Rumination as a measure of heat tolerance: a case study in rangeland beef in northern Australia

Chang, AZ[1]; Colusso, PI[1], Williams, TM[1]; Trotter, MG[1]

[1] Institute for Future Farming Systems, School of Health, Medical, and Applied Sciences, Central Queensland University, Rockhampton, Queensland, Australia, 4701

Key words: beef cattle, climate change, heat stress, rumination

Abstract

Climate change poses significant challenges to both productivity and welfare in extensive beef production systems. The identification of heat tolerant individuals is essential for developing resilient herds capable of withstanding increasing temperatures and prolonged periods of heat. The ability to capture relevant phenotypic data for incorporation into genomic evaluation programs, however, remains a significant limitation in extensive environments. This study reports on the use of sensor-based rumination detection to assess individual responses to increasing heat. Thirty-eight cows were equipped with accelerometer ear tags to monitor individual rumination responses to increasing heat during baseline and heat stress periods. The results highlight the potential of a sensor-based rumination detection system to identify heat tolerant individuals in extensive beef systems.

Introduction

Rising global temperatures and the increasing frequency of extreme weather events associated with climate change pose significant challenges to livestock production systems (Godde et al., 2021). In cattle, increased heat is associated with reduced feed intake (Brown-Brandl, 2008), compromised reproductive performance (Dash et al., 2016), reduced growth rates (Lees et al., 2019), and increased mortality rates (Lees et al., 2019). The implantation of strategies to develop heat tolerant herds is essential to ensure the resilience and sustainability of the extensive beef industry in the face of climate change induced pressures – one such strategy is through genomic selection.

A heat tolerance breeding value was initially developed for dairy cattle in 2017 in order to identify individuals that are capable of maintaining a higher milk, fat, and protein yields in hot and humid conditions (Nguyen et al., 2016; Osei-Amponsah et al., 2023). In contrast, developing an analogous breeding value for heat tolerance in extensive grazing systems presents significant challenges, primarily due to the difficulty in collecting relevant phenotypic data due to paddock size and limited animal monitoring and interaction.

Sensor systems offer a promising solution by enabling the continuous collection of behavioural data, supporting phenotype capture in extensive systems. One promising phenotype that is worth exploring is rumination time. Rumination is strongly correlated with a cow's productivity and overall welfare, serving as an indicator of both health and physiological status (Paudyal, 2021).

The integration of sensor systems to monitor rumination behaviour continuously in extensive environments offers an opportunity to generate high resolution phenotypic data that can be used to inform genomic investigations. This study highlights how variations in individual rumination response to heat stress in extensive beef cattle systems can be utilised to support the development of genomic estimated breeding values (GEBVs) for heat tolerance.

Methods

Animal management

This study was conducted at Belmont Research Station (23°13′S, 150°24′ E), 26km north of Rockhampton, Queensland, Australia in November to December 2023. A total of 38 multiparous cows (tropically adapted *Bos taurus*) were grazed in a 65.2 ha paddock. The paddock consisted primarily of alluvial plains, with areas of eucalypt and Brigalow forests. Grass species included spear grass, kangaroo grass, and Queensland blue grass.

Accelerometer ear tags and rumination model

The experimental animals were fitted with Axivity AX3 accelerometer devices (Axivity Ltd., Newcastle, United Kingdom) mounted on modified Allflex Maxi Female ear tags (Allflex Australia Pty Ltd., Murarrie, Australia). The accelerometers recorded data at a sampling frequency of 12.5Hz. Raw accelerometer data was retrieved using the AX3/AX6 OMGUI Configuration and Analysis Tool (Open Movement, Newcastle, United Kingdom). A total of 240 features were generated from the raw data using a mixed model epoch approach (Chang et al., 2022b). A machine learning model for rumination detection was subsequently developed for each animal using the methodology described by Chang et al. (2022a). The individualised rumination models were then applied to calculate daily rumination time across the experimental period.

Weather data

Weather data was obtained from the Bureau of Meteorology station at Rockhampton Aero (site number: 039083), located approximately 16km from the research site. Dry bulb temperature and relative humidity were captured at one minute intervals. The temperature-humidity index (THI) was then calculated at one minute intervals and subsequently summarised to a daily value. The THI was calculated using the formula described in Mader et al. (2006):

$$THI = 0.8 \times T + RH \times (T - 14.4) + 46.4$$

Where

T = dry bulb temperature (ºC)

RH = relative humidity, expressed in decimal form

Statistical analysis

A linear mixed effects model was generated in R using the 'nlme' package to evaluate the relationship between rumination time and mean daily THI (Pinheiro et al., 2020). Mean daily THI was a fixed effect, while individual animals were included as a random effect to account for repeated measures (Fogarty et al., 2020). The analysis aimed to establish baseline rumination levels and identify the threshold at which a significant change in rumination time was observed relative to mean daily THI. The proportion of change in rumination time was quantified by comparing the average rumination time before and after the critical THI threshold.

