# Influence of Using Fan and Sprinkler Cooling Systems on Physiological Responses of Heat-Stressed Holstein Cows

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## Abstract

Lactating dairy cattle produce large amounts of heat due to digestion and metabolic processes; this heat must be exchanged with the environment to maintain normal body temperature.

The Temperature Humidity Index (THI) could be used to evaluate thermal stress caused by the environment. This index combines relative humidity (RH) and ambient temperature (Ta) into a single value to estimate the potential environmental heat load. An environment is generally considered stressful for cattle when the THI exceeds 72. Sprinkling and supplemental airflow to reduce heat stress (HS) has been evaluated in many studies.

Thirty Holstein dairy cows were used in this study to evaluate the effect of three different cooling systems on physiological responses, including rectal temperature (RT), respiration (RR) and heart rate (HR), during August and September, with daily average Ta between 73 and 86°F (23 and 30°C) and Rh between 67 and 91% at Sari City, Northern Iran.

Control cows had access to six fans (C). A second group was cooled with twelve fans (F), and the third group of cows was cooled with twelve fans and sprinklers (F/S). The maximum THI during the trial ranged from 73.1 to 99.7 (83.63 ± 3.333).

Ta, and as a result THI, were less ($P<0.05$) in F/S (77.8 ± 6.58°F and 74.9 ± 5.62) and F (82.4 ± 7.44°F and 78.8 ± 6.44) groups compared to the C group (83.7 ± 7.71°F and 79.9 ± 6.64).

The average of RT (103.1 ± 1.02°F; 39.5 ± 0.566°C), RR (79.2 ± 10.2 breaths/min) and HR (79.4 ± 4.32 beats/min) of cows in the C group were higher ($P < 0.05$) than those in the F (102.6 ± 0.96°F [39.2 ± 0.638°C], 67.7 ± 12.8 and 77.3 ± 3.98) and S/F (101.7 ± 0.94°F [38.7 ± 0.521°C], 55.1 ± 12.7 and 76.7 ± 4.60) groups, respectively.

These results indicate that a cooling system based on spray and fans is an effective alternative to alleviate the negative effects of HS on physiological responses in lactating Holstein cows under warm and humid conditions.

## Résumé

La digestion et les processus métaboliques engendrent une grande quantité de chaleur chez les bovins laitiers en lactation. Cette chaleur doit être dissipée dans l'environnement afin de maintenir la température normale du corps.

L'index de température humidité (ITH) pourrait être utilisé pour évaluer le stress de température causé par l'environnement. Cet index combine l'humidité relative (HR) et la température ambiante (Ta) en une seule valeur pour estimer la puissance calorifique à dissiper d'un environnement. L'environnement est généralement considéré stressant pour les bovins lorsque l'ITH dépasse 72. L'arrosage et la ventilation ont été évalués dans plusieurs études afin de réduire le stress de chaleur.

Un total de 30 vaches laitières Holstein ont été utilisées dans cette étude afin d'évaluer l'effet de trois systèmes différents de refroidissement sur les réponses physiologiques, incluant la température rectale, la fréquence respiratoire et la fréquence cardiaque. L'étude a été menée pendant les mois d'août et de septembre dans la ville de Sari, Iran du nord, avec des températures moyennes variant de 73 à 86°F (23 to 30°C) et une humidité relative variant de 67 à 91%.

Les vaches témoins (T) avaient accès à six ventilateurs. Un autre groupe était rafraichi avec 12 ventilateurs (V) et le dernier groupe de vaches était rafraichi avec 12 ventilateurs et des arrosoirs (V/A). Les valeurs maximum de l'ITH durant l'essai variaient de 73.1 à 99.7 (83.63 ± 3.333).

La température ambiante, et par conséquent l'ITH, était moindre (P < 0.05) dans le groupe V/A'(77.8 ± 6.58°F and 74.9 ± 5.62) et dans le groupe V (82.4 ± 7.44°F et 78.8 ± 6.44) que dans le groupe T (83.7 ± 7.71°F and 79.9 ± 6.64).

