Nutritional Influences on Horn Quality and Hoof Health

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Take Home Messages

- Clinical lesions of the cattle hoof are the result of or at least associated with poor hoof horn quality.
- Formation of claw horn is a complex process which essentially depends on a balanced diet and a sufficient supply with vitamins, minerals and trace elements.
- We have evidence for positive effects of biotin and zinc on horn quality and hoof health.
- Nutritional influences on horn quality can be used to improve integrity of horn and thus reduce the incidence of claw problems and lameness in dairy herds

Introduction

Lameness in dairy cows is a major cause of suffering and economic loss with up to 52% (average 20-25%) of cows becoming lame each year (Clarkson et al., 1996; Green et al., 2002). The vast majority of lameness cases are caused by a variety of non-infectious and infectious claw diseases causing severe pain, decreased milk yield, reduced reproductive performance, high culling rates and increased cost of veterinary intervention. Claw diseases are consequently a highly important economical and animal welfare issue (Whay et al., 1998, 2003). Factors affecting lameness and locomotion include but are not limited to nutrition, feeding strategies, wetness, abrasive or slippery floor surfaces and health events causing production of poor quality horn (fever, age, off-feed, metabolic disturbances, toxins/mycotoxins), inappropriate genetic selection, accelerated breeding protocols, poor peri-parturient management and farmer awareness knowledge and skills.

It is important to understand that claw diseases causing lameness are multi-

factorial in origin and that the lameness we see clinically is almost always the result of a combination of factors impacting on structural and functional integrity of the claw. Nutritional management AND cow comfort are major risk factors to be considered in the attempt to reduce lameness in dairy cattle. The significance of nutrition for a good quality of hoof epidermis and reduction of foot problems in cattle herds is generally accepted. Looking at nutrition a considerable body of evidence is available for the impact of protein, carbohydrates, non-forage fibre, fibre length, and various other macro nutritional management factors pertaining to ruminal function and performance of the dairy cow during the transition period.

There is a broad consensus that most of the clinical lesions of the cattle hoof are the result of or at least associated with poor hoof horn quality (Greenough, 1991). Consequently many attempts have been made to improve hoof health by improving the quality of hoof horn as part of the lameness management in dairy herds. During the last 10 -15 years more attention has been given to the influence of vitamins, minerals, and trace elements on horn quality and hoof health and the use of vitamins, minerals and trace elements in prevention of claw diseases (Geyer, 1998; Koller et al., 1998; Mülling et al., 1999). Minerals, vitamins and trace elements are involved in numerous biochemical pathways during horn production. Most information is available for biotin and zinc (Tomlinson et al., 2004).

This paper summarizes the processes involved in formation of claw horn focusing on the influence of nutritional factors on horn production, horn quality and hoof health.

■ Horn Quality And Function Of The Claw

The bovine claw fulfils protective as well as mechanical functions. The performance of the claw is genetically determined and limited. In dairy cows under conditions of intensive husbandry systems the claw is permanently challenged by external environmental factors such as flooring and hygiene and very often in addition by internal factors such as metabolic stress or systemic disease. Good horn quality and structural and functional integrity of the claw are essential for maintaining hoof health in individual animals and on the herd level. Any weakening of the structural integrity of the claw has immediate functional consequences followed by all of its biological, economical and welfare consequences.

Horn Producing Living Epidermis

The outermost layer of the claw is called epidermis and is the horn producing tissue. Nutritional factors can influence horn production and consequently horn quality.

Formation of claw horn is a complex process which is very sensitive to nutritional and metabolic changes, hormonal effects and environmental influences. The claw epidermis consists of living epidermal cells in the deeper layers and of a thick superficial horn layer, the claw capsule or horn shoe. Production of claw horn is the result of a dynamic process occurring in the epidermis establishing a thick mechanical stable horn shoe (Mülling & Budras, 1998; Tomlinson et al, 2004). The horn producing cells are specialised for a high rate of synthesis of proteins, the so called keratins. These keratins are cross-linked and form a stable protein-complex providing mechanical and chemical stability to the horn. The second product of keratinising epidermal cells is the intercellular cementing substance. Its major function is to establish a stable connection between horn cells. This substance also protects horn cells from excessive loss of water as well as from extreme hydration (Mülling & Budras, 1998).