Results

A significant decrease in rumination time was observed when the mean daily THI exceeded 66 (Fig. 1).

Baseline rumination time varied between animals (range: 22.7% – 41.9%). When the mean daily THI reached the critical threshold, rumination decreased across all animals, with a proportionate change ranging from 35.8% to 73.8% (Fig 2).

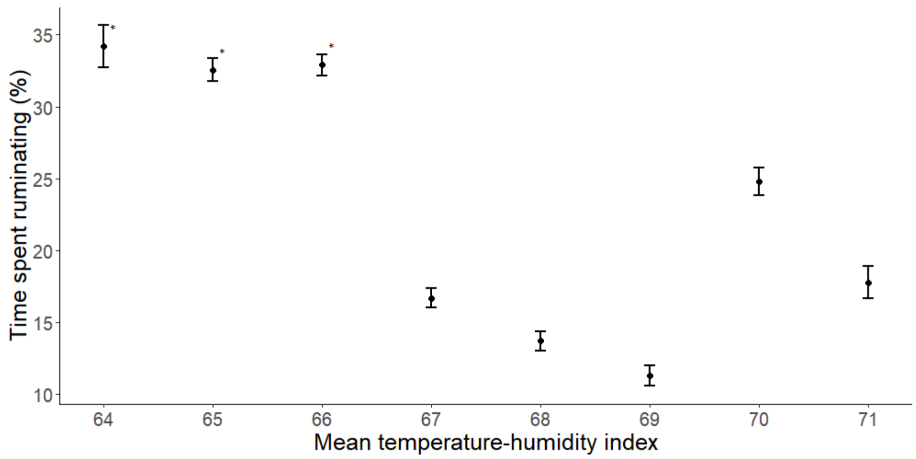

Fig 1. Time spent ruminating vs. mean temperature-humidity index. Significant differences in rumination time between groups are denoted by asterisks (P < 0.05).

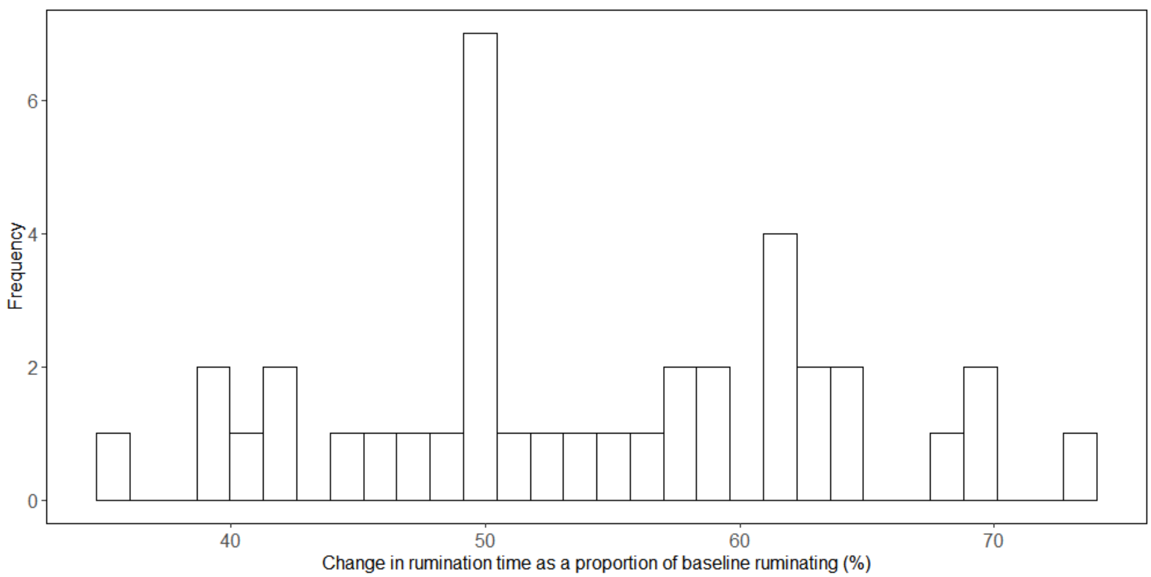

Fig 2. Frequency of the change in rumination time as a proportion of baseline rumination (mean daily THI ≤66).

