



Heat Stress in Livestock: Physiology, Behaviour, and Management

*Dr. Prince Chauhan

Assistant Professor, Khalsa College of Veterinary and Animal Sciences,
Amritsar, Punjab, India

*Corresponding Author's email: prince35chauhan@gmail.com

Rising ambient temperatures and increasingly frequent heat waves are reshaping the physiological and economic landscape of animal agriculture. Heat stress — the point at which an animal's heat load exceeds its capacity to dissipate it — disrupts feed intake, rumen function, reproduction, and welfare across virtually every farmed species, but its consequences are best documented in the dairy cow, whose high metabolic rate makes her acutely vulnerable. This article synthesises the physiological mechanisms of heat stress, its behavioural and production signatures, and the environmental, nutritional, and genetic strategies used to mitigate it. Heat stress is estimated to cost United States livestock industries billions of dollars annually, with dairy production bearing over half that burden, yet a combination of environmental modification, targeted nutrition, and — increasingly — genetic selection can recover a substantial share of these losses.

Keywords - Heat stress; thermoregulation; dairy cattle; temperature-humidity index; dry matter intake; rumen function; heat abatement; thermotolerance

Introduction: A June Afternoon in the Barn

Heat stress is not a niche problem confined to the tropic it is now one of the costliest, most under-appreciated constraints on livestock productivity worldwide, and it is intensifying as global temperatures climb (Cartwright et al., 2023; Giannone et al., 2023). Understanding it requires looking past the panting and the puddled water troughs, into the cellular arithmetic of heat production and heat loss — and then back out again, to the barn floor, where farmers translate that arithmetic into shade cloth, sprinkler timers, and feed formulations.

The Physiology of Heat Stress: When Metabolism Turns Against the Animal

Every homeothermic animal maintains a thermoneutral zone — a band of ambient temperatures within which it can hold its core body temperature steady without expending extra energy on cooling or warming itself (Kadzere et al., 2002). For a mature dairy cow, that zone sits roughly between -0.5°C and 20°C ; for a young calf, the upper boundary is lower still, since a smaller body loses heat faster but also tolerates less of a metabolic surcharge (see Figure 1). A cow's own digestion works against her here: rumen fermentation is an internal furnace, and a high-producing, high-intake cow generates substantially more metabolic heat than a dry or low-yielding one — which is precisely why the most productive animals in a herd are usually the first to show heat stress (West, 2003; Kadzere et al., 2002).

Once ambient heat and humidity push an animal past that upper boundary, homeostatic mechanisms activate to shed the excess heat: peripheral blood vessels dilate, respiration rate climbs, sweating and panting increase, and — critically — feed intake drops (Baumgard & Rhoads, 2012). This last response is where the real damage begins. Reduced dry matter intake (DMI) is traditionally viewed as the primary driver of the milk-yield decline seen in heat-stressed cows, since less feed means fewer nutrients available for milk synthesis

(West, 2003). But metabolic research over the past decade has revealed a second, independent pathway: heat stress itself — not just the resulting drop in intake — redirects fuel selection away from fat mobilisation and toward the oxidation of glucose and muscle-derived amino acids, a shift that produces less metabolic heat but comes at the cost of lean tissue and energetic efficiency (Rhoads et al., 2013). In effect, a heat-stressed cow does not simply eat less; her body actively downgrades how it burns what she does eat.

