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Effects of encapsulated niacin on metabolism and production of periparturient dairy cows

S. D. Morey,* L. K. Mamedova,* D. E. Anderson,† C. K. Armendariz,* E. C. Titgemeyer,* and B. J. Bradford*[1]
*Department of Animal Sciences and Industry, and
†Department of Clinical Sciences, Kansas State University, Manhattan 66506

ABSTRACT

Nicotinic acid (niacin) can suppress lipolysis, but responses to dietary niacin have been inconsistent in cattle. Our aim was to determine if 24 g/d of encapsulated niacin (EN; providing 9.6 g/d of bioavailable nicotinic acid) alters lipid metabolism and productivity of transition cows. Beginning 21 d before expected calving, primiparous (n = 9) and multiparous (n = 13) cows (body condition score of 3.63 ± 0.08) were sequentially assigned within parity to EN (12 g provided with ration twice daily) or control through 21 d postpartum. Liver biopsies were collected on d −21, −4, 1, 7, and 21 relative to parturition. Blood samples were collected on d −21, −14, −7, −4, 1, 4, 7, 14, and 21 relative to parturition. On d 7 postpartum, a caffeine clearance test was performed to assess liver function, and on d 21 to 23 postpartum, blood samples were collected every 8 h to monitor posttreatment nonesterified fatty acid (NEFA) responses. Data were analyzed using mixed models with repeated measures over time. A treatment × time × parity effect was observed on prepartum dry matter intake (DMI), which was caused by a 4 kg/d decrease in DMI of EN-treated multiparous cows compared with control multiparous cows during the final 4 d prepartum. A significant increase in plasma nicotinamide concentration occurred in EN-treated cows on d −7 and 21 relative to parturition. Prepartum glucose concentration decreased in treated animals, with no difference in plasma insulin concentration. Treatment × time × parity effects were detected for NEFA and β-hydroxybutyrate concentrations during the postpartum period. Plasma NEFA peaked at 1,467 ± 160 μM for control animals compared with 835 ± 154 μM for EN-treated animals. After treatments ended on d 21, no evidence was found for a plasma NEFA rebound in either parity group. A treatment × parity × time interaction was detected for liver triglyceride content, indicating a tendency for less liver triglyceride in EN-treated primiparous cows, but caffeine clearance rates were not affected by treatment. No treatment effects were observed for body condition score, body weight, energy balance, or milk or milk component production. A high dose of EN can decrease postpartum plasma NEFA concentration, but may also decrease prepartum DMI.

Key words: niacin, transition, ketosis, periparturient

INTRODUCTION

Fatty liver affects up to 50% of postpartum dairy cattle, which is costly due to milk production losses and secondary diseases such as ketosis (Bobe et al., 2004). Fatty liver occurs when cattle enter a negative energy balance (**NEB**), usually during the first 2 wk of lactation (Grummer, 1993). Lipolysis occurs as a response to the NEB and results in the liver being overwhelmed by high concentrations of plasma NEFA (Ingvartsen and Andersen, 2000). The high influx of NEFA to the liver is usually greater than its oxidative capacity, resulting in storage of NEFA as triglyceride (**TG**) within the hepatocytes (Drackley et al., 2001).

Use of niacin (nicotinic acid; **NA**) in dairy cattle is widely studied; however, results have been inconclusive or contradictory. Niacin is a B vitamin that is required in very small amounts to maintain cellular metabolism (NRC, 2001). At much higher doses, NA also has the ability to suppress the release of fat stores (Pires et al., 2007). As a widely used commercial feed additive, NA is claimed to reduce heat stress (Di Costanzo et al., 1997) and decrease postpartum plasma NEFA concentrations (Pires and Grummer, 2007). Experimentally, NA has been shown to have antilipolytic effects, causing an immediate reduction in plasma NEFA when given postruminally (Pires and Grummer, 2007). Niacin binds to the G-protein coupled receptor GPR109A, causing inhibition of adenyl cyclase activity and a subsequent reduction of intracellular cyclic AMP (cAMP), leading to suppression of lipolysis (Wise et al., 2003). This receptor also has high affinity for BHBA, a ketone that is of considerable interest in postpartum dairy cows due to the high prevalence of ketosis.

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[1]Corresponding author: bbradfor@ksu.edu

Supplemented NA has poor stability in the rumen and it is estimated that only 5% is bioavailable, making supplementation inefficient (Santschi et al., 2005). A rumen-protected form of NA (encapsulated niacin; **EN**) is commercially available, providing a more effective option for dietary supplementation of NA. This product (Niashure, Balchem Corp., New Hampton, NY) is in the form of small pellets that include a core of NA surrounded by several layers of lipids. Because these lipids are relatively insoluble in the rumen, the majority of the pellets exit the rumen intact, largely preventing microbial degradation of the EN.

