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Effect of maternal heat stress during the dry period on growth and metabolism of calves

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ABSTRACT

Preliminary studies suggest that maternal heat stress (HS) during late gestation exerts carryover effects on a calf's insulin response after weaning, but a comprehensive evaluation of how maternal HS affects calf intake, growth, and metabolic response from birth to weaning is lacking. Our objective was to evaluate the effects of maternal HS during the dry period on dry matter intake, growth, and metabolism from birth to weaning. After birth, 20 heifers born to either HS (n = 10) or cooled (CL, n = 10) dry cows were immediately separated from their dams and fed 3.8 L of colostrum from a common pool within 4 h of birth. All heifers were managed identically and weaned at 49 d of age (DOA). Calf starter intake was recorded daily, and body weight was assessed at birth and every 2 wk from birth to 56 DOA. Blood samples were collected twice a week until 56 DOA to assess hematocrit and concentrations of insulin and metabolites. To evaluate metabolic responses to maternal HS, a glucose tolerance test, insulin, and epinephrine challenge were performed on 3 consecutive days for all heifers at 8, 29, and 57 DOA. Maternal HS during the dry period did not affect heifer birth weight. Compared with HS, CL calves consumed more starter (0.53 vs. 0.34 kg/d) from birth to 56 DOA and were heavier (71.7 vs. 61.4 kg) at 56 DOA. Relative to HS calves, CL calves tended to have higher hematocrit (27.4 vs. 24.7%). No differences were found between treatments in plasma concentrations of insulin and glucose, but HS calves had higher nonesterified fatty acids and β-hydroxybutyrate concentrations after 32 DOA. Compared with CL, HS calves had a faster glucose clearance after a glucose tolerance test and a slower insulin clearance after an insulin challenge. In conclusion, maternal HS during late gestation reduces calf starter intake and growth, alters blood metabolite profile, and increases noninsulin-dependent glucose uptake.
Key words: heat stress, glucose metabolism, dairy calves

INTRODUCTION

Heat stress (**HS**) during the dry period has tremendous effects on a cow's lactational performance in the subsequent lactation and on her immune competence and metabolic adaptation during the transition period (do Amaral et al., 2010, 2011; Tao et al., 2012b). Additionally, the effects of late gestation maternal HS are carried over to postnatal life of the calf. Previous studies indicate that a calf that experiences in utero HS has impaired passive and cell-mediated immune function before weaning (Tao et al., 2012a; Monteiro et al., 2014), suggesting that maternal HS during the dry period compromises the health of the offspring. Late gestation HS also exerts long-term effects on progeny performance up to and through the first lactation. Indeed, heifers born to heat-stressed dams have a greater chance of leaving the herd before puberty due to sickness, malformation, or growth retardation compared with those from cooled dry cows (Monteiro et al., 2013). Interestingly, heifers born to HS dry cows also had a greater number of services per conception confirmed 30 d after insemination and lower milk production in the first lactation relative to those from CL cows (Monteiro et al., 2013). However, the physiological mechanisms of the effects of maternal thermal insult on postnatal performance of the offspring are not clear.

Maternal HS also alters postnatal metabolism of the offspring. Lambs born to ewes heat stressed in mid gestation develop higher insulin response to glucose (Yates et al., 2011) and lower lipolytic response to adrenergic stimulation compared with those from thermoneutral dams (Chen et al., 2010). In the dairy calf, although growth rates were similar during the prepubertal period (Monteiro et al., 2013), calves born to HS dry cows have enhanced glucose uptake after weaning, as evi-

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denced by more rapid glucose clearance after a glucose tolerance test (**GTT**) and an insulin challenge (**IC**; Tao et al., 2014). However, it is unknown if this altered glucose metabolism after weaning by prenatal HS is developed in utero or during the postnatal stage due to variable nutrient consumption. Tao and Dahl (2013) observed that calves born to HS dry cows had a higher serum insulin concentration after colostrum ingestion during the first days of life compared with those from CL cows, which suggests a stronger pancreatic response to colostral lactose ingestion or a greater insulin resistance in peripheral tissues. Additionally, the effects of maternal HS on calf starter intake, blood metabolites, and insulin during the preweaning period are unknown. Our hypothesis was that maternal HS during the dry period alters calf metabolism during the preweaning period. The objective of the present study was to examine the effect of maternal HS during late gestation on heifer calf dry matter intake, growth, and metabolism.

