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A dose-response evaluation of rumen-protected niacin in thermoneutral or heat-stressed lactating Holstein cows

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ABSTRACT

Twenty-four multiparous high-producing dairy cows (40.0 ± 1.4 kg/d) were used in a factorial design to evaluate effects of 2 environments [thermoneutral (TN) and heat stress (HS)] and a dose range of dietary rumen-protected niacin (RPN; 0, 4, 8, or 12 g/d) on body temperature, sweating rate, feed intake, water intake, production parameters, and blood niacin concentrations. Temperature–humidity index values during TN never exceeded 68 (stress threshold), whereas temperature–humidity index values during HS were above 68 for 24 h/d. The HS environment increased hair coat and skin, rectal, and vaginal temperatures; respiration rate; skin and hair coat evaporative heat loss; and water intake and decreased DMI (3.5 kg/d), milk yield (4.1 kg/d, $P < 0.01$), 4% fat-corrected milk (2.7 kg/d), and milk protein yield (181.7 g/d). Sweating rate increased ($P < 0.01$) during HS (12.7 g/m^2 per h) compared with TN, but this increase was only 10% of that reported in summer-acclimated cattle. Niacin supplementation did not affect sweating rate, dry-matter intake, or milk yield in either environment. Rumen-protected niacin increased plasma and milk niacin concentrations in a linear manner. Heat stress reduced niacin concentration in whole blood (7.86 vs. 6.89 μg/mL) but not in milk. Reduced blood niacin concentration was partially corrected by dietary RPN. An interaction existed between dietary RPN and environment; dietary RPN linearly increased water intake in both environments, but the increase was greater during HS conditions. Increasing dietary RPN did not influence skin temperatures. During TN, supplementing 12 g/d of RPN increased hair coat (unshaved skin; 30.3 vs. 31.3°C at 1600 h) but not shaved skin (32.8 vs. 32.9°C at 1600 h) temperature when compared with 0 g/d at all time points, whereas the maximum temperature (18°C) of the room was lower than skin temperature. These data suggest that dietary RPN increased water intake during both TN and HS and hair coat temperature during TN; however, core body temperature was unaffected. Thus, encapsulated niacin did not improve thermotolerance of winter-acclimated lactating dairy cows exposed to moderate thermal stress in Arizona.

Key words: niacin, dose, heat stress, lactating dairy cow

INTRODUCTION

During warm summer months, milk production decreases between 10 and 35%, which represents a costly issue in the dairy industry (St-Pierre et al., 2003). In addition to milk yield, increased core body temperature during heat stress results in altered endocrine profile and energy metabolism (Collier et al., 2008; Wheelock et al., 2010). Increasing heat dissipation, the transfer of body heat from the core to the surface, via enhanced peripheral vasomotor function and evaporative heat loss may alleviate some of the decrease on productivity. Nicotinic acid (niacin) but not nicotinamide has long been known to cause intense skin flushing (Gille et al., 2008), which increases peripheral heat loss (Di Costanzo et al., 1997). Niacin has been shown to induce prostaglandin D synthase activity (Benyó et al., 2006; Meyers et al., 2007) in Langerhans cells (Maciejewski-Lenoir et al., 2006), leading to increased blood levels of prostaglandin D (Kamanna and Kashyap, 2008) and vascular endothelial prostaglandin D2 receptors (Cheng et al., 2006) and increased skin vascularity and sweating rate (Di Costanzo et al., 1997; Zimbelman et al., 2010). A previous study in cattle demonstrated that skin temperatures decreased during periods of mild to severe heat stress in cows supplemented with 12, 24, or 36 g of unprotected niacin (Di Costanzo et al., 1997).

Earlier research evaluating dietary niacin supplementation during heat stress has used unprotected niacin, which presumably would mostly be metabolized by ru-

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men microbes (Jaster et al., 1983; Muller et al., 1986; Jaster and Ward, 1990; Campbell et al., 1994). It is estimated that only 3 to 10% of unprotected niacin escaped from ruminal degradation when feeding 2 to 12 g of unprotected niacin (Miller et al., 1986; Zinn et al., 1987; Santschi et al., 2005). Encapsulation technology dramatically increases the delivery of compounds such as niacin to the small intestine (Deuchler et al., 1998; Yuan et al., 2012). Previous studies, during summer, at the University of Arizona have demonstrated that adding 12 g/d of rumen-protected niacin (**RPN**) in the diet increased sweating rates and reduced body temperatures of lactating dairy cows exposed to heat stress (Zimbelman et al., 2010). This was subsequently repeated under commercial farm conditions, and we demonstrated reduced vaginal temperatures in lactating dairy cows supplemented with 12 g/d of RPN (Zimbelman et al., 2013). However, lower doses might be as effective in lowering body temperature and would be economically more viable for the dairy producer to use.

