478

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Use of commercial rumen boluses to evaluate hot and cold weather impacts on cattle grazing rangelands

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Abstract

Cold and hot temperatures can impact cattle health and wellbeing while grazing rangelands. Commercial rumen boluses can now remotely provide an indication of body temperature as well as an index of water intake. Ten 2-year-old Corriente heifers were monitored using smaXtec classic rumen boluses during June-August 2023 and January-February 2024 in a 312-hectare rangeland pasture near Prescott, Arizona USA. Reticular temperature measurements with and without proprietary adjustments for drinking water as well as activity indices were recorded every 10 seconds and reported as 10-minute averages. For analyses, temperatures were averaged hourly, every 3 hours and every 24 hours. During both summer and winter water-intake adjusted reticular temperatures (ART) varied by 0.6 C, and it was highest during late evening (1800 to 2159 hours) and lowest in the morning (0900 to 1159 hours). During the summer, ART was more closely associated with wet bulb globe temperature (WBGT) than air temperature, thermal heat index (THI), relative humidity and weather measures on an hourly basis. On a 24-hour basis, ART increased as WBGT and THI increased during the summer. During the winter, ART was most closely related to ambient temperature (AT) on an hourly basis. On a 24-hour basis during the winter, ART decreased during windy days, and ART initially increased with higher relative humidity and then decreased when relative humidity was over 70%. Estimated daily water intake decreased during periods of higher relative humidity during both summer and winter. Rumen boluses appear to be a useful tool to remotely monitor and study cattle responses to hot and cold weather while grazing extensive rangeland pastures.

Introduction

Livestock are regularly exposed to heat and cold stress, and impacts of predicted climate change will likely adversely affect animal wellbeing and productivity during the near future (Polley et al. 2013). Cattle must maintain a narrow range of core body temperature for optimal health. Extended exposure to high temperatures, relative humidity and solar load increase the risk of heat stress occurring during the summer (Shephard and Maloney 2023). A rise in core body temperature often followed by behavioral changes in water intake, feed intake, and activity occur during heat stress. If heat stress persists, negative effects on production, reproduction, and immune responses are known to occur (Lees et al. 2019a).

In the winter, cold stress can occur when animals are unable to maintain homeothermy due to low temperatures or wind chill (Shepard and Maloney 2023). Cattle exposed to extended cold stress, can experience a change in physiological processes, behavior, and hormone regulation, which may negatively impact performance (Wang et al. 2023) Despite, current climate trends and the public's concerns over animal welfare little research has been done to understand the extent of heat or cold stress for cattle grazing rangelands.

Rangelands are vast and often contain rugged terrain, which makes observations of cattle well-being difficult and labor intensive. Recent development of on-animal sensors, such as global positioning systems (GPS), accelerometers, and other devices, as well as the internet of things have facilitated real-time remote monitoring of the activity and health of livestock on rangelands (Nyamuryekung'e 2024). A rumen temperature bolus with radio frequency identification worked as a non-intrusive proxy for core body temperature to identify heat load in feedlot cattle (Lees et al. 2019b). The objective of this proof-of-concept study was to evaluate the effectiveness of a commercial rumen temperature bolus for monitoring the behavior and well-being of cattle in response to summer and winter weather conditions grazing a central Arizona rangeland.

Methods

The study took place at Deep Well Ranch (DWR) located 16 km north of Prescott, Arizona, United States. The study pasture NDP encompasses 312 ha with an elevation gradient of 1,460 to 1,520 meters. Deep Well Ranch falls within the Cold semi-arid (Bsk) of the Köppen climate classification and has an average annual precipitation of 487mm. The terrain is primarily rolling hills dominated by perennial grasses of black grama (*Bouteloua eriopoda* (Torri)), dropseed (Sporobolus spp.) and purple three-awn (*Aristida purpurea* Nutt).

