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Evaluation of Weather Information from On-Farm and Meteorological Stations to Assess Heat Stress in Dairy Cows in Southwest Kansas

Abstract

Heat stress represents a challenge for the dairy industry. In order for producers to implement appropriate management practices, it is crucial for researchers to assess the extent of heat stress to which cows are exposed during the summer. Temperature-humidity index (THI) may be used to determine the severity of heat stress that cows are exposed to during the summer. The objective of this study was to evaluate climate conditions by calculating THI using information from: 1) an official meteorological station, 2) loggers at the pen-level, and 3) loggers at the cow-level from a commercial dairy located in southwest Kansas. Temperature-humidity index at the cow-level was correlated with THI at the pen-level and THI from the nearest official meteorological station to the dairy. Despite the correlations, cow-level THI was 6.8 and 19.2 units greater than pen-level and station-level THI, respectively. Weather data obtained from farm-level measurements are more accurate than information collected from an official meteorological station to assess the intensity of heat stress conditions. Nonetheless, it is important to note that pen-level THI underestimates the index at the cow-level. This difference is likely to occur because of microclimates within the pen.

Keywords

dairy cattle, heat stress, temperature-humidity index, heat abatement

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Summary

Heat stress represents a challenge for the dairy industry. In order for producers to implement appropriate management practices, it is crucial for researchers to assess the extent of heat stress to which cows are exposed during the summer. Temperature-humidity index (THI) may be used to determine the severity of heat stress that cows are exposed to during the summer. The objective of this study was to evaluate climate conditions by calculating THI using information from: 1) an official meteorological station, 2) loggers at the pen-level, and 3) loggers at the cow-level from a commercial dairy located in southwest Kansas. Temperature-humidity index at the cow-level was correlated with THI at the pen-level and THI from the nearest official meteorological station to the dairy. Despite the correlations, cow-level THI was 6.8 and 19.2 units greater than pen-level and station-level THI, respectively. Weather data obtained from farm-level measurements are more accurate than information collected from an official meteorological station to assess the intensity of heat stress conditions. Nonetheless, it is important to note that pen-level THI underestimates the index at the cow-level. This difference is likely to occur because of microclimates within the pen.

Key words: dairy cattle, heat stress, temperature-humidity index, heat abatement

Introduction

Heat stress causes profound changes in dairy cows' metabolism and energy partitioning. Energy required for heat dissipation mechanisms could be used for other physiological processes, which impacts milk production, reproductive efficiency, and cow health. As a result, heat stress has major implications for the profitability of dairy farms. It was estimated in 2003 that heat stress resulted in losses of approximately \$900 million in the U.S. dairy industry.

In order to evaluate the severity of heat stress conditions for dairy cows, researchers use a temperature-humidity index (THI), which is a calculation that involves both ambient temperature and relative humidity. It has been previously demonstrated that $THI > 68$ is associated with reduced feed intake in lactating dairy cows. Nonetheless, using ambi-

ent temperature and relative humidity from official meteorological stations to calculate THI and evaluate heat stress conditions may not precisely represent climate conditions at the herd-level and cow-level.

The objective of this study was to evaluate climate conditions by calculating THI using information from: 1) an official meteorological station, 2) loggers at the pen-level, and 3) loggers at the cow-level from a commercial dairy located in southwest Kansas.