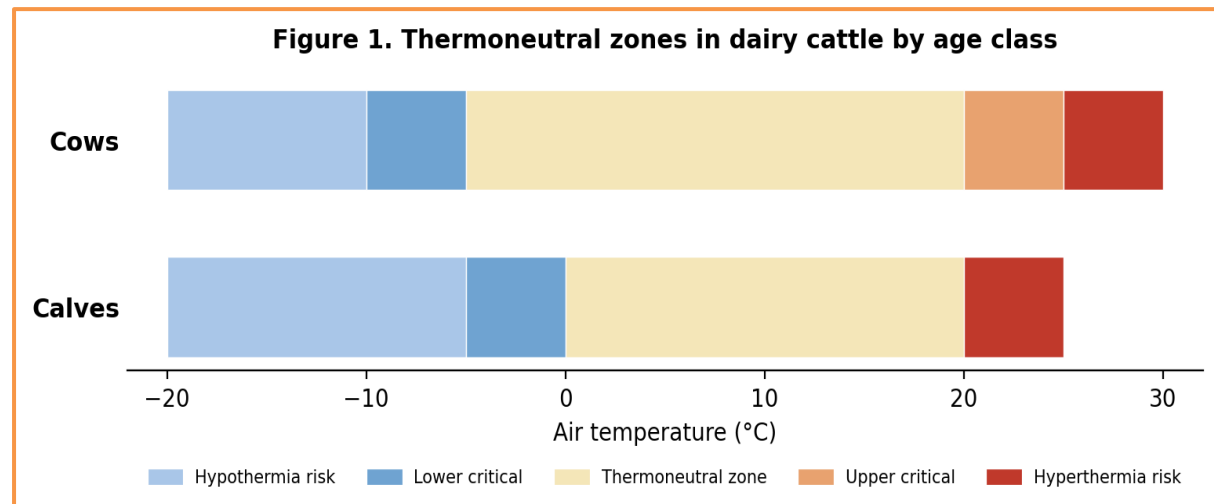


Figure 1. Thermoneutral zones in dairy cattle differ by age class; cows tolerate a wider range than calves, but both are compressed at the upper end. (Illustrative reconstruction based on ranges reported by Manzoor et al., 2019, as summarised in Herbut et al., 2021.)

The digestive consequences compound quickly. Reduced feed intake means reduced rumination, which means less saliva — the cow's principal natural buffer against acid build-up in the rumen. Combined with the fact that heat-stressed cows often shift toward smaller, more frequent meals with lower fibre content, this creates a real risk of sub-acute ruminal acidosis (SARA), further suppressing intake in a self-reinforcing spiral (Kadzere et al., 2002). Recent work has extended this picture further still, implicating oxidative stress, disruption of the hypothalamic–pituitary–adrenal axis, and shifts in gut microbial populations as parallel contributors to the production losses seen under heat load — though the microbiome findings remain inconsistent across studies and diets, and no consensus mechanism has yet emerged (Zhang et al., 2025).

Reading the Signs: Behaviour as an Early-Warning System

Long before a milk-yield report confirms a problem, a heat-stressed herd tells on itself through behaviour. The single most consistent and easily observed signal is a shift from lying to standing: a standing cow exposes more body surface area to moving air, improving convective heat loss, even though prolonged standing raises the risk of lameness and reduces blood flow to the udder (Herbut et al., 2021). Lying time can fall by several hours a day under severe heat load, while time spent standing — particularly in alleys, where cows seek out cooler, often wetted concrete — rises correspondingly. Table 1 summarises the behavioural parameters most consistently linked to heat stress across the published literature.

Table 1. Behavioural parameters associated with heat stress in dairy cattle. (Adapted from the synthesis in Herbut et al., 2021, drawing on Kadzere et al., 2002; Cook et al., 2007; Schutz et al., 2010; and related primary studies.)

Behaviour parameter	Typical direction of change	Strength of association
Feed intake / dry matter intake	Decrease	Strong
Time spent drinking / drinking events	Increase	Strong to slight
Lying time	Decrease	Strong
Time spent standing	Increase	Strong

Behaviour parameter	Typical direction of change	Strength of association
Locomotion / general activity	Decrease	Moderate
Aggressive interactions	Increase	Slight
Vocalisation	Increase	Slight
Shade-seeking behaviour	Increase	Strong
Seeking areas with better ventilation	Increase	Moderate

Feeding and drinking behaviour shift in opposite directions. As Figure 2 illustrates, dry matter intake declines steadily as air temperature rises, while water intake climbs — cows drink more often, in smaller volumes, as evaporative and respiratory water losses increase (Kadzere et al., 2002; Cardot et al., 2008, as cited in Herbut et al., 2021). A cow producing around 40 kg of milk a day in thermoneutral conditions may need roughly 135 litres of water daily; that requirement only grows as the thermometer climbs.