A total of 28 registered 2-year-old Corriente heifers grazed the study pasture. Ten of the 28 heifers were randomly selected and administered smaXtec Classic Boluses (Graz, Austria) on April 7, 2023. The boluses recorded four metrics: reticular temperature (RT), adjusted reticular temperature (ART), activity index, and a water intake index. These metrics were measured every 10 seconds then averaged into 10-minute intervals, except water intake which is averaged into a single 24-hour value. Adjusted rumen temperature is a measure of reticular temperature excluding temperature changes from drinking events. All metrics except RT use proprietary algorithms to calculate the indices. SmaXtec boluses use long range Bluetooth to communicate with a base station, which sends data in real time to the internet using a SIM card with a cellular network.

All weather data were collected at the Prescott Regional Airport, which is 7 km from the study pasture. Ambient temperature (AT), relative humidity (RH), wind speed and solar load were recorded at 5-minute intervals. Thermal Heat Index (THI) was calculated using equations from Hahn et al. (2009), and Wet Bulb Globe Temperature (WBGT) was calculated using equations from Clark et (2024).

Both the smaXtec and weather data were averaged into 3-hour and 24-hour intervals from of June 1, 2023, to August 28, 2023 (summer) and from January 5, 2024 to February 29, 2024 (winter). The smaXtec and weather information was compiled into two data sets, one for 24-hour averages and another consisting of eight, 3-hour time periods within a day.

For the 3-hour data, an independent repeated measures analysis was performed for each combination of weather and smaXtec metric. Summer and winter analyses were conducted separately. The analyses were completed using PROC MIXED in SAS (Littell et al., 2006). The covariate structure was autoregressive, AR(1). The independent variable was one of the weather metrics (ambient temperature C°, relative humidity, solar load, THI, WBGT or wind chill). The dependent variable was one of the smaXtec metrics (RT, ART, or activity index). Heifer was the subject for all analyses. Linear, quadratic and cubic effects for each weather metric were evaluated. The best fitting models were selected based on the smallest Akaike Information Criterion (AIC) score (Littell et al., 2006).

For the 24-hour data, the same approach was used for the summer and winter analyses. An independent repeated measures analysis was performed for each combination of weather and SmaXtec metrics. The covariant structure was again autoregressive AR(1). The independent variable was one of the weather metrics, and the dependent variable was one of the smaXtec metrics. The subject was heifer. Linear, quadratic and cubic effects were evaluated for each separate weather metric.

Results

Summer

Using 3-hour data, RT and ART were nearly the same in early morning and late at night (Fig. 1). A clear divergence between RT and ART occurred mid-morning (06:00 to 08:00) when RT and ART decreased. During late afternoon and evening, RT and ART increased. Reticular temperature experienced a larger drop than ART in the morning. The best fitting model for ART was a cubic relationship with WBGT (P<0.001). Initially, ART dropped as WBGT increased. Adjusted reticular temperature then gradually levelled out and increased when WBGT was greater than 15º. The second-best model for describing changes in ART was a cubic relationship with RH (P<0.001). The cubic relationship indicated that ART rapidly increased from 0% to 40%, then ART continuously declined until 85% RH at which ART increased again. The activity index showed a clear diurnal grazing pattern with higher levels in the morning and evening (Fig. 2). The best fitting model for activity was a cubic relationship (P<0.001) with RH. Modelled activity levels steadily increased as RH increased up to 50%. If RH was greater than 50% any increases in the activity index were gradual. A negative linear relationship (P<0.001) with solar load the second-best model for describing changes in the activity index.

