The Effects of an Evaporative Cooling System on Reducing Heat Load in Lactating Dairy Cows

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Summary

This study was conducted to evaluate the effect of 2 cooling systems on barn temperature, core body temperature (CBT), respiration rate, rear udder temperature, and lying time in lactating Holstein dairy cows. Twenty lactating Holstein dairy cows were randomly assigned to 1 of 2 treatment groups: CONV, where cows were housed in a conventional, open-sidewall freestall barn equipped with feedline soakers and fans located over the feedline and stalls; and TUNNEL, where cows were housed in a tunnel-ventilated freestall barn utilizing an evaporative cooling system. TUNNEL was effective at reducing barn temperature humidity index (THI) compared to CONV, but failed to alter CBT (101.5 ± 0.04°F). TUNNEL cows had reduced respiration rates (52.0 vs. 57.9 ± 2.2 breaths per minute) and skin temperatures (91.8 vs. 94.1 ± 0.6°F) compared to CONV, while TUNNEL cows had increased lying time by 1 hour per day (11.8 vs. 10.8 ± 0.3 hours per day). Overall, the evaporative cooling system (TUNNEL) was effective in reducing barn THI leading to reduced respiration rates and rear udder temperatures and increased daily lying time. No treatment differences were detected for CBT, however, likely a result of the cooler ambient conditions under which the study took place.

Introduction

Heat stress greatly affects dairy cattle every year throughout the United States. Heat stress not only reduces milk production but also 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.

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 exceeds 102.2°F for more than 16 hours per day. In addition, reproductive efficiency and fertility have been shown to decrease when CBT exceeds 102.2°F. Meanwhile, heat-stressed dairy cows increase daily standing time to increase dissipation of body heat. Ideally, high-producing dairy cows should be lying down for a minimum of 12 hours per day and it has been proposed that each additional hour of lying time results in an increase of 2.0 to 3.5 lb of milk per day. In addition, when cows do not have adequate lying times, animal welfare issues and lameness may be a concern. Cooling systems that are able to reduce CBT and increase daily lying times in summer are necessary and could greatly increase profitability of the dairy herd.

Evaporative cooling systems equipped with a fogging system have been used to decrease air temperature around the cow and increase heat exchange between the cow and the 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 barn. Fan placement and spacing is of utmost importance in order to achieve adequate effective cooling velocity over the cows. The objective for this study was to evaluate the use of high velocity fans equipped with a fogging system and measure effects on temperature humidity index (THI), respiration rate, rear udder surface temperature, CBT, and lying time in lactating Holstein dairy cows.

Experimental Procedures

This study was conducted in August 2016 at a commercial dairy in Nebraska that contained a tunnel-ventilated freestall barn and an open-sidewall, conventional freestall barn. The tunnel-ventilated barn contained ECV72 fans (72-inch diameter) provided by VES Environmental Solutions (Chippewa Falls, WI) equipped with a fogging system as the main source of cooling. Fans were located over the freestalls with fans spaced 60 feet apart. The fog system cycled on and off throughout the late morning and afternoon hours, determined by the temperature and relative humidity within the facility. The conventional freestall barn had 40-inch basket fans located over the stalls, 36-inch basket fans located over the feedbunk, and a feedline soaker system that turned on and off intermittently, determined by ambient temperature. Spacing between fans located over the feedbunk and freestalls was 30 feet. Prior to the start of the study, it was assured that stocking density and freestall dimensions were similar between barns. Both barns used sand bedding.

Twenty lactating Holstein dairy cows were randomly assigned to 1 of 2 treatment groups. Group 1 was made up of 10 cows that averaged 166 ± 34 days in milk and 40 ± 3 days carried calf. Group 2 consisted of 10 cows averaging 155 ± 9 days in milk and 40 ± 3 days carried calf. This study utilized a switchback design where both groups of cows were moved between barns every 24 h for 6 consecutive days, therefore exposing both groups of cows to each barn environment for a total of 3 days. TUNNEL consists of the time period when these 20 cows were located in the tunnel-ventilated freestall barn while CONV refers to cows located in the conventional freestall barn.