Until this experiment, no known studies have been conducted to explore the metabolic and production responses to EN in peripartum dairy cows. The purpose of this study was to determine if 24 g/d of dietary EN could suppress lipolysis enough to control plasma NEFA in postpartum dairy cattle, potentially preventing or reducing the severity of fatty liver.

MATERIALS AND METHODS

All experimental procedures were approved by the Kansas State University Institutional Animal Care and Use Committee.

Design and Treatments

A total of 22 Holstein cows (n = 9 primiparous and n = 13 multiparous) from the Kansas State University Dairy Teaching and Research Facility were randomly assigned within parity to receive either 0 or 24 g/d of EN beginning 21 d before expected calving date and continuing until 21 d postpartum. This dose was based on a typical human dose of 1 to 4 g/d (Carlson, 2006), which can be extrapolated to a dose of approximately 10 to 40 g/d for an average Holstein cow. According to product literature, the EN product was estimated to provide 40% bioavailable NA, which would result in supplementation of 9.6 g/d. Cows entered the study from June 2008 to August 2008. Dry matter intake and milk production were measured daily until d 21 postpartum. Cattle were housed in a tie-stall facility in randomly assigned stalls, milked 3 times daily (0400, 1100, and 2100 h) and fed twice daily (0700 and 1500 h) at 110% of the previous day's intake. Prepartum and postpartum diets (Table 1) were formulated to meet requirements (NRC, 2001). All cows were fed similarly, except that treated cows received 12 g of EN at each feeding mixed by hand into the top 10% of the ration.

Data and Sample Collection

Feed ingredient and TMR samples were collected every 2 wk, and corn silage DM was determined twice weekly and adjusted in ration formulations. Milk yields were recorded at each milking, and milk was sampled at every milking beginning at 4 DIM until cows exited the study.

Liver biopsies were taken on d −21, −4, 1, 7, and 21 relative to parturition. Blood was collected on d −21, −14, −7, −4, 1, 4, 7, 14, and 21. On each collection day, liver biopsies and blood samples were taken at 1300 h. Approximately 14 mL of blood was collected from the coccygeal vein and immediately emptied into 2 tubes, one containing potassium EDTA and the other containing potassium oxalate with sodium fluoride as a glycolytic inhibitor (Vacutainer, Becton Dickinson, Franklin Lakes, NJ). Both were centrifuged at 2,000 × *g* for 15 min immediately after sample collection, and plasma was harvested and frozen at −20°C until analysis. Liver samples were collected using a 14-gauge × 15 cm biopsy needle (SABD-1415-15-T, US Biopsy, Franklin, IN). Liver tissue was collected between the 10th and 11th ribs, 5 cm dorsal to a line between the olecranon and tuber coxae. The area was shaved, aseptically prepared, and anesthetized with 2 mL of subcutaneous lidocaine hydrochloride. Anesthesia was assessed by cutaneous response after 5 min, and a #11 Bard Parker blade was used to make a stab incision into the body wall. The biopsy needle was inserted cranioventrally toward the liver and approximately 100 mg of tissue was collected (total of 5 biopsies), snap-frozen in liquid N_2, and stored at −80°C until analysis. The BCS was determined by 3 trained investigators on d −21, −4, 1, 7, and 21 on a 1 to 5 scale according to Wildman et al. (1982). Cow BW was measured on d 1, 7, 14, and 21 at 1300 h.

On d 7 postpartum, a caffeine clearance test was performed to assess liver function, following the protocol of Lakritz et al. (2006). Jugular catheters (#1411, Mila International, Erlanger, KY) were placed and caffeine was administered intravenously (2 mg/kg of BW) as caffeine and sodium benzoate (C4144, Sigma-Aldrich Co., St. Louis, MO) in a sterile pyrogen-free normal saline solution (50 mg of caffeine/mL of solution). Blood was collected into K_3 EDTA-containing tubes (Vacutainer, Becton Dickinson) every 30 min for 180 min and centrifuged (15 min at 2,000 × *g*), and the plasma was removed and stored at −20°C until analysis. Catheters were maintained by flushing with 6 mL of sterile 3.5% sodium citrate solution following each collection. On d 21 postpartum, jugular catheters were placed for 48 h. Blood was collected as above every 8 h to assess if a posttreatment increase (rebound) in plasma NEFA concentration occurred.

Liver and Plasma Analyses

Approximately 20 mg of liver was placed into 500 μL of chilled PBS (pH 7.4) and homogenized. The ho-