What Really is the Role of Nutrition(ists) in Lameness?

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Lameness is a continues to be an animal welfare and impacts the economics of the dairy industry (Ventura et al., 2015; Dolecheck and Bewley, 2018). Most of the dairy cow lameness originates in the hoof (Murray et al., 1996) and in North America the most common hoof lesions are digital dermatitis (**DD**), sole ulcers (**SU**), and white line lesions (**WLD**) (Cramer et al., 2008; DeFrain et al., 2013; Solano et al., 2016). Although infectious lesions such as DD are the most common type of lesions, in most herds hoof horn lesions such as SU and WLD are costlier due to their effects on milk production and culling (Dolecheck and Bewley, 2018). Economic losses due to hoof horn lesions are difficult to quantify, yet it is becoming apparent that cows affected with hoof horn lesions are usually cows with higher production potential and production losses start prior to a lameness diagnosis (Bicalho et al., 2008). Typical production losses for cows with hoof horn lesions range from 200-500 kg plus these cows are also at increased risk of culling (Cramer et al., 2009; Huxley, 2013).

Given the importance of lameness to a dairy farm it is no surprise that there are a wide variety of stakeholders that can impact how a farm addresses lameness. Hoof trimmers are typically considered the main person by farms for both technical and herd level advice (Wynands et al., 2021). Veterinarians and nutritionists also have a role however their role is less technical and considered more advisory by farmers (Wynands et al., 2021). These differing roles can lead do some discomfort of their role and distrust of other advisors (Wynands et al., 2022).

The role of nutrition in lameness has traditionally been considered large, as acidosis was considered to play a large role (Nocek, 1997). This resulted in nutritionists becoming an easy target to blame when a herd had a lameness problem. Recently the focus of the link between acidosis and laminitis has been come under scrutiny and evidence for this link is weak (Lean et al., 2013; Randall et al., 2018).

The aim of this paper is to describe the role of nutrition and nutritional advisors in lameness. Specifically, this paper will briefly review the pathogenesis of the most common causes of lameness and conclude with opportunities for nutritionists to get more involved with lameness.

Digital Dermatitis

Digital Dermatitis is an infectious bacterial infection of the skin typically located in the interdigital cleft of the foot (ICAR Working Group on Functional Traits and International Claw Health Experts, 2020). The presentation of DD varies ranging from acute painful and ulcerated skin (M2 lesions) to hyperkeratotic or granulomatous lesions (M4 lesions) that are not as painful and more chronic in nature (Döpfer et al., 1997; Berry et al., 2012).

The development of DD requires a breakdown of the natural skin barrier (Gomez et al., 2014; Krull et al., 2016). Once this skin barrier has been broken down a synergistic group of bacteria invade the initial layers of the skin and create an inflammatory process. Several types of bacteria have been isolated from DD lesions, but Treponema species are considered a necessary component of the disease (Krull et al., 2014). Treponema species are microaerophilic, gram-negative spirochaetes that encyst to protect itself. As they invade the epidermis and damage the different skin layers, an immune response occurs that results in hyperkeratosis and proliferative lesions(Döpfer et al., 1997).

Prevention of DD typically focused on maintaining a clean environment and the use of properly designed and used footbaths containing copper sulfate or formalin (Cook, 2017; Jacobs et al., 2019). Skin has a physical, chemical, and immunological role in preventing damage and DD infections. Specific nutrients can contribute to ensuring optimum functioning of these barriers. Zinc has a role in cellular repair and replacement. Copper, Manganese and Zinc also contribute to the immune system through the regulation of specific cells, factors, and antioxidant pathways (Lean et al., 2013; Gomez et al., 2014). Similarly iodine affects the local inflammatory response and can prevent foot rot (Berg et al., 1984). A combination product containing Zn, Cu, Mn and I has been shown to reduce DD development (Gomez et al., 2014). The use a *Saccharomyces cerevisiae* fermentation product has also shown some promise as potential nutritional aid in DD control (Anklam et al., 2022).

Hoof horn lesions

Sole ulcers and WLD are both lesions of the horn due to damage to the corium. Visually this can present in clinical signs as mild as hemorrhage to necrotic tissue if the lesion was not treated in an appropriate time frame.

Hoof horn lesions such as SU and WLD are different lesions, but both are thought to be caused by trauma within the hoof and damage to the internal anatomy of the hoof through internal and external concussive forces (Newsome et al., 2016). The lesion that results from these forces is thought to depend are oriented toward in the hoof (Le Fevre et al., 2001; Lischer et al., 2002; Newsome et al., 2016). The first time a cow develops a SU or WLD changes in the hoof anatomy occur, primarily the suspensory apparatus (Lischer et al., 2002; Tarlton et al., 2002) and the supporting structures under the third phalanx or pedal bone (Bicalho et al., 2009; Newsome et al., 2017). Once the function of these structures is impaired, extra concussive force is exerted on the horn-producing tissue, leading to the disruption of horn production, inflammation,

exostosis, and, eventually, the formation of SU and WLD (Newsome et al., 2016). Once these lesion are present the pedal bone continues to change due to the inflammation in the corium resulting in exostosis, increasing the chance of chronic lameness due to a cycle of excessive concussive forces (Newsome et al., 2016). Therefore, it is important to consider previous lameness history when evaluating a dairy's records.

