

Biotin, Hoof Health and Milk Production in Dairy Cows

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Do Ruminants Need Supplemental B-Vitamins?

The water-soluble, or B-vitamins include thiamin (B₁), riboflavin (B₂), pyridoxine (B₆), cobalamin (B₁₂), niacin, folic acid, pantothenic acid, biotin, ascorbic acid and choline. With a few exceptions, mammals synthesize niacin, ascorbic acid and choline endogenously. Thus the extent of limitation of these vitamins depends to some degree on the availability of their precursors: tryptophan, vitamins B₂ and B₆ for niacin; glucose for ascorbic acid; and methionine, folic acid and vitamin B₁₂ for choline synthesis (McDowell, 2000). The remaining B-vitamins must be obtained entirely from the diet or microbial synthesis.

Ruminants have been assumed not to require supplemental B-vitamins due to the pre-gastric synthesis occurring in the rumen. However few of the B-vitamins have ever been studied in high producing dairy cows. In swine, genetic selection for more rapid and efficient lean growth has increased their responsiveness to dietary B-vitamin fortification, up to 470% of NRC levels (Stahly, 1995). Although adult ruminants may not display obvious vitamin deficiency signs (hoof lesions may be an exception), B-vitamins may still be limiting nutrients with respect to optimal rumen fermentation, intermediary metabolism, reproduction or immune function. High producing dairy cows would seem particularly susceptible to marginal B-vitamin status due to their large metabolic capacity and high metabolic turnover rate during lactation.

Biotin Synthesis and Status of Dairy Cows

Biotin is a known required co-factor for microbial enzymes involved in propionic acid synthesis and other aspects of bacterial metabolism (Baldwin and Allison, 1983). All of the predominant species of cellulolytic bacteria in the rumen require biotin, and do not synthesize biotin (ibid). Omission of biotin significantly reduces both cellulose digestion and propionic acid synthesis by rumen organisms in vitro (Milligan et al., 1967). Diet can influence rumen biosynthesis of biotin. Successive studies by De Costa Gomez et al (1998) using the RUSITEC artificial rumen system, showed that biotin synthesis was reduced by approximately 50% as the diet forage to grain ratio was decreased from 80% to 50% forage or less. Therefore rations typically fed to lactating cows may reduce net biotin synthesis in the rumen.

Studies on biotin synthesis, absorption, kinetics and balance have been conducted in both lactating and non-lactating cattle (Frigg et al., 1993, 1994; Miller et al., 1986; Kluentner et al., 1994, 1995; Steinburg et al., 1993, 1995). Typical biotin intake from feedstuffs is 3-6 mg/day. In poultry and swine biotin availability from feeds ranges from

100% in corn to near 0% in wheat (Frigg, 1984). Molasses has the highest biotin content of common feed ingredients with 0.7 to 1.0 mg per kg and 75% availability (Frigg, 1984).

Rumen synthesis of biotin has been estimated at 0-4 mg/day and net biotin absorption calculated to be 3-5 mg per day. For example, Miller et al. (1986) reported that biotin uptake was 0.5 to 2 mg per day in steers fed different grain sources.

The bioavailability of oral biotin has averaged 50% in lactating and non-lactating cows (Frigg et al., 1993). Oral biotin intake has a linear effect on both plasma and milk biotin concentrations (Steinberg et al., 1994). This response has been replicated in the research trials with biotin in cattle. The half-life of absorbed biotin in cattle has been measured at 8-16 hours (Frigg et al., 1994). Biotin is apparently synthesized but not well absorbed from the large intestine of cattle as evidenced by the negative biotin balance recorded in some balance studies (Steinberg et al., 1995).