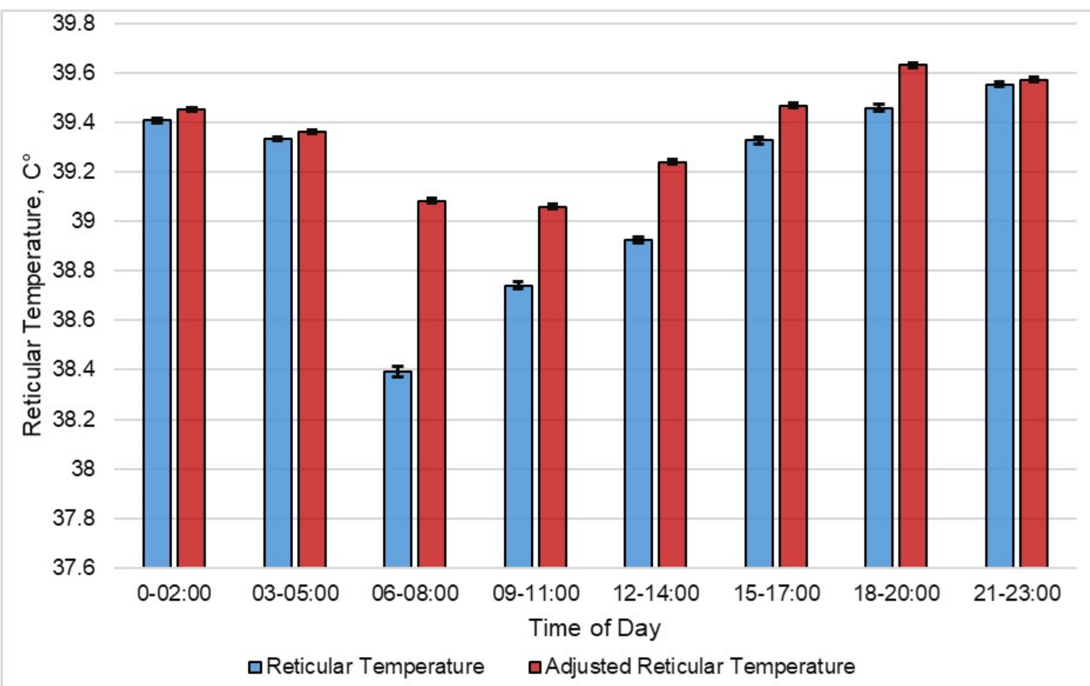

Figure 1. Least-square means of reticular temperature (RT) and adjusted reticular temperature (ART) averaged for each 3-hour period during the summer period. Error bars represent standard errors.

Using 24-hour averages, the best fitting model for ART was a quadratic relationship with WBGT ($P<0.001$) The model suggested that ART decreased when daily WBGT was less than 16. However, ART increased if daily WBGT values were greater than 16. The THI was the second-best predictor of ART with a positive linear relationship. As THI increased, ART increased. The water intake index decreased linearly with increasing RH ($P<0.001$). Days with the highest water intake had the lowest relative humidity. The second-best weather metric for modelling changes in the water intake index was a linear relationship with solar load with a linear relationship ($P<0.01$). The water intake index increased with increasing solar load.

Winter

Like the summer study, RT and ART were similar in early morning and late at night (Fig. 3). Both RT and ART started decreasing at 06:00 and reaching a low between 09:00 and 11:00 then increasing in the afternoon. A quadratic relationship ($P<0.001$) with ambient temperature was the best model for describing changes in ART using 3-hour data. As AT increased to 2°C, ART also increased, but at warmer temperatures ART began to decrease. There was also a quadratic relationship ($P<0.001$) between ART and wind chill with a quadratic relationship. Adjusted reticular temperature increased until wind chill reached zero, after zero ART declined with increasing wind chill. The best fitting model for the activity index (3-hour data) was a quadratic relationship with wind speed ($P<0.001$). The activity index increased with increasing wind speed until approximately 6 m/s. At higher wind speeds the activity index began to decline.

The best fitting model for ART using 24-hour data was a cubic relationship with wind speed ($P < 0.01$). The model suggested ART gradually increased with increasing wind speed until 5 m/s. After wind speeds surpassed 5 m/s, ART increased more rapidly. The activity index was also related to wind speed using 24-hour data. Activity increased linearly ($P<0.001$) with wind speed. Like summer, the water intake index was related ($P<0.001$) to relative humidity (quadratic relationship). Water intake was lower at higher levels of humidity.

