Differential sensitivity of milk protein and milk yield to heat stress in a robotic pasture-based dairy system

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Problem statement

Heat stress (HS) is a major environmental challenge affecting dairy cow productivity globally, and is associated with reduced feed intake, altered metabolism, and impaired productivity (Rakib et al., 2024). Temperature-humidity index (THI) is widely used to quantify HS impact in dairy cattle. Although the effects of THI on milk yield (MY) are well documented, less is known about the relative sensitivity of milk composition, particularly milk protein, under pasture-based robotic dairy systems. Understanding which production traits respond earlier to HS may improve early detection and management strategies in pasture-based dairying systems.

This retrospective study evaluated longitudinal effects of HS load on MY and milk protein in a robotic pasture-based dairy system. Our aims were to: 1) to quantify the relationship between the THI and MY and milk protein, 2) identify lagged effects and THI thresholds associated with production decline, and 3) compare the sensitivity of herd MY and milk protein to HS load in a robotic pasture-based dairy system.

Study site and data

Location: Dookie dairy farm, University of Melbourne
System: Pasture-based dairy with robotic milking
Animals: Holstein-Friesian cows (2,594 herd records from 2016–2023)
Climatic data: Nearby meteorological station
HS indicators: THI and adjusted THI (incorporating solar radiation and wind speed) (Mader et al., 2004).

Methods

Pearson correlations between production traits and same-day, lagged (1–3 days), and 3-day average THI.
Segmented regression analysis to identify THI breakpoint associated with MY and milk protein.

The solution/Innovation

Key results/impacts

- Increasing THI significantly reduced MY and milk protein concentration ($P < 0.05$).
- Strongest correlation of MY with 3-day lagged THI ($r = -0.41$; $P < 0.001$), observed above ≥30 kg/d MY threshold.
- Greater milk protein sensitivity to HS load than MY at lower production level.
- Above 41.7 THI threshold, milk protein declined by approx. 0.015% per unit increase in 3-day average THI.
- MY breakpoints occurred at 55.2–57.1 THI, with no significant decline beyond these thresholds.

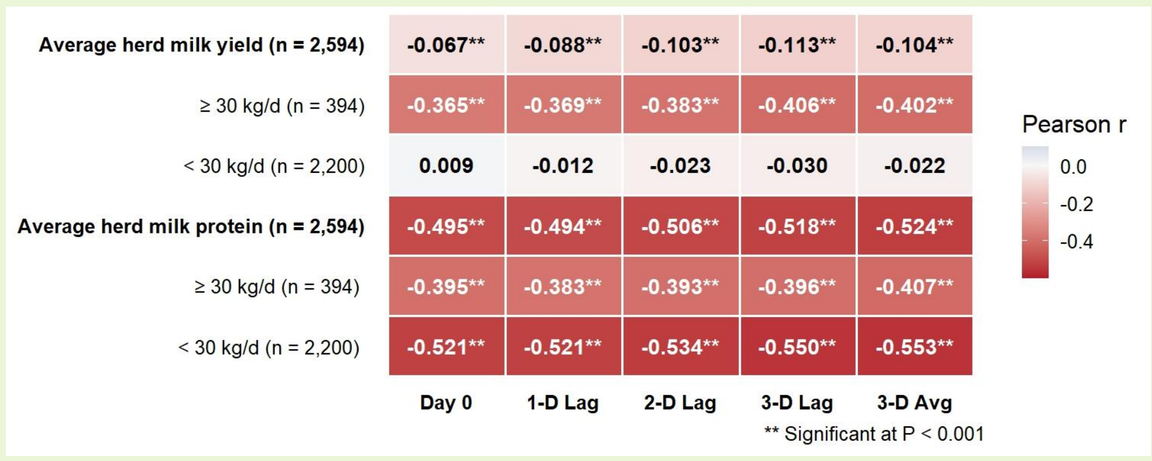

Fig. 1. Heatmap of Pearson correlation matrix of same-day and lagged THI (0–3 days and 3-day rolling average) vs. herd MY and milk protein content. Data stratified by a 30 kg/d MY threshold.

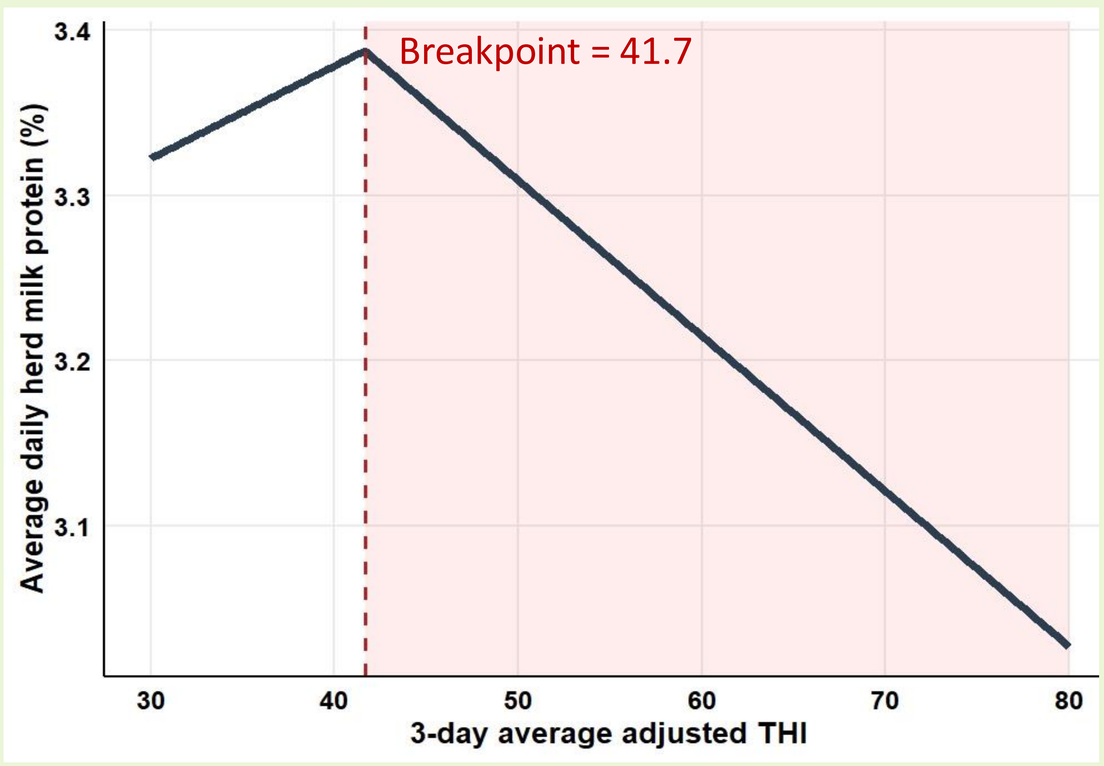

Fig. 2. Broken-line regression of herd milk protein against 3-day average adjusted THI. Vertical dashed line indicates the breakpoint where the response changes significantly.

Scalability and regional relevance

The outcomes of this investigation are particularly relevant to regions where pasture-based dairying predominates. The approach relies on routinely available farm production and meteorological data, and incorporates an adjusted THI that includes solar radiation and wind speed, thereby providing a more realistic representation of HS load on dairy cows under field conditions. Milk protein was identified as a more sensitive early-warning indicator of HS than MY, with concentrations beginning to decline beyond an adjusted THI breakpoint of ~41.7 (3-day average), potentially enabling earlier detection of HS under pasture-based dairy conditions.

Partners and donors involved

- The University of Melbourne
- Dookie Robotic Dairy Farm

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