Nutritional Approaches to Combat Lameness in Ruminants

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ABSTRACT

Lameness remains a significant challenge in the livestock industry worldwide, affecting both animal welfare and farm productivity. It not only affects animal welfare but also correlates with reduced milk yield, feed intake, and reproductive performance. Proper nutrition and management practices are vital for promoting healthy hooves in livestock. This paper reviews the nutritional requirements and management strategies essential for preventing lameness, particularly focusing on dairy cattle. It discusses the importance of amino acids, minerals (such as calcium, copper, zinc, cobalt, and manganese) and vitamins (A, D, E, and biotin) in maintaining hoof health. Additionally, it emphasizes the significance of proper feeding management practices, including offering forage before grain, monitoring dry matter intake, analyzing total mixed ration particle size, and incorporating dietary buffers. By implementing tailored feeding and management strategies, it is possible to mitigate lameness issues and ensure sustainable productivity and fertility in dairy cattle herds.

INTRODUCTION

Lameness poses a significant challenge to the livestock production industry, persisting as a widespread issue among cattle herds and sheep flocks globally, including those in India. This problem detrimentally impacts both animal welfare and farm productivity and sustainability. Lameness can arise from various factors, including

infectious diseases (such as Digital Dermatitis), foot injuries, hoof disorders (like laminitis), nutritional deficiencies, metabolic disorders, and genetic predispositions. External factors like poor flooring, rough terrain, overcrowding, and inadequate hoof trimming practices can also contribute to lameness. One particularly concerning condition is Digital Dermatitis (DD), an infectious foot skin disease causing pain and distress to millions of ruminants. Apart from its evident impact on animal welfare, DD also correlates with decreased milk yield, feed intake, and reproductive performance. Sufficient nutrition and effective management practices are crucial for promoting and sustaining healthy hooves in livestock. Ensuring optimal levels of vitamins and minerals is also imperative for hoof health. During transition periods, careful feeding management is vital to mitigate physiological and behavioral changes that may lead to metabolic disorders and lameness. Implementing feeding and management strategies tailored to specific requirements is essential for effectively managing this challenge and safeguarding sustainable productivity and fertility in dairy cattle.

Lameness:

Lameness in farm animals is a significant yet often underestimated condition that detrimentally impacts reproductive performance and productivity. Recognized as a key indicator of welfare in dairy cows, lameness manifests through various symptoms such as discomfort, pain, injury, and distress, hindering the cow's ability to interact socially and with her environment. The consequences of lameness include reduced body weight and condition, decreased feed intake due to mobility limitations, and shortened longevity. Additionally, milk production and fertility suffer as a result, leading to higher rates of involuntary and premature culling. Moreover, lameness predisposes animals to other diseases such as displaced abomasum, ketosis, and mastitis.

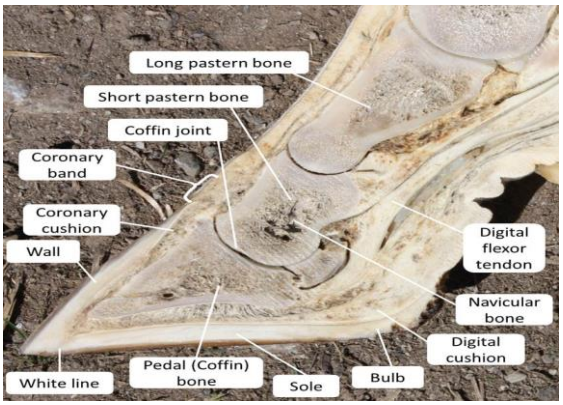

Figure 1. Bovine hoof

Prevention:

Maintaining the health of keratinized tissues within the hoof is a fundamental aspect of preventing lameness in animals. The nutrient flow process, regulated by hormonal controls, significantly influences the quality and integrity of these tissues. Any compromise in nutrient supply to the cells responsible for keratin formation results in the production of substandard keratinized tissue. This, in turn, heightens the risk of claw disease development and may eventually culminate in lameness.

