Wayamba Journal of Animal Science – ISSN: 2012-578X; P635-P646 2013
First Submitted October 06, 2012; Number 1346913770

ROLE OF BIOTIN IN PREVENTION OF LAMENESS IN DAIRY CATTLE-REVIEW

Pragya Bhadauria[1], S.S. Lathwal[2] ,Y.S. Jadoun[3] and S.S. Bhadauria[4]
[1,2]Department of Livestock Production & Management, [3.]Division of Dairy Extension, National Dairy Research Institute, Karnal-132001 (Haryana), India.
[4]Dept. of Animal Breeding & Genetics, College of Veterinary Science & A.H, Rewa MPPCVV, India

[*]Corresponding author: bhadauriapragya28@gmail.com

Lameness is a multifactorial disease or abnormality that causes the cow to change the way it walks. Nutritional management continues to be a major focal point in the attempt to reduce lameness in dairy cattle. Scientific research is reporting significantly improved hoof health with dietary biotin supplementation. Biotin is a B-complex water-soluble vitamin that is essential nutrient for all animals. Biotin is possibly the vitamin of greatest importance to the keratinization process involved in pathways for amino acid metabolism, cellular respiration, gluconeogensis, and fatty acid synthesis. It is involved in the differentiation of epidermal that will become the hoof horn, in the production of keratin and intracellular cementing substance. Although biotin is present in many feedstuffs, scientists do not know how much of it is actually available to meet the cow's needs. There have been few studies in any species on the bioavailability of the biotin found in feedstuffs. Increasing the bioavailability of biotin improves its utilization and thus contributes to an improved integrity of claw. Ruminants produce biotin as a result of bacterial fermentation, however ruminants receiving proportionately high-grain thus predisposing them to lactic acidosis which reduced the microbial synthesis of biotin tend to have more hoof problems especially during periparturient period and in early lactation. More recent studies have shown that in dairy cattle fed 10-20 mg per head supplemental biotin daily, hoof health was improved and the incidence of the common hoof problems was reduced.

Keywords: Lameness, Biotin, Keratinization, Integrity of claw, Ruminants

Lameness is a disease or abnormality that causes the cow to change the way it walks (its gait). Although many factors have long been recognised as contributing to lameness (Livesey and Fleming, 1984; Peterse *et al.*, 1984; Manson and Leaver, 1989), as it is a multifactorial disorder like physiological, nutritional, managemental, environmental, genetic factors etc. The losses incurred due to lameness are so high that it ranks just after reproductive failure and mastitis (Baggott 1982; Esslemont and Kossaibati 1997). Affected animals show a marked decline in body weight, milk yield and reproductive efficiency (Garbarino *et al.*, 2004). With added costs of treatment, culling and replacement, the total loss may be around 4–5% of a typical farm income (Enting *et al.*, 1997).

Nutritional management continues to be a major focal point in the attempt to reduce lameness in dairy cattle (Nocek, 1997). Recent scientific research is reporting significantly improved hoof health with dietary biotin supplementation. Other studies have found greater milk production and improved reproductive efficiency with dietary supplementation of this B vitamin (Bergsten *et al*., 1999; Fitzgerald *et al*., 2000; Midla *et al*., 1998; Zimmerly and Weiss, 2001; Singh and Lathwal , 2009). Biotin is a B-complex water-soluble vitamin also called vitamin H that is essential nutrient for all animals. Although ruminants produce biotin as a result of bacterial fermentation, the requirements for biotin and other B-group vitamins in cattle have been reevaluated (Girard, 1998). Biotin is essential for ruminants and studies have been conducted on biotin synthesis, absorption, and balance in lactating and nonlactating cattle (Miller *et al.,* 1986; Frigg *et al.,* 1992; Kluenter *et al.,* 1993; Steinberg *et al.,* 1995). In this regard, biotin supplementation has been used successfully for many years to improve claw and hoof health in pigs and horses (Brookes *et al.,* 1977; Geyer and Schulz, 1994). Indications that biotin insufficiency might affect foot and hoof health first appeared in research with biotin-deficient poultry and swine. In those studies, dermatitis, loss of feathers or hair, and softening of normally hard tissues such as claws all pointed to a role in production of proteins such as keratin.

However, for several decades very little research was published on the effects of biotin in cattle. It has been presumed that microbes in the gastrointestinal tract normally synthesize enough biotin to meet the requirements of ruminants and the inability to produce clinical biotin deficiencies in functioning ruminants and by the consensus that adequate biotin was in normal feedstuffs or was synthesized by bacteria in the rumen and lower intestines. However, the latest research indicates that biotin supplementation may be beneficial in cattle with a history of hoof problems, especially in times of stress. Most of the recent research has centered on the effects of biotin on hoof health of dairy cows (Bergsten *et al.,* 2003; Fitzgerald *et al.,* 2000; Midla *et al.,* 1998). All these studies reported a positive response on some measure of hoof health to supplemental biotin. Many studies have investigated the biological effects of biotin on hoof health, including keratin protein synthesis and formation of the intercellular cement, which influence horn formation of the hoof, hoof strength, and claw integrity (Whitehead, 1988; Sarasin, 1994; Hochstetter, 1998; Fitzgerald *et al.,* 2000; Hedges *et al.,* 2001; Koester *et al.,* 2002). Many of the studies reported positive biological effects of biotin treatment on hoof strength (Distl and Schmid, 1994; Hagemeister and Steinberg, 1996; Midla *et al.,* 1998; Campbell *et al.,* 2000; Fitzgerald *et al.,* 2000; Hedges *et al.,* 2001; Bergsten *et al.,* 2003; Potzsch *et al.,* 2003). There were, however, limited randomized controlled studies on the clinical effect of biotin supplementation to improve hoof health and reduce the risk of lameness in dairy cows.

