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Practical Considerations for Reducing the Risk of Pododermatitis

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Summary

Introduction
Pododermatitis or foot pad dermatitis (FPD) is a type of contact dermatitis which primarily affects the foot pad of the feet and the skin on the hock joint. The incidence and severity of FPD is of both welfare and economic concern. Practical measures can be taken to reduce the risk of FPD developing and this document describes some the measures that can be taken in the areas of house environmental management, nutrition and gut health. Effective environmental management, optimal nutrition and feed programs, and sound intestinal integrity are essential in reducing the incidence and severity of FPD in poultry flocks.

Role of House Environmental Management in Reducing FPD
The most obvious contributor to FPD is quantity and quality of the bedding material. Large particle size bedding material, bedding over-use and excessive caking reduce litter quality and increase the risk of FPD. The primary cause of FPD is often wet and caked litter. Therefore proper ventilation is key to its prevention.

- The goal is to maintain relative humidity (RH) between 50 and 70%, ventilation should remove enough moisture from the litter to prevent it from becoming wet.
- Ventilation rates must be adjusted with age. As the birds grow they will deposit more moisture into the bedding and exhale more moisture into the air. Ventilation rates must be adjusted to account for this.
- Ventilation must be managed so that incoming air is conditioned before it makes contact with the birds or litter. Cold air must be brought into the house at a high level and at a sufficient velocity to allow it to be mixed with the warm in-house air before it comes into contact with the birds or litter.
- The house must be free from air leaks which will allow cold outside air to leak into the house. Such leaks will reduce air velocity through the air inlets and may cause condensation on the litter and sidewalls.

Role of Nutrition and Feeding Programs in Reducing the Risk of FPD
Nutrient density, feed composition and feeding programs have significant effects on boiler health and performance.

- Diets high in dietary protein can result in increased water consumption and wet litter.
- Indigestible carbohydrates (NSPs) from plant protein sources (e.g. soybean meal) can lead to increased fecal viscosity and adherence to foot pads. Commercially available enzymes can help reduce dietary NSP levels.
- Diets formulated with soybean meal as the primary protein source often have higher FPD incidence. Soybean meal can result in sticky and high pH fecal material which can irritate the foot pad.
- Any factor that leads to an increased water consumption (e.g. ingestion of high levels of sodium, potassium or magnesium) will contribute to wet litter conditions.

Role of Intestinal Health in Reducing the Risk of FPD
Optimal intestinal health and functionality is essential for maintaining good litter quality. Wet litter is a common result of any health or stress challenge to the integrity or function of the gut. It is important therefore that any health challenge is controlled through appropriate anti-coccidal programs and that stressors to the flock are limited.

Conclusion
FPD is a multi-factorial problem with both welfare and economic consequences. A thorough understanding of the contributing factors particularly in the areas of nutrition, gut health and environmental management, and an understanding of the appropriate control methods that should be put in place for these areas will help to reduce the incidence and severity of FPD within a flock.

The remainder of this article provides more detail on the points summarized on page one.

Practical Considerations for Reducing the Risk of Pododermatitis

Introduction

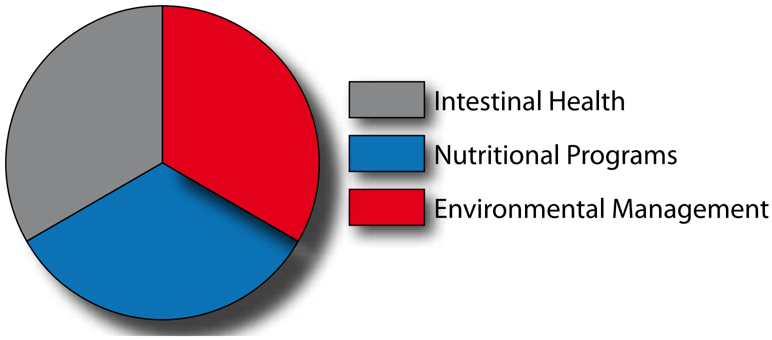
Pododermatitis or foot pad dermatitis (FPD) is a type of contact dermatitis primarily affecting the plantar surface (foot pad) of the feet, the skin on the hock joint and in severe cases can be accompanied with lesions on the breast keel area (Greene et al., 1985). Histological lesions associated with FPD indicate a non-specific dermatitis characterized by small to large ulcers with thickened keratin and epidermis, often infiltrated by inflammatory cells (Bilgili et al., 2009). Secondary FPD infections are also reported (Hester 1994). Since pain and discomfort to the bird is possible in severe cases (Martland 1984), the incidence and severity of FPD is a welfare concern (Broom and Reefmann, 2005) and an audit metric (e.g. National Chicken Council, 2005; EU Broiler Directive and various European National legislations).

