INTRODUCTION

Environmental factors, such as heat stress, influence productivity and efficiency in livestock across the globe. Compared to other mammals, cattle cannot dissipate their heat load very effectively. Therefore, temperatures that exceed the thermal neutral zone have been shown to be detrimental in growth, reproduction, immune function, and ultimately on carcass value and quality (Mader, 2003). Cattle do not sweat effectively and rely on respiration to cool themselves. A complicating factor on top of climatic conditions is the fermentation process within the rumen that generates additional heat in which the cattle need to dissipate. Heat stress reduces feed intake which contributes to cattle being in negative energy balance. Cattle under heat stress display the classic metabolic profile (i.e., elevated NEFA levels) of an animal on a decreased plane of nutrition (Wheelock et al., 2010). Additionally, increased core body temperatures during heat stress results in altered endocrine profiles (Collier et al., 2008).

Feed additives have been shown to alleviate the negative impact that is experienced by livestock cattle during periods of heat stress. Supplementation with dietary fats (O'Kelly, 1987), cation-anion supplements (Sanchez, et al., 1994), and vitamins (Muller, et al., 1986) have been shown to have positive performance effects in heat stressed cattle. Other feed supplements and blends that are commercialized to promote metabolic and immune functions during periods of heat stress could also be beneficial during periods of intense heat.

The objective of this study was to evaluate heat stress tolerance in crossbred Hereford steers during a 15-d period utilizing environmental chamber.

MATERIALS AND METHODS

The study protocol and procedures in regards to the animals were reviewed and approved in accordance with the University of Arizona Institutional Animal Care and Use Committee. Twelve crossbred Hereford steers (250 ± 100 kg) were randomly assigned to individual tie stalls in one of two environmental chambers at the University of Arizona's William J. Parker Agriculture Research Complex (Tucson, AZ). Throughout the study, steers were fed twice daily at 0600 and 1600 h according to its dietary group: Control animals (CON) received 56.7 g of placebo/hd/day and treated animal (TRT) received 56.7 g of Beef Abate/hd/day (PMI Nutritional Additives, Arden Hills, MN). An 86% concentrate diet mostly composed of steam-flaked corn and alfalfa hay formulated to meet or exceed National Research Council recommendations was used to feed steers. Feed intake was recorded daily. The steers were subject to a 14-d period of acclimation under ambient temperature conditions.
After the acclimation period, steers were exposed to either a TN environment (cyclical daily THI 27–39) or HS conditions (cyclical daily THI 70–81) for 15 d. Each TN steer was pair-fed daily to the intake level of its HS weighted cohort with the adjustment made 24 h after the intakes of the HS steers were measured. Indwelling jugular catheters were surgically inserted into steers to facilitate the acquisition of blood samples. Catheters were replaced after 7 d and inserted in the opposite jugular vein from the initial. Blood samples were collected twice daily at 0700 and 1500 h. Serum was obtained from each blood sample by centrifugation at 1,500 × g for 15 min and stored at −40 °C until assayed. Serum samples were analyzed for beta-hydroxybutyric acid (BHBA), glucose, triacylglycerides (TAG), and NEFA by EIA kits. Serum cortisol and insulin were analyzed by ELISA test kits. Performance parameters such as respiration rate, rectal temperature, and skin temperature were recorded daily at 1500 h. Respiration rate was measured by counting flank movements for 60 s. Rectal temperatures were measured using a standard digital thermometer (GLA M700 Digital Thermometer, San Luis Obispo, CA). Skin temperatures were measured by shaving a patch of skin and using an infrared temperature gun (Raynger, Raytek MX, Fluke Corporation, Everett, WA). Average daily water consumption and average daily weight gain were calculated at the end of the experimental trial.

Performance parameters and blood data were analyzed as a 2 × 2 factorial design using the PROC MIXED (SAS software version 9.4, SAS Institute, Cary, NC). Independent variables include treatment, day, environment (temp), and their respective interactions. When significant effects were observed (P < 0.05), differences between the means were evaluated.

RESULTS AND DISCUSSION

At the end of the 15-d HS or TN exposure periods, steers weights were similar (P ≥ 0.124) between treatments (Table 1). As expected, water intake and average daily intake was higher and lower respectively for steers in the HS group compared to the TN group (P < 0.01; data not shown). Intake, however, was corrected daily (pair feeding) utilizing the amount consumed in the HS steers to adjust intake of the TN pair steer. Skin temperature and respiration rates were higher for HS steers compared to the TN independent of dietary treatment (Table 1). Rectal temperature, however, was unaffected by environment (HS vs. TN) nor by dietary treatment (Table 1). In ruminants, short short-term heat acclimation is characterized by responses initiated to compensate for the increased heat stress before permanent acclimation can be obtained. Increased heat dissipation (primarily through evaporative heat loss), reduced feed intake, and increased water intake are examples of the short-term heat acclimation response (Gaughan et al., 2009a).