Discussion

The higher values of ART compared to RT during midday demonstrate the proprietary algorithm used in ART helps account for drops in reticular temperature resulting from drinking water. The temperature of the drinking water was cooler than RT, thus consuming water lowered RT. Values of ART appear more consistent than RT during periods when cattle normally drink. Thus, ART should be a better metric than RT to use as an estimate of core body temperature. However, neither ART nor RT fluctuated by more than 1°C daily. As mentioned by Shephard and Maloney, (2023) homeothermy of cattle can fluctuate by 1°C daily and varies between species, seasons, and lifestyle stages, which creates difficulty for establishing a "normal" range for core body temperature. Therefore, cattle in this study likely did not experience heat stress. More research is needed in an area with hot temperature lasting for longer durations than central Arizona, as cool nighttime temperature at the study site would likely mitigate heat load. Higher ART values were observed during periods with a higher WBGT, which suggests ranchers in the region should monitor WBGT rather than just ambient temperature or THI to identify periods with increased risk of heat stress.

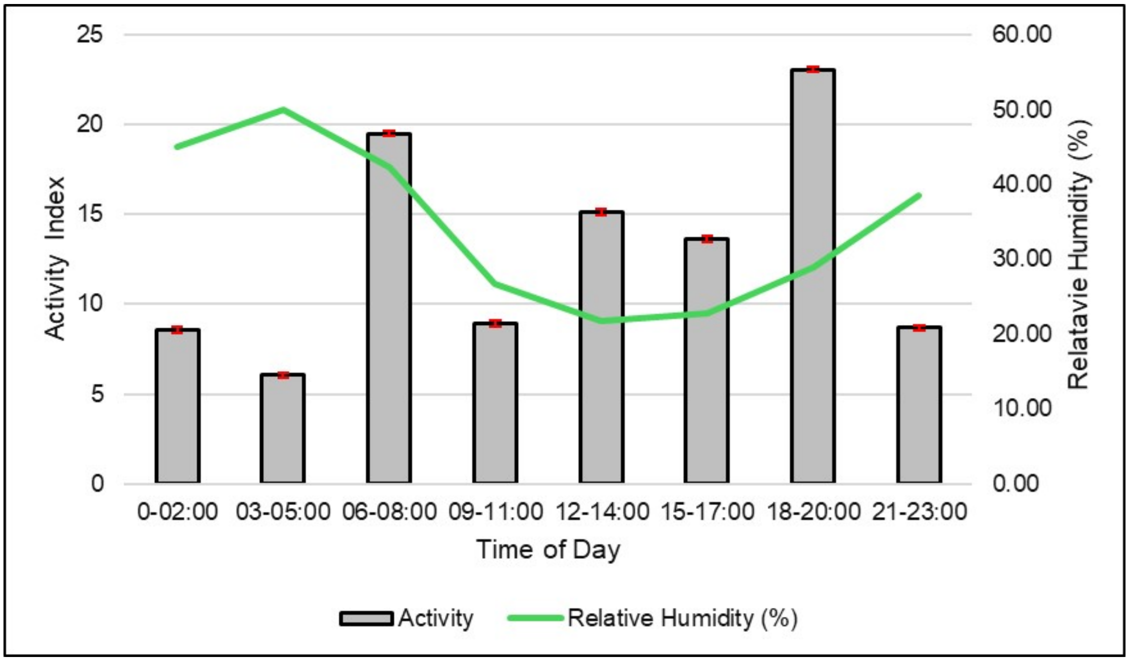

Figure 2. Relationship between the smaXtec activity index and relative humidity throughout the day during using 3-hour data. Columns are the least-square means of the activity index, and the error bars represent standard errors. Values are averages of the entire summer study period.

