce water leakage. This will keep litter drier and improve its quality, subsequently resulting in better paw quality (14). Managing the moisture underneath the water and feed lines is essential due to the fact that the birds spend the majority of their time in this area. Keeping litter dry in this area can reduce problems not only from FPD but also from hock and breast burns as well.

Bird distribution throughout the house plays a large role with litter moisture. The sudden onset of wet litter associated with higher bird densities in one area of a house compared to another is considered to have a large influence on the development FPD. Litter conditions deteriorate rapidly as litter moisture increases with increased stocking density (15). As stocking density increases, water consumption has been shown to increase per bird (16). As birds drink more water, their feces become more watery and in turn contributes to overall litter moisture. One way to combat this problem is to properly utilize migration fences year round, even in cold weather months. Migration fences put in place shortly after birds are released to the entire house from partial house brooding will ensure that they are evenly spaced out throughout the house, allowing for better litter management and temperature regulation. One simple, cost effective way to monitor bird density in the house is to add additional water meters (17). Water meters for the front, middle, and back of the house can indicate bird densities by simply looking at daily water consumption. Higher consumption in one end of the house means that there are more birds there than in the other sections of the house.

Making sure that litter is dry before spreading in the house is also important in controlling moisture and keeping houses warm during brooding (11). Storing bedding materials in a dry place before placing into houses will allow for moisture levels in the house to start off low and also save on energy costs associated with fan usage and heaters. Making sure the base of litter is thick and evenly spread out will help alleviate moisture problems down the road.

CONCLUSIONS AND APPLICATIONS

1. Built up litter programs (windrowed and caked out) were shown to produce more Grade A paws than completely cleaned out houses.

2. Controlling moisture through proper ventilation rates, drinker line management, and making sure litter is dry and placed at least 3 inches deep can prevent problems associated with excessive moisture later in the flock.

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3. A 3 point scale that ranges from 0-2 was used to score paws, with 0 being a paw with no lesion (none), 1 moderate lesion (mild), and 2 severe lesions (severe).

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Figure 6.1. Paw scoring system (From left to right: score of 2, score of 1, score of 0)