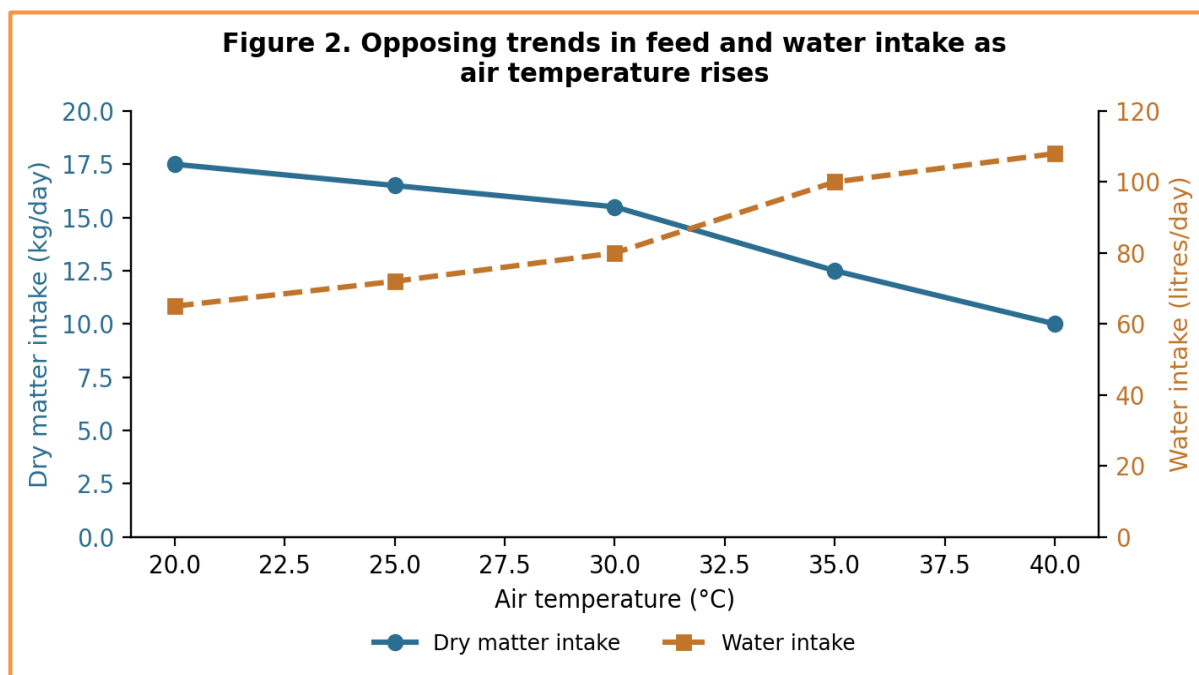


Figure 2. Illustrative trend in dry matter intake and water intake as air temperature rises, redrawn from the pattern reported by Cardot et al. (2008), as summarised in Herbut et al. (2021).

Management Strategies: Environmental, Nutritional, and Genetic

Because heat stress operates on both sides of the energy equation — raising the heat load an animal must shed while simultaneously cutting the intake that fuels her production — effective mitigation has always required a two-pronged approach: modify the environment, and adjust the diet to match what the cow can still manage to eat (Warren, 2019). Table 2 summarises the principal strategies in current use, spanning both the long-standing tools described in dairy industry guidance and more recent nutritional refinements.

Table 2. Environmental, nutritional, and genetic strategies for heat-stress mitigation in dairy cattle.

