Effect of Supplemental Biotin on Performance of Lactating Dairy Cows[1]

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Introduction

Biotin is a B-complex vitamin that is essential for cattle. However, for several decades very little research was published on the effects of biotin in cattle. This lack of interest was probably caused by 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. In the last few years, renewed interest in on the effects of supplemental biotin for cattle has developed. Most of the recent research has centered on the effects of biotin on hoof health of dairy cows (Bergsten et al., 1999; Fitzgerald et al., 2000; Midla et al., 1998). All these studies reported a positive response on some measure of hoof health to supplemental 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 should be studied.

Biotin Biochemistry

This topic will only be discussed briefly, a more thorough discussion can be found in Weiss and Zimmerly (2000). Biotin is involved in pathways for amino acid metabolism, cellular respiration, gluconeogensis, and fatty acid synthesis. Four enzymes require biotin as a cofactor: acetyl-CoA carboxylase, pyruvate carboxylase, B-methylcrotonyl-CoA carboxylase, and propionyl-CoA carboxylase. Biotin is covalently linked to each of these enzymes and transfers a carbon unit from the substrate to the product. An overview of the pathways that involve biotin-containing enzymes is shown in Figure 1.

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.

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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, 1999). 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 glucose. In mice, the activity of this enzyme is reduced when biotin is clinically deficient (Mock, 1999). 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.

Effects of Biotin on Rumen Metabolism

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.

Sources of Biotin

Feeds commonly fed to dairy cows contain variable concentrations of biotin (Table 1). 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. 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, data on the quantity of biotin synthesized by ruminants are extremely limited and variable. No data are available with lactating dairy cows. In studies with steers (Miller et al., 1986; Zinn et al., 1987) at low dry matter intakes (less than 6 kg/d) or in nonlactating cows consuming approximately 15 kg of hay dry matter (Frigg et al., 1992), estimates of ruminal synthesis of biotin ranged from 0 to 2 mg/day (approximately 0.8 mg/kg of digestible organic matter intake). 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. This could be a reason why positive responses to supplemented biotin are often observed in recent experiments but were not observed in earlier research when cows were fed high forage diets.

Data on the bioavailability of biotin to cattle are limited. In one study, the bioavailability of dietary biotin (supplemental and basal) averaged about 50% (Frigg et al., 1992). This is much lower than values obtained with chicks and humans (about 100%). Supplemental biotin consistently increases plasma and milk concentrations of biotin showing that at least some of the supplemental biotin is absorbed by cows. Typical plasma concentrations of biotin in cows not fed supplemental biotin are 20 to 35 ng/ml. When cows are supplemented with 20 mg of biotin/day, plasma concentrations are typically 40 to 70 ng/ml.

Effects of Biotin Supplementation on Milk Production

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. Because of the large number of animals needed for hoof health studies, most of these experiments are conducted on commercial herds. Actual milk yield or intake data on individual cows are usually not obtained from this type of study and the possibility of confounding between pen and treatment effects are possible. Two of the three field studies reported increased milk production when supplemental biotin was fed (Table 2). The two positive studies used cows with high milk production (approximately 10,000 kg/305 days). The study that did not show increased milk production with supplemental biotin used low producing cows (approximately 5800 kg/305 days). That study was also conducted with grazing cattle but the two positive studies used cows housed in confinement and fed silage and hay-based diets.

Because the field trial data and the biochemistry of biotin suggest that supplemental biotin might increase milk production, we (Zimmerly and Weiss, 2001) conducted a controlled study with lactating cows. At approximately 14 days before calving, cows were fed 0, 10, or 20 mg of supplemental biotin per day. The experiment continued until 100 days of lactation. The diets were identical among treatments except for the supplemental biotin and contained approximately 24% alfalfa silage, 22% corn silage, 4% alfalfa hay, 29% ground corn, 10% soybean meal, 6% heat-treated soybeans, and 5% other protein sources, minerals, and vitamins.

Dry matter intake was not affected by treatment, but milk production increased linearly ($P<0.05$) with increasing biotin (Table 3). Milk composition was not affected by treatment, but milk true protein yield (g/day) increased linearly with increasing supplemental biotin. The milk production response to supplemental biotin was observed by the first week of lactation and was maintained during the 100 day trial (Figure 2). Measures of energy balance and rumen metabolism were not affected by treatment. These data suggest that the response to supplemental biotin was not caused by increased energy availability but rather to a repartitioning of nutrients to milk. This suggests, but does not prove, that biotin may affect glucose production by lactating dairy cows.

Plasma and milk concentrations of biotin were increased linearly with increasing biotin supplementation (Figure 3). An interesting but unexplained observation was the spike in plasma and milk biotin concentrations we observed in supplemented cows at parturition. The concentrations of fat soluble vitamins are at their lowest point at calving. The significance of this finding is unknown.