BIOCHEMISTRY OF BIOTIN

Biotin is involved in pathways for amino acid metabolism, cellular respiration, gluconeogensis, and fatty acid synthesis. There are four biotin-containing enzymes found in mammalian cells—acetyl-CoA carboxylase, B-methylcrotonyl-CoA carboxylase, propionyl-CoA carboxylase, and pyruvate carboxylase. All four enzymes require biotin to become activated (Weiss and Zimmerly, 2000). Biotin is covalently linked to each of these enzymes and transfers a carbon unit from the substrate to the product. Although acetyl-CoA carboxylase and pyruate carboxylase require biotin, it is unlikely that supplemental biotin affects the activity of those two enzymes. Both of those enzymes are extremely important, are tightly regulated, and have a high priority for biotin. Activity of those enzymes are probably not reduced until a clinical biotin deficiency develops and since a clinical deficiency of biotin has not been produced in ruminants, the activity of those enzymes is probably not influenced by feeding supplemental biotin to dairy cows.

The other two biotin-containing enzymes (B-methylcrotonyl-CoA carboxylase and propionyl-CoA carboxylase are less tightly regulated and respond to differences in biotin status in humans and laboratory animals suggesting that cattle may respond to biotin supplementation. B-methylcrotonyl-CoA carboxylase is an enzyme involved with breaking down the amino acid, leucine, into products that can be used as energy sources. When biotin is limiting in humans, other metabolites are produced and excreted in the urine (Mock, 1996). If the activity of this enzyme is limited by a marginal deficiency of biotin in cattle, a large response in production would not be expected when biotin is supplemented. Propionyl-CoA carboxylase is an extremely important enzyme for ruminants but is relatively unimportant in nonruminants. This enzyme is involved with the pathway that converts propionate to

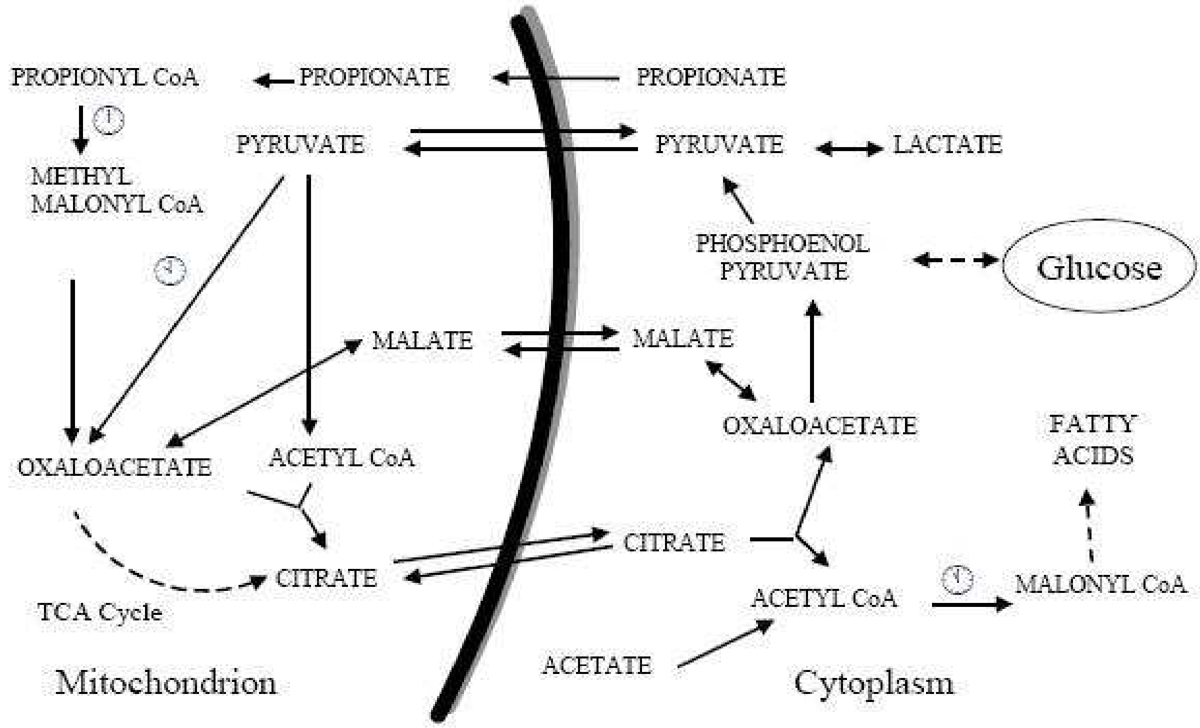

Fig 1: An overview of the pathways that involve biotin-containing enzymes

glucose. In mice, the activity of this enzyme is reduced when biotin is clinically deficient (Mock, 1996). In rats fed a low biotin diet, but without clinical signs of biotin deficiency, activity of propionyl-CoA carboxylase appeared to be reduced (Kramer *et al.,* 1984). Propionate is a minor metabolite in nonruminants but is the major glucose precursor in ruminants. Lactating cows must synthesize large amounts of glucose from propionate and if the activity of propionyl-CoA carboxylase is limited by biotin availability, a response to supplemental biotin in glucose production and milk production is possible. The effects of supplemental biotin on the activity of this enzyme in cattle have not been investigated. However ruminants receiving proportionately high-grain diets lack sufficient biotin in their rumen leads to lactic acidosis which is main contributing factors in lameness of dairy cows (Nocek, 1997).

