Effects of Environmental Factors on Body Temperature of Feedlot Cattle

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Summary

Tympanic temperature of 32 Angus steers (919 ± 7.5 lb) was measured with Micro-T ibuttons or the Stowaway data loggers. Environmental variables were collected using weather stations located in the pens to evaluate factors influencing body temperature. A multiple regression analysis was used to evaluate the effects of these factors on body temperature of feedlot cattle. Tympanic temperature tended to be higher for Stowaway compared to Micro-T data loggers (102.6 vs. 102.41ºF ± 0.072, respectively; P = 0.053). Tympanic temperature was driven primarily by outgoing solar radiation and wind speed (R^2=0.79).

Introduction

During hot conditions cattle are exposed to an extra heat load as a result of a combination of weather conditions and high-energy diets. Core body temperature (BT) is used as an indicator of cattle comfort. Likewise, it has been widely accepted that in healthy adult cattle, BT ranges from 99.5 to 104.0ºF. However, BT is not a constant; rather it shows small circadian fluctuations, which follow the same pattern of changes observed in some environmental variables. Therefore, our objectives were: 1) compare devices to record tympanic temperature, and 2) assess the relationship of different environmental variables on tympanic temperature of feedlot cattle.

Procedure

The relationships among environmental variables and tympanic temperature (TT) were studied during July 5 to 12 of 2007 at the Haskell Agricultural Laboratory in Concord, Neb. A total of 112 predominantly Angus and Angus crossbred steers (7 head/pen, 919.3 ± 7.5 lb) were fed a finishing diet based on dry-rolled corn (76% DM). In each pen, two steers received a Micro-T ibutton data logger, whereas two other steers received a Stowaway data-logger (n = 64). The environmental variables were collected hourly from a weather station located in the feedlot pens. The dry matter intake (DMI) and daily water intake (DWI) were collected daily by pen and then divided by the number of steers in each pen to obtain an estimation of individual water consumption. Data were analyzed graphically using Microsoft Office Excel 2007®, and statistically using JMP® and SAS®. The devices were compared by means of a t-test and an analysis of repeated measures. A multiple regression analysis using the stepwise procedure in SAS was conducted in order to identify the main factors affecting TT. The environmental variables included in the analysis were: air temperature (AT), soil temperature (ST), soil surface temperature (SST), wind speed (WS), relative humidity (RH), temperature-humidity index (THI), solar radiation, plus DMI and DWI. Likewise, data for each one of the four components of solar radiation were collected hourly. Data on incoming and outgoing shortwave radiation were collected using two precision spectral pyranometers (Eppley Lab. Inc.), whereas incoming and outgoing longwave radiation data were collected using two precision infrared radiometers (Eppley Lab. Inc.). Simultaneously, net solar radiation also was collected using a REBS Net Radiometer model Q-7.1 (Radiation and Energy Balance Systems, Inc.).

Results

Device Comparison

Figure 1 displays the average hourly TT for each device, showing similar patterns. The minimum TT was observed early in the morning before sunrise (0600 to 0700). After sunrise, TT increased rapidly and reached the maximum at about 1700 to 1800. The mean TT recorded tended to be slightly higher with the Stowaway device than the Micro-T (102.6 vs. 102.41ºF ± 0.072, respectively; *P* = 0.053). When data were analyzed using the repeated measure procedure, effects for type of device and time of day (*P* = 0.0475 and *P* < 0.0001, respectively) were detected, but there was no interaction between device and hour (*P* = 0.79).

