A Case Study to Evaluate Cooling in Grazing Dairies

R. M. Orellana Rivas, J. K. Bernard, and S. Tao

Introduction

Environmental heat stress negatively influences the performance of dairy cows, and is one major constraint to the dairy industry, especially in the Southeastern region of the US due to the hot and humid climate. Cows maintain homeothermy by balancing the heat gain from their environment with metabolical heat production and heat loss to the environment (West, 2003). At a high ambient temperature and relative humidity, the thermo-balance of the cow is disrupted because of increased heat gain and reduced heat loss, leading to increased body temperature, reduced feed intake, and impaired productivity such as lower milk production. For grazing dairy cattle, heat stress results in reduced grazing activity, lower forage intake, and inefficient utilization of pasture. Therefore, heat stress not only negatively impacts animal performance but also substantially influences the entire plant/animal system. As a consequence, it causes significant economic loss to dairy producers. In the entire US dairy industry, the annual loss of milk production by heat stress alone was estimated to be $1.2 billion (Key et al., 2014).

To minimize the negative influences of heat stress on dairy cows, appropriate cooling strategies should be implemented. Although many research trials have been focused on heat abatement in confinement dairies, optimal cooling strategies in grazing dairies have not been identified. Providing shade is an effective approach to block solar radiation (Roman-Ponce et al., 1977; Collier et al., 1981), but the effectiveness of shade on body temperature and performance depends on climate. In a temperate climate, cows exposed to shade have no differences (Palacio et al., 2015) or slight decreases in body temperature during the hottest time of the day (Kendall et al., 2006) relative to non-shaded cows. Consequently, cows cooled by shade under moderate heat stress have similar (Palacio et al., 2015) or small increases in milk production (~3%, Kendall et al., 2006; Van laer et al., 2015) compared with non-cooled cows. In contrast, in a tropical climate (i.e. Florida), cooling with shade dramatically decreases cows' body temperature and respiration rate, and largely improves milk production by ~11-20% (Roman-Ponce et al., 1977; Collier et al., 1981). In addition to shade, utilization of evaporative cooling (sprinklers and fans) in the holding area before milking has proved to be effective in reducing body temperature after milking and improving milk production by ~4-5% among cows in grazing based dairies (Valtorta and Gallardo, 2004; Gallardo et al., 2005).

In the Southeastern area of the US, such as Georgia, sprinklers installed on the irrigation pivot are commonly used for heat abatement on pasture along with sprinkler systems in the holding pen before milking. Other cooling strategies may or may not exist, and vary from farm to farm. The diversity of management and cooling options in grazing dairies makes it difficult to make a general recommendation for all farms. Thus, it is necessary to conduct heat abatement evaluations for individual dairies to provide specific recommendations from which general recommendations can be derived. This past summer, 2016, we conducted a study to evaluate the cooling systems used by three hybrid dairies operated by the same owner.

Materials and Methods

Information on the Dairies

The 3 dairies located near Waynesboro, GA all share a similar climate. The dairies have the same nutritionist, and use similar general management and nutritional plans. The numbers of lactating cows in farm A, B, and C were 675, 445, and 515, respectively. Because all dairies do not record individual daily milk production, daily bulk tank yields during the 3-d period of heat audit were used to calculate the average milk yield. Average milk yield was 19.0, 16.6, and 19.3 kg/d/cow for farms A, B, and C, respectively, during the period of heat audit. The milking and feeding schedules and other management details were obtained from descriptions provided by farm managers. All three dairies had rotary parlors with open holding pens equipped with sprinklers for cooling. While grazing during the day, cows in all three dairies were cooled by a sprinkler system attached to pivots without access to shade. Cows were milked twice daily at a similar time in the morning (~ 0400 h) and afternoon (~ 1500 h), and fed a partial TMR (pTMR).