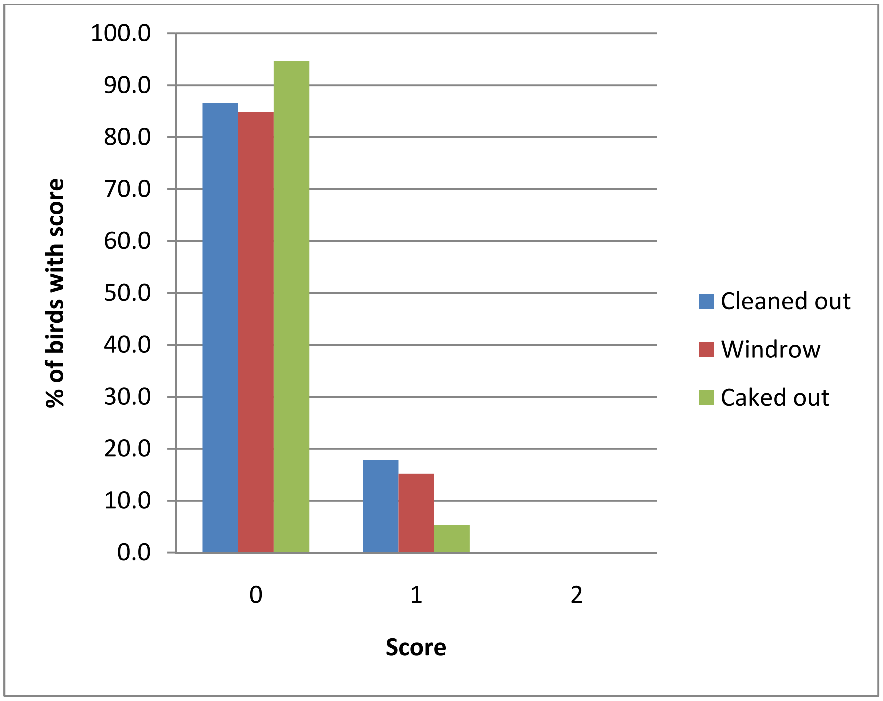

Figure 6.2. Paw scores at d 14 for different litter systems

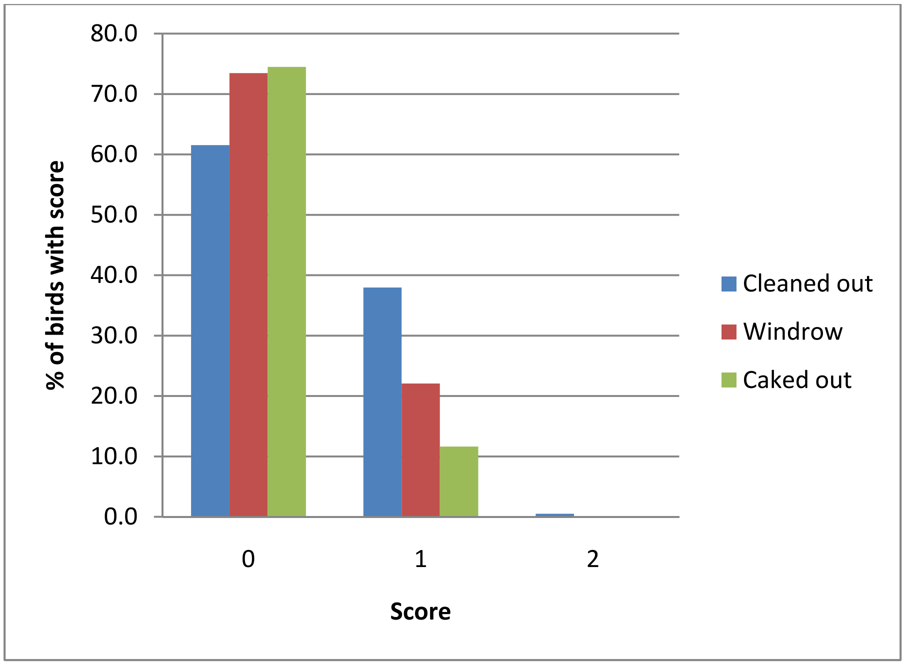

Figure 6.3. Paw scores at d 28 for different litter systems

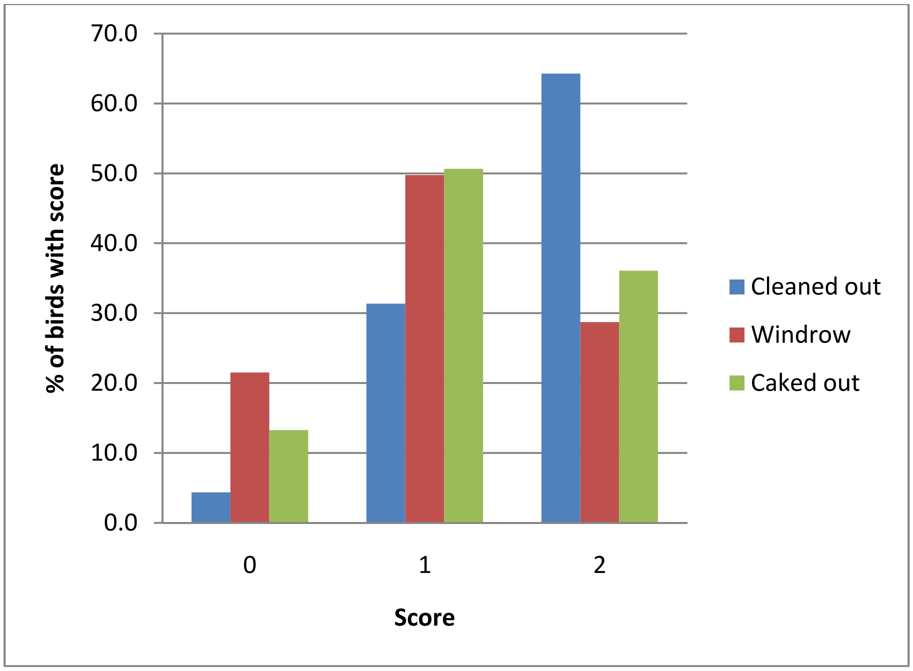

Figure 6.4. Paw scores at d 42 for different litter systems

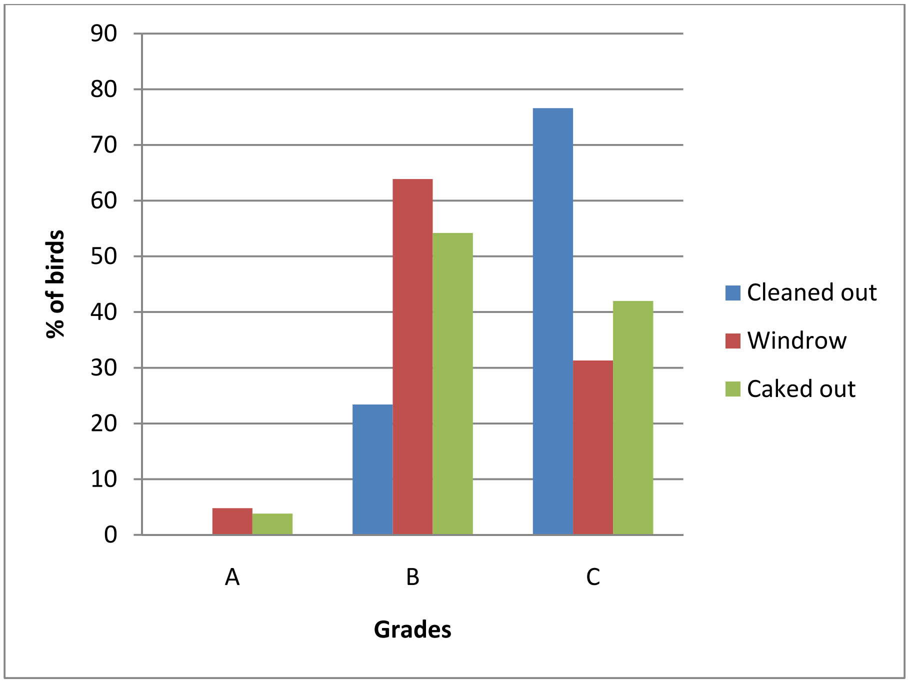

Figure 6.5. Paw grades in the plant at d 56 (A, B, C) for different litter systems

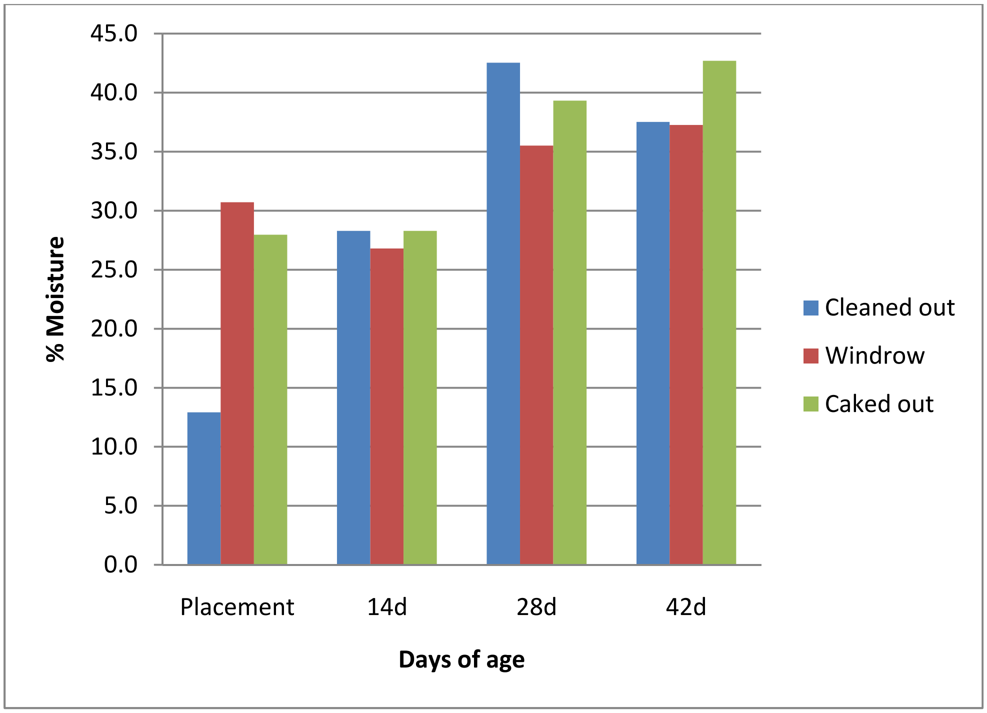

Figure 6.6. Litter moisture levels with different litter systems (%)

CHAPTER 7

EFFECT OF RELATIVE HUMIDITY ON LITTER QUALITY AND FOOTPAD DERMATITIS IN BROILERS[1]

[1] Shepherd, E.M. and B. D. Fairchild. To be submitted to *Poultry Times*

SUMMARY

Relative humidity (RH) inside broiler houses is an important factor with bird performance especially in warm weather. Equally as important is the RH relationship to paw quality. Incidence and severity of footpad dermatitis (FPD) is greater when RH is higher. In this study the effects of RH on litter quality and subsequent paw quality were examined on the incidence of FPD lesions by testing used and fresh litter at depths of 1, 3 and 5 inches of litter.

There was no effect of litter type and depth on bird performance and livability throughout the study. Birds with no FPD lesions were significantly higher in the fresh shavings 1 inch pen at day 28 and 35 than all other treatments ($p \leq 0.05$). This treatment also had a significantly lower incidence of severe FPD lesions at day 35 than all of the other treatments. There were no differences in paw quality by day 42. The fresh 1 inch treatment has significantly higher moisture than all other treatments at day 21, 28, 35, and 42 but was driest on the surface due to pen placements near fans. Litter moisture was very high in all treatments and was believed to be the main factor in overall poor paw quality.