MATERIALS AND METHODS

Animals and Experimental Design

The University of Florida Institute of Food and Agricultural Sciences Animal Research Committee approved the treatments and animal handling before beginning the trial. The animal study was conducted at the Dairy Unit and Calf Unit of the University of Florida from August to December, 2014. Briefly, at approximately 45 d before expected calving, multiparous Holstein cows were dried-off and randomly assigned to 1 of 2 groups, HS or cooling (**CL**), based on parity and mature equivalent milk production of the just completed lactation. All cows were housed in the same barn, but the stall areas for CL cows were equipped with fans and soakers, whereas those for HS were not. The ambient temperature and relative humidity in the stall areas for HS and CL cows were measured every 15 min by Hobo Pro Series Temp probes (Onset Computer Corporation, Pocasset, MA) during the entire dry period, and the temperature-humidity index was calculated based on Dikmen et al. (2008). Rectal temperature was assessed (1430 h) and respiratory rate was determined (1500 h) on a daily basis during the dry period.

Only heifer calves (HS, n = 10 and CL, n = 10) were enrolled in the current study. After calving, all calves were immediately removed from their dams and fed 3.8 L of colostrum from the same pool within 4 h after birth by esophageal feeder. Calves were housed in individual wire hutches on sand bedding and managed in the same manner thereafter. The day of birth was considered as 0 d of age (**DOA**). One heifer born to the HS dam suddenly died due to unknown reasons at 6 DOA, but the data collected before death were still included in the statistical analyses.

Intake, Growth Measures, and Sample Collection

From 1 DOA, calves were fed 6 L/d of pasteurized milk divided into 2 equal feedings, in the morning (0700 h) and in the afternoon (1700 h), until 41 DOA, and then only in the morning (3 L/d) until weaning at 49 DOA. Samples of pasteurized milk were collected thrice weekly (AM and PM; Sunday, Tuesday, Thursday) throughout the study and analyzed for concentrations of lactose (4.7 ± 0.32%), fat (3.25 ± 0.42%), protein (3.37 ± 0.24%), and SCC (855 ± 447 × 10^3/mL) by a Bentley 2000 NIR analyzer at the DHIA Laboratory (Belleview, FL). Calf starter (Cornerstone, Purina Feed, Grey Summit, MO) and water were offered ad libitum starting at 1 DOA. The amount of starter offered and refused (~10%) were recorded daily for each calf. Samples of the starter were collected once weekly and dried at 55°C for 48 h to determine the moisture content.

The BW, withers height, heart girth, and hip height were measured at birth, 14, 28, 42, and 56 DOA, before morning feeding to evaluate growth. Blood samples were collected via jugular venipuncture into sodium-heparinized Vacutainer tubes (Becton Dickinson, Franklin Lakes, NJ) at 1, 4, 7, 11, 14, 18, 21, 25, 28, 32, 35, 39, 42, 46, 49, 53, and 56 DOA before morning feeding and immediately placed in ice. Hematocrit was assessed and then samples were centrifuged at 2,619 × *g* at 4°C for 30 min and plasma collected.

Metabolic Tests

All heifers were subjected to the metabolic tests consisting of an intravenous GTT, IC, and adrenaline challenge (**AC**) at 8, 29, and 57 DOA. The 3 metabolic tests were performed on 3 consecutive days in a randomized sequence. The actual dates were not different between treatments ($P > 0.7$) and averaged 8.8 ± 0.4, 30.1 ± 0.4, and 58.0 ± 0.5 DOA for GTT; 8.9 ± 0.4, 30.0 ± 0.4, and 58.1 ± 0.5 DOA for IC; and 9.1 ± 0.3, 30.7 ± 0.3, and 58.1 ± 0.4 DOA for AC. Animals were fasted overnight before the metabolic tests. A catheter (16 gauge × 7.5 cm, Extended Use MILACATH, MILA International Inc., Erlanger, KY) was inserted into a jugular vein of each calf at least 1 h before the first metabolic test.

During GTT, 0.3 g/kg of BW (Stanley et al., 2002; Yari et al., 2010) of glucose (dextrose 50%, wt/vol; Phoenix Scientific Inc., St. Joseph, MO) was infused