La température rectale moyenne (103.1 ± 1.02°FThe average of RT (103.1 ± 1.02°F; 39.5 ± 0.566°C), la fréquence respiratoire moyenne (79.2 ± 10.2 respirations/min) et la fréquence cardiaque moyenne (79.4 ± 4.32 battements/min) dans le groupe T étaient plus élevées (P < 0.05) que celles dans le groupe V (102.6

± 0.96°F [39.2 ± 0.638°C], 67.7 ± 12.8 et 77.3 ± 3.98) et dans le groupe V/A (101.7 ± 0.94°F [38.7 ± 0.521°C], 55.1 ± 12.7 et 76.7 ± 4.60).

Ces résultats indiquent qu'un système de refroidissement combinant des arrosoirs et des ventilateurs représente une alternative efficace pour réduire les effets négatifs du stress de chaleur sur la réponse physiologique des vaches Holstein en lactation dans des conditions chaudes et humides.

## Introduction

Normal physiological processes require that the body temperature be maintained by the thermoregulatory system within 1.8°F (1°C) of its normal temperature under ambient conditions.[7] The most comfortable environmental temperature range for dairy cattle is between 41 and 77°F (5 and 25°C),[14,19] which is regarded as the thermoneutral zone (TNZ). Within this zone, minimal physiological cost and maximum productivity are normally achieved.[9] Effects of heat stress (HS) on cows begin to be observed above 75.2°F (24°C).[12]

Dairy cattle in many regions are subject to high ambient temperature (Ta), relative humidity (RH) and solar radiation for extended periods. This compromises the ability of the lactating cow to dissipate heat, resulting in HS. As a result, the cow develops numerous physiological mechanisms for coping with this stress. Unfortunately, these responses have negative effects on the physiology of the cow. However, the animal's high productivity is directly associated with metabolic heat production, which aggravates the problem of maintaining homeothermy under conditions of high temperature. Research also indicates that rectal temperature (RT), respiration rate (RR) and heart rate (HR) are affected by HS,[16,25] therefore RT, RR and HR may be used as indicators of HS. HS brings many challenges, but with proper facilities and management it can be alleviated to an acceptable level, including water sprays and fans under shades.[1] Cooling improves heat balance, reduces HS[13] and decreases RT, RR and HR.[18,22]

There is no doubt that increasing the avenues for heat dissipation from the heat-stressed cow improves performance. The traditional approaches include: 1) use of shade to block solar radiation; 2) increase in evaporative cooling with fans and/or sprinklers; and 3) cooling air in the cow's immediate environment.[4] Such techniques increase body heat loss and reduce rate of increase in RT.[5,6]

The objective of this study was to evaluate the effect of three different cooling systems on some physiological responses of Holstein heat-stressed cows, including RT, RR and HR, and to examine the relationship between Temperature-Humidity Index (THI) and the physiological responses in a warm-humid climate.

## Materials and Methods

### Cows, housing and cooling systems

The trial was conducted from July 20th to September 20th, 2002, at the Commercial Dairy Farm (Mahdasht) in Northern Iran near Sari City, approximately 1500 miles (250 km) north of Tehran, which is situated at 36° 34' north latitude, 53° 5' east longitude and at an altitude of 16 m. Seventy-two Holstein dairy cows, post-calving and non-pregnant with average daily milk yield of 62.7 ± 1.43 lb (28.35 ± 0.65 kg; first to fifth lactation), were placed in three barns (24 head per barn). In every barn, 10 cows were randomly assigned to one of three treatments, and randomized by days-in-milk and lactation number. All cows were weighed (1180 ± 159 lb; 536.2 ± 72.1 kg) at the start of the trial. The cows were kept in three camps adjacent to each other.