The facilities, pTMR feeding schedule, and the cooling systems for each of the dairies differed (Figure 1). On farm A, cows remained in the feedlot and had access to the pTMR for ~3.5 h after each milking. The cooling systems included overhead misters that only operated during the afternoon feeding. No shade or fans were provided. On farm B, cows remained in the feedlot for pTMR feeding from 2 h before until 2 h after each milking. The feeding pen was a covered barn with an open ridge. The overhead sprinkler system only operated during afternoon feeding before milking. No fans were installed in the feeding pen. On farm C, cows were fed a pTMR after the morning milking and remained there for ~3.5 h, but in the afternoon the cows were provided access to the feedlot from 1 h before until ~3.5 h after milking. The feedlot was a covered barn with an open ridge with fans and soakers installed over feed bunks, which were operated by a temperature controller similar to the cooling system used in a freestall barn.

Heat Audit

On July 25, 2016, 10 lactating cows were randomly selected from each dairy and fitted with a temperature recording device (iButton, Maxim Integrated, San Jose, CA) coupled to a controlled internal release device (CIDR, Zoetis, Kalamazoo, MI) to measure vaginal temperature every 10 min over a 3-d period. The average days in milk (**DIM**) for selected cows were 227 and 264 for farm A and C, respectively. The DIM for selected cows of farm B were not available because the calving dates of cows were not recorded. Because a similar breeding protocol was used for all three dairies, the DIM for selected cows in farms 2 should be similar to farm 1 and 3. To assess the degree of heat stress, environmental data (air temperature, relative humidity, wind speed) were collected from a local weather station (Midville, GA). The genotype of cows was identified by phenotype. There were 4 Holsteins, 1 Jersey, and 5 Holstein×Jersey (**H×J**) crosses in farm A; 7 Holsteins, 1 Jersey, and 2 H×J crosses in farm B; and 6 Holsteins, 1 Jersey, and 3 H×J crosses in farm C. Body condition score (**BCS**) was assessed at the same time when temperature probes were inserted and were not different among farms (3.15, 3.30, and 3.13 for farms A, B and C, respectively, $P = 0.47$).

Statistical Analyses

The mean and standard deviation of environmental data were calculated by PROC UNIVARIATE procedure of SAS 9.4. The PROC GLM procedure of SAS was used to analyze BCS, and least squares means ± SE of the mean (**SEM**) are reported. Vaginal temperature data were standardized to 30-min intervals by cow and analyzed as repeated measures using PROC MIXED procedure of SAS. Two separate analyses were performed to examine the effect of farm or breed on body temperature. To assess the farm effects, the statistical model included fixed effects of farm, day, time of a day, and their interactions, with breed and cow nested within farm as random variables. To analyze the breed effect, the statistical model included fixed effects of breed, day, time of a day, and their interactions, with farm and cow nested within breed as random variables. Due to the limited animal numbers (one per farm), the data of Jersey cows were not included in the analyses for breed effect. Data are reported as least squares means ± SEM.

Results and Discussion

The sunrise time during the heat audit was approximately 0630 h and the sunset was around 2030 h (http://www.georgiaweather.net/index.php?variable=SM&site=MIDVILLE). As shown in Figure 2, within a day, the lowest air temperature and highest relative humidity occurred around 0500 h, and the peak ambient temperature occurred around 1500 h. Wind speed was the strongest in the afternoon and was above 10 km/h, which would facilitate cow cooling (Brouk et al., 2004).