Serum concentrations of insulin (P = 0.003) and glucose (P < 0.001) were lower for HS steers while serum NEFA (P = 0.0156) concentrations increased in HS steers (Figures 1 and 2). Triacylglycerides concentrations tended to increase for steers under HS conditions (P = 0.0618). Serum concentrations of cortisol and BHBA were not affected by HS exposure (data not shown). Over the length of the experimental period supplementation with Beef Abate affected serum concentrations of HS steers (Figures 1 and 2). These responses tended to occur after days 9–10 and again in days 12–14. Beef cattle are less sensitive than dairy cattle to heat stress due to the overall decrease in endogenous heat production (lower plane of production, reduced heat increment of feeding, etc.; Bernabucci et al., 2010). Variability in the length of acclimation period ranges from 9 d for Angus and Charolais to 14 d for Polled Hereford (Hereford and Santa Gertrudis had intermediate values (12 d); Senft and Rittenhouse, 1985) which coincided with some of the treatment responses in the present study.

IMPLICATIONS

Information on the impacts of short-term exposure of beef cattle to high THI conditions are

Table 1. Effects of environment and treatment on performance parameters in beef steers with or without dietary supplement (BeefAbate)

|                      | Heat stress (HS) | Thermoneutral (TN) | P value     |
|----------------------|-----------------|--------------------|-------------|
|                      | CON  | TRT  | CON  | TRT  | SEM  | Env. | TRT × Env. |
| Rectal temp (°C)     | 38.57| 38.62| 38.57| 38.47| 0.04 | NS   | NS         |
| Skin temp (°C)       | 37.18| 37.15| 32.34| 31.34| 0.12 | <0.0001| <0.0001    |
| Respiration (Breaths/min) | 51.1 | 49   | 27.6 | 27.6 | 0.91 | <0.0001| NS         |
| Weight change (kg/day)| 0.82 | 0.62 | 1.23 | 3.02 | 0.82 | NS   | NS         |
| Average daily intake (kg/day) | 7.01 | 7.56 | 8.39 | 8.62 | 0.16 | <0.0001| NS         |

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limited in the literature. In this study, crossbred Hereford steers showed marginal negative effects in performance and biochemical parameters after a 15-d exposure to medium-to-high THI conditions. Supplementation with the feed additive blend product Beef Abate improved, delayed, or tended to improve some of the negative impacts of heat stress during specific time points during the experimental period suggesting potential benefits in commercial situations. Further studies

Figure 1. Effects of heat stress (HS) or thermoneutral (TN) environments on serum NEFA (µmol/L) and TAG (mg/dL) levels on beef steers. Open boxes represent TN and checkered boxes represent HS. Effects of dietary supplementation TRT on HS beef steers over a 15-d experimental period. Solid line with triangle represent TRT and dashed line with square represent CON. *P < 0.05; **P < 0.01. TAG = triacylglycerides.

Figure 2. Effects of heat stress (HS) or thermoneutral (TN) environments on serum insulin (ng/mL) and glucose (mg/dL) levels on beef steers. Open boxes represent TN and checkered boxes represent HS. Effects of dietary supplementation TRT on HS beef steers over a 15-d experimental period. Solid line with triangle represent TRT and dashed line with square represent CON. *P < 0.01.
are needed under higher THI condition or during longer periods of exposure to better examine the full impact of heat stress on feedlot steers and the benefits of supplementation under these conditions.

**LITERATURE CITED**

Bernabucci, U., N. Lacetera, L. H. Baumgard, R. P. Rhoads, B. Ronchi, and A. Nardone. 2010. Metabolic and hormonal acclimation to heat stress in domesticated ruminants. Animal. 4:1167–1183. doi:10.1017/S175173111000090X

Collier, R. J., J. L. Collier, R. P. Rhoads, and L. H. Baumgard. 2008. Invited review: genes involved in the bovine heat stress response. J. Dairy Sci. 91:445–454. doi:10.3168/jds.2007-0540

Gaughan J.B., N. Lacetera, S. E. Valtorta, H. H. Khalifa, L. Hahn and T. Mader. 2009a. Response of domestic animals to climate challenges. In Ebi, K. L., I. Burton, and G. R. McGregor, editors. Biometeorology of adaptation to climate variability and change. Heidelberg (Germany): Springer Science; p. 131–170.

Mader, T. L. 2003. Environmental stress in confined beef cattle. J. Anim. Sci. 81(E. Suppl. 2):E110–E119.

Muller, L. D., A. J. Heinrichs, J. B. Cooper, and Y. H. Atkin. 1986. Supplemental niacin for lactating cows during summer feeding. J. Dairy Sci. 69:1416–1420. doi:10.3168/jds.S0022-0302(86)80549-5

O’Kelly, J. C. 1987. Influence of dietary fat on some metabolic responses of cattle to hyperthermia induced by heat exposure. Comp. Biochem. Physiol. 87A:677–682.

Sanchez, W. K., M. A. McGuire, and D. K. Beede. 1994. Macromineral nutrition by heat stress interactions in dairy cattle: review and original research. J. Dairy Sci. 77:2051–2079. doi:10.3168/jds.S0022-0302(94)77150-2

Senft, R. L., and L. R. Rittenhouse. 1985. A model of thermal acclimation in cattle. J. Anim. Sci. 61:297–306.

Wheelock, J. B., R. P. Rhoads, M. J. Vanbaale, S. R. Sanders, and L. H. Baumgard. 2010. Effects of heat stress on energetic metabolism in lactating Holstein cows. J. Dairy Sci. 93:644–655. doi:10.3168/jds.2009-2295