Key words: relative humidity, litter, footpad dermatitis, broiler

DESCRIPTION OF PROBLEM

Relative humidity's (RH) impact inside broiler houses is sometimes poorly understood and is an environmental factor that is not monitored as closely as it should. This is an oversight when one realizes the interaction between litter quality, temperature, ammonia (NH_3), and RH. As temperature increases, the ability of the air to hold moisture increases, thus RH goes down. For every 20°F (11°C) increase in temperature, the moisture holding capacity of the air doubles (1). When air is cooled the moisture holding capacity of air decreases which results in an increase in RH. This can lead to wetter floors in times of cold weather when minimum ventilation is used. In cold weather, broiler producers try to avoid higher heating costs by reducing the amount of cold air brought into houses by decreasing ventilation rates. While this may save some money on heating costs, the negative effects on bird health and performance from increased levels of RH and NH_3 will be more costly in the terms of reduced growth rate and poor feed conversion (2). As less fresh air is brought into the house, the air inside becomes saturated with moisture. Typically it is recommended that broiler house RH be kept between 50 and 70% to prevent litter from being too dry or too wet. If air is brought into the house improperly such as through cracks or if it falls on the water and feed lines instead of making it to the middle of the house, the birds could be chilled and the floor will become wet. The air needs to be brought in the inlets and directed along the ceiling where it can be heated and mixed, allowing for a great moisture absorption capacity (3, Figure 7.1). One way to accomplish bringing in fresh air without increasing heating costs is the use of attic inlets (4). Attic inlets have been shown to allow 20% more ventilation without increasing heating costs because warmer air from the attic is brought in that does not have to be heated as much as the outside air that enters the inlets.

In warm weather, birds lose a considerable amount of body heat via evaporation from panting. The ability of birds to release this heat is heavily influenced by RH levels inside the house. As levels increase, the air becomes saturated and cannot cool the bird down effectively. The bird then begins to pant harder to try to remove heat. This is turn causes the bird to use energy to try and self regulate its body temperature; the energy that could have gone to growth and development which in turn will result in poor feed conversion (5, 6).

High RH can also increase litter moisture levels which then increase NH_3 levels (7). As litter becomes wetter, it makes an environment that is conducive to bacteria grow, producing more NH_3 as they break down fecal material for food. Increased levels of NH_3 have been shown to impair performance and increase the susceptibility to respiratory infections such as air sacculitis (8). Birds that are in contact with the wet litter have been reported to have higher cases of footpad dermatitis (FPD), hock burn, and breast burn lesions than birds on drier litter (9). In this study, the effect of RH on litter moisture and FPD lesions was observed.

MATERIALS AND METHODS

Four hundred fifty broilers were placed in individual 20 ft^2 (1.9 m^2) pens on fresh and used pine shavings (Figure 7.2). Twenty-five birds were placed in each of 18 pens at a bird density of 0.7 ft^2/bird (0.07m^2/bird). There were a total of 6 treatments (2 types of litter and 3 litter depths) with 3 pens per treatment. Treatments included 1, 3, and 5 inches of used and fresh litter (2.5 cm, 7.6 cm, and 12.7 cm). Birds were fed standard industry diets, including a crumbled starter (d 0-21) and a pelleted grower (d 21-42). Birds had unlimited access to food and water via a hanging tube feeder and nipple drinker line.

Birds and feed were weighed on a pen basis weekly until the end of the study. Litter moisture was sampled weekly and analyzed for moisture throughout the study for each pen starting at chick placement (10). Paws were evaluated using a 3 point visual scoring system (11, 12, Figure 7.3). Paws were scored by the same researchers throughout the entire study. Performance data were analyzed using the General Linear Model (GLM) procedure of SAS. P values ≤ 0.05 were considered significant (13, 14).

RESULTS AND DISCUSSION

In this study, environmental control was not fully achieved; RH levels approached 90% leading to litter moisture levels that often exceeded 30%, with a maximum of 49% (Table 7.1). The 1 in fresh shavings treatment had the highest moisture levels throughout the study starting at d 21. The high litter moistures beginning in wk 3 coincide with RH levels near 70% inside the house during this time period (Figure 7.4). When it was noticed that the litter was becoming wetter, ventilation rates were increased, dropping the RH levels nearly 30%. The RH started to rise again in wk 4 and approached 80%. The RH hovered around the mid 80% range until ventilation rates were increased again during the wk 5, dropping the RH down another 30%. The levels began to rise again near the end of the study, reaching 90%. These levels were much higher than optimal range of around 50-70%. This high RH caused litter moisture to stay above 30% from wk 3 until the end of the study in all treatments.

Treatments had no effect on performance with body weights, feed conversion, and livability not being different at d 21 and 42 (Table 7.2). There were significantly more birds with no FPD lesions in the fresh 1 in pen than all other treatments at d 28 and 35. The fresh 1 in pen had a significantly lower incidence of severe lesions at d 35 than all of the other treatments (Table 7.1).

The finding of better paw quality with shallower litter depths was unexpected. Previous research has shown better paw quality with shallower depths (15, 16) but also with deeper depths (17). Litter acts as a sponge to absorb moisture and move it away from the birds. In general, the deeper the litter, or bigger the sponge, the better moisture absorption, resulting in better paws. The current study's observation of better paw quality with fresh shallow litter compared to all other treatments is difficult to explain. From an evaporation standpoint, used litter would have a greater moisture release capability due to a larger surface area from a smaller particle size. The litter moisture levels appear to support this theory with shallow fresh litter having almost 50% moisture by the end of the study. It is thought that the placement of these shallow fresh pens near fans may have confounded these data.

When collecting litter from these shallow fresh litter pens for moisture analysis the litter was observed to cake more quickly than expected but then formed a hard dry crust on the top of the cake. This caked layer of litter served as a barrier for the birds from the wet sticky litter beneath. The other treatments further away from the fans caked over as well but never formed that hard dry crusty top. Those birds were left in contact with the wet litter for a longer time, leading to worse paw quality. The caked litter and the separation of better paw quality in the shallow fresh pens coincide with increased ventilation during wk 3. This is the time period when RH began to climb and litter moisture increased. The increase in ventilation in the wk 3 allowed those shallow pens near the fans to form a dry crust on top, reducing the moisture exposure to the birds, and thus improving paw quality in wk 4.

At first glance the data seems confusing and contradicting to recent research findings of better moisture control and paw quality with deeper layers of litter (18). When the ventilation rates and RH are examined, it can be seen why placement near fans allowed broilers in the shallow treatment pens to have better paw scores. Control of RH is very important to keep houses drier and reduce problems associated with high litter moisture. Further research is needed to examine the effect of different litter depths of fresh and used litter under conditions where RH can be controlled accurately.

CONCLUSIONS AND APPLICATIONS

1. As relative humidity increased, litter moisture increased, and paw quality decreased.
2. Litter depth and type had little effect on bird performance and livability.
3. Moisture control early is critical to prevent excessively wet litter and poor paw quality later in the flock.