Conclusions

Available data consistently shows increased milk production when high producing, early lactation cows are fed 20 mg of supplemental biotin per day. Cows at lower production (20 kg/day) did not respond to supplemental biotin. Some authors attributed the increase in milk production to improved hoof health, but our data show that milk production can be increased independent of improved hoof health. The mode of action of supplemental biotin is not known but altered ruminal metabolism (higher propionate production) or increased glucose synthesis by the cow might be responsible.

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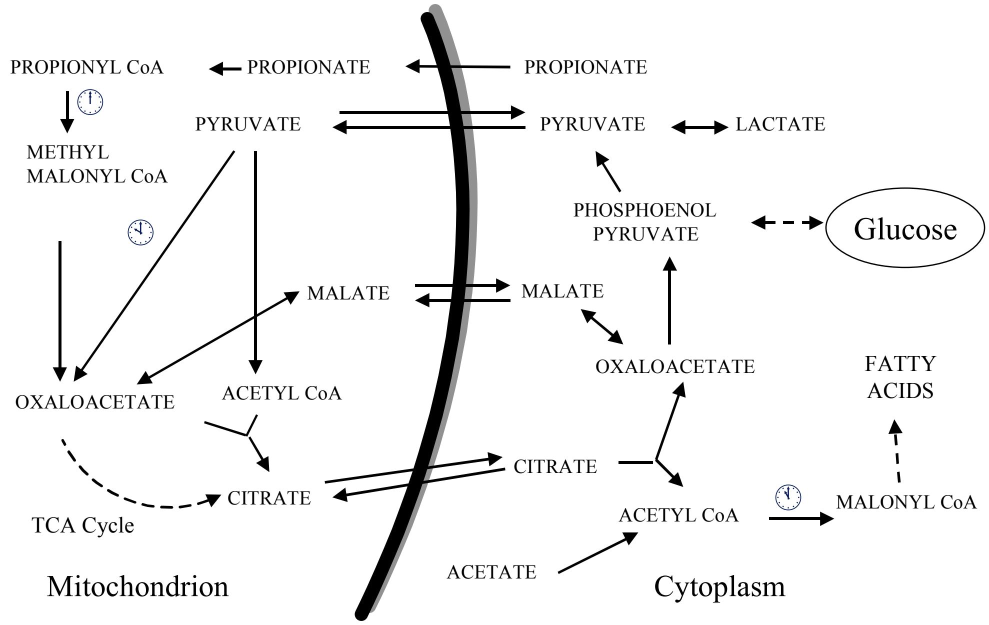

Figure 1. Gluconeogenic and lipogenic pathways that involve biotin. ∈=pyruvate carboxylase; ∉ = acetyl-CoA carboxylase; ∠= propionyl-CoA carboxylase. B-methylcrotonyl-CoA carboxylase participates in the leucine catabolism pathway and is not shown.

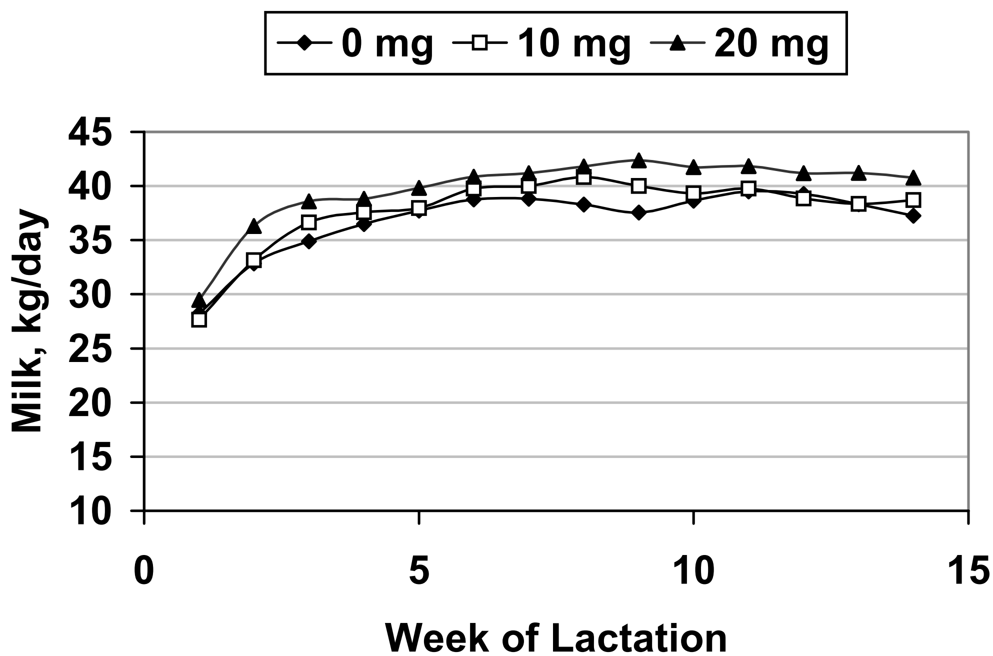

Figure 2. Milk production by cows fed 0, 10, or 20 mg of supplemental biotin per day (Zimmerly and Weiss, 2001).