Nutritional Management of lameness:

The nutritional requirements for preventing bovine lameness encompass a range of components, including carbohydrates, protein, trace minerals, and vitamins. Proper nutrition must be considered alongside other factors to address lameness as a herd issue. The level of carbohydrates in the ration significantly influences ruminal metabolism. The amount of carbohydrates needed to induce ruminal acidosis varies based on factors such as feed processing methods, adaptation periods, the cow's nutritional status, and the frequency of carbohydrate feeding. The non-fiber carbohydrate (NFC) fraction is notably more digestible and undergoes quicker digestion compared to NDF (Neutral Detergent Fiber).

An overabundance of NFC can hinder fiber digestibility, diminish acetic acid production, and potentially result in rumen acidosis. It's crucial to account for factors such as grain particle size, moisture content, and processing method, alongside the NFC level in the ration. Depending on the digestibility of the NDF present, it is recommended to maintain NFC levels between 30 and 40 percent of the total ration dry matter.

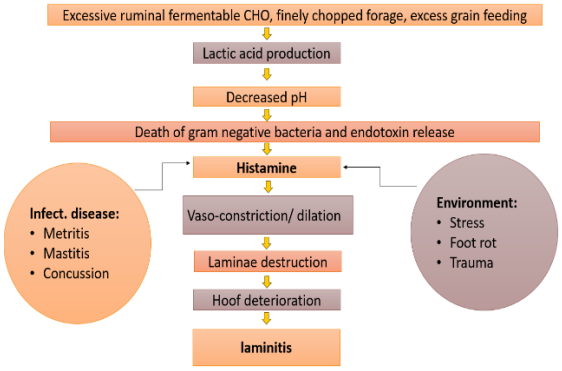

Figure 2. Relationship between nutrition, disease and environment on development of laminitis

Nutrients required for proper hoof health:

Amino acids:

- Amino acids such as cysteine (Cys), histidine (His), and methionine (Met) are essential for establishing the structural integrity of keratinocytes (Ekfalck et al., 1990).

- According to the National Research Council (NRC) in 2001, high-producing dairy cows may struggle to produce sufficient metabolizable protein to meet the demands of milk production, particularly during early lactation when dry matter intake is reduced.

- This insufficiency of metabolizable protein in early lactation may lead to inadequate protein synthesis by developing keratinocytes, potentially resulting in the production of inferior hooves.

- In dairy cows, the necessary nutrients for horn production include amino acids, especially sulfur-containing ones like cysteine, fatty acids such as linoleic and arachidonic acid, essential trace elements like zinc, minerals like calcium alongside vitamins such as biotin, play critical roles in supporting the development, growth, and maintenance of epithelial and skeletal tissues, including the claw epidermis.

Calcium: It is crucial for the processes of keratinization and cornification. It is involved in activating epidermal transglutaminase, which in turn facilitates the cross-linkage of keratin fibers in the cell envelope and regulates the terminal differentiation of epidermal cells. Transglutaminase also plays a vital role in activating the final step in the production of mature, fully cornified keratinocytes. Insufficient calcium provision to maturing keratinocytes, whether caused by hypocalcemia or inadequate vascular supply, can lead to decreased transglutaminase activity and the development of dyskeratotic horn.

Copper: Copper is essential for various biological processes in animals. It activates enzymes such as cytochrome oxidase, which is vital for aerobic respiration, lysyl and thiol oxidases for maintaining cell structure, ceruloplasmin for iron absorption and transport necessary for hemoglobin synthesis, and superoxide dismutase, which, alongside zinc, helps neutralize harmful oxygen metabolites (NRC, 2001). In hoof health, copper plays a crucial role through the enzyme thiol oxidase, which strengthens horn structure by crosslinking keratin filaments (O'Dell, 1990). Additionally, connective tissue strength, including tendons and laminae, relies on copper, facilitated by the enzyme lysyl oxidase, which forms cross linkages between collagen fibers. The recommended dietary copper content for dairy cattle varies between 9 and 16 ppm depending on the stage of the life cycle (NRC, 2001).

Zinc: Its 3 key functions in the keratinization process: catalytic, structural and regulatory.

Catalytic: found in enzymes such as RNA polymerase, alkaline phosphatase, alcohol dehydrogenase and the carbonic anhydrases.