Experimental Procedures

Lactating ($n = 9$) and dry ($n = 2$) cows from a commercial dairy located in Southwest Kansas were randomly enrolled in the study in 4 replicates from June 13 to July 15, 2014. Cows were fitted with a halter that had an attached temperature logger (HOBO U23 Pro v2; Onset Computer Corp., Pocasset, MA) to assess temperature and humidity at the cow-level. Loggers were fitted inside a hose (2 inches in diameter and 3 inches in length) to avoid being removed by other cows and the hose was attached to the halter with high resistance tape. At the pen-level, ambient temperature and humidity were collected by placing temperature loggers (HOBO U23 Pro v2) approximately 10 feet above ground level. In addition, calibrated iButton temperature loggers (DS1922L, Embedded Data Systems, Lawrenceburg, KY) fitted in blank CIDR inserts were used to collect vaginal temperature. Measurements were collected in intervals of 5 minutes for 3 or 5 consecutive days. Data from the nearest meteorological station, approximately 10 miles from the dairy, were also collected. Information was recorded in intervals of 20 minutes. In order to adjust for intervals of 5 minutes, measurements were used three times. Using ambient temperature and relative humidity collected from on-farm temperature loggers and the meteorological station, THI was calculated using the equation: $T - (0.55 - (0.55 \times RH/100) \times (T - 58))$; where T and RH are dry bulb temperature ($^{\circ}F$) and relative humidity, respectively. Lactating cows were housed in two-row free-stall barns equipped with fans and with access to a dirt exercise lot. Lactating cows had access to an evaporative cooling system (fans and sprinklers) in the holding pen. Dry cows were housed in open dry lots with access to shade. Data were analyzed by ANOVA for repeated measures using the HPMIXED procedure of SAS.

Results and Discussion

Temperature-humidity indices at the cow-, pen-, and station-level are outlined in Figure 1. Average THI was greatest ($P < 0.01$) at the cow-level (cow-level = 91.9 ± 1.1 ; pen-level = 85.1 ± 1.1 ; and station-level = 72.8 ± 1.3). Despite the use of heat abatement strategies, vaginal temperature was greater ($P < 0.01$) for lactating cows compared with dry cows (102.2 ± 0.07 vs. 101.9 ± 0.07 $^{\circ}F$). It is likely that this difference is attributed to greater metabolic heat production associated with milk production of lactating cows. There was no ($P = 0.96$) interaction between productive status and time of the day, which indicates that variations of vaginal temperature across the day were similar in lactating and dry cows (Figures 2A and 2B). Temperature-humidity indices at the cow-level gradually decreased from 18:00 to 24:00 and started increasing at approximately 08:00. Vaginal temperatures, however, did not decrease as rapid as THI. Furthermore, there was a lag for vaginal temperature to increase in relation to the increase in THI in the morning (Figures 2A and 2B).

Temperature-humidity index at the cow-level had a linear relationship with THI at the pen- and station-level (Figures 3A and 3B). Temperature-humidity index at the pen-level better explained the variability of THI at the cow-level than THI at the station-level ($r^2 = 0.82$ vs. $r^2 = 0.76$). This suggests that calculation of THI using ambient temperature and relative humidity collected at the pen-level is more accurate than calculating THI from the meteorological station.

It is possible that several factors influence THI at the cow-level. Amount of time spent under shade, relative humidity at the cow-level, and proximity with other animals are potential aspects that may create a microclimate at the cow-level. The pattern of variation of THI across the day was independent of the location of the devices (Figure 1), however, THI at the cow-level was significantly greater, which indicates that microclimate at the cow-level is important to consider. Other studies also compared THI from measurements collected from on-farm and official meteorological stations. Findings from those studies are consistent with the work reported herein.

In conclusion, THI from measurements obtained from loggers located at the pen-level have greater correlation with the THI at the cow-level than THI from measurements collected from an official meteorological station. Nonetheless, THI at the cow-level was 7 units greater than THI at the pen-level. This information indicates that climate conditions assessed by on-farm loggers may be used to estimate the intensity of heat stress cows are being exposed to, but it is important to recognize that THI at the pen-level might be underestimated compared with THI at the cow-level.