Prevention of hoof horn lesion is multifactorial with hoof trimming, standing time and the transition period thought to play a key role (Stoddard and Cramer, 2017; Randall et al., 2018). Nutritionally excessive carbohydrates and protein have been suggested as causes of hoof horn lesions. Evidence for this hypothesis is limited (Randall et al., 2018) and in some studies the environment (housing/flooring) has a larger impact than diet (Bergsten and Frank, 1996). However is has been suggested that glucose availability (Lübbe, 2015) at the cellular level and insulin concentration and peripheral tissue insulin sensitivity during the period of negative energy balance in early lactation are important factor in SU development (Wilhelm et al., 2017). This supports the epidemiological evidence that the transition period is associate with hoof horn lesion (Proudfoot et al., 2010; Omontese et al., 2020).

Like DD development trace minerals play a role in promoting optimum hoof health. The development of keratin requires adequate supply of both macro and trace minerals. For example calcium is required for an enzyme required in the final differentiation step of keratinocytes (Tomlinson et al., 2004). Similarly, sulfur containing amino acids (Methionine and cysteine) provides cell wall rigidity(Tomlinson et al., 2004; Lean et al., 2013). Zinc has various roles in the keratinization process and mixing of Zn sources can improve hoof health (Nocek et al., 2000; Lean et al., 2013). Like zinc, copper is involved in various enzymes that provide strength to the cell matrix and intracellular cementing substance(Tomlinson et al., 2004; Lean et al., 2013). When it comes to vitamins biotin is the vitamin that is the most important as it is a cofactor for various enzymes and is essential for the formation of the lipids in the intracellular cementing substance (Mülling et al., 1999). Biotin has been show to improve hoof health (Hedges et al., 2001; Bergsten et al., 2003) however it requires long term supplementation (Pötzsch et al., 2003).

Roles for nutritionists

It is clear nutritionists have a role to play in formulating diets that meet or exceed the requirements for optimum hoof health. There are likely herds in which specific minerals, vitamins or nutritional additives will be effective and other herds where they will not reduce lameness (Nocek et al., 2000; Hedges et al., 2001). What causes this difference between herds is still unclear and hence it provides an opportunity for advisors to evaluate suitability. One tool that is exists is the use of a risk assessment (van Huyssteen et al., 2020; Wynands et al., 2022). A recent study found that although the risk assessment was long it allowed team members to focus on important areas (Wynands et al., 2022). This risk assessment can be found at https://conservancy.umn.edu/handle/11299/226886. This same study used a team based collaborative approach between veterinarians, hoof trimmers and nutritionists to work with

farms that resulted in increased collaboration and alignment of goals for common farms (Wynands et al., 2022). These findings suggest that there is a role for nutritionists to become involved with other stakeholders to address lameness in herds where it is a farm priority.

To properly improve communication and collaboration between on-farm stakeholders it is imperative that there is good data collected related to lesions found by the hoof trimming. Specifics of setting up a lameness recording system can be found at https://z.umn.edu/lamenessmanagerwebinar. Nutritionists, due to their regular interactions and data analysis of dairy records, are well suited to either assisting dairies in setting up the system or monitoring the data to ensure performance is meeting the farm's goals. To properly develop and use a recording system will require hoof trimmers and nutritionists to work together and use common language for lesions and causes. Of note is that records should be evaluated considering the lameness history of cows and the effectiveness of interventions should be evaluated on the number of new lesions not all lesions.

Finally, since nutritionists play a large role in all aspects of feeding management it is important to understand the relationship between errors in feeding management and lameness. The biggest impact is likely going to come from ensuring cows have consistent access to feed. Cows waiting for feed induces excessive standing. Standing time plays a key role in the development and recovery of lameness and anything that causes a cow to stand excessively is problematic (Cook, 2020; Tucker et al., 2021). Next since the transition period is a key source of inflammatory process in a cow's life (Bradford et al., 2015) it is important to ensure a cow's transition period is as uneventful as possible. Finally, the low inclusion nature of minerals and vitamins make proper mixing and delivery of diets critically important (Oelberg and Stone, 2014).

Conclusion

There are various opportunities for nutritionists to play a role in improving lameness across the dairy industry. This will require moving beyond solely ensuring the diet contains the proper amount of nutrients and feeding management is adequate. Seeking out opportunities for collaboration with other on-farm stakeholders is key to truly create lasting change on dairy farms.

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