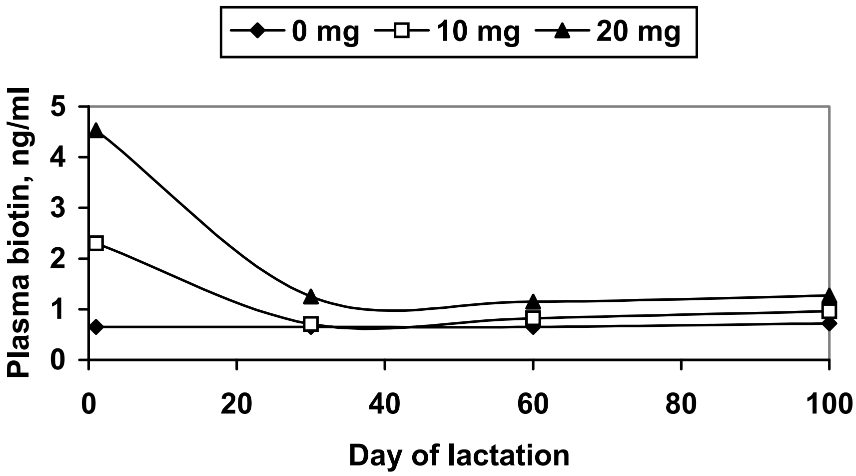

Figure 3a. Concentrations of biotin in plasma of lactating cows fed different amounts of supplemental biotin (Zimmerly and Weiss, 2001).

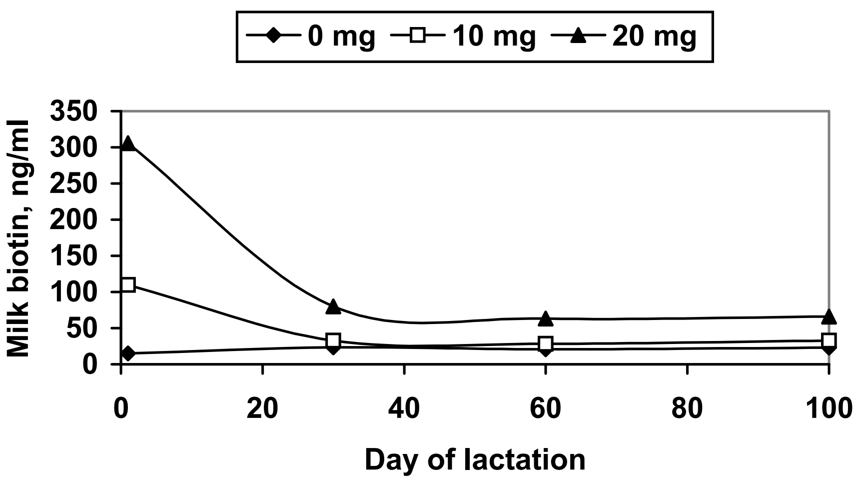

Figure 3b. Concentrations of biotin in milk from cows fed different amounts of supplemental biotin (Zimmerly and Weiss, 2001).

Table 1. Concentrations of biotin in some common feedstuffs.

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

Table 2. Summary of experimental results on the effect of supplemental biotin on milk production.

Reference	Treatment	Design	Response
Midla et al., 1998	0 or 20 mg/d	Field study, pen fed, one farm (OH)	+320 kg of 305 d mature equivalent milk (12,110 kg for trt vs. 11,790 kg for control, $P<0.05$)
Bergsten et al., 1999	0 or 20 mg/d	Field study, supplement via computer feeder, one farm (WA)	+878 kg of adjusted 305 d milk yield ($P<0.01$). Rolling herd average = 9800 kg
Fitzgerald et al., 2000	0 or 20 mg/d	Field study, 10 farms per treatment, pasture fed (Australia)	No effect on milk yield approximate yields were 19 kg/d for control and 18 kg/d for treatment
Zimmerly and Weiss, 2001	0, 10, or 20 mg/d	Controlled study, 15 cows/treatment, first 100 d of lactation	Linear ($P<0.05$) effect. 36.9, 37.8, and 39.7 kg/d for 0, 10, and 20 mg treatments.

Table 3. Production responses by early lactation dairy cows (calving to 100 days in milk) to supplemental biotin (Zimmerly and Weiss, 2001).

	0 mg/day	10 mg/day	20 mg/day
Dry matter intake, kg/d	19.4	19.8	19.9
Milk*, kg/d	36.9	37.8	39.7
ECM[1], kg/d	37.0	36.8	38.6
Milk fat, %	3.63	3.50	3.45
Milk fat, kg/d	1.31	1.26	1.32
Milk protein, %	3.03	3.05	3.01
Milk protein*, kg/d	1.11	1.13	1.18

[1]Energy-corrected milk.
* Significant ($P<0.05$) linear effect of treatment.