The highly active horn producing epidermal cells depend on a sufficient and balanced supply of nutrients and oxygen. Required nutrients for horn production are: amino acids, especially sulphur containing amino acids such as cysteine, fatty acids such as linoleic and arachidonic acid, minerals, in particular calcium and trace elements like zinc, and vitamins, in particular biotin (Tomlinson et al., 2004). The supply with all these substances comes from the blood vessels in the connective tissue beneath the epidermis. Mechanical overload and tissue compression interfere with the perfusion of blood vessels and with supplies to horn producing tissue. Bioactive molecules deriving from metabolic activity or systemic disease will impact on vascular walls and perfusion. Both reduced perfusion and alterations in the vessels themselves will impair horn production and finally provoke horn of inferior quality leading to a significant weakening of the horn capsule and an increased susceptibility of the claw to damage and lesions.

▪ Required Nutrients For Horn Formation In The Epidermis

Amino Acids

The amino acids cysteine, histidine and methionine play key roles in production of good quality horn (Ekfalck, 1990; Ekfalck et al., 1990). Fraser and MacRae (1980) reported that the formation of bonds between cysteine residues is an integral step in the final stage of horn formation.

Calcium

The onset of lactation places a large demand on mechanisms of calcium balance in the animal and most cows develop some degree of hypocalcemia

at calving (Goff and Horst, 1997). Calcium plays an important role in the process of horn production as the calcium concentration in the epidermis controls horn formation. Calcium is required for the activation of an enzyme which is essential for the final steps in the production of the mature horn cell (Mülling et al., 1999). Insufficient calcium supply or availability due to hypocalcemia may lead to reduced quantity and/or quality of claw horn. This may also provide an explanation for the horn rings consistently observed associated with pregnancy in cows.

Zinc

Zinc is a component of over 200 enzymes, several of them involved in the processes of horn production. Zinc plays a role in formation of the structural keratin proteins. Several studies have shown that organic zinc improves claw integrity. In a yearlong study cows fed an additional 200 mg/d of organic zinc had fewer cases of foot rot, heel cracks, interdigital dermatitis and laminitis than cows not fed zinc (Moore et al., 1989). Of beef cattle receiving 216 mg/d of organic zinc, 2.5% had foot rot while 5.5% of cattle not receiving zinc had foot rot (Brazle, 1993). Zinc requirements for dairy cows vary by stage of lactation. Milk production creates a significant drain on zinc stores, thus zinc requirements are highest in early lactation (NRC 2001). Insufficient supplies of bioavailable zinc, during the periparturient period and during lactation, may predispose cows to production of inferior horn tissue.

Copper

Copper is essential for activation of many enzymes. Copper activates an enzyme which is responsible for formation of the chemical bonds between keratin filaments (O'Dell, 1990). This process is essential for structural strength on the cellular level giving rigidity to the horn cells. Cattle suffering from a subclinical copper deficiency are more susceptible to heel cracks, foot rot and sole abscesses (Puls, 1984).

Selenium

Selenium may contribute to protection and maintenance of the intercellular cementing substance. Excessive supplementation of selenium may be damaging to horn cells by reducing the number of chemical bonds between keratin proteins (Combs, 2000). The horn becomes soft and unstable. Larson et al. (1980) reported that dairy cows supplemented with 50 mg of injectable selenium (over 6.6 x NRC requirement) during the dry period suffered severe claw problems in the postpartum period. They indicated that between 48 and 69% of cows receiving the supplemental selenium injection had increased lameness, sore feet, deformed claws and loss of hair from the tail versus 28 to 30% claw problems in non-supplemented cows.