The incidence of FPD can vary from 0-100% in broiler chicken flocks (Ekstrand et al., 1998). Over the past decade there has been a tremendous demand for chicken feet (paws) in Asian markets (Christensen, 1996). Quality downgrading results in a sharp drop in the price received for the exported chicken paws (Bilgili and Hess, 1997).

Practical measures can be taken to reduce the risk of poultry developing FPD problems. This document describes some practical considerations in the areas of nutrition, gut health and house environmental management.

Risk Factors in the Etiology of FPD

Current information on the etiology of FPD points to a complex interaction of three important risk factors:



Effective environmental management, optimal nutrition and feeding programs and sound intestinal integrity are essential to minimizing the incidence and severity of FPD in poultry. Rearing infrastructure (i.e., types of housing, feeders, drinkers, heating and ventilation systems, bedding) and management programs (i.e., stocking density, lighting programs, clean-out program and target market weight) set the stage for environmental management programs. Ventilation programs, especially minimum ventilation rate and air speeds, are critical in reducing condensation and in removing moisture from the house (and litter).

The incidence of FPD can vary among commercially available strain-crosses (Renden et al., 1992; Ekstrand et al., 1998 Kestin and Sorenson, 1999; Bilgili et al., 2006). FPD incidence and severity is higher in broiler chicken flocks marketed at heavy compared to light weights (Bilgili et al., 2006). This is not surprising, because more pressure is exerted per area of foot pad with higher body mass. The combination of heavier market weight and increased fecal load (i.e., nitrogenous) in the litter provides prolonged and continuous skin irritation (Stephenson et al., 1960; McIlroy et al., 1987; Menzies et al., 1998). On the contrary, Ekstrand (1997) observed that birds slaughtered at an older age and fed on less nutrient-dense diets had lower incidence of FPD due to better healing of the lesions.

Effect of gender on FPD has often been confounded by market weights. In general, higher incidence and severity was observed in males compared to females (Stephenson et al., 1960; Bruce et al., 1990; Cravener at al., 1992; Menzies et al., 1998; Bilgili et al., 2006), although some observed no gender effect (Berg, 1998). Skin from female broilers is thinner, contains less protein and collagen matrix, and is considered to be more susceptible to skin injury and ulceration than males (Harms et al., 1977).

High stocking rates put correspondingly greater pressure on flock management and often results in rapid deterioration of litter quality (McIlroy et al., 1987; Gordon, 1992). Higher stocking densities can also lead to poorer air quality, higher relative humidity and increase the “fecal load” on the litter, leading to a higher prevalence of FPD, hock and breast lesions (Cravener et al., 1992; Harms et al., 1997).

Role of House Environmental Management in Reducing the Risk of FPD

Birds spend most of their life in close association with the bedding/litter material. Hence, the most obvious contributor to FPD is either quantity and/or substandard quality bedding material. Although some have reported little effect of litter materials on FPD (Bruce et al., 1990; Lien et al., 1998), recent research (Bilgili et al., 2009) showed that the incidence of FPD varied among bedding materials, paralleling litter moisture and caking scores. It is natural for chickens to peck, scratch and work the bedding/litter material. This behavior helps in aeration, further reducing particle size of the litter by breaking down large clumps. However, large particle size bedding material, bedding over-use, and excessive caking deteriorate litter quality resulting in less working up of the litter by the birds. Bedding materials with sharp edges (e.g. large particle size wood chips, chopped straw) may contribute to FPD by causing small puncture wounds or shearing on the foot-pad through abrasive action.

