How to successfully implement mechanical cooling for dry cows and preweaning dairy calves

Jimena Laporta, PhD

Department of Animal & Dairy Sciences University of Wisconsin-Madison, Madison WI 53706

Abstract

As the dairy industry evolves, so do the strategies employed to maintain animal welfare, productivity and sustainability to accompany and maximize its progress. High temperatures and humidity can lead to heat stress, a critical issue affecting dairy cattle at all stages of life, including lactating cows, dry cows, growing heifers and preweaning calves. Effectively managing heat stress through interventions like mechanical cooling is essential to improve animal health and production efficiency, leading to overall farm sustainability. Mechanical cooling systems are among the most effective methods for managing heat stress in dairy cattle. While the fundamental principles remain similar, the timing and approach may vary depending on the climate characteristics, housing, age and physiological status of the animals. This presentation explores the implementation of cooling strategies, focusing on dry cows and preweaning calves. Our work underscores the significance of recognizing early signs of heat stress and implementing appropriate mitigation strategies, even for non-lactating cows.

Heat stress and heat dissipation mechanisms in cattle

The primary sources of heat stress include high ambient temperature, humidity, and solar radiation. Heat stress is particularly problematic for dairy cattle because it can lead to reduced feed intake, compromised immune function, decreased milk production and even reproductive issues (Bernabucci et al. 2014). Although calves and dry cows are less susceptible to heat stress than lactating cows, they are still vulnerable and may have long-term effects on their health and productivity on themselves and their progeny (Laporta et al., 2020).

Dairy cows dissipate heat through several physiological and behavioral mechanisms to maintain their body temperature and prevent heat stress. The primary ways dairy cows manage heat dissipation are conduction, convection, radiation, and evaporation. By using these mechanisms, dairy cows attempt to balance heat production and loss to maintain their core body temperature within a safe physiological range. However, when environmental conditions exceed their ability to dissipate heat effectively, heat stress occurs and can negatively impact their health, milk production and overall welfare. In other words, heat stress occurs when cattle cannot dissipate excess body heat, leading to elevated body temperatures and subsequent physiological and behavioral changes.

Convection is when heat is transferred from the cow's body to the surrounding air through convection. When the air is cooler than the cow's body, heat is lost from the skin's surface to the air. This process can be enhanced by airflow (e.g., fans), which increases air movement around the cows. Cows dissipate heat through radiation by emitting infrared energy from their body surfaces to cooler surroundings. This process is most effective when cows are in an environment with a lower temperature than their body temperature. Heat is transferred via conduction when it passes directly from the cow's body to a cooler surface through contact. For example, cows may lie down on cooler ground to help dissipate body heat. However, this method is less significant compared to other heat dissipation methods. Another route for heat dissipation is evaporation. Cows have sweat glands distributed across their skin. However, cows have fewer and less effective sweat glands than other animals, making sweating a less efficient cooling mechanism. When cows experience heat stress, they increase their respiratory rate/frequency. By breathing faster, cows lose heat through evaporative cooling from the respiratory tract. This is particularly important when temperatures are high and humidity is low. This often leads to "panting". Yet, when humidity rises, these mechanisms become less effective.

Cows often change their behavior to cope with heat as a first line of defense (Becker et al., 2020). They seek shade (to reduce direct exposure to solar radiation), decrease feed intake (to minimize metabolic heat production), and increase water intake (to counteract fluid loss and facilitate evaporative cooling). During heat stress, blood flow to the skin increases (peripheral vasodilation) to help dissipate heat through the skin into the surrounding air.

When do cattle begin to experience heat stress?

Heat stress benchmarks for lactating (milking) cows have been established and widely implemented in the industry. The Temperature humidity index (THI) considers the ambient temperature and humidity levels and assesses the heat load in dairy cows. Generally, a THI threshold of 68 indicates heat stress at which milk production starts to decline (Zimbelman et al., 2009). Yet, thresholds as low as 52 for cow activity, including reduced lying and increased standing times, have been reported for lactating cows (Müschner-Siemens et al., 2020), all associated with poor welfare. Farmers routinely monitor weather conditions, including ambient (absolute) temperature and THI, and implement heat abatement strategies. Yet, most available data has been generated for lactating cows in subtropical and arid climates. While the upper Midwestern and other regions in the U.S. may not experience the extreme heat of arid or subtropical regions, high humidity during summer can still pose a risk to cow welfare and productivity in cattle. We identified the need to expand this knowledge to non-lactating cattle, such as youngstock and dry cows, and we began a series of studies in 2018 to fill this gap. In 2021, we established heat stress benchmarks for young dairy calves in Wisconsin's continental climate (Dado-Senn et al., 2023). Previous work from our group also established heat stress benchmarks for dairy calves (Dado-Senn et al., 2020a) and dry-pregnant cows (Ouellet et al., 2021) in subtropical climates. Table 1 summarizes the available information to date and the gaps that remain.