SOURCES OF BIOTIN

Biotin is naturally present in plants and thus in the diets fed to dairy cows. Biotin is present in many foods and feedstuffs. Biotin is found in nature as free and protein-bound forms. Proteases in the digestive system degrade the bound form, releasing biocytin (the vitamin coupled to lysine). This bond can be degraded only under the action of a very specific enzyme (biotinidase), which is found in the pancreatic secretions and brush-border membrane, releasing biotin in its free form. (Santschi *et al*., 2005). However, not all of this biotin is bioavailable. Although biotin is present in many feedstuffs, scientists do not know how much of it is actually available to meet the cow's needs. There have been few studies in any species on the bioavailability of the biotin found in feedstuffs. In research with poultry, however, scientists have reported that less than half of the microbiologically determined biotin in feedstuffs is biologically available. It is also known that only d-biotin is biologically active. Feeds commonly fed to dairy cows contain variable concentrations of biotin. Generally higher protein feeds contain more biotin than feeds with low concentrations of protein. Feeds that are byproducts of fermentation such as brewers and distillers grains contain high concentrations of biotin (Weiss, 2001). Molasses can contain very high concentrations of biotin. For typical mixed diets, biotin concentrations range from 0.2 to 0.4 mg/kg of dry matter. Those concentrations will result in intakes of dietary biotin from unsupplemented diets of 4 to 10 mg of biotin/day for average lactating dairy cows. Bacteria in the rumen and large intestine can synthesize biotin that can then be absorbed by the cow. However,

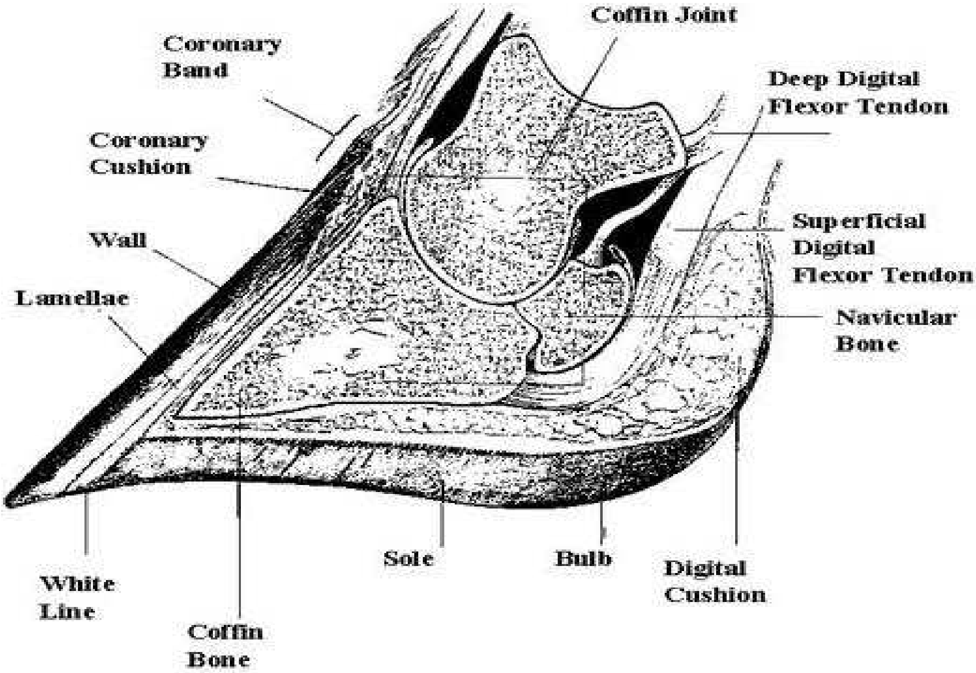

Fig 1: Cross section of the bovine claw

data on the quantity of biotin synthesized by ruminants are extremely limited and variable. No data are available with lactating dairy cows.

In ruminants, microbial synthesis of biotin occurs in the rumen and digestive tract. Historically, it has been assumed that that the mature ruminant animal does not require biotin supplementation because its ruminal microbes are able to synthesize enough of these compounds to avoid deficiency symptoms (McDowell, 2000). However high-concentrate rations may decrease biotin synthesis by microbes of the rumen. High proportions of readily fermentable sugars and starch in the ration produce acidic conditions in the rumen that result in imbalances among microbial species. Abel and Gomez (1997) reported that acidic rumen conditions reduced the microbial synthesis of biotin. This may help explain why higher-producing dairy cattle, which are more likely to receive high-concentrate rations, tend to have more hoof problems than other cows. Also, changes in the forage to concentrate ratio of the diet are known to alter the microbial activity of the rumen (Allison 1965; Institut National de la Recherche Agronomique 1978) and are therefore likely to affect the amount of vitamins produced. This suggests that rumen synthesis may be insufficient, particularly around calving or during early lactation. Moreover, getting a precise idea of the amount of each vitamin being synthesized in such a dynamic environment as the rumen is difficult, due to the continuous flow of digesta.

ARCHITECTURE OF HOOF

The hoof is an extremely important structure in an animal’s body. Although an animal with hoof problems may be able to function, chances are that optimal animal production and performance will be reduced depending upon the severity of the problem (Blowey, 1993).

The horn is a hard surface, structurally similar to the human fingernail, but functionally like the epidermis of the skin.

Table 1: Sources of Biotin

Feed	**Biotin, mg/kg of dry matter**
Starchy grains	0.090
Soybean meal	0.270
Wheat midds	0.330
Hay crop forages	0.450
Distillers/brewers grains	0.600
Cane molasses	0.800

Keratin is a family of fibrous structural proteins found in horns or hooves of all animals. Hoof quality is a fairly sensitive indicator of overall nutritional state. Although it can be modified by genetic factors or extremes of environmental conditions, if one or more key "ingredients" needed for growing healthy hooves is inadequate, hoof quality will suffer. Slight imbalances in hoof nutrition and structure can cause a breakdown of integrity and function. Many of these claw abnormalities occur in early lactation (Green *et al.,* 2002) and may be the result of nutritional deficiencies or hormonal changes occurring in dairy cattle at this stage of lactation. Many physiological changes occur in late gestation and into early lactation of the dairy cow that affect nutrient uptake and flow. During the process of keratinization, epidermal cells rely upon the dermal layers for the supply of nutrients, macro and trace minerals, and vitamins. This supply must be provided entirely via diffusion from blood vessels in the underlying dermis because the epidermis is an avascular tissue (Mulling *et al.,* 1999). Hendry *et al*., (1999) reported that little is known about the control mechanisms for nutrient flow and rate of hoof keratinization. Correct nutritional management is known to have a critical influence on horn quality. The architecture of these cells is typical of strong durable horn. Biotin is key nutrient that positively influences horn quality. Biotin optimises the production of keratin and the process of keratinisation – keratinisation is the process of producing strong fibrous proteins to create tough body structures (such as hooves), the presence of biotin increases the efficiency of this process.

