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Relationship between nutrition factors and development of food pad dermatitis (FPD)

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Abstract: Nowadays, foot pad dermatitis and the associated loss of production and income is one of the major problems in intensive broiler chicken production. The third most valuable part of a broiler chicken is the legs. In the case of FPD, losses are realised as animals with foot pad dermatitis (FDP) eat, drink, and move less, and their performance is reduced, which causes serious loss of income. It also raises animal welfare concerns and can cause food safety problems. Development of the FPD and its frequency is influenced by several factors, individually or in combination: genetics, management, and feeding. In this article, we review the feeding causes of the development of FDP. Feedstuffs, rich in soluble NSP substances, low energy concentration in the diet, or luxury protein supply lead to low quality of the litter, predisposing birds to FPD. In addition, some minerals (Na, K, Cl) stimulate water consumption, while deficiency of others (Zn, Cu, Mn) affects epithelial tissue development and thus might provoke FPD.

Keywords: nutrition, poultry, foot pad dermatitis

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Introduction

Foot pad dermatitis (FPD) or contact dermatitis is a frequent inflammatory process in poultry species, which most commonly occurs in broiler chicken and turkey flocks. This is a disease which can cause foot pad change, from the surface to the deep skin layer, and depending on the condition, it may indirectly cause significant losses in production (Pié Orpí, 2020).

FPD is not a new problem, as it was already described in the 1980s (Greene et al., 1985; Mcferran et al., 1983). The disease probably existed even before this period, but no great importance was attached to it. This is supported by a publication of Greene et al. (1985), in which a skin disease affecting commercial broilers in Northern Ireland in 1978 was reported. Before this, little research was done on the disease because it was not considered to cause serious economic consequences, so the reasons for its development and the underlying problems were not in the focus of research. Before the 1980s, the chicken leg had minimal economic importance and together with the feather and blood, was a useless part of the chicken body (Shepherd & Fairchild, 2010).

However, from the mid-1980s, the demand for legs suddenly and continuously increased. Within a short period hicken legs, which were considered worthless, have become a valuable product of the poultry industry due to the intensively increasing market for it in Asia. The demand for quality foot ends was such high that the local production on the Asian continent was not able to meet it alone. Therefore, Far East became a net importer of chicken legs, which urged Europe and America to try to supply. Today about 60% of the US income from poultry export to China is realised in the form of paws comprising up to 300 thousand tons (Market Intelligence Team, 2020). However, legs are marketable only if they are served in perfect physical condition (Christensen, 1996). This change made the chicken leg the third most valuable product of the broiler chicken industry, following the breast and the wing (Shepherd & Fairchild, 2010). In China (Hong Kong), Thailand, and some other Far East countries, the popularity of legs (or rather paws) is constantly high and still increasing, while the price is often even beyond that of chicken meat. However, in the US and the European Union, only negligible quantities can be sold on a few sub-markets (Berkhout, n.d.).

However, the development of plantar ulcers is not only a marketing issue, but other economic consequences are also important, as animal weight gain is regularly reduced due to FPD (Martland, 1985). This results from reduced activity of the affected animals, so they move less due to the sore walk. As in FPD, there is constant inflammation on the foot, and some of the energy and nutrients are taken with the feed being used to recover, so a lower amount of nutrients remains available for growth. Furthermore, reduced activity can lead to decreased feed and water intake, resulting in weight loss, increased susceptibility to secondary infections, and consequently, higher mortality rate and seized product at the slaughterhouse (Pié Orpí, 2020). According to Jim (n.d.) prevalence of plantar ulcer is estimated to be between 20-100% within each flock.

