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Effect of biotin and pantothenic acid on performance and concentrations of avidin-binding substances in blood and milk of lactating dairy cows[1]

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ABSTRACT

We hypothesized that pantothenic acid reduces the absorption of biotin in lactating dairy cows. Therefore, the objective of this study was to evaluate the plausible interaction between biotin and pantothenic acid on production performance and concentration of avidin-binding substances (ABS), an indicator of biotin concentration, in blood and milk of lactating dairy cows. Eight primiparous and 16 multiparous Holstein cows were assigned to 1 of 4 diet sequences in a replicated 4 × 4 Latin square design with 18-d periods. Cows were housed in a freestall barn and fed once daily (0730 h) by means of a Calan gate system (American Calan Inc., Northwood, NH). Treatments consisted of a control diet that contained no B-vitamins, a biotin diet that contained 0.87 mg of biotin per kilogram of dry matter (DM), a pantothenic acid diet that contained 21 mg of pantothenic acid per kilogram of DM, and a biotin plus pantothenic acid diet that contained 0.87 mg of biotin and 21 mg of calcium pantothenic acid per kilogram of DM. Four different concentrates were prepared in a commercial feed mill. These concentrates were mixed with corn silage and grass hay and delivered ad libitum as a total mixed ration. Biotin supplementation did not affect DM intake, milk yield, or milk fat, protein, lactose, and milk-urea-nitrogen concentrations. Fat, protein, and lactose yields were not affected by treatments. The fat-to-protein ratio was <1 and similar among all treatments. Biotin supplementation did not increase the concentration of ABS in plasma. The supplementation of pantothenic acid did not affect the concentration of ABS in plasma when either supplemented alone or in combination with biotin. Biotin supplementation increased the concentration of ABS in milk relative to control. Contrary to our hypothesis, the supplementation of pantothenic acid did not decrease the concentration of ABS in milk relative to the control. When cows were supplemented with both biotin and pantothenic acid, the concentration of ABS in milk was similar to that of cows supplemented with biotin alone. In conclusion, pantothenic acid did not affect the concentrations of ABS in plasma and milk, suggesting that increasing dietary supply of pantothenic acid did not inhibit biotin absorption.
Key words: biotin, pantothenic acid, avidin-binding substance, absorption

INTRODUCTION

Biotin is a water-soluble vitamin that is synthesized by plants and several microorganisms. Because they cannot synthesize biotin, mammals rely on intake through the diet and on microbial synthesis in the gastrointestinal tract to meet their biotin needs. Biotin supplementation increased milk yield of lactating cows in several studies (Midla et al., 1998; Zimmerly and Weiss, 2001; Majee et al., 2003), although this response has been inconsistent (Fitzgerald et al., 2000; Majee et al., 2003; Rosendo et al., 2004). Fitzgerald et al. (2000) showed that biotin supplementation did not affect milk yield in low-producing cows. Ferreira et al. (2007) showed that biotin supplementation increases milk yield in high-producing, but not in low-producing, dairy cows. Majee et al. (2003) stated that potential negative interactions among B-vitamins may have reduced lactation performance when cows were fed high doses of biotin plus B-vitamins compared with cows fed biotin alone or low doses of biotin plus B-vitamins.

A facilitated mechanism in the brush-border membrane of the enterocytes allows the absorption of biotin against a concentration gradient in the intestine of rats (Said and Redha, 1987), rabbits (Said and Derweesh, 1991), and humans (Said et al., 1987, 1988). This transport is sodium dependent (Said and Redha, 1987; Said et al., 1987, 1988) and greatest under acidic conditions (Said et al., 1988). Biotin absorption through this transporter can be decreased by biotin analogs (Said and Redha, 1987; Said et al., 1987; Said and Derweesh, 1991) and pantothenic acid (Said, 1999), showing that this transporter is not specific for biotin. The activity of the biotin transporter varies depending on the site within the intestine (Said et al., 1988) and on

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biotin status (Said et al., 1989). Using brush-border membrane vesicles, Said et al. (1989) observed that biotin transport increased in biotin-deficient rats and decreased in biotin-supplemented rats. Prasad et al. (1998) transfected placental cDNA that encodes this transporter into uterine cells and observed that the transport of biotin into these cells was substantially increased. This increase was inhibited by pantothenic acid and lipoic acid, but not by myoinositol, showing that the transporter is specific for biotin, pantothenic acid, and lipoic acid. The increased transport of biotin and pantothenic acid was not observed in the absence of sodium, implying sodium dependence. Prasad et al. (1998) named this transporter as sodium-dependent multivitamin transporter (**SMVT**).

