J. Dairy Sci. 98:458–477
http://dx.doi.org/10.3168/jds.2014-8384

Increasing intake of essential fatty acids from milk replacer benefits performance, immune responses, and health of preweaned Holstein calves

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ABSTRACT

The objective was to evaluate the effect of feeding increasing amounts of essential fatty acids (FA) in milk replacer (MR) during the first 60 d of life on growth, health, and immunity of Holstein calves. Calves were born from dams fed low concentrations of total and essential FA during the last 2 mo of pregnancy. Newborn calves were blocked by sex and parity of the dam and assigned randomly to receive 1 of 4 MR treatments (T). Hydrogenated coconut oil and soybean oil were mixed with emulsifier and commercial MR powder to prepare the following 4 MR containing 0.119 and 0.007 (T1), 0.187 and 0.017 (T2), 0.321 and 0.036 (T3), and 0.593 and 0.076 (T4) g of intake per kg of metabolic body weight ($BW^{0.75}$) of linoleic acid and α-linolenic acid, respectively. At 30 d of life, concentrations of essential FA (linoleic acid and α-linolenic acid) in liver increased, whereas concentrations of C12:0, C14:0, C16:0, and C20:3n-9 decreased linearly with increasing intake of essential FA. Body weight gain and feed efficiency were optimized when male calves consumed T2, whereas gain by female calves tended to increase linearly with increasing intake of essential FA during the first 30 d of age. However, these responses to treatment were not maintained after initiation of concentrate feeding at 31 d of life. Over the 60-d preweaning period, wither and hip heights were improved in both sexes as intake of essential FA increased up to T3. Some measures of health and immunity were affected by replacing some coconut oil with soybean oil. Severity of diarrhea tended to decrease linearly; plasma concentrations of haptoglobin during diarrhea were lower in T2, T3, and T4; phagocytosis by blood neutrophils tended to peak for calves fed T2; in vitro proliferation of stimulated blood lymphocytes was greater for calves fed T2; in vitro stimulated blood cells produced more IFN-γ (up to T3 for males and T2 for females), concentrations of serum IgG against ovalbumin injections were increased in males fed T2 or T3; and skin-fold thickness increased in response to an intradermal antigen injection of all calves fed up to T4. Across sex and under the conditions of the present study, mean daily intakes of linoleic acid between 3 to 5 g/d and intakes of α-linolenic acid between 0.3 and 0.6 g/d during the first 30 d of life promoted growth of preweaned Holstein calves, possibly by improving their immune status.

Key words: calf, essential fatty acids, growth, immunity

INTRODUCTION

Attainment of good growth and health during the preweaning period is the main goal of those rearing dairy calves, as excess morbidity and mortality can significantly affect profit. Compared with that of other species, the immune system of calves is immature in early life (Godden, 2008). Calves must rely on their innate immune system for protection against initial pathogens as their adaptive immunity system develops (Chase et al., 2008). Dietary provision of the correct amounts of essential nutrients is beneficial to the growth and health of newborn calves. Linoleic acid, first identified as an essential nutrient for rats fed fat-free diets (Burr and Burr, 1930), should be beneficial to newborn calves but research to document this is lacking. Those authors identified poor growth, dermatitis, poor reproduction, and death as symptoms of long-term linoleic acid deficiency in rats suffering from "low fat disease." Much later, α-linolenic acid was identified as an essential FA by the role of its derivative, docosahexaenoic acid (**DHA**; C22:6n-3), in brain development using specific tests of retinal and brain function in monkeys and rats (Neuringer et al., 1988; Anderson and Connor, 1989).

Supplementing milk replacer (**MR**) with different sources of FA improved the growth of preweaned calves (Jenkins et al., 1985, 1986; Jenkins and Kramer, 1986). However, for those studies, classical symptoms of an essential FA deficiency (e.g., poor growth, dermatitis, death) were not detected as reported by others feeding fat-free diets to preweaned ruminants (Cunningham

Received May 19, 2014.
Accepted September 23, 2014.
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and Loosli, 1954; Lambert et al., 1954). Moreover, feeding lower amounts of linoleic acid caused an immediate decline in concentrations of linoleic acid in plasma and erythrocytes of rats but an increase in that of preruminant calves, indicating that calves may have a lower dietary requirement, a greater efficiency of conservation, or a greater ability to mobilize linoleic acid from adipose tissue (Sklan et al., 1972). These ruminant studies used only growth, incidence of diarrhea, and FA profile of plasma and tissue, including the ratio of C20:3n-9 to C20:4n-6, to assess calf responses to dietary fats. Efforts should be made to establish FA intakes that optimize animal health, rather than identifying minimal amounts that are sufficient only for growth (Cunnane and Guesnet, 2011). Therefore, metabolic profile, severity of diseases, and measures of immune function should be considered in assessment of essential FA deficiency.