No farm effect was observed for vaginal temperature during the heat audits (39.39 vs. 39.56 vs. 39.55°C for farm A, B, and C, respectively, SEM = 0.07°C, $P = 0.16$), but a farm by hour interaction was observed ($P < 0.01$, Figure 3). From 2200 h to 0130 h of the next day, no differences were observed for vaginal temperature of cows between farms ($P > 0.10$), indicating that cows from three dairies maintained similar heat strain during this time frame. However, from 0200 h to 0400 h, cows on farm B had a dramatic decrease in vaginal temperature compared with cows on farm A and C, perhaps due to the moving cows from the pasture to feedlot at an earlier time of day. It is possible that feedlot environment was different from that of the pasture and facilitated cooling. Since the environmental data for the feedlot and pasture were not measured in current study, it not clear if this is a factor or not. From 0430 to the time when cows left the feedlots to pasture, the vaginal temperature decreased gradually perhaps due to a combination of the decreasing ambient temperature, and holding pen and feedlot cooling. Cows on farm C had the most rapid decrease in vaginal temperature among three dairies, indicating that the feedlot cooling system (soakers + fans) rapidly cooled cows compared with farm A and B. After leaving feedlots, the vaginal temperature slightly increased for cows on farm B and C possibly due to the heat accumulation when walking to the pasture. In contrast, cows in farm A maintained their body temperature. The reason for the discrepancy in body temperature at the different farms is unknown but may be due to the different walking distance between the feedlot and pasture for farm A relative to B and C. Cows on all three dairies were rotational grazed (12 h/rotation), but the distance between feedlot and pasture after each milking was not recorded.

During the day between milkings, the sprinkler systems on pivots, coupled with the strong wind, maintained cow body temperature; however, it seems that the pivot cooling had limited capacity to further reduce body temperature of cows. Cows on farm A had the lowest vaginal temperature during the day relative to those in farm B and C ($P < 0.01$). This observation suggests that the pivot sprinklers are sufficient to maintain body temperature, but the degree of cooling may be affected by the types of nozzles, the distance between nozzles, pressure of water, and other factors. The relatively low relative humidity (47-75%) during the day should improve the effectiveness of cooling as well. In contrast to farm A, cows on farms B and C were moved to the feedlot before milking, resulting in a slight decrease in vaginal temperature before milking. Interestingly, cows at all dairies had similar vaginal temperatures during milking indicating that the sprinklers in the open holding pen were similar in their effect on body temperature. Depending on their heat load before entering the holding pen, the body temperature increased or decreased to a similar body temperature, which was maintained during milking. During the afternoon feeding, cows on farm A maintained a lower vaginal temperature compared with those on farms B and C, providing additional evidence of the effectiveness of the sprinkler system used for the open feedlot. The increased body temperature observed for cow at farm B after milking suggests that shade alone was not adequate to cool cows. However, the higher vaginal temperature observed for cows on farm C was unexpected given the expected cooling normally provided by the combination of soakers and fans. Perhaps the system was effective in cooling cows at feeding but was not sufficient to maintain cow body temperature when cows left feed bunks after eating. The vaginal temperatures of cows at all dairies increased after the PM feeding as they walked from the feedlots to pastures. Relative to other two farms, the spike in vaginal temperature of cows on farm B may be due to moving earlier (~ 1730 h) when air temperature was high and solar radiation was strong. The vaginal temperature of cows in farm B gradually decreased from 2000 to 2100 h and then remained constant until the next day due to the decreasing air temperature. In contrast, cows on farm A had increased vaginal temperatures after returning to pasture until ~ 2200 h, suggesting further heat accumulation even though the ambient temperature was decreasing. Interestingly, the vaginal temperature of cows on farm C did not change before dark (~ 2130 h), suggesting the pivot cooling successfully maintained body temperature.