BIOLOGICAL FUNCTIONS OF BIOTIN

Biotin, however, is involved in many metabolic pathways directly involved with milk synthesis. Because of the ever increasing productivity of dairy cows, the effects of supplemental biotin on milk production and metabolism of dairy cows was extensively studied (Bergsten *et al*., 1999; Fitzgerald *et al*., 2000; Singh *et al.,* 2011). Biotin plays a key role in the synthesis of glucose (an important energy source), protein and fat, and is involved in a diverse array of critical metabolic pathways. Biotin is a cofactor for microbial enzymes involved in propionic acid synthesis (Baldwin and Allison, 1983) and is also present in carboxylase-containing enzymes critical to gluconeogenesis and other metabolic roles in mammals (Mock, 2005). Amino-acid metabolism, cellular respiration, gluconeogenesis, and lipogenesis involve enzymes that require biotin (Mock, 1996). Biotin acts as a co-factor in carboxylase enzymes and thus plays an important role in both gluconeogenesis and fatty acid synthesis.

With regard to keratin formation, biotin-dependent enzymes are directly involved in the synthesis of lipids and glucose, with particular importance placed on synthesis of long-chain fatty acids (Meyer *et al.*, 1998; Weiss and Zimmerly, 2000). In this regard, significant differences in the fatty acid profile of horn tissue of cattle with claw lesions have been observed (Offer and Logue 1998). The hypothesis is that biotin improves the quality and quantity of lipids in the intercellular matrix that in turn improves membrane structure and function. Biotin is essential for the formation and integrity of the keratinized tissues (claws, and footpads) (Maynard *et al.,* 1979). It is involved in the differentiation of epidermal cells, and in the production of keratin and intracellular cementing substance (Mulling *et al.,* 1999). Biotin is necessary for synthesis of keratin, a hard structural protein involved in horn production. Healing has to be done from the inside. Protein, not biotin, is the primary constituent of the structural and protective tissues of the hoof. The role of biotin is to help break down the protein (amino acids) for faster action. This is why mega doses of protein with a few milligrams of biotin plays an important role in hoof health. The faster the amino acids work, the quicker the hoof heals. Mulling *et al*., (1999) demonstrated that biotin was essential for the formation of complex lipid molecules in the intracellular cementing substance (ICS). They also demonstrated, in biotin-deficient calves, that biotin deficiency affected keratinizing epidermal cells, as well as the composition of the intercellular cement (Mulling *et al.*, 1997). The first signs of biotin deficiency appear as dermatitis and softening of normally hard tissues such as horn. Research in pigs and horses has shown that biotin positively influenced the integrity of the hoof horn (Geyer, 1998).

ROLE OF BIOTIN IN HOOF HEALTH

Biotin is possibly the vitamin of greatest importance to the keratinization process. Several studies have shown that biotin can increase horn quality and promote horn formation (Hochstetter, 1998; Higuchi and Nagahata, 2001) and thus increase resistance against (Midla *et al.,* 1998; Campbell *et al.,*2000; Fitzgerald *et al.,*2000) and improve healing (Lischer *et al.,*1996) of claw lesions in cattle. The hoof of cattle contains the structural protein keratin, which forms an internal support lattice, similar to steel girders inside a building. Likewise, the cells that form the hoof horn are bonded together by a cementing substance similar to mortar in a brick wall. Biotin is specifically required for production of keratin, a tough, insoluble protein that is the chief structural component of horn tissue (and of human fingernails as well) and the cementing substance of hoof horn. Biotin is essential for the formation and integrity of the keratinized tissues (skin, hair, claws, and footpads) in mammals and birds (Maynard *et al.,* 1979). It plays an important role in differentiation of the epidermal cells that will become the hoof horn. More recently, biotin supplementation has also been reported to stimulate the production of intracellular cementing substance (ICS), a combination of glycoproteins and complex lipids that bond horn cells and harden the horn tissue. Biotin has long been recognized as an essential nutrient for the formation of sound hoof horn, the modified epidermal tissue that forms the hard outer casing of the hoof wall and sole. The supply of nutrients during the horn-forming process has a major influence on horn quality. If the supply of nutrients to the corium is sub-optimal for whatever reason, horn quality will be compromised. The incidence of many common hoof disorders are strongly influenced by the strength of the horn capsule. The aim is to achieve horn of good quality that has good biomechanical properties. Poor quality horn with an impaired, weakened structure, increases susceptibility to hoof disorders. Results from histological and biochemical studies have indicated that there are improvements in the inter- and intracellular ultrastructure of horn as a result of dietary biotin supplementation (Hochstetter, 1998). Biotin supplementation created a more defined and cohesive structure (Fritsche, 1990). Indeed, when researchers have induced clinical biotin deficiencies in calves, the signs have included soft, crumbling hooves along with skin lesions and hair loss. Biotin deficiencies in swine, poultry and horses have resulted in dermatitis and cracks and fissures in the feet and toes.

