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Effects of difructose anhydride III on serum immunoglobulin G concentration and health status of newborn Holstein calves during the preweaning period

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ABSTRACT

This experiment was performed to investigate the effects of increases in passively acquired immunoglobulin G (IgG) by difructose anhydride (DFA) III supplementation on subsequent serum IgG concentration and health status in calves during the preweaning period. Thirty newborn female Holstein calves were paired by birth order, and 2 calves in each pair were fed 2 L of the same batch of colostrum within 2 h and at 10 h after birth, and followed by 2 L of the same batch of pooled colostrum at 20 h after birth. One calf from each pair was assigned to the control (n = 15) or treatment (n = 15) group. All calves in the treatment group received 18 g of DFA III at each feeding from birth to 7 d of age, whereas calves in the control group did not receive DFA III. Blood samples were collected before feeding at 0, 10, 20, and 36 h, and 4 and 7 d of age, and sampling was repeated at 7-d intervals thereafter until 49 d of age for serum IgG analysis. Calves were monitored daily for diarrhea and respiratory diseases. Serum IgG concentrations peaked at 36 h of age in both groups. Apparent efficiency of IgG absorption and peak serum IgG concentration were higher in the treatment group than in the control group. Using multiple regression analysis, we showed that peak serum IgG concentration in the newborn calves was positively correlated with colostral IgG concentration and DFA III supplementation. Moreover, peak serum IgG concentration (36 h of age) positively influenced subsequent serum IgG concentration until 35 d of age for all calves in both groups. The treatment group had higher serum IgG concentration from 20 h to 21 d of age than the control group. However, we detected no differences between the groups in number of calves with diarrhea or respiratory disease.

Key words: calf, difructose anhydride III, immunoglobulin G, infectious disease

INTRODUCTION

Diarrhea and respiratory disease are the most significant causes of calfhood morbidity and mortality (Johnson et al., 2011; Uetake, 2013). These health problems are associated with failure of passive immunity transfer via colostrum feeding (Paré et al., 1993; Wittum and Perino, 1995; Furman-Fratczak et al., 2011). Thus, provision of adequate serum IgG through consumption of colostrum is well accepted and established as improving the health status of newborn calves (Weaver et al., 2000; Godden, 2008). Absorption of ingested IgG through the intestine of newborn calves is possible for only a short period after birth. Because of the maturation process of the neonatal intestinal epithelium, absorption of colostral IgG is the highest within 2 h after birth, gradually declines with age, and completely ceases during the first 24 to 36 h after birth in newborn calves (Weaver et al., 2000; Furman-Fratczak et al., 2011). Peak serum IgG concentrations are achieved at 36 to 48 h of age (Weaver et al., 2000; Furman-Fratczak et al., 2011) and gradually decline thereafter (Weaver et al., 2000; Chase et al., 2008; Nonnecke et al., 2012). Although the calf's own immune system becomes active at approximately 1 wk of age (Devery et al., 1979; Hassig et al., 2007; Chase et al., 2008), endogenous immune function does not reach a protective level until approximately 7 wk of age (Hassig et al., 2007; Chase et al., 2008; Nonnecke et al., 2012). Thus, after intestinal absorption of colostral IgG ceases, serum IgG concentration declines until endogenous IgG production begins in the calf (Hassig et al., 2007; Chase et al., 2008; Nonnecke et al., 2012). The most common diseases (diarrhea and respiratory disease) occur before establishment of complete protection by endogenous IgG in calves (Furman-Fratczak et al., 2011; Johnson et al., 2011). The occurrence and incidence of these diseases during the preweaning period were negatively associated with passive immune transfer via colostrum in calves (Paré et al., 1993; Wittum and Perino, 1995; Furman-Fratczak et al., 2011). Therefore, it is important for the improvement of health status to achieve as high a serum IgG concentration as possible

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in the newborn calves, especially before the adequate development of its own immune system, by enhancing passive immunity.