Although all dairies share the similar management, nutrition, and climate, it is important to recognize that there might be other discrepancies among dairies in addition to the pTMR feeding schedule and feedlot facilities. The data analysis and interpretation described above aim to enhance the understanding of different cooling managements, but the possibility that the differences in vaginal temperatures observed is due to other factors cannot be excluded. The holding pens for all three dairies utilized a sprinkler system without shade or fans, but effectively maintained body temperature to a degree. The effectiveness of the cooling system may depend on evaporation of the mist by direct sunlight and breeze to create a cooled microenvironment around cows. The sprinklers mounted on the pivots require a similar principal for cooling on pasture. However, it seems that the pivot sprinklers can only maintain cow body temperature and are not as effective as the holding pen sprinklers. This may be due to differences in the type of the nozzles and output in the holding pen compared with those on the pivot. It is important to reduce the heat load gained by cows as they travel from the feedlot to the pasture, especially in the afternoon. An exit lane shower may be a valid option to soak cows to increase the potential for evaporative cooling under sunlight (Kadzere et al., 2002) when cows travel from the feedlot to the pasture. The time when cows leave the feedlot in the afternoon also influences cows' body temperature. Compared with cows on farms A and C, cows on farm B had dramatic increases in vaginal temperature after leaving the feedlot indicating a greater heat accumulation due to the higher ambient temperature and stronger solar radiation. Thus, one should avoid moving cows during the hottest time of a day. Except for cows on farm C where cooling was provided before dark, the body temperature of cows on farms A and B continued to rise after returning to pastures in the afternoon, indicating heat accumulation. To prevent this, additional heat abatement should be provided during the evening. It appears that pivot cooling was successful for maintaining body temperature of cows before dark but the effectiveness may be reduced at night because of the lack of evaporative cooling by lower ambient temperature and higher relative humidity (Kadzere et al., 2002).

Based on these results, it is recommended that producers: 1) Implement exiting lane cooling to soak cows thoroughly after feeding to increase evaporative cooling and minimize heat accumulation as they walk from the feedlot to the pasture; 2) Move cows to pasture later in the afternoon when the air is beginning to cool; 3) Provide additional cooling before midnight on pasture by keeping the pivot cooling system operating, however, more research is needed to confirm the effectiveness of pivot cooling after dark; and 4) Improve the effectiveness of holding pen cooling by adding fans to enhance evaporative cooling.

In the present study, the effects of genotype on regulation of body temperature were evaluated. Regardless of the farm, both genotypes (Holstein vs. H×J) had similar body temperatures during the day (39.49 vs. 39.49°C, SEM = 0.07°C, P = 0.94, Figure 4), but an interaction of genotype by hour ($P < 0.01$) was observed (Figure 4). Compared with Holsteins, H×J cows had higher vaginal temperatures around the afternoon milking (P = 0.05, ~ 1500 h) but lower body temperatures after the afternoon feeding ($P < 0.05$, 1800 – 1900 h). In contrast, Dikmen et al. (2009) reported that H×J cows had lower vaginal temperature during much of a day compared with Holsteins on a Florida grazing dairy. The differences observed in body temperature patterns between Dikmen et al. (2009) and present study may be due to differences in the type of farms (total grazing vs. hybrid dairies), milking time (0800 and 2000 h vs. 0400 and 1500 h), and other factors not evaluated that influence the regulation of body temperature. The specific pattern of body temperature in current study between genotypes suggests distinct differences in heat dissipation and accumulation between Holsteins and H×J crossbreds. Compared with Jerseys, Holsteins have a larger body size and surface area, but a smaller ratio of body surface area to body weight (Johnson et al., 1961), resulting in greater metabolic heat production and less efficient heat dissipation when no cooling is provided. Similarly, H×J crossbreds have smaller body size than Holsteins (Heins et al., 2008a, b). When evaporative cooling is provided, i.e., in the holding area before milking, the larger surface area of Holsteins may result in greater heat dissipation through evaporation (Kadzere et al., 2002), thereby reducing body temperature at a faster rate compared with crossbred cows. In contrast, when cooling or shade was deprived after feeding, the larger surface area of Holstein cows leads to greater heat accumulation by radiant heat transfer (Kadzere et al., 2002) resulting in a more rapid increase in vaginal temperature relative to the crossbred.