EFFECTS OF BIOTIN ON RUMEN METABOLISM

Biotin is synthesized in the rumen in varying amounts depending on the composition of the diet (forage:concentrate ratios; Abel *et al.,*2001). Microorganisms in the rumen synthesize biotin and other B vitamins, and an absolute biotin deficiency has not been demonstrated in ruminants (Roberts and Baggott, 1982). Estimates of ruminal synthesis of biotin ranged from 0 to 2 mg/day (approximately 0.8 mg/kg of digestible organic matter intake, Frigg *et al.,*1992). If those values are appropriate for lactating dairy cows, a typical cow consuming 20 kg of dry matter/day would synthesize 0 to 10 mg of biotin each day. Ruminal synthesis rate of biotin might be related to the diet. An in vitro study reported that biotin synthesis was reduced as the concentration of dietary forage was reduced (Da Costa Gomez *et al.,* 1998). In that study, biotin synthesis was reduced by about 50% when the in vitro substrate was 50% forage and 50% concentrate compared to an in vitro diet with about 80% forage. A study with duodenally canulated steers, however, reported no difference in biotin flow to the small intestine when steers were fed diets with 90% corn grain or 70% alfalfa meal (Miller *et al.,* 1986). If higher concentrate diets do indeed reduce ruminal biotin synthesis, then supply of biotin may be reduced when higher concentrate diets are fed to dairy cows. Mock (1996) reported that biotin deficiency was tied to insufficient pyruvate-carboxylase activity and due to an insufficient conversion of lactate to pyruvate resulting in cellular lactic acidosis. It may be possible that ruminants receiving proportionately high-grain diets lack sufficient biotin in their rumen to convert lactic acid to pyruvate and then oxaloacetate, thus predisposing them to lactic acidosis. Canadian research suggested that cattle fed high grain diets are subject to potential biotin deficiency since the rumen microbes responsible for biotin synthesis are sensitive to low rumen pH (Girard, 1998). Nocek (1997) reported lactic acidosis as one of the possible contributing factors in lameness of dairy cows. Such conditions can occur in the periparturient period and in early lactation (Blowey *et al.*,2000; Da Costa Gomez *et al.*,1998; Roberts and Baggot, 1982).

All the major cellulolytic bacteria in the rumen require biotin for growth (Baldwin and Allison, 1983). In two studies (Bentley et al.,1954; Milligan et al.,1967), supplemental biotin increased fiber digestion in vitro. Bacteria also require biotin to produce propionate. Propionate production by mixed ruminal bacteria was reduced in vitro when biotin was not included in the culture media. These data suggest that supplemental dietary biotin may alter ruminal metabolism and result in either increased fiber digestion (result in higher energy values of feeds) or in increased propionate production which could increase glucose production by the cow.

EFFCT OF BIOTIN SUPPLEMENTATION ON HOOF HEALTH

During the last few years, several studies have been published on the effects of supplemental biotin on lactating dairy cows (Bergsten *et al.*, 1999; Fitzgerald *et al.*,2000; Midla *et al.*,1998; Zimmerly and Weiss, 2001). Most of these experiments were designed to determine the effect biotin has on hoof health. These studies and field observations led Distl and Schmid (1994) to assess the role of biotin as a nutrient for responsive claw disorders in dairy cows. Scientists have offered several possible reasons why unsupplemented cows would have a biotin insufficiency and thus reduced hoof strength. Hoof and foot problems were reduced when these species received biotin supplementation in various research studies (Zenker *et al.*,1995). More recent studies have shown that in dairy and beef cattle fed supplemental biotin, hoof health was improved and the incidence of the common hoof problems was reduced. In a clinical study with 100 first-lactation heifers, Midla *et al.*, (1997) reported that 27 percent of the unsupplemented control heifers had rear lateral white line separation and 20 percent of the controls had rear medial white line separation. In the heifers receiving 20 mg biotin per head daily, however, only 10 percent of the animals had rear lateral white line separation, and only 2 percent had rear medial white line separation. Differences were significant 100 days after supplementation began (100 days into lactation). In a field study of 180 dairy cattle, Hagemeister and Steinberg (1996) reported that the animals receiving 10 mg per day of supplemental biotin had significantly less incidence of sole ulcers and heel erosion than unsupplemented controls. In studies that induced biotin deficiency in calves, the animals did indeed exhibit soft hooves that were prone to crack--along with poor weight gains, rough hair coats and scouring. In other studies (Hurstel, 1983), fattening veal calves fed supplemental biotin at 500 mg/kg of dry milk replacer showed improved growth rate, weight for age, and feed conversion compared to unsupplemented calves. Potzsch *et al.*, (2003) reported biotin supplemented at 20 mg/d for longer than 6 months reduced white line disease in multiparous cows by 45% in 8.5 cases per 100 cow years. However, the effect of biotin in primiparous cows was not significant. The effect of biotin supplementation on various foot lesions and hoof ceramide composition of toe (wall) and sole portions of hooves was studied in crossbred dairy cattle. A significant decline was observed in heel erosions and sole avulsions along with total disappearance of white line fissures and double soles in the biotin supplemented cattle resulting in decrease in the overall disease score. (Randhawa *et al.*, 2008). Singh and Lathwal (2009) reported that biotin supplementation had a signifaicant ($P< 0.01$) effect on recovery period of hoof lesions as well as locomotion score. Above studies indicate that biotin reduced the incidence of white line abnormalities in particular and other claw diseases, such as sole hemorrhage, sole ulcers, digital dermatitis, and heel erosion.

EFFCT OF BIOTIN SUPPLEMENTATION ON PLASMA BIOTIN LEVELS

Midla *et al*., (1998) reported a decrease in plasma biotin levels of dairy cows 25 DIM, returning to constant levels from 100 DIM until the end of lactation. Roberts and Baggott (1982) reported that lame cows had lower plasma biotin levels when compared with cows with no history of lameness, and studies have shown that orally administered biotin raises plasma (Zinn *et al.,*1987) and milk (Frigg *et al.,*1992) biotin levels in dairy cows. Lactating dairy cows with a history of lameness have been found to have lower plasma biotin levels (Roberts and Baggott, 1983). Cooke and Brumby (1983) fed supplemental biotin at 20 mg/head/day for four months to a herd of Friesian cows with severe lameness, and the animals showed 50 percent reduction in lameness from hoof horn weakness. In this study, cows fed supplemental biotin also had significantly increased plasma biotin levels compared to controls. Results showed a significant impact on claw parameters in direct proportion to increased plasma biotin when the cows received the vitamin as an oral 20 mg/day supplement for 11 months. Frigg *et al.*, (1993) noted that feeding supplemental biotin at 20 mg/head/day increased serum biotin levels from 300-800 ng/l to 3,000-8,000 ng/l in yearling heifers. In these studies, increases in serum levels suggest that about 50 percent of supplemental biotin escapes rumen degradation and is bioavailable to the animal. Lischer *et al*., (1996) reported a significant correlation between short-term healing of claw lesions and serum biotin levels, which had been elevated with dietary supplementation of 20 mg biotin per head daily. The rate of new horn formation over the lesions was significantly increased in supplemented cows. So it is hypothesized that biotin supplementation may benefit cows during the period of high demand on the cow, around calving, and during early lactation.