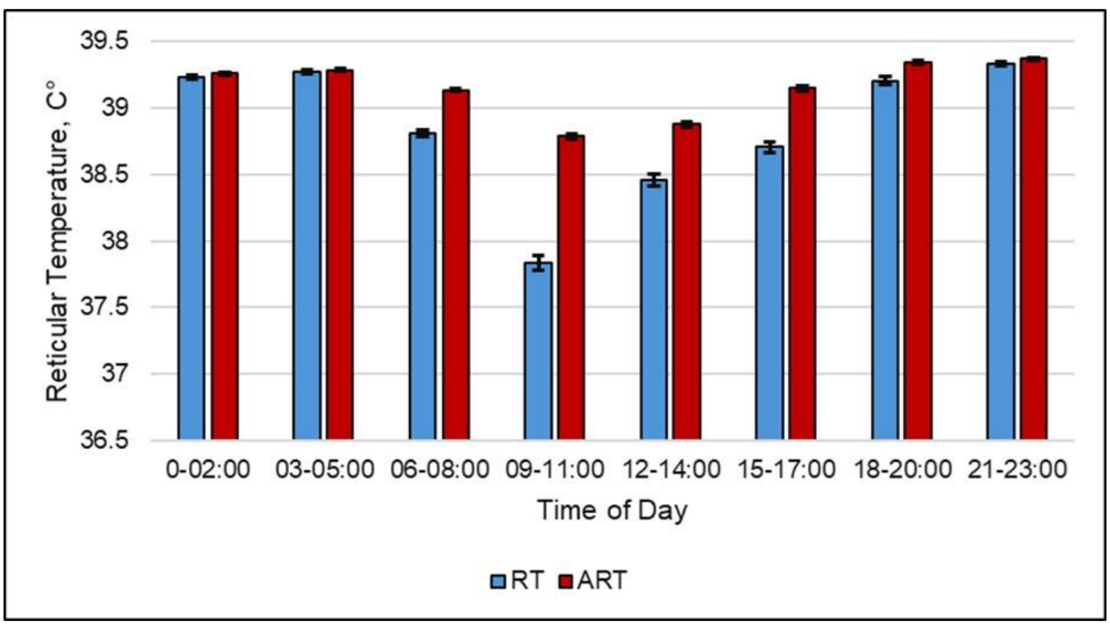

Figure 3. Least-square means of Reticular Temperature (RT) and Adjusted Reticular Temperature (ART) during 3-hour periods averaged over the winter study period. Error bars represent standard errors.

Relative humidity was related to many of the smaXtec bolus metrics in both 24-hour and 3-hour summer data sets. We found the strong association of RH and smaXtec metrics to be surprising because humidity is typically low at this Arizona study site. We speculate the reason RH is so influential is due to the association with monsoonal weather patterns. Periodic rains and cloudy weather occur during the monsoon season (July and August), which likely reduces solar load and ambient temperature. The water intake index decreased when RH levels increased throughout the study. Days with higher RH are correlated to wetter days in the region. During periods of high RH, there may have been moisture on the vegetation, potentially reducing cattle water demand.

During the winter, AT was useful for modelling adjusted reticular temperature within a day. However, wind and relative humidity were more associated with ART than other weather variables on a daily time scale. Wind speed was associated with daily activity changes. Estimated water intake appeared to decrease during periods of higher relative humidity. The impact of wind, relative humidity, and temperature suggest storm events likely influence cattle behavior and ART (a potential proxy for core body temperature) on rangeland during winter months. In this study, cattle appeared to either adapt to cold conditions or were not exposed to cold conditions long enough to result in cold stress. There were no apparent periods when cattle ART decreased for a sufficient time to suggest cold stress. If these boluses are to be used for detecting cold stress, more research in an area with colder conditions than central Arizona is needed.

The combination of a core body temperature metric (ART, adjusted reticular temperature) and an activity index were recorded every 10 minutes and the boluses reliably transmitted the data daily. This technology is promising and shows potential to monitor the well-being of cattle grazing rangelands throughout the summer and winter. The smaXtec rumen boluses worked well with very few issues. This sensor has potential for ranchers and researchers remotely monitor rangeland cattle behavior and core body temperature, but more research is needed in other locations and with other cattle breeds.

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