Throughout the study, ambient temperature and relative humidity were measured with 2 weather stations located throughout the farm. Within each barn, 3 weather stations were placed throughout the pen to track pen temperature and relative humidity. Each cow also received an intravaginal stainless-steel temperature logger attached to a blank controlled internal drug-releasing device that recorded vaginal temperature, a measure of CBT. In addition, each cow was fitted with an electronic data logger attached to the right hind leg, allowing daily lying time to be measured.

Individual cow measurements of respiration rate and rear udder temperature were taken daily at 1000 h and 1600 h. Respiration rate (breaths per minute) 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 thermography gun.

Results and Discussion

Average daily ambient temperature during the study was 72.1 ± 3.4°F and average relative humidity was 78.1 ± 14.2%, resulting in an average THI of 70.1 ± 4.6 during the study. Ambient temperature and THI during the study period were less than anticipated. Barn THI was reduced for TUNNEL compared to CONV ($P = 0.04$) with the primary difference being detected during the afternoon hours (Figure 1). The differences observed between barns were expected and indicate more effective cooling for TUNNEL due to the fogging system reducing air temperature within the barn.

Core Body Temperature

Core body temperature did not differ ($P = 0.79$) between treatment groups, with an average of 101.5 ± 0.04°F for CONV and TUNNEL (Figure 2). While there were numerical differences between treatment groups for categorical CBT (Table 1), CONV, and TUNNEL cows spent similar amounts of time within each CBT category (< 101.5, ≥ 101.5, and ≥ 102.2°F) resulting in a lack of treatment effect ($P > 0.05$).

Respiration Rate and Skin Temperature

Respiration rates were reduced in TUNNEL cows compared to the CONV (Table 2). CONV had an average daily respiration rate of 57.9 ± 2.2 breaths per minute (BPM), while TUNNEL had an average respiration rate of 52.0 ± 2.2 BPM ($P < 0.01$). When broken into the morning (0900 h) and afternoon (1600 h) time periods, respiration rates were reduced for TUNNEL cows in the morning (48.6 vs. 52.9 ± 2.0 BPM; $P = 0.03$) and afternoon (55.4 vs. 63.0± 2.6 BPM; $P < 0.01$) periods (Table 4).

Rear udder skin temperature averaged 94.1 and 91.8 ± 0.6°F for CONV and TUNNEL, respectively ($P < 0.01$; Table 2). When broken into the morning (0900 h) and afternoon (1600 h) periods, udder temperature was reduced for TUNNEL cows both in the morning (90.5 vs. 93.4 ± 0.5°F; $P < 0.01$) and afternoon (93.2 vs. 94.8 ± 0.7°F; $P < 0.01$) periods.

Lying Time

Cows on the CONV treatment had reduced lying time by 1 hour per day compared to TUNNEL (10.8 vs. 11.8 ± 0.3 hours/day; Table 2). When data were divided into 3 different time periods between milkings (Table 4), TUNNEL cows spent a greater ($P < 0.01$) percentage of time within each period lying down. Cows on the CONV treatment averaged 11.8 ± 0.6 lying bouts per day, which was greater than TUNNEL cows (10.8 ± 0.6 bouts/day, $P = 0.01$; Table 2). Lying bout duration was greater ($P < 0.01$) for TUNNEL compared to CONV and averaged 69.3 and 57.5 ± 3.3 minutes per bout (Table 2). During the 1200 to 1800 hour time period, there was a significant treatment effect ($P < 0.05$) where TUNNEL cows had greater lying bout duration (90.1 vs. 61.8 ± 7.2 minutes/bout; Table 4). This indicates that the evaporative cooling system was effective at keeping cows cool during the hottest part of the day, allowing cows to continue lying for a longer duration and therefore resulting in increased total daily lying times.

Conclusions

Results of the current study show that the evaporative cooling system used in the tunnel-ventilated freestall barn was effective at reducing barn THI. This resulted in reduced respiration rates and rear udder temperatures for TUNNEL cows, while CBT did not differ between treatments. Interestingly, lying bout duration was maximized during the afternoon period (1200 to 1800 h) for TUNNEL cows, indicating effective cooling by the evaporative cooling system utilized. This led to increased daily lying time by 1 h/d for TUNNEL cows. Had this study been conducted under warmer ambient temperatures, greater differences between treatment groups for CBT would have been expected.

