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Effects of feeding an immunomodulatory supplement to heat-stressed or actively cooled cows during late gestation on postnatal immunity, health, and growth of calves

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ABSTRACT

Heat stress during late gestation negatively affects the physiology, health, and productivity of dairy cows as well as the calves developing in utero. Providing cows with active cooling devices, such as fans and soakers, and supplementing cows with an immunomodulating feed additive, OmniGen-AF (OG; Phibro Animal Health Corporation), improves immune function and milk yield of cows. It is unknown if maternal supplementation of OG combined with active cooling during late gestation might benefit the developing calf as well. Herein we evaluated markers of innate immune function, including immune cell counts, acute phase proteins, and neutrophil function, of calves born to multiparous dams in a 2 × 2 factorial design. Dams were supplemented with OG or a bentonite control (NO) beginning at 60 d before dry off and exposed to heat stress with cooling (CL) or without active cooling (HT) during the dry period (~46 d). At birth, calves were separated from their dams and fed 6.6 L of their dams' colostrum in 2 meals. Calf body weight and rectal temperature were recorded, and blood samples were collected at birth (before colostrum feeding) and at 10, 28, and 49 d of age. Calves born to either CL dams or OG dams were heavier at birth than calves born to HT or NO dams, respectively. Concentrations of serum amyloid A were higher in the blood of calves born to OG dams relative to NO and for HT calves relative to CL calves. In addition, calves born to cooled OG dams had greater concentrations of plasma haptoglobin than calves born to cooled control dams. Neutrophil function at 10 d of age was enhanced in calves born to cooled OG dams and lymphocyte counts were higher in calves born to OG dams. Together these results suggest that adding OG to maternal feed in combination with active cooling of cows during late gestation is effective in mitigating the negative effects of in utero heat stress on postnatal calf growth and immune competence.
Key words: feed supplement, acute phase protein, hematology, neutrophil

INTRODUCTION

Exposure of dairy cows to heat stress during the dry period, 6 to 8 wk before calving, reduces milk production in the following lactation (Tao et al., 2011), alters metabolism, and compromises both the innate and adaptive immune function of the cow (do Amaral et al., 2009, 2010, 2011; Tao et al., 2012b). Heat stress not only adversely affects the cow, but recent research also points to short- and long-term consequences of maternal heat stress during late gestation on the calf in utero. Calves born to heat-stressed cows are lighter at birth, and this difference in weight continues through puberty (Monteiro et al., 2016a). Heifers born to heat stressed cows have lower fertility and produce less milk, at a rate of 5 kg/d through 35 wk of their first lactation relative to in utero-cooled heifers (Monteiro et al., 2016b). Moreover, in utero heat stress affects calf metabolism postnatally and induces alterations in immune development (Tao et al., 2014; Dahl et al., 2016; Guo et al., 2016; Monteiro et al., 2016a). Specifically, heat-stressed calves in utero have lower absorption of IgG from colostrum (Tao et al., 2012a; Monteiro et al., 2014; Laporta et al., 2017) and have lower rates of peripheral blood mononuclear cell (**PBMC**) proliferation, which persists to at least 56 d of age. (Tao et al., 2012a). Together, these studies indicate compromised passive immune transfer and adaptive immunity during early life of heat-stressed calves in utero.

Heat stress abatement, by providing fans and soakers during the dry period (late gestation), improves lactation performance, metabolism, and immune function of cows and their calves (Tao and Dahl, 2013; Dahl et al., 2016). Additionally, nutritional management practices