Table 1: Environmental benchmarks at which animal-based physiological indicators of heat stress change abruptly by climate and life stage.

Life stage	Climate	Enviromental benchmark	Rectal temperature (THI)	Respiration rate (THI)	Source
Dry-pregnant cow	Sub-tropical southeastern climate	Begin to rise	77	77	Ouellet et al., 2022
Pre-weaned dairy calf	Sub-tropical southeastern climate	Begin to rise	67	65	Dado-Senn et al., 2020
Dry-pregnant cow	Temperature/ continental midwestern climate	Begin to rise	No data	No data	No data
Pre-weaned dairy calf	Temperature/ continental midwestern climate	Begin to rise	69	69	Dado-Senn et al., 2023

Nutritional strategies to alleviate the effects of heat stress on dairy cattle

Advances in genetic, management, and nutritional strategies have been applied to mitigate the detrimental effects of heat stress in dairy cows. From the nutritional standpoint, researchers have evaluated several potentially available nutritional strategies to address this challenge, including dietary fat (i.e., palmitic acid), dietary fiber (i.e., beet pulp), dietary microbial additives (i.e., yeast), minerals (i.e., chromium, selenium, zinc), vitamins (i.e., vitamin A, C, B3), metal ion buffer, plant extracts (i.e., and other anti-stress additives (i.e., monensin). Yet, there is variable and inconsistent evidence for the efficacy of these nutritional strategies in alleviating the detrimental effects of heat stress in dairy cows. Min et al. (2019) identified approximately fifty different dietary interventions derived from these eight types of nutritional strategies that may provide an appropriate means of mitigating heat stress on a particular dairy and the degree of heat stress cows are experiencing. To date, altering the environment is generally an easier and faster way to improve welfare, production, and reproduction performance than improving genetic selection for heat-tolerant traits (West, 2003).

Shade and mechanical heat abatement strategies in mature dairy cows

Over the past 40 years, many researchers have focused on cooling cows in confinement-based settings to study heat abatement strategies. It has traditionally been considered that cooling systems (shades, ventilation, water spray or soaking, and fans) can effectively alleviate the negative effect of heat-stressed dairy cows). For a comprehensive literature review, see Fournel et al. (2017). Providing shade is a critical and relatively inexpensive component of heat stress management in dairy cattle. Natural shade from trees or artificial shade structures (e.g., cloth roof on metal or wood frame with wheels or skids and gable roof structure) can significantly reduce the heat load on cows (i.e., direct exposure to solar radiation). However, it does not affect the surrounding environment. Shade requirements, materials and dimension recommendations, particularly for open lot pasture cows without access to a barn, can be found in the USDA Natural Resources and Conservation Service Practice Standards (**https://www.nrcs.usda.gov/sites/default/files/2022-09/Livestock_Shelter_Structure_576_NHCP_CPS_2019.pdf**). A study providing portable artificial shade to dairy cows (Palacios et al., 2015) reported behavioral and physiological improvements in cows, with only minor modifications in productivity. Shade appears to be more effective when combined with mechanical cooling systems. Another study evaluating different shades in dairy cows reported an overall reduction in thermal indices for shaded vs. unshaded cows (Valtorta et al., 1997).

Mechanical cooling systems are designed to reduce the environmental temperature around dairy cattle or, in some cases, to trigger thermoregulation mechanisms directly on the cow, helping them maintain normal/physiological body temperatures even during periods of high heat. These systems include fans, sprinklers, misters and ventilation systems, which can be used individually or in combination to achieve optimal cooling. The most commonly used for cooling purposes are low-volume, high-speed basket fans. The Wisconsin Dairyland Initiative (**https://thedairylandinitiative.vetmed.wisc.edu**) provides practical recommendations for fan placements and maintenance to ensure optimal outcomes. As reviewed Fournel et al. (2017), ventilated cows have a lower rectal temperature and respiration rate, a higher conception rate, and increased feed intake compared with control cows, and produced 1 kg/day more milk.