Differences in milk yield may also contribute to the distinct patterns of body temperature between genotypes. Compared with crossbreds, Holsteins produce higher volumes of milk (Heins et al., 2008a, b; Prendiville et al., 2010), which may increase their intolerance to heat stress. However, data collected from both confinement and grazing dairies in Florida suggest that there is no correlation between milk yield and body temperature of cows (Dikmen et al., 2009;

Dikmen and Hansen, 2009), indicating that differences in milk yield shouldn't influence body temperature. In the current study, due to the low cow numbers, Jersey were excluded from the analyses. Future studies with large animal numbers are warranted to examine the effect of genotype on cow thermo-regulation under different management systems in grazing dairies.
One cow in farm B was diagnosed with mastitis during the first day of the heat audit and was moved to an area close to the milking parlor without cooling or shade. Her vaginal temperature is depicted in Figure 5 along with others from farm B over the 3-d period of the heat audit. The mastitic cow had much a higher body temperature relative to her herdmates, which is presumably due to a combination of a feverish response to mastitis and the lack of cooling. This observation emphasizes the importance of improving cow comfort during a disease event by providing cooling.

In conclusion, the cooling systems using in the holding area of milking parlor and irrigation pivot were effective in maintaining cow body temperature; however, an exit lane shower after milking or feeding is recommend to improve evaporative cooling while cows walk back to the pasture. Holsteins and H×J cows had distinct patterns of body temperature change in response to cooling and solar radiation.

Figure 1. Photos of the hold area of milking parlor (1a) and partial TMR feeding areas of farm A, B, and C (1b, c, d, respectively). All farms have similar cooling systems in their holding pens.

Figure 2. Average environmental variables at Midville, GA during the 3-d period of heat audit (July 25-27, 2016).

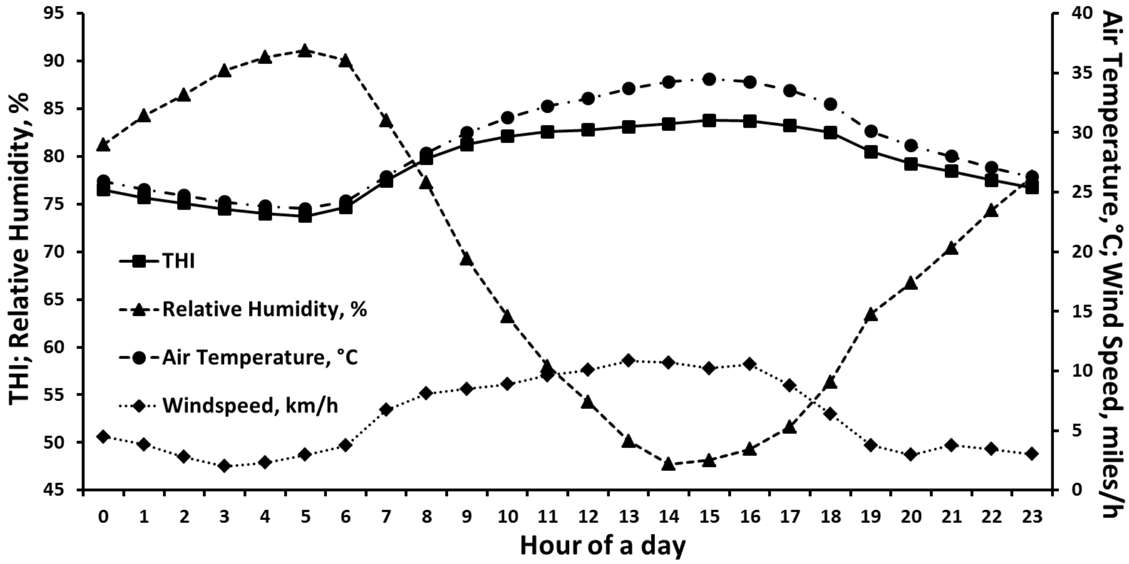


Figure 3. Vaginal temperatures of cows on three dairies. Square (■) with solid line, circle (●) with dashed-dotted line, and triangle (▲) with dashed line represent the vaginal temperature of cows in farms A, B, and C, respectively. Double arrow lines with the adjacent letters represent the period when cows were exposed to cooling on pasture for each of the farms. The solid and open pentagons represent the approximate times cows were leaving from and returning to pasture, respectively. $**P \leq 0.01$, $*P \leq 0.05$, $\dagger P \leq 0.10$.