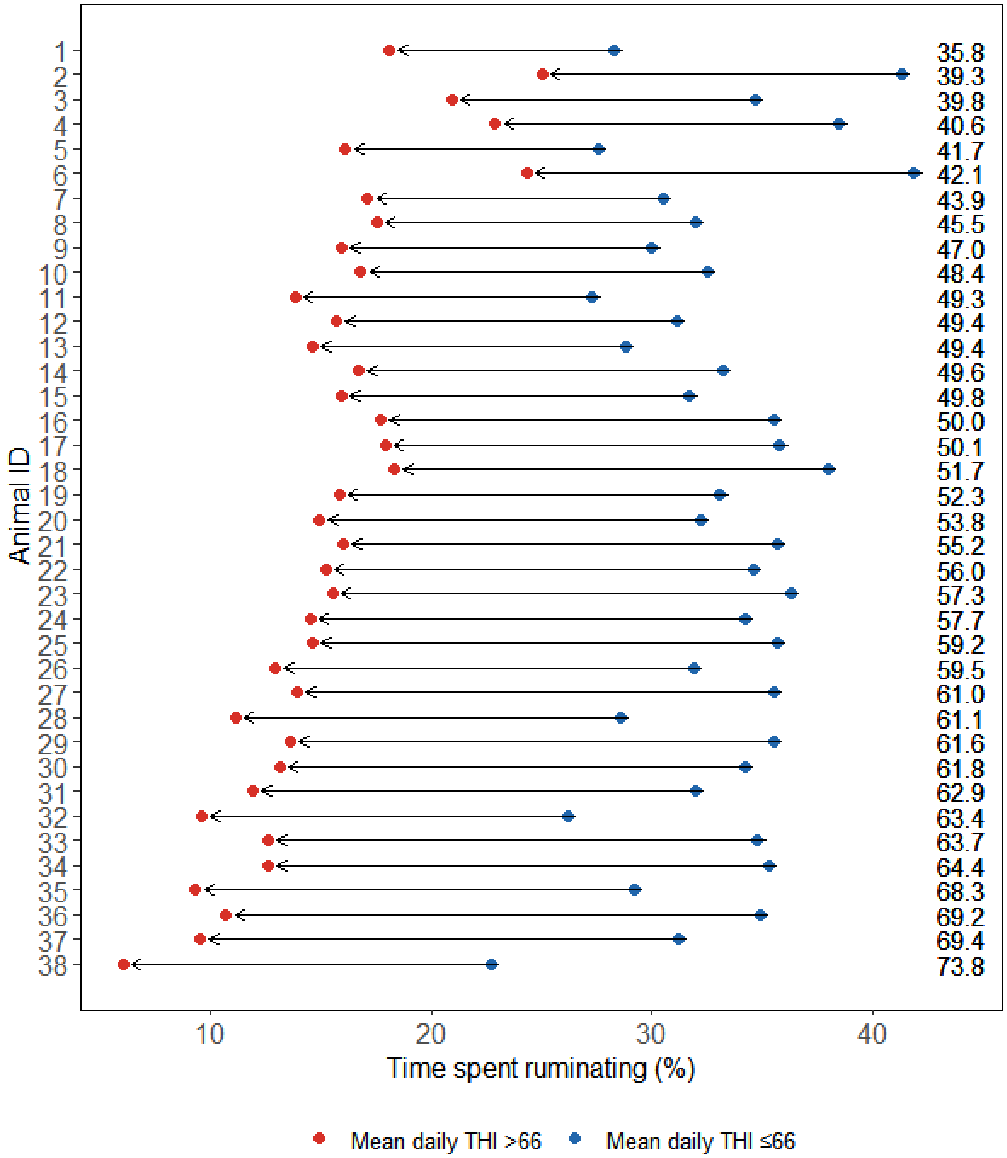

Fig 3. Time spent ruminating by individual experimental animals below and over the critical mean daily temperature-humidity index (THI) threshold. Labels refer to the change in rumination time as a proportion of baseline rumination (mean daily THI ≤66).

Discussion

The findings of this study support existing literature indicating that rumination decreases with increasing heat (Soriani et al., 2013; Moretti et al., 2017; Antanaitis et al., 2024). When exposed to increased heat, humidity, and solar load, cattle engage in various behavioural and physiological strategies to maintain thermoregulation, including reducing rumination (Soriani et al., 2013). Despite the variability in baseline rumination time and the degree of reduction, the decrease in rumination across all animals when the mean THI threshold reaches 66 underscores the potential of rumination as a reliable indicator of heat stress in extensively grazed cattle.