The most common water systems for evaporative cooling are foggers, misters and soakers. The evaporation of water into warm air uses energy and reduces the air temperature while increasing relative humidity (Renaudeau et al., 2012).

Fogging systems operate at high pressure and disperse very fine water droplets into the air using a ring of fogging nozzles and circulation fans. The fog droplets are immediately spread into the fan's air stream, quickly evaporating. This process cools animals as the cooled air is blown over their bodies and as they breathe in the chilled air (House, 2016).

Misting system, generate larger droplets (15 and 50 μm in diameter) than fogging systems, but they cool the air using the same principle.

Soaking Systems apply a larger volume of water directly to the cattle's skin allowing the water to penetrate the hair coat and reach the skin, effectively cooling the animal's body surface. This method works well in both humid and dry climates because it cools the skin directly, instead of relying on evaporation from the air. It typically operates on a low-pressure system that intermittently releases water, often in cycles (e.g., on for 1-3 minutes and off for 5-15 minutes). Water soakers are more beneficial in humid climates where mister cooling is less effective as the air is already saturated with moisture, reducing evaporation rates. For a review see Van Os et al., (2019).

In hot and humid climates such as Florida, lactating cows and dry cows have been successfully cooled using water soaker systems in combination with high-speed fans (e.g., typically fans ON 24/7 and intermittent water soakers activated every five minutes for one minute). This system is effective in lowering thermal indices improving feed intakes and rescuing milk yield in lactating cows and dry cows' subsequent lactation (Toledo et al., 2020; Ouellet et al., 2020). In continental climates, such as Wisconsin fans and tunnel-ventilated barns are most commonly used to promote heat abatement via convection. Fans serve an important function for continental summer heat abatement by providing fast-moving air on the cows, helping them dissipate heat and increase resting time (Reuscher et al., 2023).

Heat abatement strategies for dairy calves: pre- and postnatally

The impact of heat stress on calves is often overlooked, as the focus is primarily on the milking herd. Over the past 15 years, it has become increasingly evident that heat stress affects cattle of all ages. When dry pregnant cows are heat stressed, not only does it affect their welfare and future productivity, but it also impacts the developing fetus they carry which is undergoing the last trimester of gestation. Calves born from heat-stressed dams have reduced health, survival and performance (Laporta et al., 2020). Cooling pregnant dry cows has been shown to be a feasible (Ferreira et al., 2016) and successful strategy on the farm to prevent the loss of milk in the dam and ensure successful lactation and survival of her offspring (Ouellet et al., 2020).

Similar to adult dry and lactating cows, newborn and preweaned calves experience heat stress during extreme hot weather and benefit from heat abatement assistance. Calves, being much smaller than adult cattle, produce less body heat from rumination and have a larger relative surface area for heat loss. However, even within their thermoneutral zone, calves can feel discomfort and activate their natural thermoregulatory mechanisms. Under heat stress, calves utilize extra energy to maintain their core body temperature. If heat stress is detected in calves, there are fewer established abatement strategies to combat the heat stress.

Most heat abatement research in dairy calves to date has focused on improving calf hutch material and design, shade supplementation, hutch orientation (Bakony et al., 2021), improving hutch ventilation through window kits (Reuscher et al., 2024), or propping up the rear of the hutch (Moore et al. 2012). These studies report positive yet conflicting results in improving hutch microclimate and thermoregulatory outcomes. Beyond shade and hutch adaptations, there is minimal investigation into more active forms of heat stress abatement, such as fans, misters and soakers in individually- or group-housed dairy calves. The effectiveness of active ventilation in altering calf thermoregulation depends on the type of ventilation provided, climate, housing strategy and severity of heat stress. Active ventilation via fans inside a barn improved calf respiration rates and average daily gain (Hill et al., 2011). In a subtropical climate, indoor group-housed calves provided basket fans at the calf-resting level (one 42" fan every eight calves), achieving ~ 2.0 m/s wind speed, reduced RR, RT and ST, and improved feed intake relative to calves that provided natural ventilation (Dado-Senn et al., 2020b). Conversely, individually housed calves in a similar climate did not improve thermoregulatory responses when provided active ceiling fan ventilation (one every 40 calves) versus natural ventilation (Montevecchio et al., 2022).