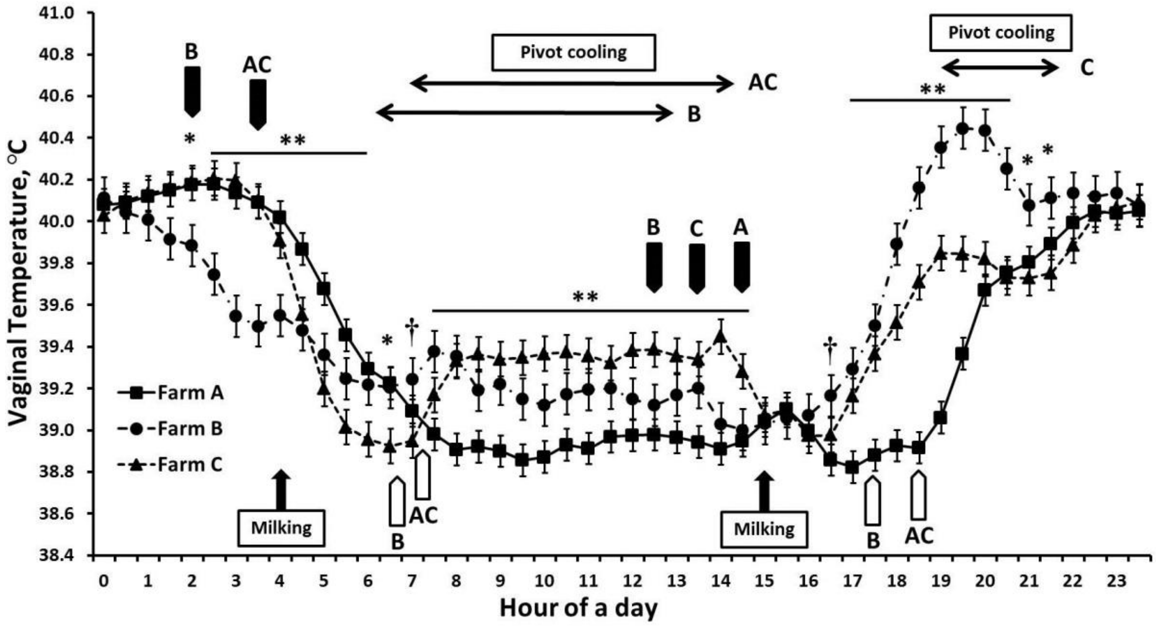


Figure 4. Vaginal temperatures of Holsteins and Holstein×Jersey crossbred cows. Square (■) with solid line, and circle (●) with dotted line represent the vaginal temperature of Holsteins and Holstein×Jersey crossbred, respectively. ***P* ≤ 0.01, **P* ≤ 0.05, †*P* ≤ 0.10.