Hoof Health and Dairy Herd Profitability

A national survey of beef and dairy slaughter cattle found that 40.2% of culled dairy cows and 29.1% of culled dairy bulls displayed obvious clinical symptoms of lameness, i.e. "founder, misshapen or cracked hooves, arthritis, foot rot, structural abnormalities, broken leg or non-ambulatory" (Roeber et al., 2000). A number of papers have documented the costs of lameness in dairy cattle and discussed causes and prevention in detail (Bergsten, 1995; Guard, 2000; Hoblet et al., 2000; Shearer and van Amstel, 2000; Sprecher et al., 1997). Estimates of the incidence of clinical lameness in U.S. and Canadian dairy herds range from 15 to 50%, while costs have been calculated at \$210-\$346 per treated case. Increased involuntary culling, decreased reproductive performance and decreased milk production have been identified as the three largest cost factors in lameness (Guard, 2000). In a dairy herd with a 35% cull rate, the average cow herd-life is 2.9 years (Silva, 1986). With excellent management the break-even age of replacement heifers entering a dairy herd is 3.1 years (Cady and Smith, 1996).

Hoblet et al (2000) note that in their survey of hoof lesions in 13 high-producing Ohio dairy herds there was no relationship between a dairy producer's perception and the actual incidence of hoof disease. The use of a practical lameness scoring system (Sprecher et al., 1997) in conjunction with a professional hoof care program is a useful approach to assessing and correcting hoof disease in dairy herds.

Lameness in dairy cattle is a multi-factorial disorder. Control of lameness in dairy herds requires a multidisciplinary management approach involving the herd manager, veterinarian, hoof trimmer and nutritionist. Environment, nutrition and correct hoof trimming are three major areas of concern.

Lesions associated with subclinical laminitis result from impaired production of hoof horn (Hoblet et al., 2000). The process of hoof horn formation is directly dependent on

the integrity of the capillary blood supply in hoof corium and the concentration of essential nutrients in the blood. Marginal nutrient status can reduce the integrity of hoof horn, particularly under stressful environmental conditions when the rate of hoof horn production may increase, during bouts of sub-clinical laminitis or when physiologic stress temporarily interrupts the growth of hoof horn (Blowey, 1993).

Effects of Supplemental Biotin on Hoof Health

Prior to studies in cattle, biotin was known to affect the health and integrity of skin, hair, footpads in poultry, hooves in swine and horses and fingernails in humans (Bryant et al., 1985; Hochman et al., 1993; Josseck et al., 1995; McDowell, 2000; Reilly et al., 1998). The hypothesis of the biotin research studies in cattle was that if biotin status of cattle is marginal, then supplemental biotin should result in a significant reduction in hoof lesions. The results of a number of these studies are summarized below.

Response of Hoof Disorders to Supplemental Biotin

Sole Ulcer and Heel Horn Erosion.

A controlled field study of 180 dairy cows (Hagemeister and Steinberg, 1996; Voigt et al., 2000) reported that cows fed 10 mg/day supplemental biotin exhibited a significant reduction in the incidence of sole ulcer and heel horn erosion over a 2-year period. Days open were reduced in the biotin group during the second year. As will be discussed below, response time of similar hoof disorders was more rapid (6 to 10 months) when 20 mg/day of biotin was fed continuously.

White Line Separation.

A controlled clinical study was conducted using 100 first-lactation heifers on a large, commercial dairy herd in Ohio (Midla et al., 1998). Heifers were fed either 0 or 20 mg/day of supplemental biotin from calving through the first lactation. Biotin supplementation resulted in a significant reduction in white line separation by 100 days in lactation and a significant increase in 305-day milk production (693 lb).

Recently, Hedges et al. (2000) conducted a five-herd, controlled field trial based on 900 cow lactations. Cows in five commercial herds were blocked according to hoof health history, parity and milk production and assigned to receive either 0 or 20 mg/day supplemental biotin. Individual feeding of biotin took place during milking so that both treatments could be applied on each farm. Survival analysis was used to assess the effects of biotin on lameness. Supplemental biotin significantly reduced the incidence of lameness from white line separation with a risk ratio of 0.54 compared to controls. Similar to Midla et al. (1998), the effect of biotin on white line integrity became noticeable after 130 days of supplementation. This corresponds to the apparent turnover rate of hoof horn in the white line.

Digital and Interdigital Dermatitis (Hairy Heel Warts and related disease).

A controlled, clinical trial with 56 dairy cows over 11 months found that 20 mg/day supplemental biotin resulted in a significant reduction in the incidence of interdigital dermatitis and sole bruising (Distl and Schmid, 1994). Similar results were

found in a randomized clinical field trial with 40 dairy cows where 20 mg/day of biotin resulted in a reduction in the incidence of interdigital dermatitis over an 8 to 12 month period (Hochstetter, 1998). However in a British study (Hedges et al., 2000) there was not a significant effect of supplemental biotin on the incidence of digital dermatitis.