■ Role Of Vitamins In Horn Production

Biotin (Vitamin H)

A water-soluble "B" vitamin, biotin (vitamin H) is the vitamin of greatest importance to horn production. Biotin is essential for the formation and integrity of skin, hair, claws and footpads in mammals and birds (Maynard et al., 1979). Biotin is a cofactor for enzymes used in a diverse array of metabolic pathways (Mock, 1996). Biotin is essential for two major events during horn production: keratin protein synthesis and formation of the intercellular cement (Sarasin, 1994; Whitehead, 1988). Improved quality of the intercellular cement, and resulting from this, improved cell to cell adhesion, occur under biotin supplementation (Hochstetter, 1998; Koester et al, 2002). In dairy cows it was demonstrated that supplemented animals had a reduced susceptibility to claw diseases such as sole ulcers, dermatitis digitalis, and horn erosion. Looking at the hoof horn of supplemented animals on the histological level the horn cell connection was improved (Hochstetter, 1998; Koller et al., 1998; Schmidt, 1995).

In calves fed a biotin depleted diet, the biotin deficiency affected keratinizing epidermal cells as well as composition of the intercellular cement (Mülling et al., 1999). Research in pigs and horses has shown that biotin positively influenced the integrity of the hoof horn (Geyer, 1998).

Ruminants are able to produce biotin in the rumen. However, high grain (> 50% of DM) rations reduce ruminal synthesis of biotin *in vitro* (DaCosta-Gomez et al., 1998). Several studies indicate that dairy cows respond favorably (improved claw integrity and reduced lameness) when provided supplemental biotin (20 mg/animal/day) for a period of greater than 6 months (Fitzgerald et al., 2000; Hedges et al., 2001; Weis and Zimmerly, 2000). In a study of five dairies with a total of 900 cows, Pötzsch et al. (2003) reported biotin supplemented at 20 mg/d for longer than 6 months reduced white line disease in multiparous cows by 45% to 8.5 cases per 100 cow years. These studies indicate that biotin reduced the incidents of white line abnormalities in particular and to a lesser extent other claw diseases such as sole hemorrhage, sole ulcers, digital dermatitis, and heel erosion.

Vitamin A

Vitamin A is needed for normal growth and development and for maintenance of skeletal and epithelial tissues including the claw epidermis (NRC, 2001). Vitamin A plays an important role in developing the structure and quality of horn tissue.

Nutrition And Claw Pathology

The composition of the diet, the preparation of the diet and the way it is fed, but also the feeding behaviour are risk factors for laminitis (Bergsten and Muelling, 1994). These factors interfere with rumen fermentation and metabolism. Ruminal acidosis, often the result of improper feeding management, has frequently been associated with laminitis and is thought to be a major cause for laminitis in cattle. There are, however, studies where no correlation between a low ruminal pH (<5.8) and claw lesions was detected. The same study showed a significant increase in sole lesions 8 to 12 weeks after calving when the diet was changed suddenly from high to low fibre compared to feeding the same diet all the time. This as well as numerous other studies have in common that they identify the transition period as a problematic time with a high risk of developing laminitis.

Many physiological changes occur in the transition period. Despite the tremendous quantity of research conducted on nutrition and physiology of transition cows, this period remains a problematic area on many commercial dairy farms, and metabolic disorders continue to occur at economically important rates (Burhans et al., 2003). Green et al. (2002) reported that incidents of first lameness were highest three months after calving, suggesting that factors affecting horn growth during the dry period and in early lactation result in production of inferior horn and subsequent lameness in early lactation.

Summary

Formation of claw horn is a complex and structured process of cellular changes that transform living, highly functional epidermal cells into mechanical very stabile horn cells. This process of horn formation is sensitive to nutritional influences, hormones and environmental influences.

Integrity of claw horn is an important prerequisite for claw health which in turn is required for overall animal well-being, productivity and potential profitability. Nutritional factors play a major role in determining the quality and integrity of the horn within the genetically determined framework. When nutrient supply to horn producing cells is compromised, horn of inferior structural and functional integrity is produced. Inferior horn quality increases the potential for development of claw disease and may ultimately lead to lameness. Calcium, zinc, copper, Vitamins A, D & E and biotin all play important roles in production and maintenance of good quality claw horn.

The concept of a multi-factorial etiology of claw diseases is as valid as it ever was. Multi-factorial means that practically every aspect of dairy cow

management has to be scrutinized for its potential impact on the claw. Nutrition AND cow comfort are key factors in effective prevention of lameness in dairy cows.

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