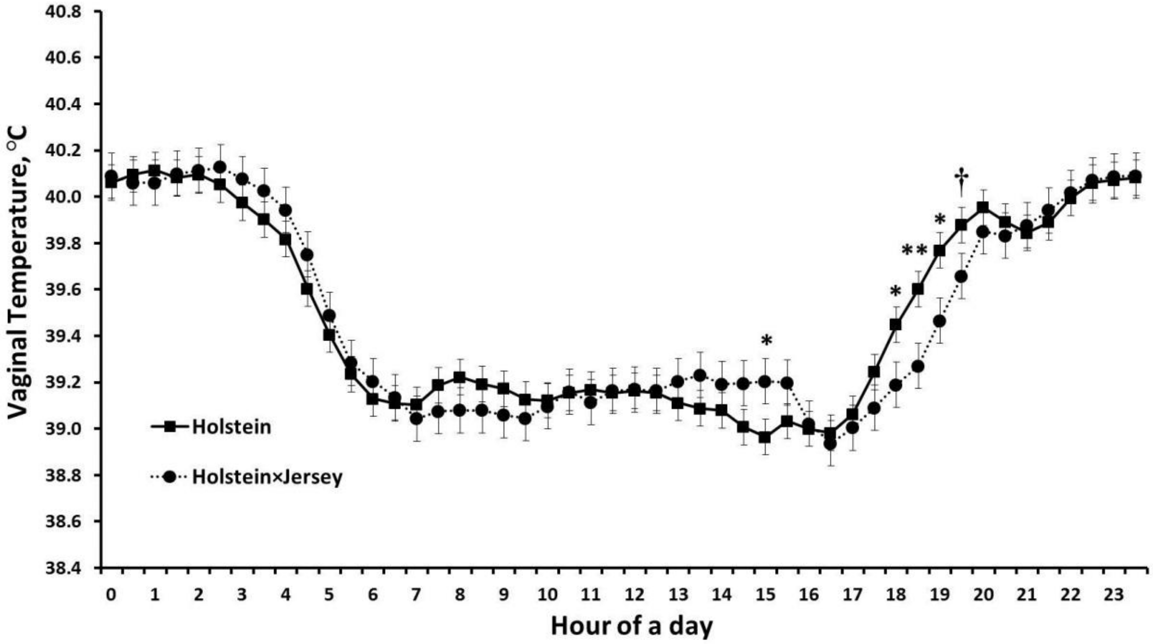
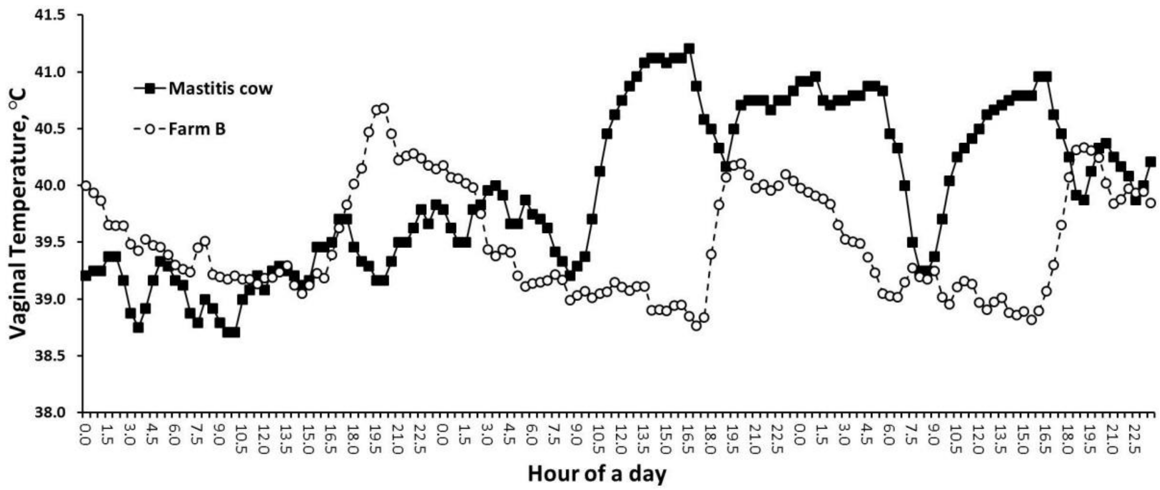


Figure 5. Vaginal temperatures of the mastitic cow and her herdmates in farm B.



REFERENCES

Brouk, M.J., J.P. Harner, J.F. Smith, W.F. Miller, and B. Cvetkovic. 2004. Responses of lactating Holstein cows to differing levels and direction of supplemental airflow. Proceedings of Dairy Day 2004. Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Collier, R. J., R. M. Eley, A. K. Sharma, R. M. Pereira, and D. E. Buffington. 1981. Shade management in subtropical environment for milk yield and composition in Holstein and jersey cows. J. Dairy Sci. 64:844-849.