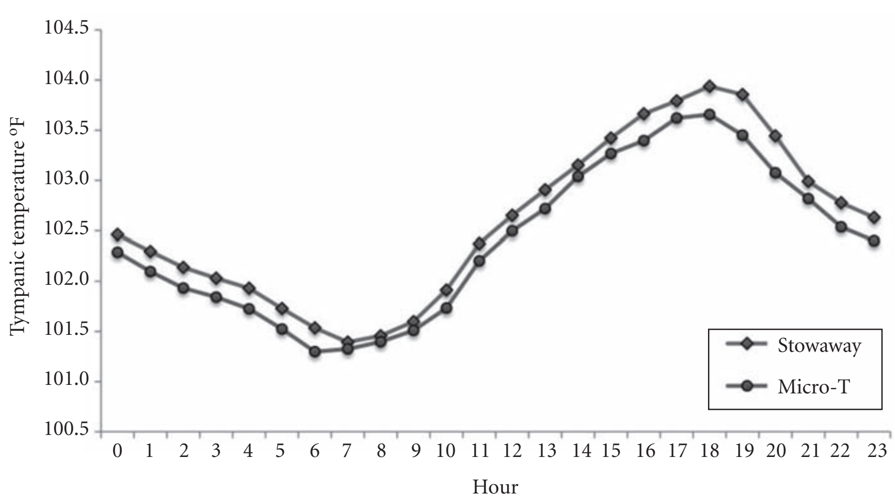

Figure 1. Average tympanic temperature for the period of study by device.

Environmental Factors Affecting Tympanic Temperature

A summary of environmental variables collected is presented in Table 2. The ST and SST were 6.7 and 8.3 degrees higher than AT. However, maximum ST was 4.8 degrees lower than maximum AT, and maximum SST was 22.6 degrees higher than AT. In addition, there was a lag of two hours between maximum SST and maximum AT. The AT reached the maximum around 1600, whereas SST reached maximum at 1400. Average daily net solar radiation (NSR) was 144.26 W*m^{-2}, but ranged from -65.3 during the night to 519.4 W*m^{-2} in the afternoon. The incoming shortwave radiation (SRsin) averaged 320 W*m^{-2}, whereas outgoing longwave radiation (SRlout) averaged 455 W*m^{-2}. The hourly averages of THI, AT, ST, SST and WS showed a similar pattern: an increase after sunrise and a decrease after sunset. The exception to this pattern was RH, which showed an opposite pattern. The largest changes were observed in WS, SST and RH, whereas moderate changes were observed in THI and AT. In addition, maximum SRsin and shortwave outgoing solar radiation (SRsout) were reached in the afternoon between 1200 and 1400 (Figure 2). On the other hand, longwave incoming solar radiation (SRlin) and SRlout presented less variability through the day. Net solar radiation, which is the balance of the incoming and outgoing fluxes from shortwave and longwave streams, follows the same pattern as SRsin.

Modeling Tympanic Temperature

The effects of each of the components of solar radiation plus AT, ST, SST, WS and RH variables were assessed together using multiple regression analysis in order to identify those variables that are important to predict BT. These variables were used as predictors, whereas the TT was used as a response variable. The TT was positively correlated with SST (0.73), ST (0.78), THI (0.80), AT (0.81) and SRlout (0.86). Likewise, SRlout was highly correlated with THI (0.93), AT (0.98) and SST (0.91). In order to select the best model, different procedures of selection were assessed (Cp, MSE, SBC, AIC, R^2, Adj R^2 and the multiple regression stepwise procedure). The model including SRlout, ST, AT and WS explains 83.3% of the variability in TT. However, the collinearity analysis demonstrates the existence of redundant information in the variables AT, ST and RSlout. Thus, AT and ST were dropped from the model. After removal of those variables, the model included two factors

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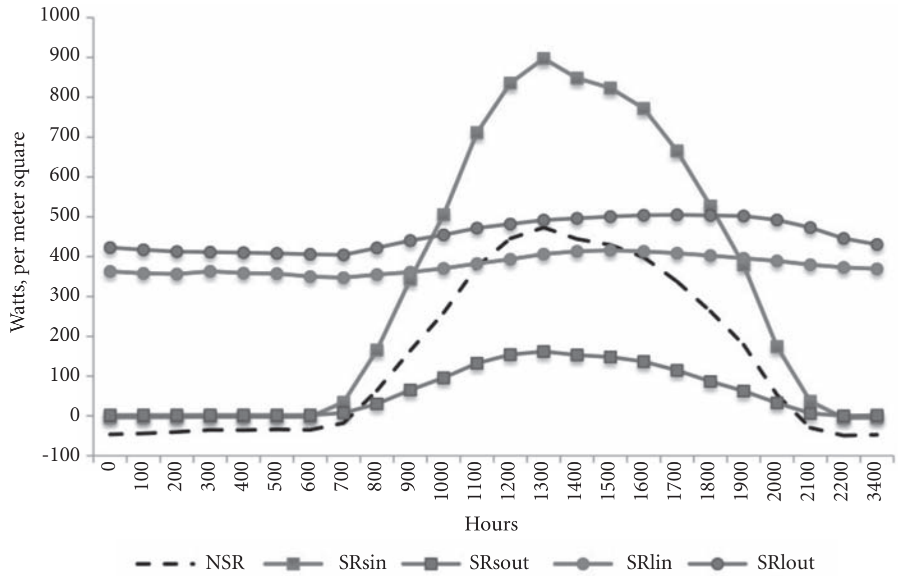