Table 1. Effect of cooling treatment on time (hours/day) spent within each categorical core body temperature (CBT) for each treatment throughout the study

	Treatment[1]			
CBT,[2] °F	CONV	TUNNEL	Standard error	*P*-value
< 101.5	13.4	14.2	1.08	0.20
≥ 101.5	7.9	7.3	0.59	0.16
≥ 102.2	2.7	2.5	0.59	0.69

[1]CONV refers to cows housed in the open-sidewall conventional freestall barn, while TUNNEL refers to cows housed in the tunnel-ventilated freestall barn.
[2]CBT was broken into 3 categories: hours/day with CBT < 101.5°F; h/d with CBT ≥ 101.5°F but < 102.2°F; and h/d with CBT ≥ 102.2°F.

Table 2. Effect of cooling treatment on respiration rate, udder temperature, and lying time data for each treatment throughout the study

	Treatment[1]		Standard	
Item	CONV	TUNNEL	error	*P*-value
Respiration rate, breaths/min	57.9	52.0	2.2	< 0.01
Udder temperature, °F	94.1	91.8	0.6	< 0.01
Lying time, hours/day	10.8	11.8	0.3	< 0.01
Lying bouts, number/day	11.8	10.8	0.6	0.01
Lying bout duration, min	57.5	69.3	3.3	< 0.01

[1]CONV refers to cows housed in the open-sidewall conventional freestall barn, while TUNNEL refers to cows housed in the tunnel-ventilated freestall barn.

Table 3. Effect of cooling treatment on respiration rate and udder skin temperature during the morning and afternoon observation periods for each treatment throughout the study

	Treatment (Trt)[1]			*P*-value		
Item	CONV	TUNNEL	Standard error	Trt	Time	Trt × Time
Respiration rate, BPM[2]						
0900 h	52.9	48.6	2.0	0.03	< 0.01	0.32
1600 h	63.0	55.4	2.6	< 0.01	< 0.01	0.32
Udder temperature, °F						
0900 h	93.4	90.5	0.5	< 0.01	< 0.01	0.10
1600 h	94.8	93.2	0.7	< 0.01	< 0.01	0.10

[1]CONV refers to cows housed in the open-sidewall conventional freestall barn, while TUNNEL refers to cows housed in the tunnel-ventilated freestall barn.
[2]Breaths per minute.

Table 4. Effect of cooling treatment on the percent of time spent lying down within 3 time periods throughout the day

	Treatment (Trt)[1]			*P*-value		
Item	CONV	TUNNEL	Standard error	Trt	Time	Trt × Time
Lying time, %						
0400-1000 h	51.6[a]	58.5[b]	0.03	< 0.01	< 0.01	0.36
1200-1800 h	42.7[a]	54.4[b]	0.03			
2000-0200 h	49.2[a]	57.7[b]	0.03			
Lying bouts, n/time period						
0400-1000 h	2.9	3.1	0.21	0.15	0.06	0.24
1200-1800 h	2.7	2.6	0.21			
2000-0200 h	2.8	3.1	0.21			
Lying bout duration, min						
0400-1000 h	76.9	80.4	7.22	0.01	0.88	0.02
1200-1800 h	61.8[a]	90.1[b]	7.22			
2000-0200 h	76.0	77.7	7.22			

[1]CONV refers to cows housed in the open-sidewall conventional freestall barn, while TUNNEL refers to cows housed in the tunnel-ventilated freestall barn.
[a,b]Means within a row with differing superscripts differ ($P \leq 0.05$).