Acknowledgments

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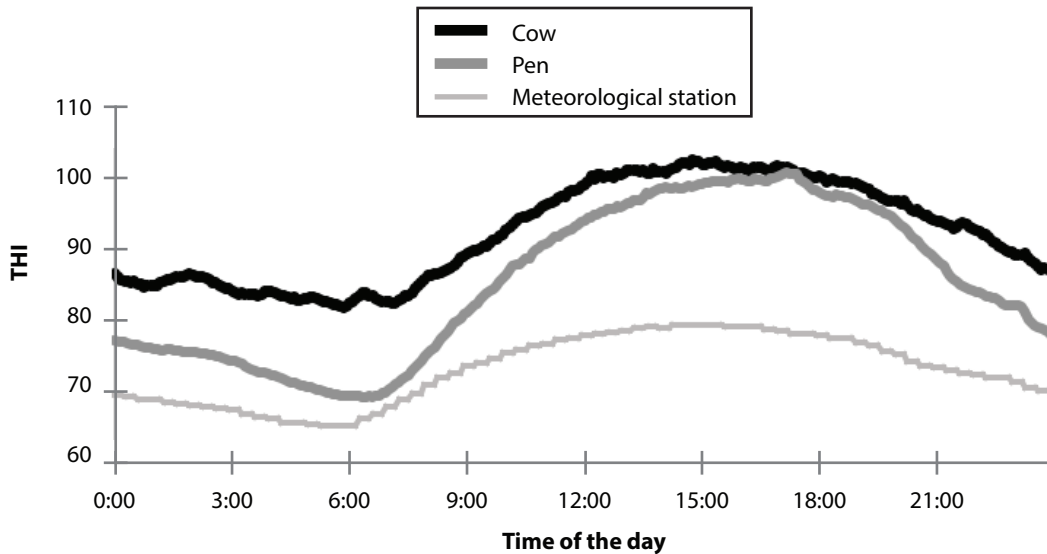


Figure 1. Temperature-humidity index (THI) during the study period at the cow-level, pen-level, and from the nearest meteorological station.