The existence of ascorbic acid, RNA, DNA, free aldehyde groups, and alkaline phosphatase within keratinizing cells indicates substantial cellular activity.

Structural: Zn-finger proteins facilitate protein-to-protein interactions, primarily affecting cellular differentiation or proliferation.

Regulatory: Zinc plays a crucial role in regulating calmodulin, protein kinase C, thyroid hormone binding, and inositol phosphate synthesis. Calmodulin binds calcium and transports it into the cytosol when activated, which is vital for the final stages of keratinocyte development. Protein kinase C, which is also dependent on calcium, phosphorylates proteins, providing energy for the differentiation process.

Cobalt: Cobalt's main physiological function is its involvement in the synthesis of vitamin B_{12} within the rumen. A deficiency in vitamin B_{12} can disrupt both protein and energy metabolism, potentially leading to lameness. The recommended dietary cobalt content for lactating dairy cattle is 0.11 ppm.

Manganese: Manganese has an indirect impact on the keratinization process. Mn is necessary for activating enzymes like galactotransferase and glycosyltransferase, crucial for synthesizing chondroitin sulfate side chains of proteoglycan molecules. These proteoglycans are fundamental in forming normal cartilage and bone structures. Animals experiencing a shortage of manganese may exhibit skeletal irregularities, such as crooked legs and shortened tendons, which can result in a condition known as foot knuckling. Additionally, manganese is involved in activating enzymes such as pyruvate carboxylase, which initiates the first step of carbohydrate synthesis. This process, essential for gluconeogenesis and cellular energy production, is vital for producing high-quality horn tissue.

Significance of vitamins in production and maintenance of healthy claw horn:

Vitamin A is crucial for the development and quality of keratinized horn tissue and cell differentiation. (Olson, 1996). Vitamin D influences keratinization by aiding in the absorption and mobilization of calcium in the body. Vitamin E plays a vital role in maintaining the integrity of keratinized tissues, as the intercellular cementing substance comprises lipid-rich material (Mülling et al., 1999). A deficiency in these vitamins may result in oxidative stress within cells, potentially leading to lameness and poor horn tissue production in transition dairy cows fed low levels of Vitamin E. Biotin is especially important during the keratinization process of the hoof, being essential for the formation of complex lipid molecules in the intercellular cementing substance.

Feeding management:

- Effective control of lameness and laminitis can be achieved through proper nutrition and appropriate feeding management practices.
- It's advisable to offer hay or some forage before providing grain to the animals.
- Herds consuming a total mixed ration (TMR) should undergo regular monitoring of dry matter intake, especially for high-moisture feeds.
- Particle size is crucial for both forages and grains, as finely processed forages or

total mixed rations with inadequate fiber levels can exacerbate lameness issues.

- Analyzing the particle size of the TMR aims to assess the distribution of feed and forage particles consumed by the cows.

- Regular analysis of the herd's TMR should be conducted at least quarterly to ensure nutrient levels align with intended targets.

- Dietary buffers should be incorporated into the diet, typically at 0.80 percent of the total ration dry matter. However, solely relying on offering buffers free-choice to cows for correcting rumen acidosis should be avoided.

- Particle size, processing methods, and moisture content can influence the ruminal availability of structural and non-fiber carbohydrates, all of which should be considered when formulating rations to control lameness.

CONCLUSION:

Preventing lameness is crucial for reducing its impact on cow welfare and the economic losses faced by dairy farmers. Lameness is commonly associated with intensified production, intensive feeding, and confined rearing conditions in dairy operations. Implementing appropriate feeding strategies that balance nutritional requirements and ensure proper feeding management can significantly reduce the incidence of this economically significant ailment in dairy cows, which is often overlooked. Careful consideration should be given to feeding high-concentrate diets to prevent the onset of acidosis. It's important to limit the time cows spend standing on concrete surfaces and avoid rushing them when walking on abrasive surfaces to minimize the risk of foot injuries. Priority should be given to treating the primary ailment, while also providing nutritional support to accelerate the inflammatory and wound healing processes.

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