An open structure on the farm was divided into three parts, so that in the first part, the control group (C), was kept under six fans directed toward the heads of the cows (north side), and cows were taken six times per day to a defined place and wetted as usual. A second group (F) of cows was exposed to twelve fans installed under the roof as two rows of six, and a third group (F/S) of cows was cooled with twelve fans like the second group, plus a sprinkler cooling system (eight nozzles) that was turned on above 73.4°F (23°C) every 15 minutes for 30 seconds. All fans were 27.5 inches (70 cm) in diameter, and were installed 9.9 feet (3 m) above the ground.

### Data collection

Ta and RH were recorded at the three barns while taking physiological parameters. The THI was calculated by the equation: THI = Tdb − [(0.55 − 0.55RH)(Tdb − 58)], where Tdb is the dry bulb temperature (°F) and RH the percentage of relative humidity expressed in decimals.[11,17,24]

RT, RR and HRs were recorded at eight and 13 hours. RT was measured by inserting a 10-cm veterinary mercury thermometer approximately 60 mm into the rectum for 30 seconds, and temperatures were rounded to one decimal in all cows. RR and HR were determined using a stethoscope (by adspection) for a half-minute, and reported as the number per minute.

### Data analysis

Analysis of variance for RT, RR and HR was carried out using SAS by Proc GLM.[21] To estimate the regression coefficient (RC) of RT, RR and HR on THI and body weight (BW), Proc REG was used separately for the three treatments. The statistical model was: $Y_{ijk} = m + T_i + H_j + Cov(THI)_{ijk} + Cov(BW)_{ijk} + e_{ijk}$ where: $Y_{ijkl}$ = observation (RT, RR or HR), m = overall mean, $T_i$ = the fixed effect of ith treatment (C, F or F/S), $H_j$ =

the fixed effect of jth measurements time (08 or 13 h), Cov(thi) =covariate effect of one of RT, RR and HR of kth cow on THI, Cov(BW) = covariate effect of one of RT, RR and HR of kth cow on the cow weight and eijk = random residual error.

## Results and Discussion

*Climatological data results*

During the trial, average daily Ta and RH were 80.4° F (26.9°C) and 76.7%, respectively. This temperature was suggested to be the upper-limit temperature at which Holstein cows may maintain their thermal balance.[6] Others have reported increases in RT when lactating cows are subject to temperatures above their TNZ[15,20,25] TA and THI were less (P<0.05) in the F/S group (77.83 ± 6.579 and 74.95 ± 5.616) and F group (82.37 ± 7.438 and 78.83 ± 6.443) compared to the C group (83.68 ± 7.705 and 79.95 ± 6.642) (Table 1).

*Effects of heat stress on the physiological responses*

In the present study, HS, as indicated by THI, altered (P< 0.05) all the measured physiological parameters. Cow comfort was increased by the cooling systems, with lower RT, RR and HR being observed in the cooled groups.

The C group exhibited a higher average RT (P< 0.05) than cows in the F and S/F groups, while the F group tended to differ from S/F (P< 0.05). Results of the two cooling treatments also differed (P < 0.05) from each other. These data clearly demonstrate the benefits of cooling. The cooling systems proved effective in maintaining RTs 0.58°F (0.32°C) (F) or 1.4°F (0.77°C) (S/F) below that of the C group cows. A lower RT was maintained in the S/F group than in F and C. A reduction in RT was also reported by Igono *et al*[10] when a spray and fan system was used, and by Turner *et al*[23] using sprinklers and a fan. Armstrong and Hillman,[2] using a portable calorimeter, observed average RTs of 101.3°F (38.5°C) for a S/F group, and 102.2°F (39.0°C) and 103.1°F (39.5°C) for F and shade groups, respectively.