As it was mentioned above, FPD is not only an economic problem, but it has an animal welfare approach, as well. Plantar ulcer must be painful (Algers & Berg, 2001), but it has not yet been scientifically evaluated (Heitmann et al., 2018). However, it was revealed that the gait of birds affected by FPD becomes unstable (Harms & Simpson, 1975), and also their posture is less stable (Hester, 1994). In other livestock species, gain stability is an important indicator of foot pain, as it is reported for cattle, (Weary et al., 2006), for sheep (Gigliuto et al., 2014) and for swine (Grégoire et al., 2013) too. Thus, FPD might be a potential indicator of animal welfare also in poultry.
However, there is still another food safety approach, as ulcers might affect product quality and generate potential food chain hazards due to the prevalence of secondary infections. In such cases, the first line of defence, the skin itself, is damaged, so the lesions give direct way for bacteria (e.g., *Staphylococcus aureus* and *E. coli*) to enter, they reach the bloodstream, and with that, they can be spread in the body (Pié Orpí, 2020; Shepherd & Fairchild, 2010).

Development of Foot Pad Dermatitis

Based on our knowledge, many factors play a role in the development of FPD (e.g., genetics, management, and nutrition). Most of them can be responsible even alone for the disease, but usually, they occur in combination with each other. The most important factors proven to be involved in the development of foot ulcers are genotype and sex; stocking density; microclimate of the building (room temperature, humidity, and ventilation, light regime/season); physical and microbiological status of the litter (type of bedding material, hygiene and depth of litter); type and setting of certain technological elements, primarily drinkers; feed composition (excessive amount of some nutrients, lack of others); and related to this structure of the intestinal mucosa and composition of the intestinal microflora (Amer, 2020; Swiatkiewicz et al., 2017).
Nutritional factors are especially important,

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as they affect water intake, moisture content and viscosity of the digesta, consistency of the excreta, and thus litter quality (Swiatkiewicz et al., 2017). This article aims to provide an overview of nutritional factors involved in the development of FPD.

Nutrition and FPD

Based on literature data, the energy, protein, fat, vitamin, and mineral content of the diet might contribute to the development of inflammation, thus to the development of FPD (Jeon et al., 2020). de Jong et al. (2015) found that when feeding a *low-energy* feed mixture, the severity of inflammatory changes in the foot pads increases in broiler chicken flocks. Since the feed consumption of birds is a function of the energy concentration in the diet, reduced energy content increases the feed intake and, thus, the protein and mineral intake. Simultaneously, water consumption is enhanced, accompanied by the elevated moisture content of the excreta and, consequently, of the litter. Wet litter softens the surface of the foot pad, thus predisposing to the formation of plantar ulcers.

As fat is a good energy source for birds, energy concentration also depends on the *fat content* of the diet. Low-quality fats reduce digestibility and result in pasty excreta, impairs litter quality (Pié Orpí, 2020). As digestibility depends on the fatty acid composition of the dietary lipids and unsaturated fatty acids, they have better bioavailability than saturated ones. Diets rich in unsaturated fatty acids have higher energy content and better intestinal absorption rate than those contain mainly saturated lipid sources (Celebi & Utlu, 2006). Birds fed a high-fat diet are also more prone to FPD due to producing more viscous excreta (Bilgili et al., 2006). However, in a recent study by Fuhrmann and Kamphues (2016), high dietary fat concentration (11%) did not significantly affect litter quality and FPD incidence compared to a diet with normal fat content (5.5%).

Some other components in the feed are also proven to influence the prevalence of FPD. Based on literature data, one of the most important predisposing dietary factors is the group of *nonstarch polysaccharides (NSP)* (J. Hess et al., 2004). These fibre components reduce the energy concentration of the feed and exert an anti-nutritive effect by limiting the access of digestive enzymes to nutrients, slowing down the movement of the digesta in the intestine (Khadem et al., 2016; Knudsen, 2014). In addition, the soluble fraction of NSP absorbs water; the viscosity of the digesta is increasing (Hetland et al., 2004), which negatively affects the digestibility and absorption of nutrients (Cozannet et al., 2017). Altogether, the higher the NSP content of the diet, the lower the metabolizable energy content and feed efficiency (Zduńczyk et al., 2020). However, the presence of NSP substances in poultry diet is inevitable, as common components like soybean meal (210g/kg) or wheat (113g/kg) have relatively high fibre content (Zduńczyk et al., 2020). Therefore, there are currently two options to prevent the harmful effect of NSP substances. We might replace the NSP-rich ingredients in the diet or at least reduce their inclusion rate. However, it is not easy because there are no optimal alternatives.

