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Prepartum supplementation of nicotinic acid: Effects on health of the dam, colostrum quality, and acquisition of immunity in the calf

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ABSTRACT

Nicotinic acid (NA) has been shown to reduce lipolysis, alter milk components and the ruminal environment, and increase blood flow. Increased blood flow to the mammary gland during colostrogenesis might increase nutrients and immunoglobulin concentration of colostrum. Twenty-six multiparous Holstein cows were housed in a tiestall barn. Cows were blocked by expected calving date and randomly assigned to 1 of 2 treatments 4 wk prepartum: (1) 0 g/d of NA (control, CON) or (2) 48 g/d of NA (NA). Total mixed ration amounts fed and refused were measured daily to determine dry matter intake. Blood samples were collected from dams every Monday, Wednesday, and Friday from the coccygeal vein or artery and were analyzed for glucose, nonesterified fatty acids (NEFA), and β-hydroxybutyrate (BHB). Colostrum was collected and weighed within 90 min of parturition. Colostral immunoglobulin G (IgG) concentration was analyzed using radial immunodiffusion assay. Calves were removed from their dams before suckling and weighed within 30 min after birth. Calves received 3 L of a lacteal-based colostrum replacer that provided a total of 225.8 g of IgG within 2 h of birth. Calf blood samples were collected via jugular venipuncture at 0 and 24 h of age and analyzed for IgG concentration and determination of apparent efficiency of absorption. Colostrum yield, dry matter intake, IgG yield, and fat and solids percentage of colostrum did not differ between treatments. Serum concentrations of glucose and BHB were not affected by treatment. We detected an effect of week on serum glucose concentrations at calving and on serum BHB concentrations at 1 wk postpartum. There was a treatment by week effect for serum NEFA concentrations at 1 wk postpartum, where cows that received NA prepartum had higher serum NEFA concentration than CON cows, indicating that a NEFA rebound occurred. No differences were observed for calf body weight, 0- or 24-h serum IgG concentration, or apparent efficiency of absorption. Supplementation of NA increased IgG concentration in colostrum from 73.8 to 86.8 g/L. Results indicate that 48 g/d of supplemental NA during the prepartum period improved colostrum quality.
Key words: nicotinic acid, prepartum, colostrum, dairy calf, immunoglobulin G

INTRODUCTION

Effects of supplemental nicotinic acid (**NA**) on metabolism in pre- and postpartum cattle have been widely studied (Neihoff et al., 2009a), but little is known about its possible effects on colostrum quality or calf immunity, which are key factors for dairy farm success and profitability. Acquisition of immunity in the neonate is dependent on consumption of high-quality colostrum. A nationwide evaluation of colostrum quality in the United States found that >60% of colostrum does not meet industry recommendations of ≥50 g of IgG/L and a total plate count <100,000 cfu/mL (Morrill et al., 2012). The USDA National Animal Health Monitoring System (NAHMS, 2007) reported that one-fifth of heifer calves do not achieve successful passive transfer. Supplemental NA can increase blood flow, which may increase nutrients and immunoglobulin concentration in colostrum if supplemented during colostrogenesis.

Colostrogenesis is a unique stage in prepartum mammary gland development when maternal immunoglobulins are transferred from the blood into mammary secretions (Barrington et al., 2001). This distinct phase of development begins about 3 wk prepartum and ceases just before parturition and the onset of lactation (Brandon et al., 1971). Immunoglobulin G is the most abundant immunoglobulin present, accounting for 85 to 90% of total Ig (Butler, 1969; Sasaki et al., 1976; Larson et al., 1980). Due to the 6-layer synepitheliochorial placenta in bovines, transfer of maternal

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immunoglobulins does not occur in utero, rendering the calf hypogammaglobulinemic (Lopez et al., 1988). For this reason, it is vital that calves receive high-quality colostrum as soon as possible after birth and within 24 h, before complete gut closure occurs (Arthington et al., 2000). Calves that do not receive colostrum will lack necessary antibodies and many other nutrients to fight disease and survive. At 24 h of age, calves should achieve a minimum of 10 g/L of IgG in plasma (Quigley and Drewry, 1998).

Proper nutrition in the prepartum period affects acquisition of immunity in the newborn calf (Burton et al., 1984; Hough et al., 1990) and colostrum quality (Fatahnia et al., 2012). During the last trimester, the developing fetus requires greater nutrients, as total fetal weight gain is greatest during this time (Bell, 1995). Proper feeding of the prefresh cow requires meeting the needs of both the dam and the developing fetus.