The cooling systems reduced the RR of Holstein cows by 12 (F) and 24 (S/F) breaths/min compared to the C group, respectively (P<0.05). Armstrong *et al*[3] reported a difference of 26 breaths/min in a group of Holstein cows cooled with a system based on sprays and fans, compared to the use of shades alone. In the present study, the cooling system reduced RR, but the average number of breaths per minute was higher than 50 (Table 2), the maximum point considered for the RR inside the TNZ of cattle. As a result, this cooling system resulted in partial relief of HS, so that the use of environmental modifications should be part of an integral management program for Holstein cows in hot climate zones. A similar response was reported by Turner *et al*,[23] who reported 16 breaths/min less in Holstein cows under a cooling system, compared with those provided shades alone. In a study conducted by Brouk *et al*,[8] average respiration rates were higher (P<0.05; 101.0 vs 72.6 breaths/min) for controls compared to cows treated with wetting cycles every five minutes with supplemental airflow.

The cooling system resulted in a significant difference (P< 0.05) in HR among the three treatments. Table 2 shows a difference of two-plus beats per minute in cows in group F (77.32 ± 3.978 beats/min), and a difference of three beats per minute in cows in group S/F (76.69 ± 4.604 beats/min) compared to cows in group C (79.40 ± 4.316 beats/min).

Furthermore, RT, RR and HR recorded indicated an increase of 0.9080 ± 0.00277°F (0.50442 ± 0.00154°C),

**Table 1.** Mean and SD of Ta and THI in the three treatments.[a]

|  | Ta (°F) | THI |
|---|---|---|
| Variables | Mean ± sd | Mean ± sd |
| C | 83.68± 7.705 | 79.95±6.642 |
| F | 82.37±7.438 | 78.83±6.443 |
| F/S | 77.83±6.579 | 74.95±5.616 |
| Average | 81.29±7.669 | 77.91±6.600 |

[a]All differences observed were significant (*p*< 0.05).

**Table 2.** Means and SD of RT, RR and HR in the three treatments.[a]

|  | RT (°C) | | RR | | HR | |
|---|---|---|---|---|---|---|
| Variables | N | Mean ± SD | N | Mean ± SD | N | Mean ± SD |
| C | 191 | 39.49 ± 0.5664 | 199 | 79.18 ± 10.24 | 199 | 79.40 ± 4.316 |
| F | 204 | 39.17 ± 0.6380 | 209 | 67.69 ± 12.77 | 209 | 77.32 ± 3.978 |
| F/S | 217 | 38.72 ± 0.5213 | 217 | 55.09 ± 12.71 | 217 | 76.69 ± 4.604 |
| Average | 612 | 39.11 ± 0.6574 | 625 | 66.98 ± 15.50 | 625 | 77.76 ± 4.455 |

[a]All differences observed were significant (*p*< 0.05).

0.86705 ± 0.00749 breaths/min and 1.00282 ± 0.00357 beats/min for each unit increase in THI, and 0.12571 ± 0.000614°F (0.06984 ± 0.00034123°C), 0.11899 ± 0.00131 breaths/min and 0.13876 ± 0.00075147 beats/min for each unit increase in BW for C, F and F/S cows, respectively; all were significant ($P<0.05$). These data suggest that F and F/S cooling were not sufficient to completely eliminate HS in cows because the maximum THI measured (83.63 ± 3.333) under the cooling systems remained high enough to increase physiological responses, according to Armstrong.[1]

## Conclusions

Optimal production requires facilities that will prevent excessive environmental heat load, while assisting cattle to dissipate surplus body heat. Combined use of shade, sprinklers and fans can alleviate much HS when the systems are properly designed. Sprinkler-fan cooling can be accomplished in two ways. The first is by direct evaporation from the skin surface of the cows through use of fans. The second is by direct conduction, by cooling the cows' skin with sprinklers. In hot and humid subtropical regions, effective evaporative cooling always requires the use of forced ventilation. Fans without sprinklers will not be effective. A combination of fans, wetting, shade and well-designed housing can help alleviate the negative effect of high temperatures on dairy cows.

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