Healing of Sole Ulcer.

A clinical field study of 236 claw lesions with exposed corium in 160 cows in 82 dairy herds found that cows fed 20 mg/day of biotin experienced significantly better healing of the lesions (Lischer et al., 1996). A regression analysis of the data found a highly significant linear relationship between serum biotin concentration and the rate of new horn formation over the lesions. A recent study (Hochstetter, 1998) reported that supplemental biotin resulted in increased keratinization and cementing hoof horn and an increase in biotin concentration in the live epidermis (horn forming) tissue layer of the hoof.

Vertical Fissures and Horizontal Ridging of the Hoof Wall.

A controlled field study of 265 purebred Hereford cows with a 37% incidence of vertical fissures (sand cracks) of the hoof wall was conducted. Supplementing a balanced mineral program with 10 mg/day of biotin resulted in a 50% reduction in the incidence of new vertical fissures and coronary band lesions (Campbell et al., 2000). A controlled study of 100 dairy cows in Washington State reported that 20 mg/day of supplemental biotin reduced the incidence of horizontal ridging of the hoof wall and sole hemorrhage over a 12-month period (Bergsten et al., 1999).

General Lameness in Seasonally Calved Dairy Cows.

One of the larger and more recent trials (Fitzgerald et al., 2000) took place with pastured dairy cows in the Atherton region of northern Australia. Lameness is a problem in this region due to factors such as: seasonal calving during the wet season, the diet of high quality pasture with supplemental grain, and the long walking distances to and from milking by way of partially paved/partly mud cow lanes. A total of 20 farms (10 control and 10 biotin supplemented) with a total of 2700 cows participated in the study. Both the farmers and the evaluators were blind to the treatments to prevent bias. The net result after 4 months was that the cows fed 20 mg/day of biotin had a significant reduction in overall lameness, antibiotic treatments, and application of hoof shoes (Cowslips®; American Giltspur, Inc., Sarasota, FL). The participating farmers kept track of lameness during the trial. The economics of biotin were favorable at the Australian milk price of ~\$9.30/cwt. In addition to effects on hoof health, somatic cell count was significantly reduced in biotin supplemented cows. Analysis of reproduction data indicates that biotin supplemented cows had a significant reduction in days open of 5 days (R. Elliott, personal communication). These results revealed that in addition to a beneficial effect of biotin on hoof health, hoof disorders are not limited to confinement housing systems. Rather hoof lesions and lameness appear to be more related to the overall "hoof stress" load in a herd. Increased hoof stress increases the need to rebuild hoof horn and therefore the need for essential nutrients.

Mechanism of Biotin Effects on Hoof Horn Quality

Mulling et al (1999) have reviewed the effects of essential nutrients, including biotin, on hoof horn formation and structure. They reported that biotin deficiency in calves resulted in an impairment of the normal keratinization process and a reduction in the intracellular cementing substance between the horn cells. Both these processes affect hoof horn quality. Using cell culture techniques, Sarasin (1994) determined that biotin was required for complete differentiation of the bovine epidermis and for production the 48 kDa, 56 kDa and 56.5 kDa keratin proteins. This is consistent with previous observations that biotin stimulates the incorporation of amino acids into protein, and increases the intracellular concentration of cGMP (Mock, 1992). Biotin supplementation has resulted in increased tensile strength of hoof horn in both horses (Geyer and Schulze, 1994; Zenker et al., 1995) and cattle (Schmid and Geyer, 1995). Biotin supplementation has also been observed to increase several qualitative measures of hoof horn quality such as tubule density, presence or absence of micro-cracks and disruption of the normal pattern of hoof horn histology (Kempson et al., 1989; Hochstetter et al., 1998; Zenker et al., 1995; Geyer and Schulze, 1994). These studies indicate that when the concentration of biotin in the epidermis becomes limiting for hoof horn synthesis, that there is a significant reduction in the quality of hoof horn produced. Hoof horn production is a continuous process and so it is important to maintain the biotin status of cows at optimal levels throughout the lactation cycle.