The other option is to degrade the NSP substances in the feed, which can be reached with fortifying the diet with *exogenous fibrinolytic enzymes* (like xylanase, glucanase, mannanase). They enhance the digestion of polysaccharide complexes; thus, they help to release and digest the starch and protein content of the endosperm (Bedford & Schulze, 1998). In line with this, a commercial xylanase product increased starch digestibility, and AME (apparent metabolizable energy) in chickens fed a wheat/soybean meal-based diet (Choct et al., 1999). Furthermore, xylanase and β-glucanase were successfully used to degrade NSP in wheat- and barley-based poultry diets (Choct, 2006). A new approach involves the use of enzyme cocktails (multi-carbohydrases) and aims to degrade the spectrum of NSP (Cozannet et al., 2017; Mikulski et al., 2017). Nagaraj et al. (2007) showed that an enzyme blend of cellulase, xylanase, galactosidase, amylase, and protease added to the corn/soy diet reduced the viscosity of the digesta and the incidence of FPD lesions in broiler chickens.

Some other feed additives seem to enhance the efficiency of enzyme supplementation. For example, research results of Dersjant-Li et al. (2015) and Flores et al. (2016) have shown that dietary supplementation of feed enzymes (xylanase, amylase, and protease cocktail) combined with probiotic bacteria is also efficient in reducing litter wetness and FPD occurrence. However, there are contradictory results in the literature, like Cengız et al. (2012). It was reported that supplementation of a corn-soy diet with different enzyme preparations (galactosidase, xylanase, protease, amylase, glucanase, or mannanase) did not affect litter moisture and the incidence and severity of FPD. Similar results were observed when a mixture of NSP hydrolyzing enzymes was added to a high barley diet (Cengiz, Köksal, et al., 2012).

According to some literary sources, in the case of *excessive protein intake*, the excess protein in the body of the birds is metabolized into uric acid and excreted from the body. As a result, the nitrogen content of the litter will be higher, which can turn into ammonia and cause inflammation through its corrosive effect, which can contribute to the development of plantar ulcers (Pié Orpí, 2020). This effect is further enhanced by the increased protein intake increases the birds' water consumption and, their water excretion, thus the moisture content of the litter. This, due to the softening of the sole pad, promotes the initiation of inflammatory processes. In line with this, Ferguson et al. (1998) (from 21.5% to 19.6% crude protein) and Bilgili et al. (2006) (from 21.0 to 19.7% crude protein) found that reducing the protein concentration of the feed significantly reduced the moisture content of the litter and, in this connection, the frequency of FPD.

Besides feed energy and fibre, *feed protein source* seems to play a role in FPD. The disease incidence is higher when only plant protein sources are consumed than when the diet contains some proteins of animal origin (Cengiz et al., 2013; Hossain et al., 2013; Nagaraj et al., 2007). Eichner et al. (2007) also reported increased litter moisture and FPD severity in chickens fed an all-vegetable diet based on maize, toasted soybean, and soybean meal, in comparison with birds fed with diets containing 10% poultry by-product meal. However, similar changes were also found in the same experiment when some of the toasted soybean was replaced with corn gluten meal. This suggests that not the protein quality (amino acid composition or digestibility) itself is responsible for the effect. Still, it is rather due to the different electrolyte content of the different protein sources.