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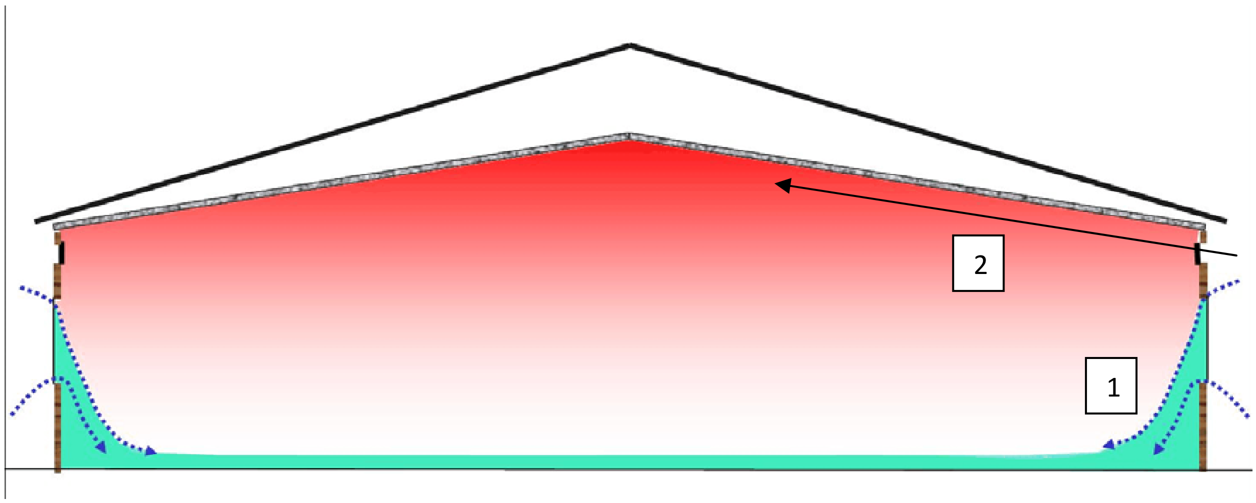

Figure 7.1. Improper air flow (1), proper air flow (2)

Figure 7.2. Pen setup for litter depth treatments throughout the study

Figure 7.3. Paw scoring system (From left to right: score of 2, score of 1, score of 0)

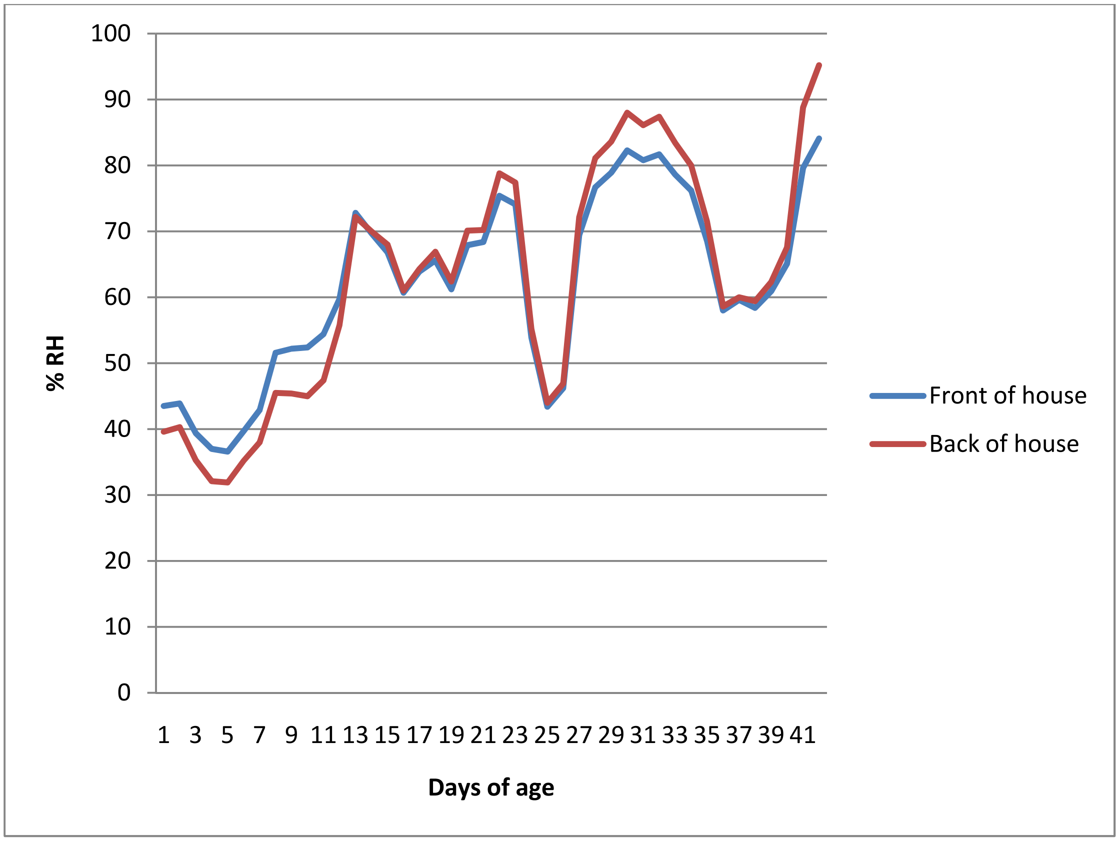

Figure 7.4. Indoor relative humidity in the test facility during the study (%)

Table 7.1. Influence of litter depth on litter moisture (%) and incidence of footpad lesions (%) [1, 2]

Age	21 d of age				28 d of age			
Treatment	Moisture	None	Mild	Severe	Moisture	None	Mild	Severe
Used 1 inch	$32.6^{B}\pm0.94$	23.8 ± 11.5	54.4 ± 9.8	21.9 ± 12.5	$35.6^{BC}\pm0.85$	$6.7^{b}\pm4.8$	36.9 ± 12.3	56.4 ± 14.9
Used 3 inch	$33.8^{B}\pm0.70$	36.3 ± 6.6	47.2 ± 4.8	16.5 ± 11.1	$38.1^{B}\pm0.52$	$10.9^{b}\pm1.1$	61.4 ± 7.4	27.7 ± 8.1
Used 5 inch	$29.1^{B}\pm0.64$	47.0 ± 13.2	44.3 ± 9.0	8.7 ± 4.4	$33.3^{BC}\pm1.67$	$8.4^{b}\pm2.3$	63.8 ± 9.8	27.8 ± 12.1
Fresh 1 inch	$42.5^{A}\pm1.62$	47.1 ± 0.8	34.2 ± 6.3	18.7 ± 5.9	$45.1^{A}\pm2.85$	$30.2^{a}\pm5.7$	48.1 ± 8.1	21.7 ± 3.3
Fresh 3 inch	$31.8^{B}\pm3.67$	26.9 ± 16.6	42.7 ± 10.0	30.3 ± 7.6	$35.0^{BC}\pm1.47$	$4.1^{b}\pm2.3$	34.3 ± 11.0	61.6 ± 12.8
Fresh 5 inch	$28.6^{B}\pm2.63$	35.0 ± 7.1	45.2 ± 5.8	19.7 ± 1.5	$33.3^{BC}\pm1.05$	$4.3^{b}\pm2.3$	50.5 ± 8.2	45.2 ± 5.8
Age	35 d of age				42 d of age			
Treatment	Moisture	None	Mild	Severe	Moisture	None	Mild	Severe
Used 1 inch	$41.1^{B}\pm0.87$	0^{B}	16.0 ± 10.0	$84.0^{a}\pm10.0$	$36.6^{B}\pm2.17$	0	14.9 ± 4.8	85.1 ± 4.8
Used 3 inch	$38.5^{BC}\pm1.88$	$8.3^{B}\pm2.6$	20.3 ± 4.3	$71.3^{a}\pm3.7$	$36.4^{B}\pm0.81$	2.7 ± 1.3	23.1 ± 3.1	74.2 ± 4.4
Used 5 inch	$32.2^{D}\pm1.23$	$4.2^{B}\pm2.4$	31.3 ± 5.2	$64.5^{a}\pm7.3$	$33.2^{B}\pm1.82$	5.6 ± 3.7	8.3 ± 0.0	86.1 ± 3.7
Fresh 1 inch	$49.4^{A}\pm1.72$	$22.2^{A}\pm7.1$	34.8 ± 11.0	$42.9^{b}\pm5.0$	$47.9^{A}\pm1.47$	18.0 ± 7.1	19.5 ± 8.5	62.6 ± 2.2
Fresh 3 inch	$39.9^{BC}\pm1.07$	$4.1^{B}\pm2.3$	21.1 ± 7.0	$74.8^{a}\pm7.7$	$36.4^{B}\pm1.65$	2.7 ± 2.7	22.8 ± 12.6	74.6 ± 11.2
Fresh 5 inch	$35.1^{CD}\pm2.26$	$1.4^{B}\pm1.4$	23.8 ± 5.4	$74.7^{a}\pm4.0$	$34.6^{B}\pm2.94$	2.9 ± 1.4	15.7 ± 7.3	81.4 ± 6.0