To our knowledge, the presence of a biotin transporter similar to SMVT in the gastrointestinal tract of dairy cows, or any other ruminant, has not been determined. Chatterjee et al. (1999) showed that the uptake of biotin was inhibited when cells containing transfected intestinal SMVT from rats were incubated with pantothenic acid. Based on the assumption that biotin uptake in dairy cows occurs via a SMVT system, for this study we hypothesized that increasing pantothenic acid supply reduces the absorption of biotin in lactating dairy cows. Therefore, the objective of this study was to evaluate the plausible interaction between biotin and pantothenic acid on production performance and concentration of avidin-binding substances (**ABS**), an indicator of biotin concentration, in blood and milk of lactating dairy cows.

MATERIALS AND METHODS

Animals, Housing, and Diets

All procedures involving animals were approved by the Institutional Animal Care and Use Committee of Virginia Tech. Eight primiparous (511 ± 41 kg of BW and 74 ± 18 DIM at the beginning of the experiment) and 16 multiparous Holstein cows (624 ± 51 kg of BW and 94 ± 33 DIM at the beginning of the experiment) were assigned to 1 of 4 diet sequences in a replicated 4 × 4 Latin square design, with 6 independent squares and 18-d periods.

Cows were housed in a 24-stall pen within a freestall barn. Cows were fed once daily (0730 h) by means of a Calan gate system (American Calan Inc., Northwood, NH). Cows were trained to find their door for a 2-wk period before the beginning of the study.

Treatments consisted of a basal or control diet that contained no B-vitamins, a biotin diet that contained 0.87 mg of supplemental biotin (Rovimix Biotin 2%, DSM Nutritional Products Inc., Parsippany, NJ) per kilogram of DM, a pantothenic acid diet that contained 21 mg of supplemental pantothenic acid (Rovimix Calpan, DSM Nutritional Products Inc.) per kilogram of DM, and a biotin plus pantothenic acid diet that contained 0.87 mg of supplemental biotin and 21 mg of supplemental pantothenic acid per kilogram of DM. The basal diet was formulated to meet nutrient requirements (NRC, 2001) for a 630-kg lactating dairy cow producing 42 kg of milk per day. The concentration of biotin was chosen to supply approximately 20 mg of biotin per day based on a 22.5-kg daily DMI (Zimmerly and Weiss, 2001; Majee et al., 2003; Ferreira et al., 2007). The concentration of pantothenic acid was chosen to supply approximately 475 mg of pantothenic acid per day, which was the lowest dose used by Majee et al. (2003).

Four different concentrates were prepared in a commercial feed mill (Southern States Cooperative, Vinton, VA). These concentrates were mixed with corn silage and grass hay (Table 1) and delivered ad libitum (~5% refusals, as-fed basis) as a TMR. Mixing and delivery was performed using a Calan Data Ranger (American Calan Inc.). The amount of feed offered and refused was measured daily. Cows were milked twice daily (0300 and 1300 h), and milk weights were automatically recorded at each milking. The average of the daily milk yields and DMI from d 13 to 18 of each period was used for statistical analysis.

Sample Collection and Analysis

Composite samples of feed ingredients and feed refused were collected at the end of each period (d 13 to 18). All feed samples were dried in a forced-air oven (55°C) until a constant weight was reached, and they were ground to pass through a 1-mm screen of a Wiley mill (Thomas Scientific, Swedesboro, NJ). Crude protein concentration was calculated as percent N × 6.25 after combustion analysis using a Vario El Cube CN analyzer (Elementar Americas Inc., Mount Laurel, NJ). Neutral detergent fiber concentration was determined using the Ankom200 Fiber Analyzer (Ankom Technology, Macedon, NY) with sodium sulfite and α-amylase (Ankom Technology). Acid detergent fiber and lignin concentrations were determined sequentially. After determining ADF weights, residues were incubated for 2 h in 72% sulfuric acid within a 4-L jar that was placed in a DaisyII Incubator (Ankom Technology). Starch concentration was determined using the acetate buffer method of Hall (2009) with α-amylase from *Bacillus licheniformis* (FAA, Ankom Technology) and amyloglucosidase from *Aspergillus niger* (E-AMGDF, Megazyme International, Wicklow, Ireland). Ash concentration