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Niacin delivery to the intestinal absorptive site impacts heat stress and productivity responses of high producing dairy cows during hot conditions

S.R. Wrinkle[a,*], P.H. Robinson[a], J.E. Garrett[b]

[a] *Department of Animal Science, University of California, Davis, CA 95616, USA*
[b] *Quali Tech Inc., 318 Lake Hazeltine Dr., Chaska, MN 55318, USA*

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A B S T R A C T

Heat stress resulting in animal production losses costs the dairy industry hundreds of millions of dollars annually, especially in tropical and semi-tropical areas. Niacin is a dietary supplement which typically induces flushing (*i.e.*, increased blood flow to the skin), causing a decrease in core body temperature, which has been shown to reduce heat stress in dairy cows. Our objective was to determine if use of a rumen protection technology to deliver niacin (RPNi) to the intestinal absorptive site is effective in alleviating heat stress in dairy cows and increasing productive performance. Two 2 × 2 factorial experiments, each with 28 d periods, were conducted on a commercial dairy farm in central California (USA). In Experiment 1, 2 pens of ∼180 early lactation multiparity Holstein cows were used and, in Experiment 2, 2 pens of ∼180 mid-lactation mixed parity Holstein cows were used. The basal total mixed ration, of 171 g/kg crude protein, 332 g/kg neutral detergent fiber and 147 g/kg starch on a dry matter (DM) basis, was the same for all cows with the exception of RPNi added to the treatment total mixed ration. The RPNi was added to treatment pen diets at a consumption level of 19 g of RPNi/d, which was estimated to deliver ∼6 g of intestinally absorbable niacin/d as determined by evaluation of the RPNi. In Experiment 1, respiration rates (RR) and panting scores (PS; a 1–4.5 visual score of the extent of panting in a cow) were measured 4 times/d in subgroups of ∼35 cows/pen. The RR were lower ($P=0.02$) at 09:00 h, but not impacted at other times of the day, while PS were lower ($P \leq 0.01$) at 04:30, 09:00 and 20:30 h, but not impacted at 16:30 h, in cows fed RPNi compared to control. However, RR and PS were relatively low overall due to the cooler than normal summer weather. There was no difference in DM intakes or milk yields, but milk fat proportion was lower in RPNi cows ($P<0.01$). In Experiment 2, where PS and RR were not measured, DM intake and milk yield did not differ between treatments, with the exception of fat proportion, which was higher in RPNi cows ($P<0.01$). While indicators of heat stress were improved for cows fed RPNi, this slight increase in cow comfort did not result in increased DM intake or productivity. Differences in milk fat responses in our early lactation cows suggest lipid metabolism in the cows was affected by intestinal niacin delivery, most likely by reducing

Abbreviations: ADF, acid detergent fiber; ADFom, ADF without residual ash; BCS, body condition score; BU, back udder; BW, body weight; CP, crude protein; DDGS, dried distillers grains with solubles; DIM, days in milk; DM, dry matter; EE, ether extract; FFA, free fatty acid; aNDF, amylase-treated neutral detergent fiber; aNDFom, aNDF without residual ash; NE_l, net energy for lactation; PS, panting score; RPNi, ruminally protected niacin; RR, respiration rate; SCC, somatic cell count; SU, side udder; SG, specific gravity; TG, triglycerides; THI, temperature humidity index; TMR, total mixed ration; VLDL, very low density lipoproteins.

* Corresponding author. Tel.: +1 661 312 6280.
E-mail address: srwrinkle@ucdavis.edu (S.R. Wrinkle).

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plasma triglyceride production. A reduction of plasma triglyceride production was also likely in the mid-lactation cows but, because they were producing less milk and consuming a similar amount of DM, dietary fat intake was likely able to compensate for the reduced *de novo* synthesis.

1. Introduction

Dairy cows suffering from heat stress during the summer exhibit decreased feed intake and activity, as well as increased respiratory rates, peripheral blood flow and sweating (West, 2002). All of these responses have deleterious effects on their performance resulting in lower milk yield and component levels, as well as lower conception rates (Berman, 1968; Thatcher et al., 1974; Johnson, 1976). These losses in production result in substantial economic losses for dairy producers worldwide. Animal production losses, as well as capital and operating costs to minimize effects of heat stress were estimated by St-Pierre et al. (2003) to be $897 million annually in the USA. Thus, it is common for dairy producers to alter the ambient environment of dairy cows by installing fans, sprinklers and shaded areas in pens. While research has been completed on nutritional management strategies under hot conditions (NRC, 2001), it is uncommon for dairy producers to make dietary changes to decrease the incidence of heat stress.