[1] Means ± Standard Error of the Mean
[2] None = no lesions present, Mild = lesions ≤ 7.5mm, Severe = ≥ 7.5mm
[a-b] Means within a column without a common superscript are different ($P \leq 0.05$)
[A-D] Means within a column without a common superscript are different ($P \leq 0.01$)

Table 7.2. Influence of litter depth on broiler performance[1]

	1 to 21d of age			1 to 42d of age		
Treatment	Weight (g)	FC[2]	Livability	Weight (g)	FC	Livability
Used 1 inch	873.1±24.1	0.84±0.03	93.4	2430.7±8.7	2.01±0.13	89.3
Used 3 inch	885.7±17.3	0.80±0.01	97.4	2313.8±7.9	1.93±0.03	96.0
Used 5 inch	935.9±8.8	0.80±0.02	94.7	2317.0±21.4	2.01±0.13	92.0
Fresh 1 inch	921.0±9.4	0.80±0.02	98.7	2462.5±76.2	1.76±0.06	97.3
Fresh 3 inch	906.6±2.9	0.78±0.02	98.7	2385.9±110.8	1.83±0.05	97.3
Fresh 5 inch	949.5±35.4	0.78±0.03	94.7	2418.9±63.7	1.86±0.02	92.0

[1] Means ± Standard Error of the Mean
[2]FC= Feed Conversion adjusted for mortality
[a-b]Means within a column without a common superscript are different ($P \leq 0.05$)

CHAPTER 8

HISTOLOGICAL FINDINGS OF EARLY LESION DEVELOPMENT IN FOOTPAD DERMATITIS[1]

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ABSTRACT

Footpad dermatitis (FPD) is a skin condition that affects the plantar surface of the footpad in broilers and turkeys. This condition has become a serious issue for the poultry industry from concerns with animal welfare, food safety, and also as a considerable loss of revenue from paw sales to Asian markets. Previous histopathological examinations of this condition have centered on existing lesions, not when they are in the early stages of development. It may be more useful to understand the early progression of these lesions in order to better understand the causes and possible methods of prevention. In this study young broiler feet were examined for microscopic changes associated with FPD. It was found that the keratin layers become degenerate, possibly due to moisture, and begin to shear. The shearing leads to a rapid turnover of keratinocytes to form keratin and further weakening of the keratin layer. These layers shear off completely, heterophils infiltrate the area, and lesions develop. The progression of these lesions is occurring long before any changes in the skin structure can be seen by the naked eye.

Key words: broiler, footpad dermatitis, lesion, histology

INTRODUCTION

Footpad dermatitis (FPD) is a skin condition that leads to paw downgrades and condemnations that results in significant financial loses for poultry companies. Revenue from chicken paws in 2008 alone was worth $280 million (US Poultry & Egg Export Council, 2009). This condition causes necrotic lesions on the plantar surface of the foot pads in growing broilers and turkeys. This condition not only causes financial loss, but is also an animal welfare concern in both the US and in Europe (National Chicken Council, 2010; Berg, 2004; Berg and Algers 2004).

Histologically in FPD lesions, hyperkeratosis and separation of the keratin layers was seen at 6 wk of age in turkey poults. Lesions tended to be more superficial at this age but by 16 wk there were more severe ulcerations. Lymphocyte, granulocyte, and lymph follicle populations increased in the dermis adjacent to the lesions (Platt et al., 2001). Mild lesions show heterophils in the stratum germinativum and also defects in keratin formation (Martland, 1984). Heterophils were also found in the dermis, sub-epidermis, and epidermis along with basophils in the stratum corneum (Greene et al., 1985). Vacuoles containing heterophils have been found in the epidermis and inside blood vessels of the foot pad (Greene et al., 1985; Harms and Simpson, 1975; Martland, 1984, 1985). Greene et al. (1985) observed complete destruction of the keratin and epidermal layer in the center of the lesion, with necrotic tissue exposed and a mass of heterophils. In severe lesions, there was acute inflammation with a more dense cellular infiltration and a thickening of the stratum corneum which were referred to as "horned pegs" (Martland, 1984; Whitehead, 1990). The epidermis was more eroded and the dermis was filled with fluid. There was congestion and dilation of blood vessels that were sometimes found to be necrotic (Whitehead, 1990).

Little work has been done on the very early stages in the development of FPD lesions. The time period that will be observed in this study is before FPD lesions are even noticeable grossly. Lesion development most likely starts well before the first signs start showing on birds in the field. Understanding the histological changes that are occurring early on in FPD might give insight into possible ways to prevent and/or reverse the progression of lesions. This could allow for the harvesting of higher quality paws, resulting in higher profits and better animal welfare compliance for broiler companies.

MATERIALS AND METHODS

Foot pads were collected from 14 d old broilers and fixed in 10% buffered formalin for 48hrs. Representative samples were taken from each foot, routinely processed using a LEICA ASP300 tissue processor, embedded in paraffin wax using a LEICA EG1150H/C embedder, sectioned at 4-5 micron thickness using a LEICA RM2255 microtome, and then stained with routine Hematoxylin and Eosin-y dyes using a LEICA AUTO STAINER XL. Slides were then examined by light microscopy at 100x using a LEICA DMR microscope. Images are depicted at a resolution of 300DPI and 100x magnification using a LEICA DC500 camera.

RESULTS AND DISCUSSION

Paws examined were divided into 4 categories: “normal paw”, keratin changes, epithelial changes, and lesion development.

“Normal paw”

In Figure 8.1, there were no cellular changes observed and this is indicative of a paw with no signs of FPD lesion development. In it can be seen that the keratin layer is thick and compact with some normal slight sloughing of keratin.