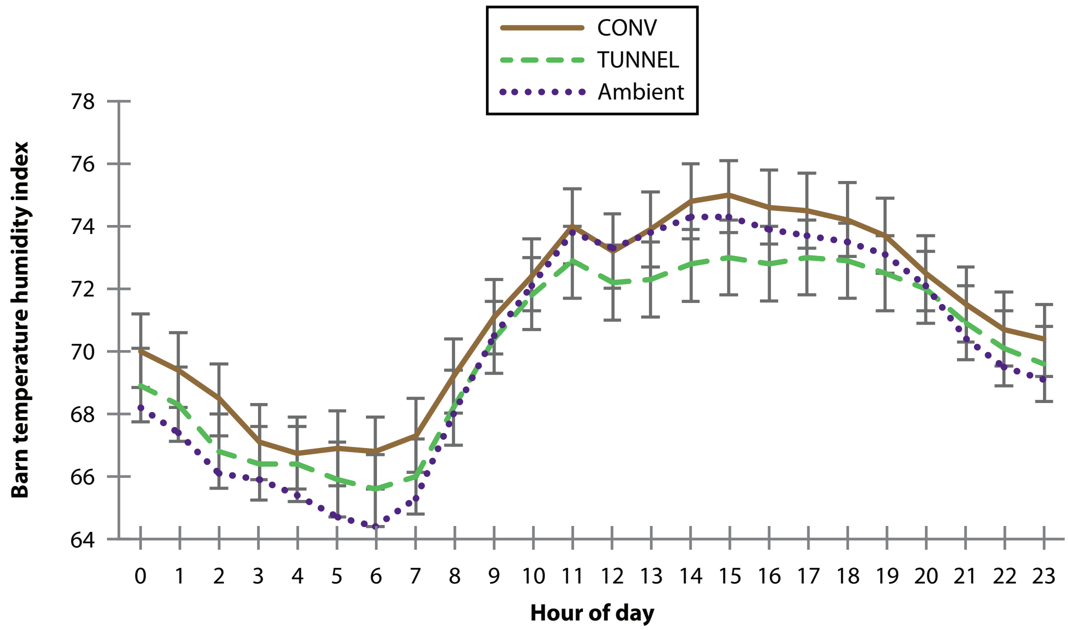

Figure 1. Effect of cooling treatment (CONV vs. TUNNEL) on barn temperature humidity index (THI) by hour of day. Ambient THI data are also shown for comparison. Treatment, $P = 0.04$; treatment × hour, $P = 0.99$.

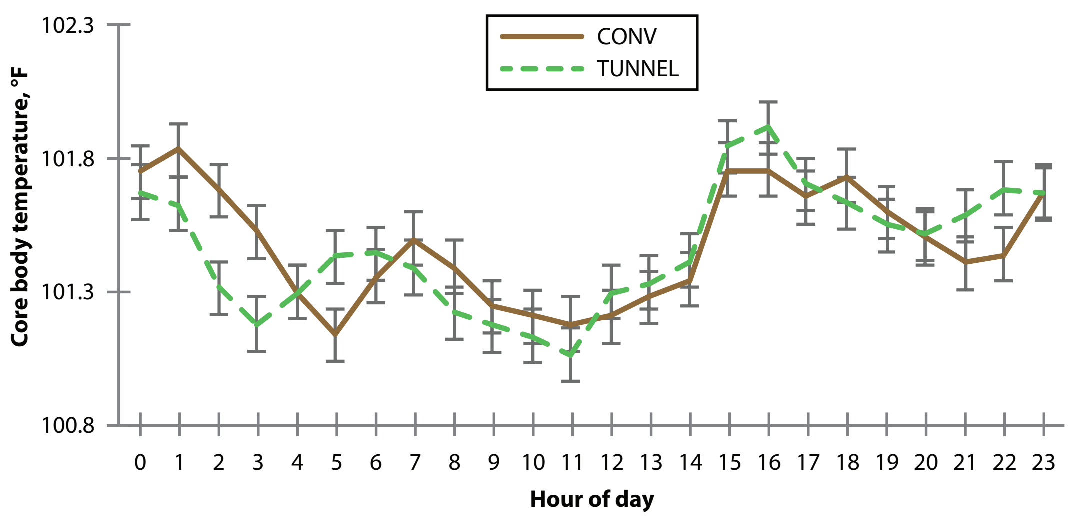

Figure 2. Effect of cooling treatment (CONV vs. TUNNEL) on core body temperature by hour of day. Treatment, $P = 0.79$; treatment × hour, $P < 0.01$.