In some cases, FPD has been observed in broiler flocks reared on relatively dry litter. However, a primary cause of FPD is often wet and caked litter. Thus, proper ventilation for moisture control in the poultry barn is a key tool which can be used for preventing the development of FPD. In warm weather, ventilation is operated primarily for temperature control, which almost always also results in effective moisture control, preventing litter from becoming wet or caked. For this reason, FPD is much less likely to become a problem under warm weather conditions. In contrast, during cold weather conditions ventilation is kept to a minimum and there is greater danger of litter becoming too wet which can lead to widespread development of FPD in the flock. In cold weather, the primary aim of ventilation must be moisture control, with temperature managed by sufficient heating and ventilation systems.

The goal is to maintain relative humidity (RH) between 50 and 70%, with ventilation air picking up enough moisture from the litter to prevent it from becoming wet.

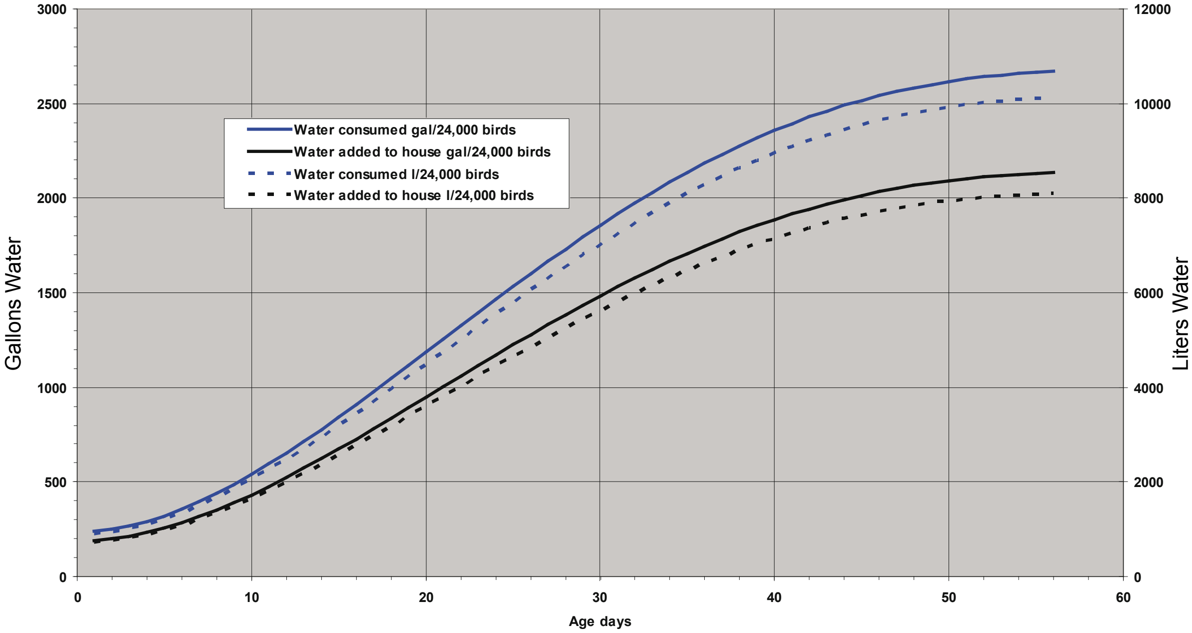
Accomplishing good moisture removal requires that managers have a thorough understanding of the principles of ventilation for moisture management within the poultry house. Successful cold-weather ventilation is especially challenging because of the apparent conflict between the need to provide heat to the house and the need to ventilate, which brings in cold outside air. Even the novice house manager or flock supervisor knows that when ventilation fans are running in cold weather it causes brooders and heaters to run, which increases fuel costs. It is less immediately obvious that failing to provide enough ventilation can also be very costly in terms of lowered flock health and performance, including development of FPD. For this reason, the term “minimum ventilation” is often thought of as meaning turning fan run times down to the bare minimum to save fuel costs in cold weather. However, that “bare minimum” must also include at least enough fan run time to assure good air quality and oxygen levels – especially considering RH. As further explained below, heating (especially earlier in the grow-out) is important for conditioning incoming ventilation air. Thus, heating and ventilation can be thought of as working in tandem rather than in opposition.