RECOMMENDED DOSES OF BIOTIN SUPPLEMENTATION IN DAIRY CATTLE

Although the evidence is beginning to suggest positive effects on hoof and claw health from biotin supplementation, there is still no standard recommendation for biotin use or levels for cattle. Scientists are looking to supplemental biotin, along with zinc and other trace minerals. Adequate biotin through dietary supplementation may help maintain harder hoof horn. Also, along with zinc, biotin is depleted under stress. At weaning and placement on feed, demand for micronutrients is greatest. The preliminary results of Bergsten *et al.*, 2003 studies show that yearling heifers receiving supplemental biotin at 10 mg per head daily had a lower incidence of sand cracks than unsupplemented animals (10% vs. 27%). Biotin and mineral imbalances must be corrected through the various seasons and production cycles. In the face of a zinc deficiency, biotin alone may help, but it may not help enough. Overall, the potential rumen shock from the switch to pasture with low fiber and high protein in the spring--after a winter of just the opposite--may be the most powerful stress factor to be controlled. Adding biotin, zinc and other nutrients to the ration may help minimize the effects of this stress on hoof health. The primary targets for dietary biotin supplementation are dairy herds with ongoing hoof problems and high producing cows fed high-grain rations. Bred replacements heifers should also be supplemented. Some studies have supplemented rations with 10 mg of biotin per head daily, but most have included 20 mg per head daily. It is recommended that heifers receive 10 to 20 mg of biotin per head daily, starting at 15 months of age as part of a heifer rearing program. It is recommended that cows receive 20 mg per head daily throughout lactation and 10 to 20 mg per head daily during the dry period.

CONCLUSIONS

Integrity of claw horn is one prerequisite for claw health, which in turn is the prerequisite for overall animal well being, productivity, and potential profitability. Formation of keratin proteins is an essential part of a systematic process of cellular changes that transform living, highly functional epidermal cells into fibrous, structural horn cells with no metabolic activity. Biotin play important role in the production and maintenance of healthy keratinized tissues. It can be

concluded that biotin concentration is altered by changes in forage to concentrate ratio, which suggests that the supply of this vitamins to dairy cows is influenced by the composition of the diet and rumen environment. A better knowledge of true requirements of ruminant animals for biotin is required to verify if ruminal synthesis provides optimal supply of these nutrients, under different dietary conditions. Increasing the bioavailability of biotin improves their utilization and thus contributes to an improved integrity of keratinized tissues, hoof and claw. Most of the studies have shown that in dairy cattle fed 10-20 mg per head supplemental biotin daily, hoof health was improved and the incidence of the common hoof problems was reduced.

REFRENCES

1. Abel, H. J., C. DaCosta Gomez I. Immig. and Steinberg W. (2001). Research note: Effect of increasing dietary concentrate levels on microbial biotin metabolism in the artificial rumen simulation system (RUSITEC). Arch. Anim. Nutr. 55:371–376.
2. Abel, H., and Gomez C. (1997). Unpublished data; Inst. Agri. Nutr., Gottingen, Germany.
3. Allison, M. J. (1965). Nutrition of rumen bacteria. Pages 369–377 in R. W. Dougherty, R. S. Allen, W. Burroughs, N. L. Jacobson, and A. D. McGilliard, eds. Physiology of digestion in the ruminant. Butterworths, Washington, DC.
4. Baggott, D.G. (1982). Losses due to lameness caused by physical contact with buildings. Technical Journal 30, 12–15.
5. Baldwin, R. L., and Allison, M. J. (1983). Rumen metabolism. J. Anim. Sci. 57:461–477.
6. Bentley, O. G., Johnson, R. R., Vanecko, S. and Hunt., C. H. (1954). Studies on factors needed by rumen microorganisms for cellulose digestion in vitro. J. Anim. Sci. 13:581-593.
7. Bergsten, C., Greenough, P. R., Gay, J. M.., Dobson, R. C. and Gay, C. C. (1999). A controlled field trial of the effects of biotin supplementation on milk production and hoof lesions. J. Dairy Sci. 82 (suppl. 1):34 (abstr.)
8. Bergsten, C., Greenough, P. R., Gay, J. M., Seymours, W. M. and Gay, C. C. (2003). Effects of biotin supplementation on performance and claw lesions on a commercial dairy farm. J. Dairy Sci. 86:3953– 3962.
9. Blowey, Roger. (1993). Cattle Lameness and Hoof Care: An Illustrated Guide. Ipswich, UK: Farming Press.
10. Blowey, R. W., Phipps, R. A., Jones, K. and Barringer, A. J. (2000). A comparison of the effects of high fibre and high starch diets on hoof lesion score in multiparous dairy cows. Pages 337–339 in Proc. XIth Int. Symp. on Disorders of the Ruminant Digit and III Int. Conf. on Bovine Lameness.
11. Brookes, P. H., Smith, D. A. and Irwin, V.C.R. (1977). Biotin supplementation of diets, the incidence of foot lesions and the reproductive performance of sows. Vet. Rec. 101:46–50.
12. Campbell, J. R., Greenough, P. R. and Petrie, L. (2000). The effects of dietary biotin supplementation on vertical fissures of the claw wall in beef cattle. Can. Vet. J. 41:690–694.
13. Campbell, J., et al., (1996). The effect of biotin on sand cracks in beef cattle.Proc. 9th Int. Symp. on Disorders of Ruminant Digit. Mitzpeh Rachel, Jerusalem.
14. DaCosta-Gomez, C. M., Masri, A. L., Steinberg, W. and H. Abel. (1998). Effect of varying hay/barley