The degree of rumination decrease varied considerably between animals, potentially reflecting differences in individual heat tolerance. These results highlight the opportunity to use rumination data in genomic evaluations to identify heat tolerant individuals. Integrating this data into targeted breeding programs could enhance herd resilience to heat stress, contributing to improved productivity and welfare under increasingly challenging climatic conditions.

Further research is required to validate the inclusion of rumination data as a phenotype for developing GEBVs for heat tolerance. The methods outlined in this study provide a framework for generating high resolution phenotypic data in reference populations, enabling the identification of genetic markers associated with heat tolerance. This could in turn facilitate the selection of individuals with superior heat tolerance, ultimately enhancing the productivity, welfare, and sustainability of extensive grazing systems in the context of climate change.

Acknowledgements

All experimental procedures were approved by the Central Queensland University Animal Ethics Committee (application number: 0000023182).

This work was funded by Meat & Livestock Australia. The authors gratefully acknowledge the assistance of J. Macor, J. Reid, and the staff at Belmont Research Station for their assistance with field work, and L.B Ryall.

References

Antanaitis R, Džermeikaitė K, Krištolaitytė J, Ribelytė I, Bespalovaitė A, Bulvičiūtė D, Palubinskas G, Anskienė L (2024) The impacts of heat stress on rumination, drinking, and locomotory behaviour, as registered by innovative technologies, and acid-base balance in fresh multiparous dairy cows. *Animals* 14(8):1169.

Brown-Brandl TM (2008) Heat stress in feedlot cattle. CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition, and Natural Resources 3(16).

Chang AZ, Fogarty ES, Swain DL, García Guerra A, Trotter MG (2022a) Accelerometer derived rumination monitoring detects changes in behaviour around parturition. *Applied Animal Behaviour Science* 247(4):105566.

Chang AZ, Swain DL, Moraes LE, García Guerra A, Fogarty ES, Trotter MG (2022b) Detection of rumination in cattle using an accelerometer ear-tag: a comparison of analytical methods and individual animal and generic models. *Computers and Electronics in Agriculture* 192:106595.

Dash S, Chakravarty AK, Singh A, Upadhyay A, Singh M, Yousuf S (2016) Effect of heat stress on reproductive performance of dairy cattle and buffaloes: a review. *Veterinary World* 9(3):235-244.

Fogarty ES, Swain DL, Cronin GM, Moraes LE, Trotter M (2020) Can accelerometer ear tags identify behavioural changes in sheep associated with parturition? *Animal Reproduction Science* 216.

Godde CM, Mason-D'Croz D, Mayberyy DE, Thornton PK, Herrero M (2021) Impacts of climate change on the livestock food supply chain: a review of the evidence. *Global Food Security* 28:100488.

Lees AM, Sejian V, Wallage AL, Steel CC, Mader TL, Lees JC, Gaughan JB (2019) The impact of heat load on cattle. *Animals* 9(6):322.

Mader TL, Davis MS, Brown-Bandl T (2006) Environmental factors influencing heat stress in feedlot cattle. *Journal of Animal Science* 84:712-719.

Moretti R, Biffani S, Chessa S, Bozzi R (2017) Heat stress effects on Holstein in dairy cows' rumination. *Animal* 11(12):2320-2325.

Nguyen TTT, Bowman PJ, Haile-Mariam M, Pryce JE, Hayes BJ (2016) Genomic selection for tolerance to heat stress in Australian dairy cattle. *Journal of Dairy Science* 99(4):2849-2862.

Osei-Amponsah R, Dunshea FR, Leury BJ, Abhijith A, Chauhan SS (2023) Association of phenotypic markers of heat tolerance with Australian Genomic Estimated Breeding Values and dairy cattle selection indices. *Animals* 13(14):2259.

Paudyal S (2021) Using rumination time to manage health and reproduction in dairy cattle: a review. *Veterinary Quarterly* 41(1):292-300.

Pinheiro J, Bates D, DebRoy S, Sarkar D, Heisterkamp S, Van Willigan B, Ranke J (2020) Linear and nonlinear mixed effects models. Available at https://cran.r-project.org/web/packages/nlme/nlme.pdf.

Soriani N, Panella G, Calamari L (2013) Rumination time during the summer season and its relationships with metabolic conditions and milk production. *Journal of Dairy Science* 96(8):5082-5094.