Short communication: The effect of temperature-humidity index on milk yield and milking frequency of dairy cows in pasture-based automatic milking systems

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ABSTRACT

Hot weather is known to negatively affect cow performance primarily through reduced feed intake and milk yield. However, little information is available on how it affects cow milk yield and milking frequency in automatic milking systems (AMS). Milking data were collected from 6 pasture-based AMS farms in Australia to assess the effect of temperature-humidity index (THI) on milk yield and milking frequency. Daily measures of average milk yield per cow and average milking frequency per cow during December to February (Australian summer) were assessed for associations with maximum, minimum, and average THI from d 0, −1, −2, and −3 in relation to the milking data. Average daily milk yield per cow was negatively associated with an increasing maximum, minimum, and average THI (−0.11, −0.08, and −0.15 kg/THI unit increase, respectively) on the collection day and up to 3 d prior. The average daily milking frequency was negatively associated with maximum THI on 1 d (−0.003/THI unit increase) and 2 d (−0.003/THI unit increase) before collection. Our results show that high THI conditions were negatively associated with milking frequency and milk yield in a pasture-based AMS and that research into management and infrastructure (cow cooling) in these systems is warranted to reduce production losses.
Key words: heat stress, summer, voluntary traffic

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Hot weather conditions are associated with reductions in dairy cow feed intake and milk yield (Garner et al., 2017). Compounding this effect, selection of cows for improved genetic potential for production has also reduced heat tolerance of dairy cows (Ravagnolo and Misztal, 2000). In this regard, the average temperature-humidity index (**THI**) threshold for reduced milk production was 72 (approximately 25°C at 50% relative humidity; Igono et al., 1992); 10 yr later, research by Bouraoui et al. (2002) found that the threshold had decreased to 68 (approximately 22°C at 50% relative humidity). In an indoor automatic milking system (**AMS**) where cows voluntarily traffic to the milking facility, greater milk yield reductions have been reported compared with cows that were batch milked in an indoor system. This trend was seen when THI exceeded 72 and the AMS cows volunteered for milking less frequently (Speroni et al., 2006). Due to the negative effect of hot weather on cow activity and performance (West, 2003a) and the greater traveling distances required by pasture-kept cows, the effect of THI on milk yield and milking frequency in a pasture-based AMS is predicted to be greater and needs to be quantified. To do this, we used milking and weather data from commercial pasture-based AMS farms to investigate the effect of THI on milking frequency and milk yield during summer. It was hypothesized that milking frequency would be negatively affected by high THI conditions on the same day and that milk yield would be negatively associated with a greater THI on previous days.

Farms that had been operating for a minimum of 2 yr and were pasture based within Victoria, Tasmania, New South Wales, and South Australia were contacted to participate in the study. We contacted 15 out of 19 eligible farms, with 6 farms accepting to take part in the study and have data captured from their AMS support software during 2015. At the time of data collection, the farms were operating with voluntary cow traffic and offered either 2 or 3 pasture allocations per day to encourage voluntary cow traffic. The farms ranged in size from 120 to 575 lactating dairy cows milked by 4 ± 2 single-box AMS (various brands) or a 24-bail

automatic milking rotary (DeLaval, Tumba, Sweden). We downloaded the maximum available history (6 mo to 4 yr) of individual cow milking records from the support software on each AMS farm. This information included cow identification, date and time of individual milking sessions, and the total milk yield (kg) from that given session. Human ethics approval to access the data was granted through the University of Sydney (approval code US, 2014/737). Animal ethics approval was not required because the study was based entirely on historical data with no intervention at the animal or herd levels.

We obtained weather data from the Australian Bureau of Meteorology (2016), from the weather station geographically closest (12–49 km) to each of the farms. Due to the distance of the weather stations from the farms, the THI values used in this study may have differed from the actual on-farm conditions and this is a limitation of the study. In addition, 2 farms used weather data from the same weather station, which was located approximately 12 km from one farm and 19 km from the other. Those farms were located approximately 7.5 km from each other, where the farthest 2 farms were approximately 700 km apart.

The weather information included hourly records of temperature (°C) and relative humidity (%). The temperature and relative humidity records were used to calculate hourly THI in Microsoft Excel (Microsoft Corp., Redmond, WA) using the following formula (Kelly and Bond, 1971):

$$THI = (1.8 \times T + 32) - (0.55 - 0.0055 \times RH)$$
$$\times (1.8 \times T - 26),$$

where T = temperature (°C) and RH = relative humidity (%).

The weather data were used to calculate 12 THI-related variables, including maximum, minimum, and average daily THI from d 0, −1, −2, and −3 relative to the milking data. The milking records from all farms during the summer months of December to February were extracted. The summer periods of 2012 to 2013 and 2013 to 2014 contained data from 3 farms totaling 270 and 268 d of milking data, respectively, and the summer period of 2014 to 2015 contained 503 d of milking data from 6 farms. Only data from summer were included to maximize the occurrence of days with a high THI and to avoid the confounding effect of stage of lactation, as most farms calved seasonally. The overall average THI was 61.6 ± 4.5 with an average milk yield of 22.3 ± 5.6 kg/cow and a milking frequency of 2.3 ± 0.3. Approximately 10% of the milking records were associated with an average THI of 68 or greater,

with an average milk yield of 19.1 ± 5.7 kg/cow and a milking frequency of 2.2 ± 0.3. Approximately 50% of records were associated with a maximum THI of 68 or greater, with an average milk yield of 21.2 ± 5.6 kg/cow and a milking frequency of 2.3 ± 0.3.

Average milk yield per cow per day and the average milking frequency per cow per day for each farm were calculated using Microsoft Excel. We used Genstat (16th edition; VSN International, Hemel Hempstead, UK) to perform a linear mixed model analysis (fitted using a REML procedure) on the data. The average milk yield per cow per day and milking frequency per cow per day were the outcome variables, each THI variable was fitted as a fixed effect (covariate), and farm was the random effect. Only univariable models were considered due to correlations among the 12 predictor variables and the difficulties in interpreting regression coefficients from multivariable models in these situations.

We found an association between all THI variables ($P < 0.001$) and the milk yield per cow per day (Table 1). The average THI had the greatest effect on milk yield (average 0.15-kg decline for every THI unit increase) over all test days (d 0, −1, −2, and −3), followed by maximum THI (average 0.11-kg decline) and then minimum THI (average 0.08-kg decline), where day −3 had the lowest effect overall. The average milking frequency per cow per day was negatively associated with maximum THI on d −1 and maximum THI on d −2 ($P < 0.05$), where average THI on d −1 and average THI on d −2 approached significance ($0.05 < P < 0.1$).

The findings of this study support the hypothesis that high THI conditions from up to 3 previous days have a negative effect on milk yield, in line with the findings by Bouraoui et al. (2002). Specifically, the average THI conditions on d 0, −1, and −2 in the current study were associated with greater reductions in milk yield compared with d −3 and the maximum and minimum THI of all days. Previous research has also reported average air temperature (West et al., 2003b) and maximum temperature (Wagner-Storch and Palmer, 2003) of up to 2 d before to be linked with milk yield variation. The average THI had the greatest effect on milk yield compared with the maximum and minimum THI across all days (0, −1, −2, and −3). This finding differs slightly from the findings of West et al. (2003b), who identified d −2 as having the greatest influence on milk yield. The magnitude of the milk yield reductions also differed, where every unit increase in THI resulted in a 0.15-kg decline in milk yield in the current study but a 0.88-kg decline in West et al. (2003b). This difference may be attributed to the normally lower production (and therefore lower susceptibility to heat stress; Collier et al., 2006) of pasture-based cows compared with