Essential Facts Managers Should Understand About Moisture Removal in the Poultry House

1. For every unit of feed a bird eats, it will drink about 1.75 units of water. Only about 20% of that water is retained and goes into bird growth. The remainder passes through the bird, much of which enters the litter in the form of fecal material but also partially into the air via respiration. Consequently, a large amount of moisture is being added to the house (primarily in the litter) which increases with flock age. Based on the aforementioned values and published Ross male broiler feed intake performance objectives (2007), **Figure 1** reveals the daily amount of water consumption and water deposited into the house by 24,000 male broilers during a 8-week grow-out period under moderate temperature conditions. At 7 days of age, one thousand male broilers may add approximately 0.69 gal (2.60 L)/hour; and by 49 days they may add around 4.52 gal (17.11 L)/ hour into the litter. Note that in this example the estimated amounts of daily water added to the house follows the bird feed consumption and, hence, growth curve. Water consumption can be influenced by a number of factors including:

a. Under heat stress conditions, birds will consume more water than those kept at cooler temperatures.
b. Birds with restricted feed access (i.e. via light restriction or physical feed restriction) will have reduced water intake.
c. Diet composition (e.g. salt, energy density, various feed supplements) and water quality can significantly affect water intake.
d. Management practices which can affect water intake include drinker height, water line maintenance (regular flushing and cleaning), drinker line location within the house and water pressure. Water pressure can be affected by the line regulator, water filter cleanliness, well pump, and power outages.

Figure 1: Approximate daily water consumption and water added to house by 24,000 male broilers during a grow-out



2. The only practical way to remove excess moisture from the house is through ventilation. To understand how ventilation air can carry water out of the house in cold, rainy or even snowy weather requires an understanding of relative humidity (RH). The amount of moisture a given volume of air can hold varies considerably according to air temperature: warmer air can hold much more water than cold air. That is, the moisture-holding capacity of air is relative to its temperature. For example, at 40°F (4.4°C), 1,000 ft^3 (28.32 m^3) of saturated air (100% RH) can hold about 6.3 oz (186 ml) of water. If we warm that air to 60°F (15.6°C), it now is capable of holding almost 12.8 oz (379 ml). Since it still contains that 6.3 oz (186 ml), it is now holding only about half of its total capacity. This means its RH has been reduced from 100% at 40°F (4.4°C) to 50% at 60°F (15.6°C).

As a rule of thumb, every 20°F (11°C) increase in air temperature doubles its moisture-holding capacity.

This characteristic explains why warming up cold and wet outside air enables it to absorb moisture from the inside air and the litter. It's the same principle that makes the ordinary clothes dryer work. **Table 1** shows amounts of water air will hold at different temperatures and RH and illustrates how cold outside air at 30°F (-1.1°C) and 100% RH will have its moisture-holding capacity increased from 4.3 oz /1,000 ft^3 to 24.3 oz/1000 ft^3 (4.3 L/1000 m^3 to 25.4 L/1000 m^3) when it is warmed to 80°F (26.7°C). At 80°F (26.7°C), its RH would drop to under 20%, enabling it to pick up 12.7 oz/1000 ft^3 (13.3 L/1000 m^3) of water from the air and litter and still be at only 70% RH (12.7 oz + the original 4.3 oz = 17 oz; 13.3 L + the original 4.5 L = 17.8 L), 70% of capacity at 80°F (26.7°C).

Table 1a: Water holding capacity in air (°F and oz water/ 1000 ft^3)

	AIR TEMPERATURE						
RH%	30°F	40°F	50°F	60°F	70°F	80°F	90°F
10	0.4	0.6	0.9	1.3	1.8	2.4	3.3
20	0.9	1.3	1.8	2.6	3.5	4.9	6.6
30	1.3	1.9	2.7	3.8	5.3	7.3	9.9
40	1.7	2.5	3.6	5.1	7.1	9.7	13.2
50	2.1	3.2	4.5	6.4	8.9	12.2	16.5
60	2.6	3.8	5.4	7.7	10.7	14.6	19.8
70	3.0	4.4	6.3	8.9	12.4	17.0	23.0
80	3.4	5.0	7.2	10.2	14.2	19.5	26.3
90	3.8	5.7	8.1	11.5	16.0	21.9	29.6
100	4.3	6.3	9.0	12.8	17.8	24.3	32.9