proportions on microbial biotin metabolism in the rumen simulating fermenter RUSITEC. Proc. Soc. Nutr. Phys. 7:30. (Abstr.)
15. Distl, O. and Schmid, D. (1994). The Influence of Biotin Supplementation on the Conformation, Hardness and Health of Claws of Dairy Cows. Tierarztliche Umschau. 49:581-588.
16. Enting, H., Kooij, D., Dijkhiuzen, A. A., Huirne., R. B. M. and Noordhuizen-Stassen, E. N. (1997). Economic losses due to clinical lameness in dairy cattle. Livestock Prod. Sci. 49:259-267.
17. Esslemont, R.J. and Kossaibati, M.A. (1997). Culling in 50 dairy herds in England. Veterinary Record 140, 36–39.
18. Fitzgerald, T., Norton, B., Elliott, W., Podlich, R. H. and Svendsens,O. L. (2000). The influence of long-term supplementation with biotin mon the prevention of lameness in pasture fed dairy cows. J. Dairy Sci. 83:338–344.
19. Frigg, M., Straub, O. C. and Hartmann, D. (1992). The bioavailability of supplemental biotin in cattle. Int J Vitam Nutr Res 63:122-128.
20. Fritsche, A. (1990). Biotin verändert das Zytokeratinmuster von kultivierten Keratinozyten. DVM thesis, Faculty of Veterinary Medicine, University of Zürich.
21. Garbarino, E. J., Hernandez, J. A., Shearer, J. K., Risco, C. A. and Thatcher, W. W. (2004). Effect of lameness on ovarian activity in postpartum Holstein cows. J. Dairy Sci. 87:4123-4131.
22. Geyer, H. (1998). The influence of biotin on horn quality of hooves and claws. Pages 192–199 in 10th International Symposium on Lameness in Ruminants, Lucerne, Switzerland.
23. Geyer, H., and Schulz, J. (1994). The long term influence of Biotin supplementation on hoof horn quality in horses. Schweiz. Arch. Tierheilk. 136 (Supp. 4):137–149.
24. Girard, C. L. (1998). B-Complex vitamins for dairy cows: A new approach. Can. J. Anim. Sci. 78(Suppl. 1):71–90.
25. Green, L. E., Hedges, V. J., Schukken, Y. H., Blowey, R. W. and Packington A. J. (2002). The impact of clinical lameness on the milk yield of dairy cows. J. Dairy Sci. 85:2250–2256.
26. Hagemeister, H. and Steinberg, W. (1996). Effects of a long-term dietary biotin administration on claw health in dairy cows. Proc. 19th Int. Symp. Disorders Bovine Digit, Jerusalem, Israel.
27. Hedges, J., Blowey, R. W., Packington, A. J., O’Callaghan, C. J. and Green, L. E. (2001). A longitudinal field trial of the effect of biotin on lameness in dairy cows. J. Dairy Sci. 84:1969–1975.
28. Hendry, K. A. K., MacCallum, A. J., Knight, C. H. and Wilde, C. J. (1999). Effect of endocrine and paracrine factors on protein synthesis and cell proliferation in bovine hoof tissue culture. J. Dairy Res. 66:23–33.
29. Higuchi, H. and Nagahata, H. (2001). Relationship between serum biotin cnocentration and moisture content of the sole horn in cows with clinical laminitis or sound hooves. Vet. Rec. 148:209–210.
30. Hochstetter, T. (1998). Horn quality of the bovine hoof under the influence of biotin supplementation. DVM Inaugural Dissertation. Journal #2176. Free University of Berlin, Germany.
31. Hurstel, O. (1983). Supplementation of calf milk replacer diets with biotin. Biotin in Ruminant Nutrition. Roche Basel Publication Index No. 1874.
32. Institute National de la Recherche Agronomique. (1978). Alimentation des ruminants. INRA Publications ed. Versailles, France. 597 pp.
33. Kluenter, A. M., Steinberg, W. and Schuep, W. (1993). Influence of biotin supplementation on the concentration of biotin in the blood plasma and milk of dairy cows. Roche