Difructose anhydride (**DFA**) III is a plant-derived, indigestible oligosaccharide that can promote calcium absorption through paracellular pathways in the intestine of rats (Mineo et al., 2004) and cattle (Teramura et al., 2015). We previously reported that supplementation of DFA III in colostrum fed to newborn calves improved absorption of colostral IgG and increased serum IgG concentrations (Sato et al., 2012; Htun et al., 2016). It has been suggested that the increase of peak serum IgG concentration after colostrum feeding could be due to improved intestinal paracellular pathway via loosening the tight junctions between intestinal epithelial cells by DFA III (Mineo et al., 2004) for greater IgG absorption in newborn calves (Sato et al., 2012; Htun et al., 2016), because DFA III has been shown to improve paracellular absorption in bovine intestine (Teramura et al., 2015). If DFA III enhances absorption of colostral IgG through a paracellular pathway, peak serum IgG might increase with DFA III supplementation, regardless of IgG concentration in the colostrum. Moreover, DFA III might also increase subsequent serum IgG concentrations after the peak and contribute to a reduced incidence of diarrhea and respiratory diseases in calves during the preweaning period. However, these expected benefits of DFA III have not yet been investigated. Therefore, the aim of this study was to assess whether DFA III improves peak serum IgG concentration, regardless of IgG concentration in colostrum, and to determine the effect of DFA III-associated increases in passively acquired IgG on subsequent serum IgG concentrations and selected health measures (diarrhea and respiratory disease) in calves during the preweaning period.

MATERIALS AND METHODS

Protocols for the experimental procedures and animal care in the present study were approved (no. 27-95) by the Animal Care and Use Committee of Obihiro University of Agriculture and Veterinary Medicine (Obihiro, Hokkaido, Japan). This study was carried out between December 11, 2014, and January 2, 2016, at the Field Science Center of Obihiro University of Agriculture and Veterinary Medicine.

Calf Enrollment

Dams were moved into individual maternity pens on their expected due date or on the day they showed signs of impending parturition. All newborn female calves were separated from their dams approximately 30 min after birth to prevent suckling. Calves were cleaned and dried with a towel, and their navels were sprayed with 7% iodine. Each calf was weighed and put into an individual calf hutch with straw bedding for 7 d. After 7 d, calves were moved to an existing group pen until weaning.

Thirty newborn female Holstein calves were paired (15 pairs) by birth order, and each pair was fed a separate batch of colostrum for the first 2 feedings and pooled colostrum for the third feeding. One calf from each pair was assigned to the control group and the other to the treatment group. All calves in the treatment group were supplemented with 18 g of DFA III (Nippon Beet Sugar Manufacturing Co. Ltd., Obihiro, Japan) at each feeding for 7 d after birth. Calves in the control group were not supplemented with DFA III.

Feed and Feeding Practice

Colostrum was harvested from the first milking of postpartum cows. When sufficient colostrum was harvested from a cow for 1 batch ($\geq$8 L), it was divided into four 2-L aliquots in aluminum zip-lock bags and stored at -20°C until used for the first 2 feedings to a pair of calves. When the amount of harvested colostrum was less than 8 L, it was stored in a refrigerator (4°C) until the second milking (postpartum) to prepare pooled colostrum for the third feeding to the calves. The pooled colostrum was divided into two 2-L aliquots in aluminum zip-lock bags and stored at -20°C until used for the third feeding to a pair of calves.

Before feeding, frozen colostrum or pooled colostrum was thawed in warm water at 40 to 45°C and poured into a nipple bottle. Calves in each pair were fed 2 L of the same batch of colostrum within 2 h and at 10 h after birth, and followed by 2 L of the same batch of pooled colostrum at 20 h after birth. From 36 h to 4 d of age, all calves were fed 2 L of fresh milk at 0800 and 1630 h. From 5 to 7 d of age, all calves were fed 2 L of milk replacer (150 g/L of Calftop EX, National Federation of Dairy Cooperative Associations, Tokyo, Japan; TDN >103%, CP >28%, crude fat >15%) at 0800 and 1630 h. All calves were fed by nipple bottle from birth to 7 d of age, and 18 g of DFA III was added to each batch of colostrum and milk replacer fed to the calves in the treatment group for 7 d after birth. From birth to 7 d of age, calves received no starter or hay, but water was freely available.

After 7 d of age, the experimental calves were moved to a group pen (5 $\times$ 7 m) bedded with sawdust, and were kept there with other calves until weaning. The average number of calves in the pen was 9.2 $\pm$ 0.4. The milk replacer during the group-housing period was the same as that fed to calves from 5 to 7 d af-