Table 1b: Water holding capacity in air (°C and L water/ 1000 m^3)

	AIR TEMPERATURE						
RH%	-1.1°C	4.4°C	10°C	15.6°C	21.1°C	26.7°C	32.2°C
10	0.4	0.6	0.9	1.4	1.9	2.5	3.5
20	0.9	1.4	1.9	2.7	3.7	5.1	6.9
30	1.4	2.0	2.8	4.0	5.5	7.6	10.4
40	1.8	2.6	3.8	5.3	7.4	10.1	13.8
50	2.2	3.3	4.7	6.7	9.3	12.8	17.3
60	2.7	4.0	5.6	8.1	11.2	15.3	20.7
70	3.1	4.6	6.6	9.3	13.0	17.8	24.0
80	3.6	5.2	7.5	10.7	14.8	20.4	27.5
90	4.0	6.0	8.5	12.0	16.7	22.9	31.0
100	4.5	6.6	9.4	13.4	18.6	25.4	34.4

Ventilation Management to Control Moisture

From a ventilation management standpoint, there are two basic steps essential for keeping RH levels in the 50-70% range and maintaining litter moisture to acceptable levels. They are:

1. ***Provide at least enough air volume flowing through the house so that when the air is exhausted it will have picked up sufficient moisture to maintain the house moisture balance at a desirable level.*** In other words, as birds grow and more moisture is deposited into the bedding and exhaled into the air, the ventilation rate must be adjusted to provide the additional ventilation volume needed to remove that moisture.

Minimum ventilation rates are based on the amount of moisture added to the house by birds at different ages, as explained above (see **Figure 1**), and the amount of moisture a given volume of air can absorb, given its initial temperature and moisture content (outside air conditions) and its moisture-holding capacity (RH) at the temperature it will be warmed to as it is brought into the house (see **Table 1**). In practice, instead of continually doing the arithmetic to make such calculations, producers typically rely on tables providing per-bird ventilation rates (ft^3/minute or m^3/hour) needed for moisture removal during each week of rearing as shown in **Table 2**.

Table 2: Example per-bird ventilation rates for proper moisture removal

	Ventilation rates/bird	
Age (weeks)	**ft^3/min**	**m^3/hr**
1	0.10	0.17
2	0.25	0.42
3	0.35	0.59
4	0.50	0.85
5	0.65	1.10
6	0.70	1.19
7	0.80	1.36
8	0.90	1.53

Ventilation rates shown in **Table 2** would be considered more than adequate for climatic conditions in moist subtropical mid-latitude climates (e.g. southeastern U.S.A.) for outside temperatures ranging from 30-60°F (-1.1-15.6°C), and could be adjusted 10-20% lower for lower outside temperatures, and 10-20% higher for higher outside temperatures.

The total ventilation rate needed is given by simply multiplying the per-bird rate times the number of birds in the flock. During minimum ventilation, a small number of fans are normally cycled on and off. Therefore, the percentage of time they would need to run to provide the total ventilation rate needed is estimated by dividing the total ft^3/min (m^3/hr) needed by the ft^3/min (m^3/hr) capacity of the fans being used.

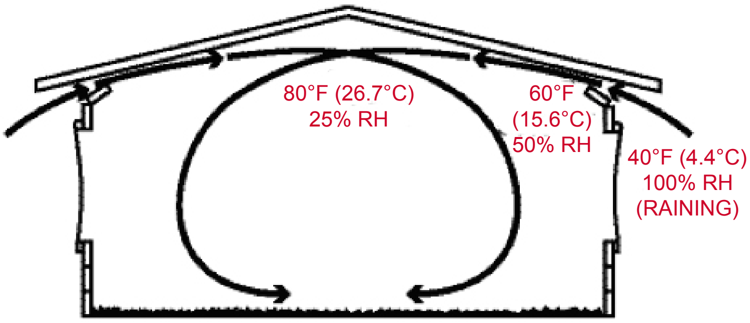
For example, in a barn with 20,000 birds during week 2, the ventilation rate needed is 0.25 ft^3/min X 20,000 = 5,000 ft^3/min (0.424 m^3/hr x 20,000 = 8,480 m^3/hr). If the fans to be used have a combined capacity of 30,000 ft^3/min (50,940 m^3/hr), then the fans need to be run one-sixth of the time (5,000 ft^3/min ÷ 30,000 ft^3/min = 0.167; 8,480 m^3/hr ÷ 50,940 m^3/hr = 0.167). Using a five-minute timer, this would mean fans would be on for 50 seconds (0.167 X 300 seconds = 50 seconds).