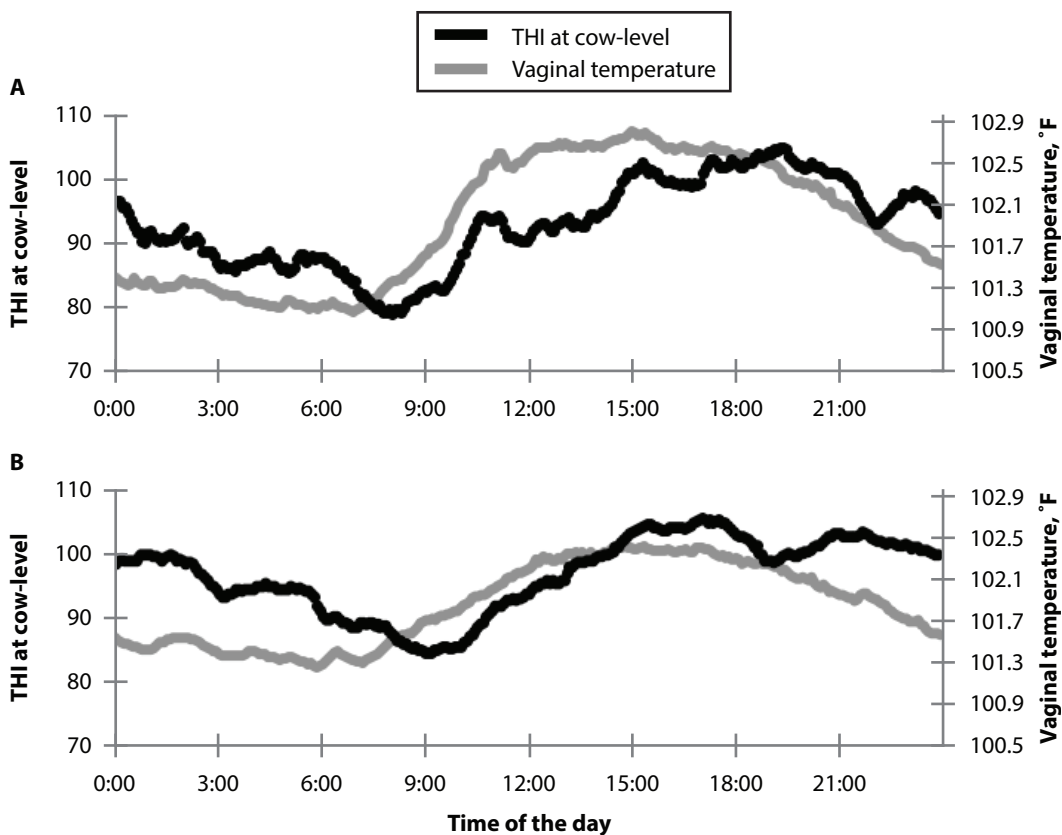


Figure 2. (A) Vaginal temperature (101.9 ± 0.07 °F) and temperature-humidity index (THI) at the cow-level (93.2 ± 1.8) of dry cows. (B) Vaginal temperature (102.1 ± 0.07 °F) and THI at the cow-level (91.6 ± 1.3) of lactating cows.

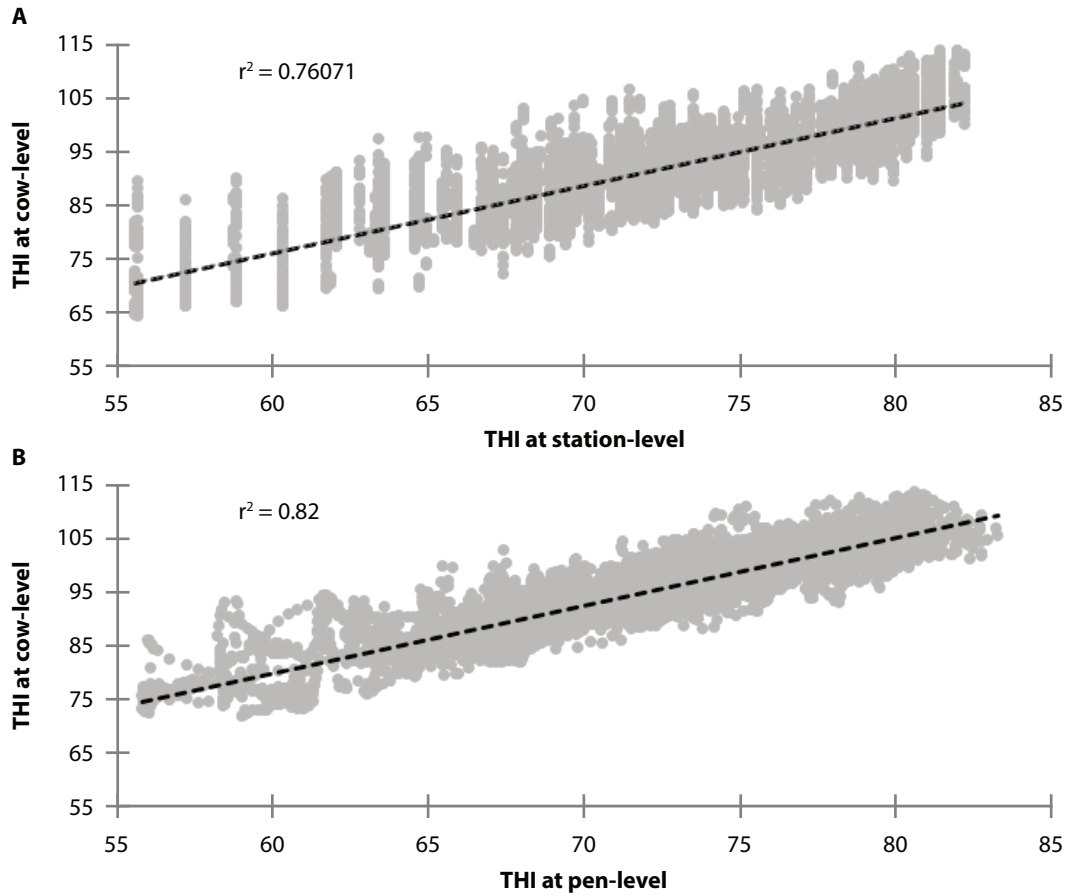


Figure 3. (A) Correlation between temperature-humidity index (THI) at the cow- and station-level ($r^2 = 0.76$). (B) Correlation between THI at the cow- and pen-level ($r^2 = 0.82$).