Res. Rep. No. B-162–112. Roche Vitamins Inc., Parsippany, NJ.
34. Koester, A., Meyer, K., Mulling, C. K. W., Scaife, J. R., Birnie, M. and Budras, K. D. (2002). Effects of Biotin supplementation on horn structure and fatty acid pattern in the bovine claw under field conditions. Pages 263–267 in Proc 12th Int. Symp. Lameness Ruminants. J. K. Shearer, ed. Orlando, FL.
35. Kramer, T. B., Briske-Anderson, M. S., Johnson, B. and Holman, R. T. (1984). Effects of biotin deficiency on polyunsaturated fatty acid metabolism in rats. J. Nutr. 114:2047-2052.
36. Lischer, C., et al., (1996). The effect of biotin in the treatment of uncomplicated claw lesions with exposed corium in dairy cows. Part II: The healing process in supplemented animals. Proc. 9th Int. Symp. on Disorders of Ruminant Digit. Mitzpeh Rachel, Jerusalem.
37. Livesey, C.T. and Fleming, F.L. (1984). Nutritional influences on laminitis, sole ulcer and bruised sole in Friesian cows. Vet. Rec. 114:510-512.
38. McDowell, L. R. (2000). Vitamins in animal and human nutrition. Iowa State University Press, Ames, IA. 793 pp.
39. Manson, F.J. and Leaver, J.D. (1989). The effect of concentrate: silage ratio and of hoof trimming on lameness in dairy cattle. Brit. Soc. Anim. Prod. 49:15-22.
40. Maynard, L. A., Loosli, J. K., Hintz, H. F. and Warner, R. G. (1979). Animal Nutrition. 7th ed. McGraw-Hill Book Co., New York, NY.
41. Meyer, K., Hazlerigg, D., Galbraith, H. and Lomax, M. A. (1998). Characterization of keratin proteins in bovine sole horn. Pages 210– 211 in Proc. 10th Int. Symp. on Lameness in Ruminants. C. J. Lischer, ed. Lucerne, Switzerland.
42. Midla, L. T., Hoblet, K. H., Weiss, W. P. and Moeschberger, M. L. (1998). Supplemental dietary biotin for prevention of lesions associated with aseptic subclinical laminitis (pododermatitis aseptic diffusa) in primiparous cows. Am. J. Vet. Res. 59:733–738.
43. Miller, B. L., Meiske, J. C. and Goodrich, R. D. (1986). Effects of grain source and concentrate level on B-vitamin production and absorption in steers. J. Anim. Sci. 62:473–483.
44. Milligan, L. P., Asplund, J. M. and Robblee, A. R. (1967). In vitro studies on the role of biotin in the metabolism of rumen microorganisms. Can. J. Anim Sci 47:57-64.
45. Mock, D. M. (1996). Biotin. Pages 220–235 in Present Knowledge in Nutrition. 7th ed. E. E. Ziegler and L. J. Filer, Jr., ed. ILSI Press, Washington, DC.
46. Mock, D. M. (2005). Biotin. Pages 189–207 in Modern Nutrition in Health and Disease. 10th ed. M. E. Shils, M. Shike, A. C. Ross, B. Caballero, R. L. Weinsier, R. J. Cousins, ed. Lippincott Williams & Wilkins, Baltimore, MD.
47. Mulling, C. K. W., Braguella, H. H., Reese, S., Budras, K. D. and Steinberg, W. (1999). How structures in bovine hoof epidermis are influenced by nutritional factors. Anat. Histol. Embryol. 28:103–108.
48. Mulling, C., Bragulla, H. and Budras, K. D. (1997). Nutritional factorsand horn quality in cattle hooves. Pages 396–397 in Proc. 9th Int. Conf. on Prod. Diseases in Farm Animals. H. Martens, ed. Stuttgart, Germany.
49. Nocek, J. E. (1997). Bovine acidosis: Implications on laminitis. J. Dairy Sci. 80:1005-1028.
50. Offer, J. E. and Logue, D. N. (1998). The effect of lameness in the dairy cow on the fatty acid profile of claw horn lipids. Pages 220–221 in Proceedings of 10th Int. Symp. on Lameness in Ruminants. C. J. Lischer and P. Ossent, Dept. of Veterinary Surgery, University of Zurich, Switzerland.

51. Peterse, D.J., Korver, S., Oldenbroek, J.K. and Talmon, F.P. (1984). Relationship between levels of concentrate feeding and incidence of sole ulcers in dairy cattle. Vet. Rec. 115:629-630.
52. Potzsch, C. J., Hedges, V. J., Blowey, R. W., Packington, A. J. and Green, L. E. (2003). The impact of parity and duration of biotin supplementation of white line disease lameness in cattle. J. Dairy Sci. 86:2577–2582.
53. Randhawa S.S., Dua, K., Randhawa, C.S. and Munshi, S.K. (2008). Effect of biotin supplementation on hoof health and ceramide composition in dairy cattle Veterinary Research Communications. 32(8):599-608.
54. Roberts, C. J., and Baggott, D. G. (1982). Biotin experiments with dairy cattle. Pages 13–20 in Proc. Roche Vit. Symp., London.
55. Santschi, D. E., Chiquette, J., Berthiaume, R., Martineau, R., Matte, J. J., Mustafa, A. F. and Girard, C. L. (2005). Effects of the forage to concentrate ratio on B-vitamin concentrations in different ruminal fractions of dairy cows. Can. J. Anim. Sci. 85: 389–399.
56. Sarasin, A. (1994). An in vitro model for organotypic epidermal differentiation: Effects of biotin. DVM Thesis. University of Zurich, Switzerland.
57. Singh, Y. and Lathwal, S.S. (2009). Impact of biotin supplementation on recovery of hoof lesions, DMI and productive performance of Karan Fries cows. Indian Veterinary Journal, 87: 365-366.
58. Singh, Y., Lathwal, S.S., Chakravarty, A.K., Gupta, A.K., Mohanty, T.K., Raja, T.V., Dangi, R.L. and Roy, B.K. (2011). Effect of lameness (hoof disorders) on productivity of Karan Fries crossbred cow. Animal Science Journal. 82:169–174
59. Steinberg, W., Kluenter, A. M., Bohn, N., Griggio, C. and Schuep, W. (1995). Biotin balance studies in dairy cows with and without biotin supplementation. Roche Res. Rep. No. B-164–549. Roche Vitamins Inc., Parsippany, NJ.
60. Weiss, W. P., and Zimmerly, (C. A. 2000). Effects of biotin on metabolism and milk yield of dairy cows. Pages 22–30 in Proc. 62nd Cornell Nutr. Conf. for Feed Manuf. Cornell Univ., Ithaca, NY.
61. Weiss, Bill (2001). Effect of supplemental biotin on performance of lactating dairy cows. Dia Internacional Ganadero Lechero Conference, October, 2001, Delicias, Chihuahua Mexico. Published in Proceedings DIGAL Conference, pages 7-17.
62. Whitehead, C. C. (1988). Biotin in der Tierernahrung. Grenzach-Wyhlen, Hoffman-La Roche, ACO Ltd., Basel, Switzerland.
63. Zenker, W., et al., (1995). Histological and physical assessment of poor hoof horn quality in Lipizzaner horses and a therapeutic trial with biotin and a placebo. Equine Vet. J. 27:183.
64. Zinn, R. A., Owens, F. N., Stuart, R. L., Dunbar, J. R. and Norman, B. B. (1987). B-Vitamin supplementation.

