Journal of Thermal Biology 63 (2017) 104–111

Contents lists available at ScienceDirect

Journal of Thermal Biology

journal homepage: www.elsevier.com/locate/jtherbio

Relationships between ambient conditions, thermal status, and feed intake of cattle during summer heat stress with access to shade

A.K. Curtis, B. Scharf, P.A. Eichen, D.E. Spiers*

Division of Animal Science, University of Missouri, 920 East Campus Drive, Columbia, MO, United States

ARTICLE INFO

Keywords:
Telemetry
Heat stress
Feedlot
Environmental physiology

ABSTRACT

Heat stress in feedlot cattle is known to reduce their performance. The challenge comes in determining reliable predictors of current and near-future changes in thermal status and performance. A 42-d study, using crossbred (*Bos taurus*) steers was conducted during summer months (July through August) to identify best environmental determinants of rumen temperature (T_{rumen}) and feed intake (FI) in feedlot cattle with access to shade. A further goal was to define the relationship between T_{rumen} and FI. Shade coverage was approximately 50%, and all animals were provided standard feedlot diets and water *ad libitum*. Intraruminal telemetric boluses recorded T_{rumen} several times each hour. Ear tags, telemetrically connected to a feed monitoring system, provided FI data using RFID technology. Data loggers recorded ambient conditions in sun and shade, along with black globe temperature. Regression analyses identified daylight black globe and air temperatures in shade, with one hour delays, as the best predictors of T_{rumen}. Prediction of FI was much less reliable. Unexpectedly, T_{rumen} was not superior to ambient variables in predicting FI. Maximum daily temperature humidity index, calculated using BG in sun with a 5-d lag, was the best significant predictor of FI. These results indicate for feedlot cattle that although air temperature alone in the shade may be the best predictor of T_{rumen} in the heat, black globe temperature in the sun may be a better determinant of feed intake over time. Additional studies are needed to verify the delayed FI response which seems unusually long.

1. Introduction

Although many mathematical models have been proposed to predict thermal strain in cattle exposed to heat stress (Gaughan et al., 1999; Brown-Brandl et al., 2005b; Mader et al., 2006; Scharf et al., 2011), they have not incorporated the impact of heat on feed intake. Daily ambient temperature-humidity index values have been shown, in general, to be negatively correlated with feed intake of cattle, and positively correlated with respiration rate, heart rate, and rectal temperature (Bouraoui et al., 2002). In addition, it has been shown that environmental stressors may not have an immediate effect on production variables, like feed intake, with shifts occurring days in the future (Spiers et al., 2004; West et al., 2003). Accurate estimates of feed intake are vital to predicting growth and to the application of equations for estimating nutrient requirements of beef cattle (National Research Council, 1987). Equations exist that predict dry matter intake over time based on independent variables, such as initial body weight and energy content of feed (National Research Council, 2000). However, long-term models based on dynamic environmental variables and tested in field situations are lacking.

Rectal or internal body temperature has been shown to be the best, single predictor of milk production by dairy cows within controlled, chamber studies (Spiers et al., 2004). Recent advances in telemetric technology now make it possible to wirelessly collect internal temperature with high resolution in field settings. Telemetry is also useful because it does not rely on cattle capture or restraint to measure this temperature. Current technologies also allow for continuous measurements of ambient conditions (e.g., air temperature, relative humidity) along with internal body temperature and feed intake.

The current study was designed to determine best predictors of T_{rumen} and FI for cattle in a feedlot environment under peak summer heat stress conditions. Selected ambient variables, T_{rumen}, and FI were continuously recorded using state-of-art technologies to derive these relationships. In addition, time offsets were incorporated into these evaluations to determine potential delays in the predicted responses.

2. Materials and methods

All cattle used in this study were subject to approval from the University of Missouri Animal Care and Use Committee. They were

* Corresponding author.
E-mail address: spiersd@missouri.edu (D.E. Spiers).

http://dx.doi.org/10.1016/j.jtherbio.2016.11.015
Received 20 August 2016; Received in revised form 3 November 2016; Accepted 21 November 2016
Available online 02 December 2016
0306-4565/

maintained in feedlots at the University of Missouri Beef Research and Teaching Farm in Columbia, Missouri (38.9516°N, 92.3286°W). Data were collected during mid-summer (July 12 to August 22).

2.1. Animals

Crossbred Black Angus (*Bos taurus)* calves used in this study has been housed on site for five weeks when the study began. A total of 26 animals (347 ± 29 kg BW) were selected at random out of a collection of 40 steers.

2.2. Animal management

Prior to the study, all calves received an RFID tag (Allflex US Inc, Dallas-Fort Worth Airport, TX) in the left ear to identify individual animals. In addition, tags facilitated feed intake (FI) measurement via a feed monitoring system (GrowSafe Systems Ltd, Airdrie, AB, Canada; Sample rate: 8/sec; Accuracy: 10 g). Initial animal treatment included a topically applied liquid anthelmintic (Cydectin, Boehringer Ingelheim Vetmedica Inc., St. Joseph, MO). All steers were subcutaneously implanted with a trenbalone acetate and estradiol pellet (Revalor IS, Intervet Inc., Millsboro, DE) on day zero.