Although ventilation rates determined as explained above are extremely helpful, managers must realize that they provide only a starting point for effective ventilation management for moisture removal. Monitoring the house to keep track of actual conditions and modifying the ventilation rates appropriately are essential to achieving top flock performance and reducing incidence of FPD. Managers are well advised to utilize a high-quality hand-held humidity measuring device (humidistat or hygrometer), as well as visually and physically inspecting the barn and litter for signs of increasing wetness. It is paramount to remember that by the time wet litter is obvious, conditions favoring FPD have already been developing for several days.

2. ***Manage ventilation airflow so incoming air is conditioned before making contact with birds or litter.*** Cold air in contact with warm litter does a very poor job of removing moisture from the litter. Incoming minimum ventilation air must be brought into the house high, through either ceiling/attic inlets, ridge inlets or perimeter inlets at the top of the wall. Air must be directed across the top of the house at a sufficient velocity to allow thorough mixing with warm air in the house before making contact with birds or litter.

Figure 2 (next page) shows an adequate minimum airflow pattern, with outside air coming in through perimeter inlets warming and drying as it travels across the top area of the house, then picking up moisture from the lower part of the house. Note that air movements and mixing in the house will be more complex than can be shown in this simplified graphic, and that in the USA and in Europe there are several variations of minimum ventilation inlet arrangements (some fan-assisted) in use. What they all have in common is keeping incoming air high in the house and drying it out as it is warmed by thorough mixing with inside air.

Figure 2: Minimum ventilation airflow to achieve adequate conditioning of incoming air



Achieving good minimum ventilation airflow requires proper adjustment of air inlets and maintaining adequate static pressure, typically around 0.10-0.12 in. (2.5-3.0 mm) water column (WC) in houses < 50 ft (15.2 m) in width. For a house width > 50 ft (15.2 m) static pressure will need to be increased (maximum 0.14 in. or 3.6 mm WC) and stirring fans and/or roof inlets will be required to allow proper air mixing in the center area of the house. It is the pressure difference between inside and outside that generates enough incoming air velocity (or "throw") to get good mixing high in the house. For this reason, the house must be "tight," with no unplanned openings that will allow cold outside air to leak into the house. Such air leaks will result in lowered air velocity through the air inlets and are likely to cause condensation on litter and sidewalls. Common sources of leaks are poorly closing fan shutters, unsealed wall plates and unsealed tunnel or sidewall curtains.

In many locations litter moisture can be lowered and RH reduced through the use of simple stirring or air recirculation fans installed in the top of the poultry house. Unlike minimum ventilation fans, stirring fans are usually on all the time instead of being cycled on and off, so that they can considerably reduce temperature stratification by keeping in-house air constantly moving. Many variations of stirring fans arranged to stir approximately 10 to 15% of the building volume, and located in such a manner not to put cold drafts on the birds, have proven immensely valuable in many colder climates for reducing FPD. Stirring fans not only promote uniform temperature distribution, but also decrease fuel costs.