Effects of Supplemental Biotin on Metabolism and Milk Production

Biotin is a required co-factor for several microbial and mammalian carboxylase enzymes. In addition to the role biotin plays in rumen bacterial metabolism, discussed earlier, biotin is a required prosthetic group for enzymes involved in propionate metabolism (propionyl-CoA carboxylase), gluconeogenesis (pyruvate carboxylase), fatty acid synthesis (acetyl-CoA carboxylase) and leucine metabolism (3-methyl-crotonyl-CoA carboxylase) (Mock, 1992). The activity of these enzymes is regulated at several levels, one of which is biotin availability. Based on data from dairy cows and other species, the activities of propionyl-CoA carboxylase (Weiss, 2000) or pyruvate carboxylase (Greenfield et al., 1999) may limit the rates of gluconeogenesis during early lactation. Hypothetically biotin availability could limit the activity of one or both of these enzymes, however no data currently exists to answer this question.

Bonomi et al (1996) supplemented 135 Italian Friesian dairy cows with 0, 2, 6 or 10 mg biotin per day either in native or rumen-protected (lipid-coated) form during the first five months of lactation. Milk production and composition were measured every ten days. The cows were housed in three commercial dairy herds whose milk was shipped to a single cheese plant in the Parma region of Italy. All cows were fed an identical ration consisting of alfalfa hay (7-8 kg), corn silage (20 kg) and a grain mix fed according to milk yield. The grain mix contained a large proportion of byproduct feeds such as flour from corn, barley, soy and wheat, various brans and beet pulp, along with

soybean meal and fishmeal as protein supplements. Biotin supplementation at 10 mg per day increased milk yield by 3.3 lbs per cow.

Midla et al (1998) reported a 2.2 lb per day increase in first-lactation milk production in heifers supplemented with 20 mg per day biotin from calving through 305 days of lactation. Associated with this increase in milk production was a significant reduction in the incidence of white line separation in the biotin-supplemented heifers.

Bergsten et al (1999) conducted a controlled field trial with 180 cows in a commercial dairy herd fed supplements by computer feeder. Cows were supplemented with either 0 or 20 mg per day biotin during lactation over a one-year period. Although lameness was not a major problem in the herd (P.R. Greenough, personal communication), there were significant reductions in hoof wall ridging and sole hemorrhage in the biotin supplemented cows. Milk production was also increased in the biotin-supplemented cows, recorded as DHIA 305 day milk yield, by 6.3 lbs per day. The size of this increase led the authors to speculate that metabolic effects of biotin accounted for a significant portion of the milk production response.

Zimmerly and Weiss (2000) fed dairy cows (n=45) either 0, 10 or 20 mg supplemental biotin per day starting 14 days before calving through 100 days of lactation. Individual milk yield and dry matter intake was recorded daily. Cows fed 0, 10 or 20 mg biotin produced an average of 81.3, 83.3 and 87.5 lbs of milk per day over the first 100 days of lactation. Biotin had a significant linear effect on milk production. The response to 20 mg biotin of +6.2 lbs per day was similar to the increase reported by Bergsten et al. (1999) of +6.3 lbs per day over 305 days of lactation. In this study the response to biotin was observed during the first week after calving and continued throughout the first 100 days of lactation. The rapid response indicated that biotin had a direct metabolic effect on milk production rather than a secondary effect via improved hoof health.

Conclusion

Dairy cows and certain rumen bacteria have a requirement for biotin that may or may not be met by rumen biotin synthesis. The positive response of hoof lesions and milk production to supplementary biotin in dairy cows is strong evidence that their biotin status is less than optimal. Beef cows have also been shown to respond positively to biotin supplementation in one trial so far (Campbell et al., 2000).

The results of these studies indicate that supplemental biotin should be considered as nutritional management tool to enhance hoof health and milk production. For optimal hoof health lactating cows should be supplemented with 20 mg per day biotin and dry cows or beef cows with 10 mg per day. For milk production, 20 mg biotin per day has resulted in the largest milk response in high producing cows, however the nature of the response in the most recent trial indicates that further increases may occur at higher levels of supplementation. However supplementation levels greater than 20 mg per day have not been tested experimentally.

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