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Effects of a supplement containing multiple types of gluconeogenic precursors on production and metabolism in Holstein bull calves during heat stress

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ABSTRACT

Glucose appears to be a preferred systemic fuel during heat stress (HS) in a variety of species. Increasing the dietary grain content can enhance the post-absorptive carbohydrate status, but providing excessive fermentable starch can cause rumen disorders and this is especially true during HS. Current study objectives were to evaluate the effects of a glycerol based supplemental product on growth and metabolic variables in Holstein bull calves during controlled HS. Before the start of the experiment, bull calves ($n=14$; 163.6 ± 30.1 kg body weight) were subjected to thermal neutral conditions [26.5 ± 3.4 °C and a temperature–humidity index (THI) of 70.4 ± 2.8] for 7 d (period 1; P1). During this period, productive parameters as well as blood metabolites were measured and used as covariates for the subsequent HS period. Following P1, a cyclical HS pattern was implemented for 21 d (P2) where daily ambient temperatures ranged from 29.1 to 39.7 °C and the THI was >74 for 24 h/d and >83 for at least 14 h/d. During P2, half of the HS calves ($n=7$) received a control diet (CON) and the other half received the control diet supplemented with a product (300 g/d) containing gluconeogenic precursors (GLU). Throughout each period respiration rate, rectal temperature and skin temperature at the shoulder and rump were recorded at 0600, 1100 and 1500 h daily. Blood samples were obtained prior to and 4 h post the a.m. feeding during both periods. Although HS markedly reduced DMI (18%) and growth as expected, supplemental GLU did not affect body weight gain. Supplemental GLU decreased the shoulder temperature at 0600 and 1500 h ($P<0.01$), and decreased respiratory rate at 1500 h ($P<0.02$). Feeding GLU did not affect blood urea nitrogen (BUN), glucose or nonesterified fatty acids (NEFA) concentrations, but increased circulating insulin prior to the a.m. feeding ($P<0.03$) and this demonstrates that GLU was effective at enhancing the post-absorptive carbohydrate status. Our results suggest that feeding supplemental GLU improves some body temperature indices but did not enhance growth performance in Holstein bull calves during HS.

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1. Introduction

Heat stress (HS) compromises efficient animal production and although difficult to accurately quantify, the economic impact on the global livestock industries is likely greater than $100 billion annually (Baumgard and Rhoads, 2013). Economic losses due to HS can be attributed to decreased milk production, increased incidence of metabolic disorders and health problems (e.g., rumen acidosis), slowed and inconsistent growth, compromised milk quality, reduced reproductive performance, and mortality (West, 1999).

A variety of amelioration strategies for HS are available, and can be implemented alone or in a coordinated manner. These include: (1) physically modifying the environment (shades, fans, evaporative cooling, etc.), (2) management adaptations (timing of milking, feeding, etc.), (3) genetic selection and (4) dietary modifications. To date, genetic selection for HS tolerance is frequently associated with production drag during thermal neutral conditions (Baumgard and Rhoads, 2013). Investing in adequate HS abatement facilities maybe financially challenging for many producers; this is especially true in developing countries and for small stakeholders. Identifying nutritional strategies that can be easily incorporated into the diet to alleviate the negative effect of HS is beneficial for optimizing production of high quality protein during the stressful summer months.