Several studies, performed primarily in rodents, have verified that the FA profile of the phospholipid fraction of immune cells reflects that of the diet and also that changes in proportions of n-6 and n-3 FA can modify the function of immune cells (Calder, 2008). Consuming sufficient amounts of linoleic acid should help the acute inflammatory response of the calf when exposed to environmental pathogens because linoleic acid serves as a precursor of proinflammatory mediators such as cytokines and eicosanoids (Calder, 2006). These compounds contribute to the activity of the all-important innate immune cells, such as monocytes and neutrophils in the early weeks of life. However, an exacerbated proinflammatory condition could impair calf health. The antiinflammatory properties of n-3 FA such as α-linolenic acid may aid in the resolution of inflammation by reducing the activity of signaling molecules and the expression of proinflammatory genes (Schmitz and Ecker, 2008). Therefore, it is critical to identify the symptoms of impaired metabolic, immune, and inflammatory processes associated with reduced intakes of essential FA to help determine actual dietary requirements.

Recent studies (Ballou and DePeters, 2008; Ballou et al., 2008) have focused on the effect of dietary n-3 FA on growth and markers of immune responses of preweaned dairy calves, whereas similar research involving n-6 FA is lacking. Hence, the hypothesis of the current study was that increasing intakes of linoleic acid and α-linolenic acid would improve immune responses of unweaned Holstein calves and, therefore, positively affect overall calf performance. The objective was to evaluate the effect of feeding increasing amounts of linoleic and α-linolenic acids in MR during the first 60 d of life on growth, health, and immunity of Holstein calves.

MATERIALS AND METHODS

Enrollment and Management of Pregnant Cows

The experiment was approved by the University of Florida's Institutional Animal Care and Use Committee and conducted at the University of Florida's dairy farm. A weekly cohort of pregnant nulliparous (n = 34) and previously parous (n = 54) Holstein cattle were enrolled in the study starting 8 wk before calculated calving day.

Prepartum animals were housed in a common lot and fed once daily (0800 h) with a single TMR formulated to have low concentrations of total (1.9%) and essential FA (0.60% linoleic acid and 0.35% α-linolenic acid, DM basis, Table 1). Nonsilage feedstuffs in the TMR were combined to form a grain mix. Bermudagrass silage and corn silage samples were collected once a week and dried for 1 h using a Koster Moisture Tester (Koster Crop Tester Inc., Strongsville, OH) for DM determination. Proportions of silages and grain mix in the ration were adjusted weekly based on weekly DM values to maintain the formulated silage-to-concentrate ratio (55.3:44.7, DM basis). Offered feed was adjusted daily to achieve 5 to 10% orts. Orts were collected and weighed daily. Weekly samples of silage and grain mix were ground to pass through a 1-mm screen using a Wiley mill (Arthur H. Thomas Co., Philadelphia, PA). Samples were composited monthly, pooled in a single sample, and analyzed using wet chemistry procedures (Dairyland Laboratories Inc., Arcadia, WI; Table 1).

Calving Management and Colostrum Feeding

Calves were born between January 4 and April 5, 2011. Pregnant animals were monitored for signs of initiating parturition at least every 2 h. Within 2 h of birth, calves were weighed and ear-tagged, and the umbilical cord was disinfected with 10% betadine solution (Purdue Frederick Co., Norwalk, CT). Calves were housed temporarily (2 to 14 h of age) in individual pens (1 m × 1 m) equipped with a heat lamp before being moved to individual wire enclosures (1 m × 1.5 m) bedded with sand.

Parturient cows were milked within 6 h of calving and colostrum was harvested. The concentration of total IgG in colostrum was measured initially using a colostrometer (Biogenics, Mapleton, OR), and only colostrum of good quality (>50 g/L of IgG) was frozen at −20°C in 4-L amounts. Immediately after being weighed, calves were given 4 L of thawed and warmed colostrum from dams participating in this study using an esophageal feeding tube.