Keratin changes

In Figure 8.2, there were early signs of structural changes in the keratin layer. The normal progression of keratinocytes is disrupted with the cells retaining their nuclei (parakeratosis) and failure to flatten into normal stratum corneum. Staining characteristics of the affected areas are paler than the surrounding normal keratin. Vasodilation and congestion of blood vessels are seen in the epidermis.

In Figure 8.3, parakaratotic hyperkeratosis was seen expanding the keratin layer. This term is used when keratinocytes do not lose their nuclei when reaching the stratum corneum layer. These altered cells in the strateum corneum do not allow for normal formation of the protective layer, thus weakening its strength (Ginn et al., 2007). External trauma is one of the causes of the hyperkeratosis. Keratin was thicker in this section as compared to the layers to the left. The keratin layer then comes off in larger sections when some type of trauma occurs as compared to Figure 8.1 where normal flaking is occurring.

Epithelial changes

In Figure 8.4, the beginnings of epithelial changes were observed. Rete peg formations developed in the stratum basale and spinosum layers and protruded into the dermis. This is typically in response to some outside trauma or irritant such as moisture and friction with bedding materials. Heterophils were seen infiltrating the dermal and epidermal regions in response to this trauma. Once again, parakaratotic hyperkeratosis was observed as keratinocytes try to rapidly produce more keratin.

Lesion development

After the keratin layer becomes weakened, the layers begin to shear apart from each other (Figure 8.5). This shearing of the keratin layers exposes underdeveloped keratin and allows for the outside stressor to come into contact with vulnerable areas of the epidermis. The shearing may also occur at the epidermal-dermal junction, exposing more vulnerable areas for lesion development (i.e., necrosis of dermis or epidermis) (Figure 8.6). At this point lesions are developing and may lead to ulcers if the area does not heal. After this stage, lesions are able to be seen grossly and would receive a paw score equal to a mild lesion.

Understanding the development of the early progression of FPD may shed some light on the causes of this condition. It appears from these findings that moisture causes the keratin layers to weaken. This weakening and shearing of keratin layers causes more keratin to be produced and forced to the outer edges of the skin to provide protection from an outside stressor such as friction with bedding materials. This new layer of keratin is not fully matured and is weaker than normal keratin. This weak keratin formation is in turn more prone to shearing within the keratin layer and also at the epidermal-dermal junctions. The epidermal layer is the last layer of defense for the vulnerable dermis. Lesions then develop as birds come into contact with increasingly irritating substances such as moisture and ammonia. Further research needs to be done to determine if keratin layers can be strengthened or possibly protected when the birds are young to prevent these lesions from progressing.

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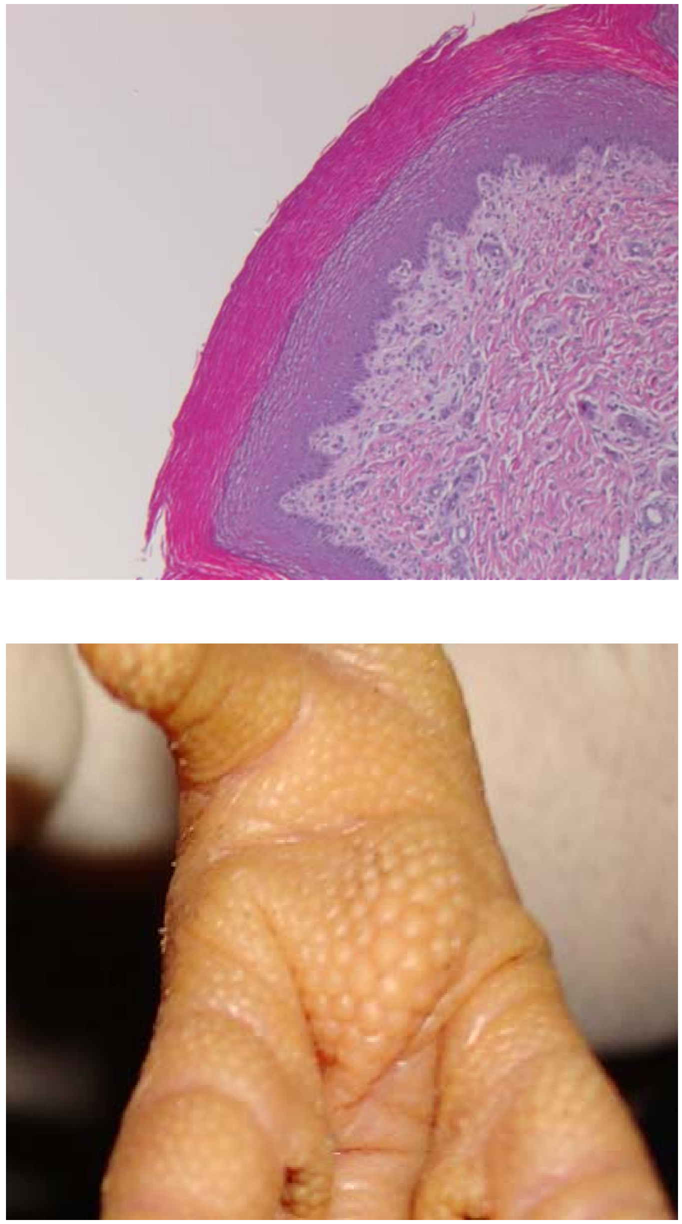