There are several nutritional strategies to consider during HS and they typically concentrate on increasing the energy density of the diet and minimizing the thermic effect of feeding (see reviews by West, 1999; Kadzere et al., 2002). Recently, some studies have demonstrated that heat-stressed farm animals including growing and lactating ruminants preferentially utilize glucose for processes other than milk and muscle synthesis (see reviews by Baumgard and Rhoads, 2012, 2013). Consequently, heat-stressed animals appear to be in a negative post-absorptive carbohydrate status and thus altering insulin action and increasing glucose availability may be a viable approach during HS (Rhoads et al., 2013). One method of enhancing hepatic glucose output is to feed additional starch, but feeding excessive grain needs to be carefully considered given that heat-stressed ruminants are susceptible to ruminal acidosis (Kadzere et al., 2002). Consequently, safely providing rumen substrates that are gluconeogenic themselves (glycerol; if absorbed intact by the intestine or rumen wall) or are metabolized into glucose precursors (propionate) may increase productivity during the warm summer months (Baumgard and Rhoads, 2012). Dietary ionophores safely increase propionate production and can increase hepatic glucose output (Baumgard et al., 2011). Another dietary option to increase propionate production is via supplementing glucose precursors, such as glycerol and propylene glycol, which have been used for prophylactic and metaphylactic treatment for ketosis (Johnson, 1954; Fisher et al., 1973).

We hypothesized that supplementing a product containing a variety of gluconeogenic molecules could enhance the post-absorptive carbohydrate status during HS and improve animal performance. Therefore, our study objectives were to evaluate the effects of a supplement containing multiple types of glucose precursors (mainly consisting of glycerol and propylene glycol), on productive performance and circulating bioenergetic markers in Holstein bull calves during HS.

2. Material and methods

2.1. Animals and experimental design

Holstein bull calves were cared for according to the guidelines of the Iranian Council on Animal Care (1995). In order to acclimate to the diet and stalls growing Holstein bull calves ($n=14$; 163.6 ± 30.1 kg BW) were selected and randomly assigned to individual tie stalls (4×2 m^2; with individual feeders and waters) two weeks prior to experiment initiation. Animals were maintained in tie-stall stanchions at the University of Zanjan's research farm. The sunlight was able to enter the facility via 2 windows, but the condition was the same for 2 groups. All calves were randomly assigned to treatments and individually fed a TMR twice a day at 0700 and 1400 h to achieve 5–10% orts. Hay (alfalfa) to concentrate (primary barley grain) ratio was 80.2:19.8 which was formulated to meet or exceed NRC (1996) requirements for energy, protein, minerals, and vitamins (Table 1). This experiment consisted of two periods (P). During P1, production variables were recorded daily for 7 d. Blood samples were collected on d 2 and 7 of P1. During P1 all calves were kept in thermal neutral conditions [26.5 ± 3.4 °C and a temperature–humidity index (THI; Buffington et al., 1981) of 70.4 ± 2.8; 14 h/10 h light/dark cycle, Fig. 1]. During P2,

Table 1
Ingredients and chemical composition of diet (DM basis)[a].

Item	
Ingredient composition (g/kg DM)	
Alfalfa hay	198.0
Ground barely grain	543.0
Ground corn grain	31.0
Fish meal	23.0
Cottonseed whole	32.0
Cottonseed meal	95.0
Beet pulp	47.0
Sodium bicarbonate	12.0
Salt	5.0
Mineral-vitamin premix[b]	14.0
Chemical composition	
Diet DM (g/kg)	927.6
ME[c] (MJ/kg DM)	11.17
Crude protein (g/kg DM)	134.0
Crude fat (g/kg DM)	27.0
TDN[c] (g/kg DM)	740.0
NDF (g/kg DM)	288.5
ADF (g/kg DM)	161.0

[a] Composition of the basal diet to which 300 g of Glukosa was added as a top-dress. Glukosa contained 330 g/kg of glycerol, 94.5 g/kg of mono propylene glycol, 70.5 g/kg of Ca propionate, 470 mg/kg of niacin and 185 mg/kg of cobalt sulfate. Effective material was 49.5% and the rest of material was colloidal silica as a carrier.

[b] Provided (per kg of DM): 700000 IU of Vitamin A; 600,000 of IU Vitamin D; 1000 of mg Vitamin E; 250 g of Ca; 200 g of Mg; 8 mg of Co; 800 mg of Cu; 40 mg of I; 3200 mg of Mn, 10 mg of Se; 3000 mg of Zn.

[c] Estimated using the NRC (1996) individual dietary ingredients.