Nicotinic acid has been used in humans as an antilipolytic remedy (Carlson, 2005). It lowers triglyceride and low-density lipoprotein cholesterol levels and alters lipolysis via a G protein-coupled receptor (**GPR**) 109A (Lorenzen et al., 2001; Tunaru et al., 2003). Recent work by Titgemeyer et al. (2011) with cattle detected the presence of GPR109A in tail head, back, and perirenal fat, longissimus muscle, liver tissue, and 5 regions of the brain: hypothalamus, thalamus, cerebellum, cerebral cortex, and brain stem. When supplemented at pharmacological doses in cattle, NA inhibits lipolysis via stimulation of GPR109A (Tunaru et al., 2003; Benyó et al., 2006). Nicotinic acid reduces adenylyl cyclase activity, causing inhibition of cyclic AMP (**cAMP**) production (Harvey and Ferrier, 2011). If cAMP concentrations fail to rise, protein kinase A will not be able to phosphorylate hormone sensitive lipase into its active form. If hormone sensitive lipase is inactive, it is unable to break down triglycerides in adipose tissue (Harvey and Ferrier, 2011), thus reducing the release of nonesterified fatty acids (**NEFA**) into the blood (Neihoff et al., 2009a; Kang et al., 2011; Morey et al., 2011).

Tissue requirements for NA in dairy cattle have not been determined experimentally (Neihoff et al., 2009a). In addition to NA supplied from feed, many mammals are able to synthesize NA from tryptophan or quinolinic acid, although dairy cattle are relatively inefficient at this conversion (Frye et al., 1991; Flachowsky, 1993). Microbial synthesis serves as another source of NA. Ruminal production of NA in a 650-kg cow producing 35 kg/d of 4% FCM was estimated to be 1,804 mg/d (NRC, 2001). However, it is speculated that ruminal bacteria do not synthesize more NA than is required for their own growth and function because de novo synthesis of the vitamin is an energy-demanding process (Hannah and Stern, 1985; Abdouli and Schaefer, 1986; Doreau and Ottou, 1996).

A major drawback of NA supplementation in humans has been an unpleasant flushing response. Tunaru et al. (2003) and Benyó et al. (2006) found that the GPR109A receptor is also involved in a cutaneous vasodilation response. The GPR109A receptor is expressed in Langerhans cells, immune cells that densely populate the skin. Activation of the GPR109A receptor causes a classic response from these immune cells: activation of a $G\beta\gamma$-mediated phospholipase C receptor (Benyó et al., 2006). Activation of this receptor causes a conformational change in membrane-embedded Ca^{2+} channels, leading to a temporary increase in Ca^{2+} concentrations in the cytoplasm. This increase in concentration activates the enzyme Ca-dependent phospholipase A_2. This enzyme catalyzes hydrolysis of phospholipids from membranes and lipoproteins, yielding arachidonic acid, a precursor of eicosanoids, such as prostaglandins. Prostaglandin E_2 and prostaglandin D_2 are released from the Langerhans cells and cause vasodilation in the skin (Benyó et al., 2005, 2006). Supplemental NA in the prepartum period could increase blood flow during colostrogenesis, resulting in a higher concentration of IgG in colostrum.

The objectives of this experiment were (1) to determine if supplementing NA during the prepartum period affects colostrum quality, DMI, or blood metabolites of the dam, and (2) to determine if NA supplementation to the dam affects IgG absorption in the calf via in utero effects. Our hypothesis was that supplemental NA during the prepartum period would increase colostral IgG concentration and decrease serum NEFA and BHB concentrations in the dam.

MATERIALS AND METHODS

Experimental Design and Animal Management

This experiment was reviewed and approved by the University of New Hampshire Institutional Animal Care and Use Committee (Protocol #131103).

Twenty-six multiparous Holstein cows were blocked by expected calving date and randomly assigned to 1 of 2 treatments: (1) 0 g/d NA (control, **CON**) or (2) 48 g/d NA (NA), both with 52 g/d of corn meal as a carrier. Treatments were top dressed at each feeding, beginning 4 wk prepartum, and continued until calving. Cows were housed in a tiestall barn, and stalls had mattresses bedded with kiln-dried sawdust. Cows had access to water at all times via automated water bowls (DeLaval, Tumba, Sweden). Each cow had an