Dikmen, S., and P. J. Hansen. 2009. Is the temperature-humidity index the best indicator of heat stress in lactating dairy cows in a subtropical environment? J. Dairy Sci. 92:109-116.

Dikmen, S., L. Martins, E. Pontes, and P. J. Hansen. 2009. Genotype effects on body temperature in dairy cows under grazing conditions in a hot climate including evidence for heterosis. Int. J. Biometeorol. 53:327-331.

Gallardo, M. R., S. E. Valtorta, P. E. Leva, M. C. Gaggiotti, G. A. Conti, and R. F. Gregoret. 2005. Diet and cooling interactions on physiological responses of grazing dairy cows, milk production and composition. Int. J. Biometeorol. 50:90-95.

Heins, B. J., L. B. Hansen, A. J. Seykora, D. G. Johnson, J. G. Linn, J. E. Romano, and A. R. Hazel. 2008a. Crossbreds of Jersey × Holstein compared with pure Holsteins for production, fertility and body and udder measurements during first lactation. J. Dairy Sci. 91:1270-1278.

Heins, B. J., L. B. Hansen, A. J. Seykora, A. R. Hazel, D. G. Johnson, and J. G. Linn. 2008b. Crossbreds of Jersey × Holstein compared with pure Holsteins for body weight, body condition score, dry matter intake and feed efficiency during the first one hundred fifty days of first lactation. J. Dairy Sci. 91:3716-3722.

Johnson, H. D., A. C. Ragsdale, J. D. Sike, J. I. Kennedy, E. B. O'Bannon, Jr., and D. Hartman. 1960. Surface area determinations of beef and dairy calves during growth at 50° and 80° environmental temperature. Missouri Agr. Exp. Sta. Res. Bull. 770:1-27.

Kadzere, C. T., M. R. Murphy, N. Silaninove, and E. Maltz. 2002. Heat stress in lactating dairy cows: a review. Livest. Prod. Sci. 77:59-91.

Kendall, P. E., P. P. Nielsen, J. R. Webster, G. A. Verkerk, R. P. Littlejohn, and L. R. Mathews. 2006. The effects of providing shade to lactating dairy cows in a temperate climate. Livest. Sci. 103:148-157.

Key, N., S. Sneeringer, and D. Marquardt. 2014. Climate change, heat stress, and U.S. dairy production. USDA-Economic Research Report #175.

Palacio, S., R. Bergeron, S. Lachance, and E. Vasseur. 2015. The effects of providing portable shade at pasture on dairy cow behavior and physiology. J. Dairy Sci. 98:6085-6093.

Prendiville, R., K. M. Pierce, and F. Buckley. 2010. A comparison between Holstein-Friesian and Jersey dairy cows and their F1 cross with regard to milk yield, somatic cell score, mastitis, and milking characteristics under grazing conditions. J. Dairy Sci. 93:2741-2750.

Roman-Ponce, H., W. W. Thatcher, D. E. Buffington, C. J. Wilcox, and H. H. Van Horn. 1977. Physiological and production responses of dairy cattle to a shade structure in a subtropical environment. J. Dairy Sci. 60:424-430.

Van laer, E., F. A. M. Tuyttens, B. Ampe, B. Sonck, C. P. H. Moons, and L. Vandaele. 2015. Effect of summer conditions and shade on the production and metabolism of Holstein dairy cows on pasture in temperate climate. Animal. 9:1547-1558.

Valtorta, S. E., and M. R. Gallardo. 2004. Evaporative cooling for Holstein dairy cows under grazing conditions. Int. J. Biometeorol. 48:213-217.
West, J. W. 2003. Effects of heat-stress on production in dairy cattle. J. Dairy Sci. 86:2131-2144.