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may help to ameliorate some of the negative effects of heat stress on immune function and lactation performance. OmniGen-AF (**OG**), a patented proprietary feed additive (Phibro Animal Health Corporation, Teaneck, NJ), was developed to support immune function and has documented immunomodulatory benefits when supplemented to ruminants and rodent models (Wang et al., 2009; Rowson et al., 2011; Ryman et al., 2013; Branson et al., 2016). For example, supplementing dairy cows with OG from −35 to 46 d relative to calving increased daily milk yield and improved innate immune response of dairy cows when challenged with a pathogen (Brandão et al., 2016). Similarly, adding OG to the feed of immunosuppressed sheep increased concentrations of circulating neutrophils and lymphocytes and increased L-selectin on the neutrophil surface (Wang et al., 2007). OmniGen-AF contains a mixture of silicon dioxide, calcium aluminosilicate, sodium aluminosilicate, brewers dehydrated yeast, mineral oil, calcium carbonate, rice hulls, niacin supplement, biotin, D-calcium pantothenate, vitamin B_{12} supplement, choline chloride, thiamine mononitrate, pyridoxine hydrochloride, riboflavin-5-phosphate, and folic acid, but the full formulation is proprietary. Additionally, OG may be beneficial for heat stress abatement in dairy cows by decreasing respiration rate and rectal temperature during lactation (Hall et al., 2014) and the dry period (Fabris et al., 2017). Moreover, cytokine gene expression was upregulated in lactating heat-stressed cows fed OG, which may be associated with improved immune function (Hall et al., 2014). However, it is unknown whether supplementation of OG cows during late gestation may affect the offspring.

Our objective was to evaluate the effect of OG supplementation to pregnant cows exposed to heat stress with or without cooling during late gestation on growth and markers of immunity of preweaned calves. We hypothesized that feeding OG to heat-stressed dams during late gestation would improve their offspring's immune function and performance during the preweaning period. Active cooling of heat-stressed dams during late gestation combined with OG supplementation was predicted to further improve these responses in the offspring.

MATERIALS AND METHODS

Animals and Experimental Design

Maternal Treatments. We conducted a trial at the Dairy Unit of the University of Florida (Hague, FL) during summer and fall (June to December) of 2015. Treatments and animal handling were approved by the University of Florida Institute of Food and Agricultural Sciences Animal Research Committee. Pregnant multiparous Holstein cows were randomly assigned to dietary treatments to receive OG supplementation (56 g/d) or no-OmniGen-AF supplementation (**NO**; 56 g/d of bentonite as a placebo, AB20, Phibro Animal Health Corporation) at 60 d before dry off. Approximately 46 d before expected calving, cows within each dietary treatment were dried off and assigned (based on parity and mature equivalent milk production of their previous lactation) to heat stress (**HT**) or cooling (**CL**) treatments. Thus, cows were divided into 4 groups (2 × 2 factorial design): cooled no OG (**CLNO**), no cooling no OG (**HTNO**), cooled OG (**CLOG**), and no cooling OG (**HTOG**). All cows were housed in the same freestall barn during the dry period, but CL cows were actively cooled using fans (J&D Manufacturing, Eau Claire, WI), over the manger and freestalls, and water soakers (Rain Bird Manufacturing, Glendale, CA), over the manger; HT cows were only provided with shade. Fans were on at all times, whereas soakers turned on automatically for 1.5 min at 5-min intervals when ambient temperature exceeded 21.1°C. Ambient temperature and relative humidity of each barn were recorded every 15 min with Hobo Pro series Temp probes (Onset Computer Corp., Pocasset, MA). The temperature humidity index (**THI**) was calculated for each barn based on the equation reported by Dikmen et al. (2008). Rectal temperature of the dams was measured twice daily (0730 and 1430 h), and respiration rates were monitored thrice weekly (1400 h) for all cows during the dry period. All cows were fed a common TMR during the lactation phase (18.5% CP, 29.8% NDF, 0.87% Ca, 0.35% P, 0.54% Na, 0.59% Cl, 0.45% Mg, and 0.23% S) and the entire dry period (15.4% CP, 34.5% NDF, 0.62% Ca, 0.37% P, 0.36% Na, 0.4% Cl, 0.3% Mg, and 0.2% S). From 60 d before dry off through dry off the supplement was mixed with the ration, whereas during the dry period it was top-dressed once daily.

Calf Management. Calves used in the current study were born to dams either supplemented or not supplemented with OG (beginning at 60 d before dry off until calving) and heat-stressed or cooled during the final 46 ± 3 d of gestation. Sixty calves were born from these dams, of which 32 were heifers (n = 8 CLNO, n = 8 HTNO, n = 8 HTOG, and n = 8 CLOG) that were followed until weaning (d 49). Four heifers, 2 from CLNO, 1 CLOG, and 1 HTOG treatment, were removed from the study due to injuries at the time of calving or due to lack of sufficient colostrum for feeding. All calves were born between July 14 and October 6. Day of birth was considered study d 0. At birth, all calves were separated from their dams and