As the supplemental dose of RPN provided to dairy cows increases, free and total-blood niacin and nicotinamide, plasma prostaglandin D, and sweating rate (assuming adequate rumen protection) should have corresponding increases. In addition, we speculated a dose-response relationship between supplemental RPN and sweating rate, water intake, and core body temperature (sweating rate and water intake increasing with dose corresponding with a decreased body temperature with increasing RPN). Therefore, the study objectives were to evaluate the effects of a dose range of RPN (0, 4, 8, and 12 g/d) on measures of body temperature, production parameters, and niacin concentrations in milk, blood, and plasma. These doses were chosen based on prior published work (Miller et al., 1986; Zinn et al., 1987; Di Costanzo et al., 1997; Santschi et al., 2005; Zimbelman et al., 2010) using RPN and studies that measured flow of niacin to the intestine.

MATERIALS AND METHODS

Animals

Twenty-four second-lactation (95 ± 3 DIM), high-producing Holstein cows (40.0 ± 1.4 kg/d) were randomly assigned to 1 of 2 replicate groups involving 12 cows each and were housed in 1 of 2 environmental rooms containing 6 individual tie stalls with separate feed and water for each stall in each room at the William J. Parker Agricultural Research Complex (Tucson, AZ) and a dose of dietary RPN (0, 4, 8, or 12 g/d). The encapsulated niacin (Niashure, Balchem Corporation, New Hampton, NY) was 65% niacin. Environmental conditions inside each room (temperature and humidity) were controlled precisely for equivalent temperature, humidity, and light cycles and were monitored with calibrated data logging equipment at 5-min intervals for the duration of the study. Throughout the experiment, cows were milked twice daily (0500 and 1700 h), and milk yields were recorded at each milking. All cows were individually fed a TMR twice daily (0500 and 1700 h), and orts were recorded daily before the morning feeding. The TMR was formulated by Dairy Nutrition Services (Chandler, AZ) to meet or exceed the predicted requirements (NRC, 2001) of energy, protein, minerals, and vitamins (Table 1). Alfalfa hay was the primary forage, with steam-flaked corn as the primary concentrate. Feed analysis was conducted by Dairy Nutrition Services on forage and concentrate components of the ration using proximate analysis. Each dose of RPN was split evenly and top-dressed on the ration at the morning and evening feeding. Each half dose was placed onto the feed and 50 mL of diluted molasses solution (14 g of molasses, 71.4% DM) was poured over it, then hand mixed into the ration. Supplementing the diet with the 4 doses of RPN and the 2 environmental conditions began on the first day of the thermoneutral (**TN**) period and was stopped after the last feeding on the last day of the heat-stress (**HS**) period.

Experimental Design

The study was a factorial design using 24 high-producing, second-lactation dairy cows randomly assigned to 1 of 4 doses of RPN (0, 4, 8, or 12 g/d) and then assigned to 1 of 2 environmental rooms that held 6 cows each. Because the 2 rooms could only house 12 cows, the design was replicated once to accommodate 24 cows. Dosing groups were balanced for parity, stage of lactation, and milk yield. Cows in each replicate were on trial for 21 d including 4 d to acclimate to the environmental chambers and 7 d of TN conditions [temperature–humidity index (**THI**) ranged from 50 to 60 for 24 h, Figure 1], followed by 7 d of HS conditions (THI ranged from 70 to 80 for 24 h, Figure 1). Temperature–humidity index was calculated by the following equation: THI = (0.81 × dry bulb temperature °C) + [% relative humidity × (dry bulb temperature − 14.4)] + 46 (Staples and Thatcher, 2002).

Thermal-Status Measurements

Body-temperature indices (respiration rate, sweating rate, skin temperature, and rectal temperatures) were collected 4 times daily (0800, 1000, 1400, and 1600 h), and vaginal temperatures were recorded at 15-min intervals. Respiration rates were determined by counting flank movements for 15 s and multiplying by 4. Sweat-