

Use of Evaporative Cooling Systems and Their Effects on Core Body Temperature and Lying Times in Lactating Dairy Cattle

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Summary

A study was performed to assess the effect of an evaporative cooling system on respiration rates, rear udder temperature (T_u), core body temperature (CBT), and resting time in lactating dairy cows. Cows were divided into two treatment groups and rotated between two facilities. Cows were either housed in a bedded pack barn (PACK) equipped with an evaporative cooling system (Cyclone fans, Chippewa Falls, WI) or a tie-stall barn (TIE) equipped with cooling cells. Cows housed in PACK had two cooling treatments: FAN (Cyclone fans only, no fog); and FANFOG (Cyclone fans and fog on). Groups of cows rotated between TIE and PACK every 8 hours, and effects of housing as well as cooling treatment within PACK were analyzed. During FANFOG, PACK cows had a reduction ($P < 0.05$) in respiration rate (breaths per minute) in comparison to TIE (69 vs 76 ± 2.4 BPM). Breaths per minute also increased significantly throughout the day for TIE but this was not the case for PACK. No differences were found in T_u between treatments. While exposed to the FANFOG environment, cows spent decreased time above 102.2°F CBT when compared to FAN. Cows housed in PACK during FAN and FANFOG also spent fewer hours/day above 102.2°F CBT vs TIE. Cows housed in TIE showed numerically greater total daily lying times during FAN and FANFOG compared to cows housed in PACK, although these results were not significant. These results confirm that evaporative cooling systems (Cyclone fans and fog) are effective at decreasing respiration rates and CBT, while having no effect on T_u and lying times in lactating dairy cows.

Key words: heat stress, evaporative cooling, core body temperature, lying behavior

Introduction

Heat stress greatly affects dairy cattle behavior and physiology every year throughout the U.S. Heat stress also reduces milk production and greatly decreases efficiencies for growth and reproduction and leads to animal welfare issues such as lameness. It has been estimated that heat stress costs the U.S. dairy industry ~\$900 million annually. Even though much progress has been made in limiting the effects of heat stress on dairy cattle, we continue to see many negative effects of heat stress annually as milk production and metabolic heat production continue to increase in today's high producing dairy cows.

Core body temperature and total daily lying time are very important in the production and profitability of dairy cattle. Maintaining a normal CBT is critical for lactating dairy cows to sustain production and reproduction throughout the summer months. Milk production has been shown to decline when rectal temperature exceeded 102.2°F for more than 16 hours/day. In addition, reproductive efficiency and fertility have been shown to decrease when CBT exceeds 102.2°F. Meanwhile, mean lying time decreased from 10.9 to 7.9 hours/day from the coolest to the hottest part of the day and time spent standing in the alley increased from 2.6 to 4.5 hours/day from the coolest to the hottest part of the day; thus there is an inverse relationship between ambient temperature and lying times in dairy cattle. Ideally, high producing dairy cows should be lying down for a minimum of 12 to 13 hours/day. It has been proposed that each additional hour of lying time results in an increase of 2.0 to 3.5 lb of milk/day. In addition, when cows do not have adequate lying times, animal welfare issues and lameness may be a concern. Therefore, cooling systems that are able to reduce CBT and increase lying times in summer are necessary and could greatly enhance profitability of the dairy herd.

Evaporative cooling systems equipped with a fogging mechanism have been used to decrease the air temperature around the cow and increase the heat exchange between cow and environment. The fog cools the air as it moves through the facility aided by the movement of air provided from strategically placed fans throughout the facility. Our objective for this study was to evaluate the effect of using high velocity fans equipped with a fogging system and its effect on respiration rates, T_{re} , CBT, and lying times in lactating Holstein dairy cows.

Experimental Procedures

This study was conducted on a commercial dairy in NE Kansas that contained a tunnel ventilated tie-stall barn and a compost-bedded pack barn fitted with 2 Cyclone fans provided by VES Environmental Solutions (Chippewa Falls, WI). The tie-stall barn contained cooling cells on the east end of the barn and seven, 4.5-ft exhaust fans on the west end. Cooling cells were turned on in the late morning (1000 – 1100 hours) and shut off in the evening (2100 – 2200 hours) each day depending on ambient temperature and relative humidity (RH) levels. The compost-bedded pack barn contained two Cyclone fans located over the bedded pack area along with a fogging system to cool the cows; fans were turned on and off at similar times as the cooling cells in the tie-stall barn. This study took place during August 2014.