Figure 8.1. Normal paw with no signs of lesions. H&E 100X

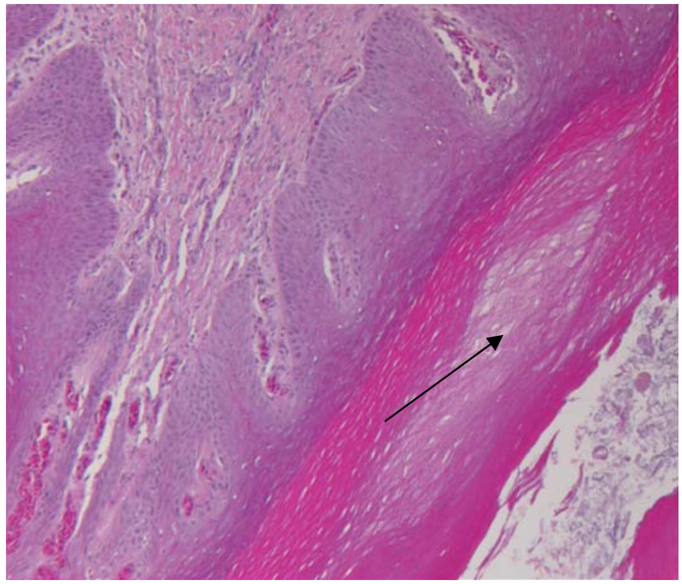

Figure 8.2. Paw with signs of early keratin structural changes. H&E 100X

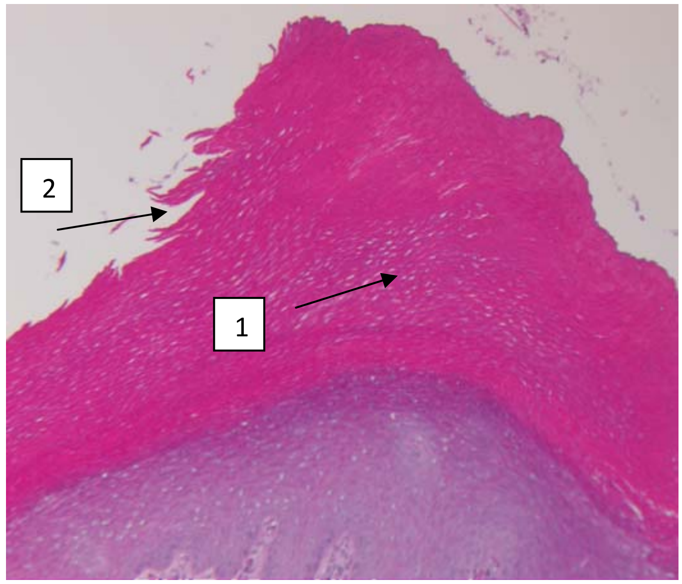

Figure 8.3. Parakaratotic hyperkeratosis (1), shearing of keratin layer (2).

H&E 100X

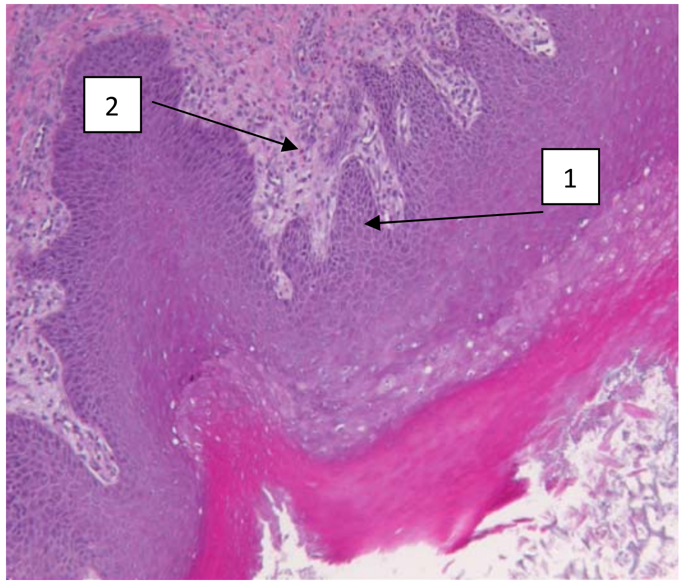

Figure 8.4. Rete peg formation (1) and heterophils infiltration (2). H&E 100X

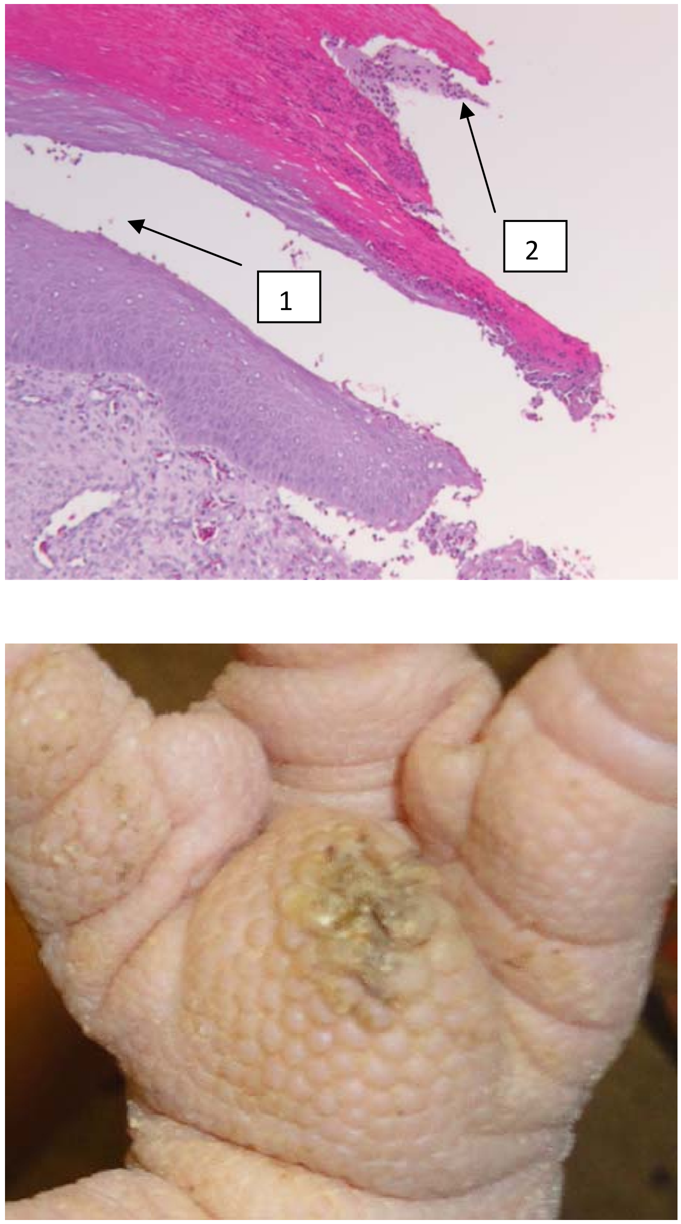

Figure 8.5. Clefting in keratin layers (1), development of serocellular crust (2).

H&E 100X

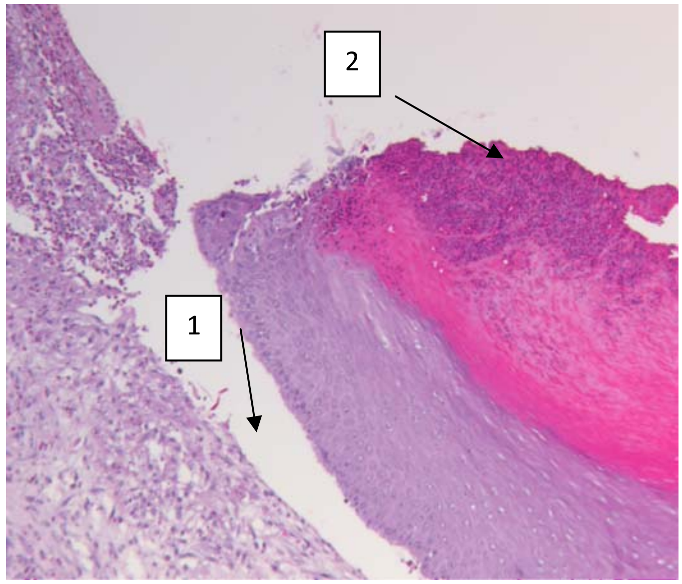

Figure 8.6. Clefting at epidermal/dermal junction (1), development of serocellular crust (2). H&E 100X

CHAPTER 9

SUMMARY AND CONCLUSIONS

1. Paw quality was found to be improved when moisture levels were reduced. Litter depth had a significant impact on lesion incidence and severity. As litter depth increased, litter moisture decreased, and paw quality improved. The greatest difference in moisture and paw scores was seen between 1 in and 5 in of litter. There were little differences between 3 and 5 in of litter. This finding has reinforced the suggestion that litter should be at least 3 in deep in broiler houses before chicks are placed.