Figure 2. Average hourly components of solar radiation for the experimental period. NSR = net solar radiation (Watts*m^{-2}); SRsin= incoming short-wave solar radiation (Watts*m^{-2}); SRsout= outgoing short-wave solar radiation (Watts*m^{-2}); SRlin= incoming longwave solar radiation (Watts*m^{-2}); SRlout= outgoing longwave solar radiation (Watts*$^{-2}$).

Table 1. Tympanic temperature summary for the period of evaluation.

Item	Stowaway	Micro-T ibutton	Average
Mean	102.60	102.40	102.50
SE	(0.073)	(0.071)	(0.071)
Maximum	105.05	104.68	104.85
Minimum	101.11	100.97	101.15
Range	3.94	3.71	3.7
Number of records	165	165	165

Table 2. Summary of averaged environmental variables collected during the period of evaluation.

Item	RH	AT	THI	WS	ST	SST	NSR	SRsin	SRsout	SRlin	SRlout
Mean	64.60	75.88	71.7	4.85	82.53	84.21	144.26	320.04	53.38	378.89	454.84
SE	(1.43)	(0.80)	(0.56)	(0.25)	(0.31)	(1.36)	(15.78)	(27.53)	(4.91)	(2.71)	(3.41)
Maximum	94.4	95.5	83.6	16.3	90.7	118.1	519.4	991.0	187.0	446.7	529.2
Minimum	33.7	51.81	52.3	1.0	73.6	52.3	-65.3	-8.4	-1.0	296.3	364.0

RH = relative humidity; AT = air temperature; WS = wind speed (mph); ST = soil temperature at 4 inches (F); SST= surface soil temperature (F); NSR = net solar radiation (Watts*m^{-2}); SRsin= incoming shortwave solar radiation (Watts*m^{-2}); SRsout= outgoing shortwave solar radiation (Watts*m^{-2}); SRlin= incoming longwave solar radiation (Watts*m^{-2}); SRlout= outgoing longwave solar radiation (Watts*m^{-2}).

Table 3. Partial regression coefficients ± SE for models assessing environmental factors affecting tympanic temperature in feedlot steers.

Parameter	Estimate	SE	Partial R^2
Intercept	92.84726	0.41423	
Longwave outgoing solar radiation	0.02196	0.00097	0.7373
Wind speed	-0.07515	0.01262	0.0492
Total R^2			0.7865

P values for all statistics < 0.0001.

explaining 78.7% of the variability (Table 3). However, autocorrelations were found among the residuals of the model (autoreg procedure SAS). Thus, a lag was detected at 1 hour and 8 hours and, when accounted for, resulted in an increase in adjusted R^2 (0.97).

The SRlout explained 74% of the variability in TT. In addition, our data indicate a high relationship among SRlout with AT and SST that can be explained because the earth and atmospheres are major sources and sinks of longwave radiation. In addition, most surfaces on the earth are close to being perfect blackbodies — that is, objects that absorb and re-emit all the radiation striking the object's surface for the longwave part of the spectrum. Therefore, the longwave radiation could be playing an important role in the amount of energy (heat) that could be absorbed by the cattle in the pens. Previous research in agriculture indicates that solar radiation flux densities vary significantly among regions due to season, time of day, surrounding terrain elevation and obstructions. Therefore more research under different geographic conditions is required in order to validate the real effect of SRlout on TT. Additionally, WS has been demonstrated to be another important environmental variable that exerts direct effects on animal physiology.

In conclusion, Micro-T data loggers can be used to collect TT without concern. In addition, for steers fed with a typical finishing diet, BT depends mainly on SRlout and WS. These results are in line with our previous observations, indicating that microclimate plays an important role in animal thermal balance.

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