Twelve lactating Holstein dairy cows were randomly assigned to 1 of 2 groups. Group 1 was made up of 6 cows that averaged 195 ± 93 DIM and 2.3 lactations. Group 2 consisted of 6 cows averaging 195 ± 137 DIM and 2.2 lactations. Both groups were moved back and forth between the bedded pack and tie-stall barns for milking every 8 hours. While one group of 6 cows was in the tie-stall barn for milking, the other group of 6 cows was located in the bedded pack barn. PACK consists of the time period when these 12 cows were located in the bedded pack barn while TIE consists of cows located in the tie-stall barn.

Throughout the study, ambient temperature and RH were measured via two weather stations placed within the barn to track barn temperature and RH. In addition, each cow was fitted with a temperature logger to track vaginal temperature (CBT) and another logger to track total daily lying time. All devices recorded at one minute intervals throughout the study.

Each day throughout the study, individual cow measurements for respiration rate, T_u , and any other signs of heat stress were taken at 0600, 1200, 1400, 1600, and 1800 hours. Respiration rate was measured by counting the number of flank movements for 30 seconds and then multiplying by 2. Body surface temperature was taken using an infrared thermometer gun (Raytek Raynger MX; Model: 4KM98).

Results and Discussion

Average temperature humidity index (THI) during the study was 78, while average daily maximum THI was 84. Peak THI occurred on day 2 and peaked at 85. Measured THI were similar between the 2 environments, allowing us to compare environments in an unbiased manner.

Respiration Rates

Respiration rates for PACK cows while experiencing the FAN and FANFOG environments were not different although there was a tendency ($P < 0.10$) for decreased respiration rates during FANFOG (74 ± 2.4 and 69 ± 2.4 BPM, respectively). No differences were found when comparing treatment groups (TIE vs PACK) while under the FAN environment. During FANFOG, however, PACK (69 ± 2.4 BPM) showed decreased ($P < 0.05$) respiration rate in comparison to TIE (76 ± 2.4 BPM; Figure 1). When comparing environment by time period, although there were no statistical differences between treatments, FANFOG had numerically lower BPM compared with FAN throughout the afternoon (Figure 2). While housed under the FAN environment with no fog, BPM were greater ($P < 0.05$) for the time periods 1400, 1600, and 1800 hours when compared to 0600 hours, and peaked at 1800 hours at 83 ± 3.8 BPM. When cows were housed with the evaporative cooling system (FANFOG), there were no differences between any of the time periods when compared to 0600 hours, and BPM actually peaked at 1400 hours (74.7 ± 3.9 BPM) and decreased thereafter for the remainder of the day.

Rear Udder Temperature

FANFOG was not effective at reducing T_u in this study. There were no differences ($P = 0.99$) in T_u between FAN and FANFOG ($95.0 \pm .32$ and $95.1 \pm .32$ °F, respectively). Although no difference was found for PACK cows when compared to TIE, PACK had numerically greater T_u during FAN and FANFOG. When comparing environment by time period, T_u was decreased for FANFOG compared to FAN during the 1800 hour time period ($P < 0.05$) but no other significant environment by period interactions were found.

Vaginal Temperature (CBT)

Much research has been conducted studying the effects of increased CBT on production and reproduction. When searching through the literature, it appears that the

critical threshold for CBT is 102.2°F and once CBT exceeds this level, major losses in both production and reproduction occur. No differences were found when comparing the overall average CBT for each treatment in this study. Cows in the FAN and FANFOG environments had an average CBT of $102.2 \pm 0.21^\circ\text{F}$, while cows located in the tie-stall barn had a CBT of $103.1 \pm 0.21^\circ\text{F}$ and $102.7 \pm 0.21^\circ\text{F}$ during FAN and FANFOG, respectively (Figure 3). These results were not significant, although there was a trend ($P = 0.07$) for reduced CBT in PACK compared to TIE cows during FANFOG. However, when looking at categorical CBT data (Table 1) significant differences were found for total time/day spent above 102.2°F CBT. While housed in PACK under FANFOG, cows showed reduced time/day above 102.2°F CBT compared to FAN (9.2 vs 14.6 hours/day, respectively; $P = 0.05$). Also, cows housed in PACK spent decreased time above 102.2°F ($P < 0.05$) versus cows housed in TIE during FAN (14.6 vs 20.3 hours/day) and FANFOG (9.2 vs 17.7 hours/day).

Lying Times

No differences were found for total daily lying time when comparing FAN to FANFOG or PACK to TIE (Table 2). Cows housed in the tie-stall barn showed numerically greater total daily lying time; however, there were no significant differences between treatments.