2.3. Temperature boluses

Ruminal temperature was recorded for each animal using telemetric, temperature transmitters (SmartStock LLC, Pawnee, OK, USA) orally placed in the rumen prior to the study using a standard bolus gun. All temperature transmissions used a radio frequency of 900 MHz to an antenna located approximately 10 m from the animal groups. A base receiver unit, which was connected to a personal computer, received the antenna signal. Each bolus transmitted data every 15 min together with the previous 11 readings to reduce data loss. Each bolus was calibrated prior to the study using a NIST (National Institute of Standards and Technology) thermometer. This was accomplished in the lab with a temperature-controlled hot water bath. Each bolus reading was compared to that of the attached NIST thermometer, and any temperature discrepancy was resolved using an individualized regression for each bolus. Sampling frequency was every 15 min, but all ruminal temperature data used for analyses was ultimately derived using the maximum 15-min value for each animal within a given hour. It should be noted that the rumen is normally hotter than other points of temperature measurement and is influenced by water intake. This sampling of the maximum hourly value minimized the erroneous incorporation into the database of thermal artifacts associated with cooling the rumen during and immediately after drinking.

2.4. Housing

Animals were kept in pens built upon inclined concrete that measured 7.32 by 16.46 m. Wood shavings were used to line pens and were periodically removed and replaced to ensure cleanliness throughout the study. The pens were 50% covered by a corrugated metal roof that provided approximately 1.88 m^2 of shelter from sun and rain for each animal. The roof sloped and height ranged from 2.62 to 5.69 m above the pen floors. The roof was uninsulated. Calves could freely move within each pen to eat, drink, or seek shade. Animals were not restricted to shade or sun conditions to allow for measurements in a “normal” feedlot environment. Pens contained automatic waterers (Richie Industries, Conrad, IA) in the uncovered areas of the pens and each waterer was shared by two pens. Each pen contained two GrowSafe bunks for feed provision and intake measurement. Bunks were located under the feedlot roof, and only one animal could eat from a bunk at a time. Steers were stratified by weight to pens and eight steers were housed per pen. Eight animals were housed in each of 5 pens, and 26 of 40 total fed steers were studied by our group.

Light intensity values were obtained using a Minolta Auto Meter light meter (Konica Minolta, Tokyo, Japan) at a height of 1.5 m from the floor. Light intensity values were measured both in and out of shade once on a perfectly clear day, and once again on a totally overcast day at the end of the study. Both sunny and overcast measurements occurred at 1300 h.

2.5. Diets

Water was provided *ad libitum* via automatic waterers. Calves were fed a feedlot receiving diet prior to study onset, and were ultimately fed one of five different standard diets containing varying amounts of fiber that were created by adjusting the ration of soybean hull to shelled corn. Study animals were not separated by diet. Diets were formulated to meet rumen-degradable protein and rumen-degradable nitrogen requirements (Russell et al., 1992) and amino acid requirements were met by incorporating Amino Plus (Ag Processing Inc., Omaha, NE) and Alimet (88% Methionine; Novus International, St. Charles, MO). Minerals were provided to meet National Research Council recommended rates for inclusion in feedlot cattle (National Research Council, 2000). Monensin was provided at the rate of 30 mg per kg of dry matter on an as fed basis (Rumensin 90; 200 g per kg Monensin; Elanco Animal Health, Indianapolis, IN) to increase feed efficiency and prevent coccidiosis. Choice white grease was included in the pelleted supplement at a rate of 20 g per kg to improve pellet quality and consistency. With the exception of the corn and hay, all ingredients were pelleted. All ingredients were combined on-site in the truck-mounted mixer.

Preliminary body weight was determined by averaging weights measured on two consecutive days at study onset. Subsequent body weights were obtained on day 35. To ensure accurate FI data, only one animal could eat from each bunk at a time. Feed was added each morning at approximately 0800 h.

2.6. Ambient measurements

Air temperature (T_a) and percent relative humidity (RH) data were collected using Data Loggers (Hobo H8 Pro; Onset Computer, Bourne MA; Accuracy: +/−0.2 °C T_a and +/−3% RH). Black globe (BG) data were obtained from black globe thermometers (i.e., hollow copper spheres; 15.24 cm diameter, matte black exterior; Bond and Kelly, 1955, Scharf et al., 2011) containing a similar temperature Data Logger and placed in the sun and shade at approximately 2.44 m from ground level to approximate the standing height of the animals. Black globes were placed just outside of animal enclosures so as to avoid damage. All devices were placed in the pens and in the immediate vicinity of the animals, in both shade and sun environments. Data were collected 24 h per day for all days. All temperature humidity index (THI) values were calculated as described by Thom (1959):

$$[(\%RH)/100]*(T_a - 14.4) + (0.8)(T_a) + 46.6(\mathit{Thom}\ 1959) \quad (1)$$

Where,

%RH=Percent relative humidity
T_a=Current air temperature in °C

Ambient measurements included hourly T_a, RH, BG_{shade}, and BG_{sun}, followed by calculation of THI, $BGTHI_{sun}$, and $BGTHI_{shade}$.

2.7. Statistical analysis

Data were collected from July 12 to August 22 during peak summer heat stress (Fig. 1). However, Days 1, 16, and 42 were excluded from analysis due to either poor data resolution or limited readings to result in a total of 39 days used in all analyses. Prior to statistical analysis, a Tukey outlier box plot (JMP®; SAS Institute, Inc, Cary, NC, USA) was