Niacin, also known as nicotinic acid or vitamin B_3, was found to be very beneficial in treating hypercholesterolemic humans by reducing LDL and increasing HDL levels (Altschul et al., 1955). Despite these promising results, a flush response, occurring in nearly all patients, was considered to be an adverse side effect to the vitamin as it increased blood flow to the epidermis resulting in warmth and redness on the skin surface and a concomitant decrease in core body temperature. Prostaglandin D2, secreted from the epidermal Langerhans cells, is the primary mediator of the niacin induced flush (Morrow et al., 1989; Maciejewski-Lenoir et al., 2006). More recently, prostaglandin E2, secreted from keratinocytes has also been shown to be involved in this mechanism (Benyo et al., 2005). Andersson et al. (1977) reported that only 1–3 mg/kg body weight (BW) is necessary for niacin to induce a flush response in humans, which lasts 40–60 min. It was recently suggested that niacin could decrease heat stress in dairy cattle because of the flush response (Zimbelman et al., 2008, 2010) since it causes a decrease in core body temperature, likely due to increased vasodilation in the skin which causes the animal's core body heat to be transferred to the skin surface where it can be dissipated. This increase in vasodilation is a natural response in most mammals when the ambient temperature rises, but the flush induced by niacin could further increase vasodilation, thus cooling the animal more effectively, as long as the outside temperature is lower than the core body temperature or fans/sprinklers are available to remove the heat from the skin surface.

While the main intestinally absorbable source of niacin for most mammals is dietary (*i.e.* feeds and feed supplements), microorganisms synthesize niacin in the rumen of cows (Porter, 1961; Zinn et al., 1987; Santschi et al., 2005a). Many common dairy cow feeds also contain niacin (NRC, 2001) indicating microbial synthesis is not the only source of niacin in dairy cows. Using ruminally and duodenally fistulated cows, Seck et al. (2010a) determined a duodenal niacin flow of 1.7 ± 0.18 g/d in eight lactating dairy cows fed alfalfa based diets (*i.e.*, high in niacin) containing 430 g/kg aNDF with no supplemental niacin. In contrast, lactating cows fed lower fiber diets (*i.e.*, 249 g/kg aNDF), had a duodenal niacin flow of 3.9 ± 0.26 g/d (Seck et al., 2010b), suggesting that microbial synthesis of niacin is increased when dietary niacin levels are reduced.

Most niacin studies aimed at reducing heat stress in dairy cows used doses of 6–36 g of nicotinic acid/day (Di Constanzo et al., 1997; Muller et al., 1986) in a free form (*i.e.*, not ruminally protected). However, only 20–50 g/kg of dietary free niacin reaches the duodenum (Zinn et al., 1987; Santschi et al., 2005a), leading to the conclusion that very little niacin escapes the rumen, but it is possible that some, or even much, of the niacin which escapes the rumen is absorbed from the abomasum. This could be why only trace amounts are found in duodenal chyme. Indeed, in a niacin absorption study in humans, Bechgaard and Jespersen (1977) found niacin to be equally absorbable from the stomach and small intestines. Nevertheless, as most researchers feeding free niacin to lactating dairy cows have shown little or no change in animal performance (Schwab et al., 2005), it is likely that most dietary niacin is degraded in the rumen, or that niacin had no impact due to sufficient microbial niacin synthesized in the rumen and rumen escape of niacin from the diet.

A number of companies market nutrients (*e.g.*, vitamins, amino acids) with a rumen protection technology which allows them to be protected from microbial degradation in the rumen by encapsulation in a fat matrix to facilitate very slow degradation in the rumen. Full digestion occurs post-ruminally because the lipases in the small intestines degrade the fat thereby allowing the nutrient to be released in, and then absorbed from, the intestine and metabolized (Voigt et al., 2006). In contrast to studies which fed niacin in a free form, Zimbelman et al. (2008, 2010) found that feeding 12 g of ruminally protected niacin (RPNi) increased heat stress tolerance in lactating Holstein cows, but they reported little change in milk production.

Our objectives were to determine if a RPNi product produced with a fat encapsulation rumen protection technology would deliver niacin (as nicotinic acid) to the intestinal absorptive site and thus alleviate heat stress in dairy cows subjected to high ambient temperatures, and thereby improve their comfort and productivity.