2. Litter particle size is an important factor to consider as well, with better paw scores being found on used litter systems versus complete clean out. Paw scores were also found to be better with birds raised on peat moss which has a very small particle sized compared to fresh or used shavings. The rates at which litter materials dry play a large role in the effectiveness of bedding materials and their impact on the development of FPD. In the current studies, it was found that peanut hulls and rice hulls had exceptional drying capabilities. This trait makes them excellent bedding materials and is probably a main reason why they are used so commonly in the south, along with being readily available and cheap. Peat moss was found to have a great ability to absorb moisture, nearly 8x its own weight in water, and a relatively fast drying time. The small particle size of peanut

hulls, rice hulls, and peat moss allows for increased drying capability, which could help growers to keep houses drier and produce better paws.

3. Footpad dermatitis lesion development starts long before they can be seen with the naked eye. Keratin layers become weakened and shear off, leaving the vulnerable layers of the epidermis and dermis in direct contact with irritating factors in the litter such as moisture and ammonia. The keratin layers may initially become weakened due to continued contact with moisture. This can be related to humans in swimming pools. As the foot pads become softened, litter friction begins to shear away the keratin layers. Unless removed from the wet litter, keratin layers could continue to weaken and be removed, starting the development of lesions.

When possible drier, smaller sized particles should be used as they produce better paws with lower incidence and severity of FPD. The current findings point to a myriad of environmental factors that may lead to the incidence and severity of FPD. Litter moisture has long been theorized to be the major contributing factor in lesion development and the current research support those reports.

Paws have become one of the most profitable part of the chicken, as little extra effort is needed to clean up, grade, and package them for sale. Companies routinely have complained about poor recoveries for Grade A paws and want to improve this area of their live production. The current research suggests increasing litter depths to combat moisture issues, but this costs money to growers. These growers receive no compensation for the quality of their paws and thus will not have any incentive to place more bedding material to achieve this goal. In order for companies to improve paw quality they will need to develop some type of compensation plan to encourage growers to use more litter. The cost of an extra inch or 2 of litter in broiler houses is minimal when realizing the increase in grade A paws they could then harvest.

The next area of research in this field that needs to be examined is the effects of fresh and used litter at different depths. This was attempted in the current studies but due to poor environmental control the results obtained were unreliable. If it turns out that 3 in of used litter results in as good or better paw scores when compared to 5 in of fresh litter, it may be practical to push for built up litter programs. Smaller particle sizes in used litter when compared to fresh shavings would seem to suggest that built up litter programs may routinely produce better paws as long as environmental control is maintained. The next area to be looked at further is genetic selection against FPD. Research by other teams this year has shown the possibility to select birds resistant to the development of FPD. Breeding broilers that can withstand wetter conditions could possibly alleviate this condition or minimize the costly effects of downgrades and condemnations to poultry companies.

APPENDICES

Appendix A: Protocol for Bedding Material Moisture Absorption and Retention

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INTRODUCTION

The main purpose of a bedding material in broiler production is to wick moisture away from the birds and to help dilute fecal material. An acceptable material for broiler production will absorb moisture readily and be able to be dried by moving warm, dry air across it. The more readily a material absorbs the moisture and the quicker it dries out with ventilation the better.

OBJECTIVES

1. Determine moisture holding potential for various materials to be used as broiler litter
2. Determine moisture retention of the material

<u>Moisture Absorption and Drying Procedure</u>:

Materials were evaluated for moisture absorption capacity along was adapted from the procedure used by Bilgili et al., 2009.

MATERIALS

<u>Material to be evaluated</u>

5 nylon socks per material
Deionized water
Scale
Pans
2 ring stands
1 metal bar
5 1000ml beakers per material
Drying oven

PROCEDURE

1. Place 80g of each material into separate pans and place in a drying oven at 71°C for 24hrs. Subtract original weight from dried weight to obtain initial moisture content.
    a. Ex: Initial weight 80g. After 24hr drying, weight= 60g.
    Initial moisture content = 80-60=20g. Initial % moisture = (20/80)*100= 25%
2. Place 40g of dried material in each of 5 nylon socks (5 reps per material).
3. Tie socks and submerge in 1000ml of deionized water in a 1000ml beaker for 24 and 48hrs (Figure A.1).
4. At the end of 24 hrs, the socks are removed from the water and hung to air-dry to remove any excess water for 30 minutes (Figure A.2).
5. Socks are gently massaged to remove water while hanging.
6. Material is removed from socks after the air drying period and weighed in a pan.
7. Material in the pan is then placed in a drying oven at 75°C and taken out and re-weighed every 30 minutes during the first 4 hours then dried for the next 24 hours.
8. Moisture retention calculation
    a. % Moisture retained= ((Soaked weight – Dried weight)/Dried weight)*100
    b. Ex: Initial dried weight = 60g. 24 hr soak weight = 100g (40g moisture).
    24 hr % Moisture = (40/60)*100= 66.67% moisture
9. The % moisture that is left after each weighing period is calculated by dividing the drying period % moisture by the 24hr soaking moisture % and multiplied by 100.
    a. Ex: 24hr soak weight 100g (40g moisture, 66.67% moisture). 60 min drying weight = 80g. (Initial dried weight = 60g). 80-60 = 20g moisture left at 60 min period. 60 min % moisture = (20/60)*100= 33.33%. % moisture left from saturated weight (100g) at 60 min= (33.33/66.67)*100=49.99%

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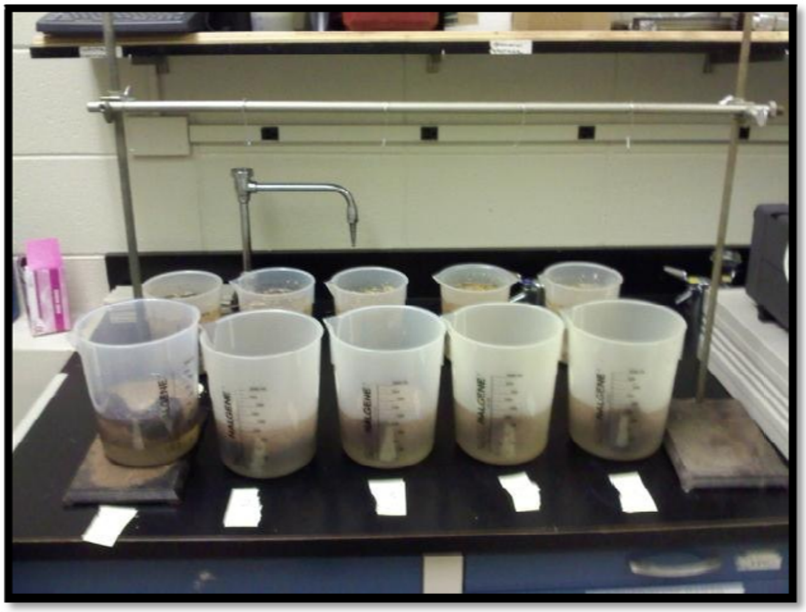

Figure A.1. Soaking procedure

Figure A.2. Air drying procedure