Fan Velocity

Total cubic feet per minute (CFM) was measured for each of the facilities. The 2 Cyclone fans in PACK were each rated at 80,000 CFM resulting in a total of 160,000 CFM. At any given time during the study, there were an average of 30 cows located in PACK, resulting in an average of 5,333 CFM/cow, far greater than the average CFM/cow within TIE. The 7 exhaust fans in TIE were each rated at ~25,700 CFM for a total of 180,000 CFM. With more cows located in TIE, however, this resulted in less total CFM/cow with an average of 1,800 CFM/cow. We recognize that this could have had an effect on the final results found in this study. It is also important to recognize that the two evaporative cooling systems were in operation for only part of the day (~10-12 hours). Therefore, any differences between treatments during the time period when the evaporative cooling systems were shut off (~2200 to 1000 hours) would be due strictly to airflow alone.

Conclusions

In summary, the evaporative cooling system (Cyclone fans and fog) used in this study was more effective when compared to another type of evaporative cooling system (cooling cells). This was shown by reduced respiration rates for PACK cows during the FANFOG environment compared to TIE cows housed under the cooling cell treatment during the same time period. We also saw reduced CBT for PACK cows exposed to the Cyclone fan and fog treatment as evidenced by decreased time/day spent above 102.2°F compared to TIE cows. However, we did not detect any significant differences in T_{re} or total daily lying times between the two treatment groups, although there was a numerical increase in lying time for TIE.

Table 1. Effect of evaporative cooling on categorical core body temperature (CBT) for each treatment in minutes/day with hours in parenthesis

CBT ³ , °F	Treatment ¹				SE
	Bedded pack barn ²		Tie-stall barn ²		
	FAN	FANFOG	FAN	FANFOG	
< 101.5	243.0 (4.1 h)	302.9 (5.0 h)	48.2 (0.8)	66.7 (1.1)	49.5
≥ 101.5	318.5 ^a (5.3 h)	585.2 ^b (9.8 h)	171.3 ^a (2.9 h)	312.7 ^a (5.2 h)	27.1
≥ 102.2	878.5 ^a (14.6 h)	551.9 ^b (9.2 h)	1220.5 ^c (20.3 h)	1060.7 ^{ac} (17.7 h)	57.5

¹FAN = Cows housed with the presence of Cyclone fans but no fog; FANFOG = Cows housed with the evaporative cooling system in full operation which included Cyclone fans and fog.

²Bedded Pack Barn = barn where cows were housed with the evaporative cooling system (Cyclone Fans); Tie-Stall Barn = barn where cows were housed with cooling cells but no Cyclone Fans. SE = standard error.

³CBT was broken into 3 categories: min/d with CBT < 101.5°F; min/d with CBT ≥ 101.5°F but < 102.2°F; min/d with CBT ≥ 102.2°F.

^{a,b,c}Means within row with different superscripts differ ($P \leq 0.05$).

Table 2. Effect of evaporative cooling on total daily lying and standing time

Item, min/d	Treatment ¹				SE
	Bedded pack barn ²		Tie-stall barn ²		
	FAN	FANFOG	FAN	FANFOG	
Lying time	475.1 (7.9 h)	504.4 (8.4 h)	632.8 (10.5 h)	616.1 (10.3 h)	60.7
Standing time	964.9 (16.1 h)	935.6 (15.6 h)	807.3 (13.5 h)	823.9 (13.7 h)	60.7

¹FAN = Cows housed with the presence of Cyclone fans but no fog; FANFOG = Cows housed with the evaporative cooling system in full operation which included Cyclone fans and fog.

²Bedded Pack Barn = barn where cows were housed with the evaporative cooling system (Cyclone Fans); Tie-Stall Barn = barn where cows were housed with cooling cells but no Cyclone Fans. SE = standard error.

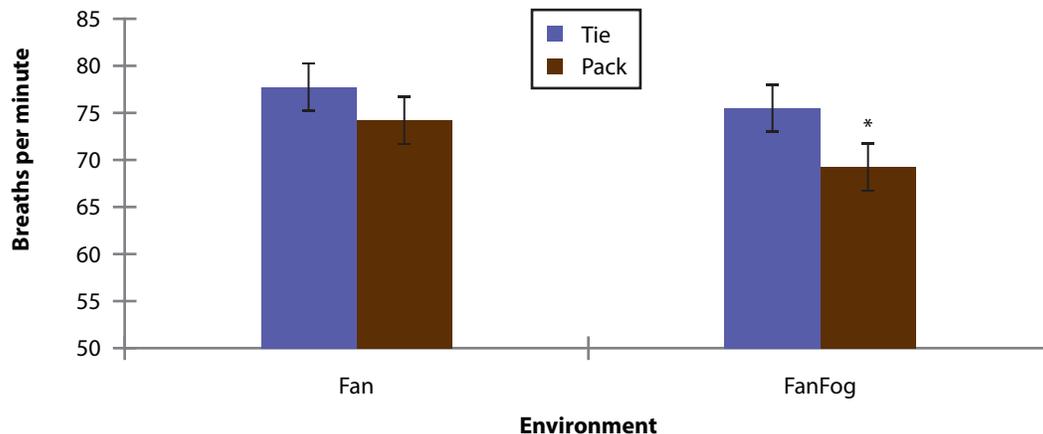


Figure 1. Least square means for respiration rates, measured in breaths/minute (BPM), for the 2 treatment groups while located under FAN or FANFOG. *P < 0.05 vs TIE.