Several studies have shown that feed *electrolyte* (Na, K, and Cl) *balance* is an important factor influencing faecal moisture content and severity of FPD. As shown in many studies with broiler chicken and turkey, high Na and K levels and high dietary electrolyte balance increase water intake and thus litter moisture content (Borges et al., 2003; Defra, 1994; Koreleski et al., 2010; Mushtaq et al., 2013; Zdunczyk et al., 2014; Ravindran et al., 2008), which in turn increases/increasing the prevalence and severity of FPD.

Harms and Simpson (1975) found that feed salinity is directly proportional to the severity of foot pad lesions. Birds fed high-salt feed excreted faeces with higher moisture content, resulting in poor litter conditions. It was observed that FPD severity was

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reduced by decreasing supplemental NaCl (Harms & Simpson, 1975). Cengiz, Hess, and Bilgili (2012) represent that a high Na concentration (0.30%) in the diet could increase water consumption and litter moisture, thus increase the incidence and severity of FPD in broiler chickens. Abd El-Wahab et al. (2013) compared the prevalence of FPD in young turkeys fed diets containing normal (0.16% Na, 0.78% K) or excessive (0.31% Na, 1.53% K) amounts of Na and K. They found that high Na and K diets led to increased litter wetness and increased FPD severity. The same results were reported by Fuhrmann and Kamphues (2016) and Koreleski et al. (2010) with a high level of K (1.45% or 1.27% respectively) supply. Similarly, Lichtorowicz et al. (2012) reported that high Na content (0.25%) in the diet of growing female turkeys resulted in higher incidence of FPD. However, in this research the abnormality was not associated with increased litter moisture.

Lack of certain vitamins (biotin, riboflavin, pantothenic acid) and minerals (e.g., zinc) can also increase the frequency of hock burn. Biotin and zinc, as important factors to maintain the optimum skin condition, can potentially prevent or moderate pododermatitis (Swiatkiewicz et al., 2017). Besides zinc, other trace elements like copper, manganese or selenium, might have some role in the development of FPD as they are central ions in certain enzymes responsible for antioxidant defence of membranes and epithelial tissues. Thus their deficiency might increase the susceptibility of foot pad.

El-Wahab et al. (2013) have evaluated the prophylactic effect of high dietary Zn and biotin supplementation on FPD in broiler chickens exposed to critically high (35%) litter moisture. According to their results, a diet containing 113 mg organic Zn/kg (Zn Met) and 2000 μg biotin/kg can reduce the severity of foot dermatitis. Youssef et al. (2012) have also presented beneficial effect of high biotin or Zn supplementation in turkeys but only on dry bedding. According to Sun et al. (2017), high biotin (1521 μg/kg) supplementation is capable to reduce the severity of FPD in broilers. Similar results were found by Zhu et al. (2012) with Peking ducks. However, no positive effect was found with biotin in turkey Mayne et al. (2007).

Zinc alone can also have some preventive effect on the development of contact dermatitis, but its efficiency seems to depend on the chemical form of the supplementation. Saenmahayak et al. (2010) reported that 40 mg/kg organic Zn complex has reduced the incidence of FPD as well as the severity of skin lesions. Also, (Manangi et al., 2012) showed that replacing inorganic trace elements (Zn, Cu, and Mn) with organic, chelated forms has contributed to significant improvements in foot pad health. Similar results were reported by J. B. Hess et al. (2001) Zn-Lys and Zn-Met complexes. There are some experiments with other minerals and other forms (nano). Organic selenium supplementation, for instance, has improved the severity of FPD in ducks (Abdel-Hamid et al., 2020), while nano zinc did not cause any significant improvement (Sevim et al., 2021).

Summary

In conclusion, foot pad disease is the result of multifactorial interactions. Several parameters are confirmed to contribute to its development, even focusing on the nutrition of birds alone. Therefore, optimal feed composition and nutrient content are key issues in preventing hock burn.

It is also clear, that though most of the predisposing factors are already known, the exact mechanism and interactions are not clarified yet. In addition, it can be established that this common problem can only be successfully alleviated with a complex approach or prevention.

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