Although active ventilation using fans is an effective and widely adopted method for heat abatement in adult dairy cattle, only one study has investigated its effectiveness in outdoor hutch-housed dairy calves. This is surprising as most U.S. calves are raised in such systems. Therefore, we investigated a solar-powered fan system for outdoor calf hutches and its effect on hutch microclimate and calf thermoregulation in a continental summer (Dado-Senn et al., 2023).

Active ventilation via fans substantially increased hutch air speed relative to hutches with only passive ventilation (rear windows open) on closed rear windows (1.76 vs. 0.19 vs. 0.05 m/s; respectively). The active ventilation provision reduced thermal indices in the morning and further decreased respiration frequency when calves were inside the hutch for 30 minutes, compared to passive and non-ventilated hutches. The ongoing work focuses on improving the efficiency of the fans for cooling purposes in outdoor hutches in summer.

Conclusions

Providing adequate heat abatement for all age groups, including lactating cows, dry cows and youngstock, is crucial for maintaining production, health and welfare in dairy herds. While substantial evidence supports the benefits of cooling strategies for mature and dry cows, the type of heat abatement needed often depends on specific climatic conditions, with humidity, playing a significant role in determining the effectiveness of these measures. More research is required to refine cooling methods for calves across different housing types. However, it is evident that, in the face of climate change, effectively managing the environments in which dairy animals live is vital for the industry's overall sustainability and for upholding animal welfare standards in production.

Acknowledgments

The author would like to express gratitude to the graduate students and postdocs who were involved in these projects at the University of Florida and the University of Wisconsin. These individuals include Thiago Fabris, Leticia Cassarotto, Bethany Dado-Senn, Marcela Marrero, Sena Field, Brittney Davidson, Grace Larsen, Emily Tabor, Anne Guadagnin, Amy Skibiel and Veronique Ouellet. The author would also like to thank Dr. Geoffrey Dahl at the University of Florida, as well as Dr. Joao Dorea, Dr. Jennifer van Os and Dr. Theresa Ollivett at the University of Wisconsin. Recognition is also extended to all undergraduates, interns and funding sources (USDA-NIFA, Southeast Milk Check-off Program, Wisconsin Dairy Innovation Hub). The author declares no conflicts of interest.

References

1. Bakony M, Kiss G, Kovacs L, Jurkovich V. The effect of hutch compass direction on primary heat stress responses in dairy calves in a continental region. *Anim Welf.* 2021. 30:315–324.

2. Bernabucci U, Biffani S, Buggiotti L, Vitali A, Lacetera N, Nardone A. The effects of heat stress in Italian Holstein dairy cattle. *J Dairy Sci.* 2014;97(1):471–486

3. Becker CA, Collier RJ, Stone AE. Invited review: Physiological and behavioral effects of heat stress in dairy cows, *J Dairy Sci*. 2020;103 (8):6751-6770

4. Dado-Senn B, Ouellet V, Lantigua V, Van Os J, Laporta J. Methods for detecting heat stress in hutch-housed dairy calves in a continental climate. *J Dairy Sci.* 2023;106(2):1039-1050.

5. Dado-Senn B, Skibiel AL, Dahl GE, Arriola Apelo SI, Laporta J. Dry Period Heat Stress Impacts Mammary Protein Metabolism in the Subsequent Lactation. *Animals* (Basel). 2021;11(9).

6. Dado-Senn B, Ouellet V, Dahl GE, Laporta J. Methods for assessing heat stress in preweaned dairy calves exposed to chronic heat stress or continuous cooling. *J Dairy Sci*. 2020;Sep;103(9):8587-8600.

7. Dado-Senn B, Vega Acosta L, Torres Rivera M, Field SL, Marrero MG, Davidson BD, Tao S, Fabris TF, Ortiz-Colón G, Dahl GE, Laporta J. Pre- and postnatal heat stress abatement affects dairy calf thermoregulation and performance. *J Dairy Sci*. 2020b;103:4822–4837.

8. Ferreira FC, Gennari RS, Dahl GE, De Vries A. Economic feasibility of cooling dry cows across the United States. *J Dairy Sci*. 2016;99:9931–9941.

