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Effects of utilizing rumen protected niacin on core body temperature as well as milk production and composition in lactating dairy cows during heat stress

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ABSTRACT

Niacin has been shown to increase resistance to thermal stress in cattle by increasing evaporative heat loss *in vivo* and cellular heat shock response by increasing gene expression of heat shock proteins 27 and 70 during thermal stress *in vitro*. To determine effects of feeding encapsulated niacin on vaginal temperature, milk yield and composition, a total of 198 primiparous and 229 multiparous lactating Holstein cows were randomly assigned in a crossover design to either control (no niacin additive, $n = 213$) or niacin (NIA; cows supplemented with 12 g/d/cow of an encapsulated niacin, $n = 214$). Treatments were balanced for days in milk (DIM), milk yield, and parity prior to the start of the study, which was conducted between August 7th and October 7th, 2007 on a commercial dairy in Arizona (USA). Cows remained on their original treatment for 30 d (period 1) and then switched to the other treatment on day 31 and continued until day 60 (period 2). Vaginal temperatures were recorded using temperature data loggers attached to a blank controlled internal drug release device and inserted into a random sub-sample of 16 cows from each pen with similar days in milk, milk yields and parity for 8 d. Effects of heat stress were more severe in period 1 due to a higher temperature humidity index compared with period 2. Dry matter intakes did not differ by treatment or period. Both period and NIA affected vaginal temperatures with NIA reducing vaginal temperatures and period 1 having higher vaginal temperatures compared with period 2. In addition, vaginal temperatures decreased ($P<0.01$) with NIA treatment during peak thermal load from 1300 to 1600 h for 4 of 8 d. A NIA by period interaction occurred for several milk production parameters. The NIA fed cows had higher milk yield in period 1 (higher heat stress) and was lower in period 2 ($P<0.01$). In contrast, NIA reduced milk fat yield in period 1 and increased it in period 2 ($P<0.01$). Both true protein and lactose yield was lower in period 1 with no effect in period 2. Supplementation of lactating cows with NIA reduced vaginal temperature, but had differing effects on milk production variables dependent on the period of the study which may be due to a more severe heat stress experienced in period 1 compared with period 2, and/or a more advanced stage of lactation in period 2.

Abbreviations: AZMET, Arizona Meteorological Network; DIM, days in milk; DM, dry matter; CIDR, cervical implant drug release, Control (0 g/d encapsulated niacin); CP, crude protein; HOBO, temperature data loggers; SNF, solids-non-fat; THI, temperature humidity index; TMR, total mixed ration; NE_L, net energy of lactation; NIA, 12 g/d encapsulated niacin; SCC, somatic cell count; VT, vaginal temperature.

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1. Introduction

Heat stress negatively impacts production of lactating dairy cows. The economic impact of heat stress on the USA dairy industry averaged over $800 million per year due to reduced performance and increased incidence of disease over a decade ago (St-Pierre et al., 2003). Milk production can be reduced 10–35% when the temperature humidity index (THI) exceeds 72 (Thatcher et al., 1974; Schneider et al., 1984). Indeed, a reduction in milk production of 0.26 kg for each unit increase of THI over 72 was reported by Johnson et al. (1962). However, the THI was developed approximately 50 ago with low producing cows (*i.e.*, <15 kg/d), constant heat stress temperatures and long intervals (2 weeks) before estimating milk yield (Berry et al., 1964). More recently, Zimbleman et al. (2008) re-evaluated THI and indicated that a more appropriate THI threshold for modern lactating dairy cows producing more than 35 kg/d of milk should be 68. A portion of the reduction in milk yield is due to decreased dry matter (DM) intake (Collier and Beede, 1985; Rhoads et al., 2009), which also reduces the amount of metabolic heat produced to prevent elevated body temperature (West, 1994). As the maintenance energy requirements of lactating dairy cows' increases during thermal stress due to biological adaptations, such as increased respiration rate, decreases in DM intake prevent the cow from meeting energy demands and so milk production declines (Collier, 1985). Nutritional management strategies to help prevent the decrease in DM intake during heat stress have been described (Beede and Collier, 1986; Armstrong, 1994) and these strategies are primarily aimed at reducing heat production by increasing dietary net energy (NE_L) concentration and reducing forage intake. A synergistic strategy to reduce heat production would be to increase heat loss (Collier et al., 2008). As the primary route of heat loss in thermally stressed cows is evaporative cooling, nutritional management strategies, which improve the ability of cattle to lose heat by evaporation (*i.e.*, sweating) would likely be beneficial during periods of thermal stress.