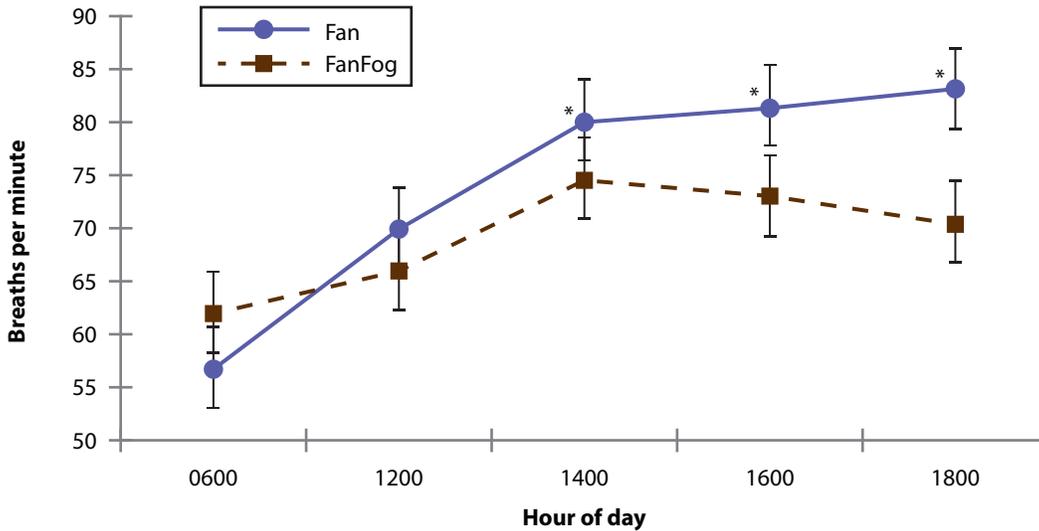


Figure 2. Respiration rates, measured in breaths/min (BPM), by time period while located in the bedded pack barn during FAN or FANFOG. *P < 0.05 vs FAN 0600 h.

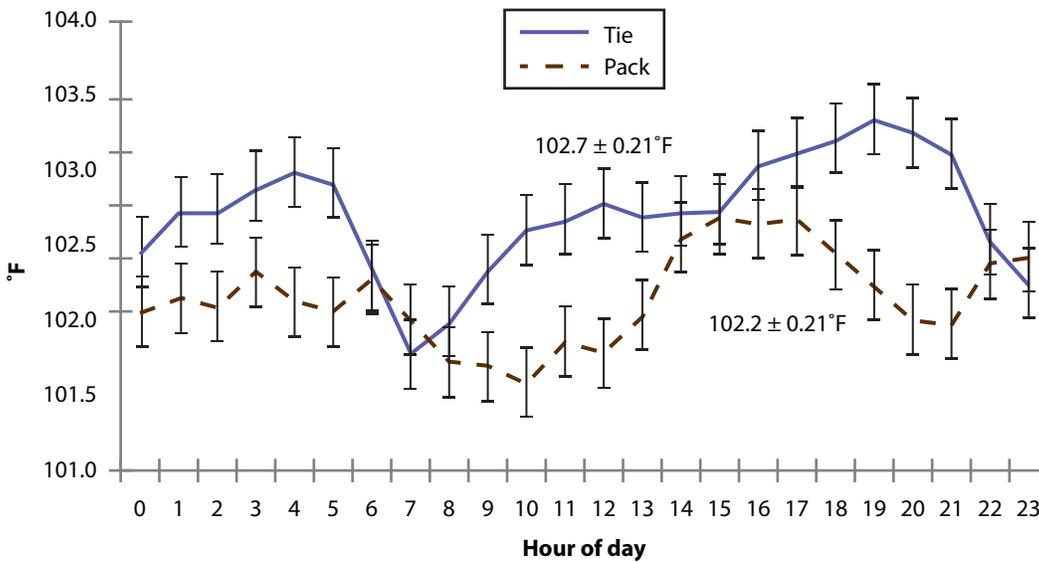


Figure 3. Core body temperature for TIE and PACK cows during the FANFOG environment only. Treatment effect: P = 0.07.