9. Fournel S, Ouellet V, Charbonneau E. Practices for Alleviating Heat Stress of Dairy Cows in Humid Continental Climates: A Literature Review. *Animals* (Basel). 2017;2;7(5):37.

10. House HK. Dairy Housing – Ventilation Options for Free Stall Barns. Accessed May 6, 2016. Available online: **http://www.omafra.gov.on.ca/english/engineer/facts/15-017.htm**

11. Hill TM, Bateman HG II, Aldrich JM, Schlotterbeck RL. Comparisons of housing, bedding and cooling options for dairy calves. *J Dairy Sci*. 2011;94:2138–2146. **https://doi:10.3168/jds.2010-3841**

12. Laporta, J, Ferreira FC, Ouellet V, Dado-Senn B, Almeida AK, De Vries A, Dahl GE. Late-gestation heat stress impairs daughter and granddaughter lifetime performance. *J Dairy Sci*. 2020;103(8):7555-7568.

13. Moore DA, Duprau JL, Wenz JR. Short communication: Effects of dairy calf hutch elevation on heat reduction, carbon dioxide concentration, air circulation, and respiratory rates. *J Dairy Sci*. 2012;95(7):4050-4.

14. Montevecchio AB, Frota W, Merenda VR, Jones KL, Martin JG III, Ballou MA, Chebel RC. Heat abatement during the pre-weaning period: Effects on growth, feed efficiency, metabolites, and insulin of male Holstein calves. *Int J Biometeorol*. 2022;66:2169–2181.

15. Min L, Li D, Tong X, Nan X, Ding D, Xu B, Wang G. Nutritional strategies for alleviating the detrimental effects of heat stress in dairy cows: a review. *Int J Biometeorol*. 2019;63(9):1283-1302.

16. Müschner-Siemens T, Hoffmann G, Ammon C, Amon T. Daily rumination time of lactating dairy cows under heat stress conditions. *J Therm Biol*. 2020;88:102484.

17. Ouellet V, Toledo IM, Dado-Senn B, Dahl GE, Laporta J. Critical Temperature-Humidity Index Thresholds for Dry Cows in a Subtropical Climate. Frontiers in Animal Science. 2021; Volume 2 – 2021. **https://doi.org/10.3389/fanim.2021.706636**

18. Palacio S, Bergeron R, Lachance S, Vasseur E. The effects of providing portable shade at pasture on dairy cow behavior and physiology. *J Dairy Sci*. 2015;98(9): 6085-6093.

19. Renaudeau D, Collin A, Yahav S, de Basilio V, Gourdine JL, Collier RJ Adaptation to hot climate and strategies to alleviate heat stress in livestock production. *Animal.* 2012;6:707–728.

20. Reuscher KJ, Cook NB, da Silva TE, Mondaca MR, Lutcherhand KM, Van Os JMC. Effect of different air speeds at cow resting height in freestalls on heat stress responses and resting behavior in lactating cows in Wisconsin. *J Dairy Sci.* 2023;106(12):9552-9567.

21.Reuscher KJ, Salter RS, Van Os JMC. Thermal comfort and ventilation preferences of dairy calves raised in paired outdoor hutches during summertime. *J Dairy Sci.* 2024;107:2284–2296. **https://doi:10.3168/jds.2023-24006**

22. Toledo IM, Fabris TF, Tao S, Dahl GE. When do dry cows get heat stressed? Correlations of rectal temperature, respiration rate, and performance. *JDS Communications*. 2020;1(1): 21 – 24.

23. Valtorta SE, Leva PE, Gallardo MR. Evaluation of different shades to improve dairy cattle well-being in Argentina. *Int Biometeorol*. 1997;41:65–67.

24. Van Os JMC. Considerations for cooling dairy cows with water. *Vet Clin North Am Food Anim Pract*. 2019;35:157-173.

25. West JW. Effects of heat-stress on production in dairy cattle. *J Dairy Sci*. 2003;86:2131-2144.

26. Zimbelman RB, Rhoads RP, Rhoads ML, Duff GC, Baumgard LH, Collier RJ. A re-evaluation of the impact of temperature humidity index (THI) and black globe humidity index (BGHI) on milk production in high producing dairy cows. In *Southwest Nutrition & Management Conference*. 2009; 158–169.