Role of Nutrition and Feeding Programs in Reducing the Risk of FPD

Nutrient density, feed composition and feeding programs have significant effects on broiler health and performance. Nutritional programs can set the stage and influence FPD directly and indirectly. High nutrient density diets (Bilgili et al., 2006) and those formulated to contain high salt levels (Mukrami et al., 2000) can result in higher incidence of FPD. Whitehead and Bannister (1981) noted that increasing dietary protein level negatively affected plasma biotin availability and thus impaired footpad skin quality. An increase in dietary protein level has been identified to cause uric acid overload in kidneys, increase water consumption and, thus, wet litter conditions (Gordon et al., 2003). Recent research has shown that high nutrient density feeds, high protein levels, and feeds formulated with high soybean meal inclusion can lead to increased levels of FPD in broilers (Nagaraj et al., 2007a). However, modern broilers are very responsive to nutrient density and subsequently, dietary nutrient density plays a critical role in maximizing margin over feed cost for meat production. A key element of this is formulating feeds for optimal amino acid density while minimizing crude protein levels. This is achieved by formulating on a digestible amino acid basis and utilizing synthetic amino acids.

Indigestible carbohydrates (i.e., non-soluble polysaccharides; NSP) from plant protein sources (soybean meal, wheat, barley) are thought to contribute to FPD by increasing fecal viscosity and promoting fecal adherence to foot pads, even when litter moisture is within acceptable levels. Commercially available enzymes can be utilized to address diets higher in NSP. Use of feed enzymes targeting NSP has shown promise in controlling FPD (Nagaraj et al., 2007b). Importantly, consult with the enzyme supplier to ensure proper inclusion levels are made and that the finished feed has sufficient enzyme activity to accomplish the purpose after considering any losses in enzyme activity that may occur during the feed conditioning process.

All vegetable diets, formulated with soybean meal as the primary protein source often result in increased incidence of FPD (Eichner et al., 2007). In the latter report, including 6-7% corn gluten meal in an all vegetable diets, which served to reduce total soybean meal inclusion, significantly reduced the incidence of FPD. Inclusion of soybean meal as the sole high protein ingredient has also received criticism since it is naturally deficient in biotin and can produce sticky and high fecal pH (Abbott et al., 1969; Jensen et al., 1970; Nairn and Watson, 1972). Given optimal conditions (pH of >8, and moisture of <60%), urolytic bacteria in the litter convert excreted uric acid nitrogen into ammonia. High fecal pH and dissolved ammonia creates a highly alkaline condition, which in turn chemically irritate foot pads. For areas of the world which use built-up litter, many of the commercially available litter treatments reduce ammonia volatilization through reduction of litter pH. These litter trreatments can help reduce FPD incidence and severity, although most treatments do not last for the life of flock (Nagaraj et al., 2007c).

Factors that increase water consumption (i.e. ingestion of high levels of sodium, potassium, or magnesium via feed and/or water) will contribute to wet litter conditions in the house. Research has shown that dietary zinc from organic sources reduces the incidence and severity of FPD under conditions of high stocking density (Hess et al., 2001; Saenmahayak et al., 2008). The adequacy of macro- and micronutrient supplementation of diets, especially trace mineral (Zn) and vitamin (biotin), should be assured to optimize skin and foot health (Patrick et al., 1942; Chavez and Kratzer, 1972; Harms and Simpson, 1975; Murillo and Jensen, 1975; Hess et al., 2001; Clark et al., 2002). Other "add-on" treatments such as the use of clay mineral binders (Van der Aa, 2008) will not cover the larger management challenges described above, but should be part of a coordinated plan to improve foot pad quality on a complex-wide basis.

Role of Intestinal Health in Reducing the Risk of FPD

Optimal intestinal health and functionality is essential for maintaining good litter quality. Any challenge to the gut (bacterial, viral or zooparasitic) will trigger sub-clinical to clinical enteritis, often manifested by diarrhea, flushing and feed passage. Wet litter is a common consequence of intestinal health challenge that must be controlled through appropriate anti-coccidial programs and management of gut microflora.

Any stressors (physical, chemical, or infectious) that affect the integrity and optimal functionality of the gastro-intestinal system can lead to enteritis, diarrhea, malabsorption, and increased feed passage, all of which rapidly increase excessive nutrient and moisture excretion into the litter. Several mycotoxins increase water consumption and wet litter production, and should be quickly ruled out as a contributing factor in the etiology of FPD.

Conclusion

FPD is a multi-factorial problem for the poultry industry with both economic and welfare consequences. Thorough understanding of contributing factors to the etiology of FPD should help producers and production managers in formulating control measures – particularly in the areas of nutrition, gut health and house environmental management.

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