Niacin (vitamin B_3) is known to increase peripheral vasodilation to increase sweat gland activity in humans and dairy cattle (Gille et al., 2008; Di Constanzo et al., 1997). However, niacin is rapidly metabolized in the rumen resulting in poor delivery to the small intestine (Campbell et al., 1994). Indeed, prior research has shown that very little niacin or nicotinamide escape ruminal degradation (30–100 g/kg; Miller et al., 1986; Zinn et al., 1987; Santschi et al., 2005). Thus past research with dairy cows evaluating dietary niacin supplementation during heat stress utilizing ruminally unprotected niacin (Jaster et al., 1983; Muller et al., 1986; Jaster and Ward, 1990; Campbell et al., 1994), almost certainly failed to evaluate impacts of niacin delivery to the small intestine.

A recent study in controlled environment rooms with low animal numbers ($n = 12$) demonstrated that cows supplemented with encapsulated niacin at a dose of 12 g/cow/d during acute thermal stress had a lower core body temperature and increased sweating rates (Zimbelman et al., 2010), which are adaptive mechanisms to allow for dissipation of more body heat to the surface area through peripheral or vasomotor function and/or increased sweating. This prevents some of the decrease in DM intake due to heat stress thereby improving milk production (Di Constanzo et al., 1997). Cows undergoing mild to severe heat stress fed encapsulated niacin at 12 and 24 g/cow/d had reduced skin temperatures and increased milk production during summer heat (Muller et al., 1986; Di Constanzo et al., 1997).

In past heat stress studies with dairy cows, niacin in the form of unprotected nicotinic acid or nicotinamide was supplemented. Both forms of niacin are synthesized in the rumen by rumen microrganisms (Santschi et al., 2005; Miller et al., 1986). Absorption through the rumen wall has been shown to occur by increasing dietary levels of niacin (Rérat et al., 1958b), but these researchers reported very little escape of niacin from the rumen. Thus beneficial effects of feeding free niacin could be due to limited niacin absorption across the ruminal wall before reaching the duodenum (Santschi et al., 2005). In order to increase delivery of niacin to the small intestine, it can be encapsulated to protect it from ruminal degradation (Santschi et al., 2005). Feeding encapsulated niacin should result in increased stability in the rumen and increased intestinal delivery compared to free niacin (Santschi et al., 2005).

The objective was to examine effects of rumen protected niacin during heat stress on milk production, milk composition and core body temperatures under commercial conditions.

2. Materials and methods

The study was conducted from August 7th to October 7th, 2007 on a 10,000 lactating cow commercial dairy near Stanfield (AZ, USA). The University of Arizona's Institute of Animal Care and Use Committee approved all protocols and use of cows. Four hundred and twenty seven lactating primiparous and multiparous Holstein cows were balanced for days in milk (DIM; 166 ± 11.0), milk yield (38.2 ± 0.21 kg/d) and parity (1.73 ± 0.20) prior to the start of the study and assigned to either a control ($n = 213$) with 0 g encapsulated niacin product/d, or with 12 g of an encapsulated niacin (NIA; $n = 214$) product/d (NIASHURE^{TM}®; Balchem Corp.; New Hampton, NY, USA) in a crossover design. The dose selected for this study (12 g/d) was chosen as the lowest dose of Di Constanzo et al. (1997). The encapsulated NIA product was 0.65 niacin and 0.35 fat matrix and was estimated to provide an actual intestinally absorbable dosage of 7.8 g of niacin/d based upon Zimbelman et al. (2010) who used the same product. All cows were fed a totally mixed ration (TMR) three times daily at 07:00, 13:00 and 19:00 h. A separate premix of NIA was made prior to TMR mixing. Twice weekly samples ($n = 16$) were collected of the TMR, which was formulated by dairy nutrition services (Chandler, AZ, USA) to meet or exceed their requirements for NE_L, crude protein (CP), minerals and vitamins (Table 1). Cows were fed for *ad libitum* intake to allow 30–50 g/kg feed refusals daily.

The TMR samples were weighed and dried at 55 °C for 12–24 h. Dried samples were chemically analyzed after being ground to pass a 1 mm screen on a model 4 Wiley Mill (Thomas Scientific, Swedesboro, NJ, USA). Moisture was determined