Strategy	Primary mechanism	Practical example
Shade provision	Blocks direct and reflected solar radiation	Tree cover, roofing, shade cloth, eave extensions
Forced ventilation	Increases convective heat loss via airflow	Barn fans, tube ventilation systems
Evaporative cooling	Removes heat through water evaporation from the skin	Sprinklers combined with fans over feeding areas
Reduced stocking density	Lowers radiant heat load between neighbouring animals	Wider pen allocation during summer

Strategy	Primary mechanism	Practical example
Nutrient-dense rations	Compensates for reduced dry matter intake	Higher-digestibility forage, added fat
Electrolyte and mineral supplementation	Replaces potassium, sodium, magnesium lost via sweat and saliva	Sodium bicarbonate, potassium buffers
Live yeast / microbial additives	Stabilises rumen pH and supports fibre digestion	Saccharomyces cerevisiae-based products
Antioxidant and vitamin support	Buffers oxidative stress from heat-driven metabolism	Vitamin E, selenium, niacin, chromium
Genetic selection for thermotolerance	Shifts population-level heat resilience over generations	Selection on the SLICK gene, hair-coat traits

Recent Trends: Precision Monitoring, Multi-Species Comparison, and the Cost of Inaction

Three developments distinguish the current heat-stress literature from that of a decade ago. First, monitoring has moved from single-indicator thresholds — most commonly the temperature-humidity index (THI) — toward multi-variable, machine-learning-based classification frameworks that integrate behavioural, physiological, and environmental data simultaneously, catching early-stage stress responses that a THI threshold alone would miss. Second, the nutritional research base has expanded beyond simple energy-density corrections toward antioxidant and gut-microbiota-targeted interventions, reflecting a more mechanistic understanding of heat stress as a systemic, not purely digestive, disruption (Zhang et al., 2025). Third, and perhaps most consequential for producers, there is now a documented multigenerational cost: calves gestated by heat-stressed dams show measurably lower birth weight, lower weaning weight, and reduced longevity, meaning that a single hot summer can suppress a herd's productivity for years after the temperature drops (Ouellet et al., 2020). Heat stress is also not exclusively a dairy-cattle problem, even though dairy cattle remain its best-studied victim. Table 3 places dairy cattle alongside other major livestock species to show how the same underlying physiology — a mismatch between heat production and heat dissipation capacity — manifests differently depending on species-specific thermoregulatory tools (sweating in cattle, wallowing in pigs, panting and wing-spreading in poultry).

Table 3. Comparative heat-stress signals and priority interventions across major livestock species. Thresholds are approximate and vary by breed, acclimatisation status, and production level.

Species	Key heat-stress signal	Typical THI/temperature threshold	Priority intervention
Dairy cattle	Reduced DMI, increased standing time	THI > 68	Shade + evaporative cooling
Beef cattle	Panting, reduced grazing	THI > 75	Shade, water access
Pigs	Increased respiration rate, reduced growth	> 25°C	Ventilation, wallows/misting
Poultry (layers/broilers)	Panting, wing-spreading, reduced feed intake	> 27°C	Tunnel ventilation, electrolytes
Goats	Reduced rumination, increased respiration rate	THI > 75 (breed-dependent)	Shade, adjusted feeding times

Conclusion

Heat stress is not a single event but a cascade: a physiological ceiling breached, a feeding decision reversed, a behavioural pattern rewritten, and — if nothing changes — a production and reproductive cost that outlives the heat wave itself. The tools to interrupt that cascade are not exotic. Shade, moving air, well-timed water, and a ration built for an animal eating less but needing more, remain the backbone of heat-stress management, now joined by finer-grained monitoring and the slow, compounding leverage of genetic selection.

References

1. Baumgard, L. H., & Rhoads, R. P. (2012). Ruminant production and metabolic responses to heat stress. *Journal of Animal Science*, 91(6), 2492–2503. <https://doi.org/10.2527/jas.2012-5451>
2. Cartwright, S. L., Schmied, J., Karrow, N., & Mallard, B. A. (2023). Impact of heat stress on dairy cattle and selection strategies for thermotolerance: A review. *Frontiers in Veterinary Science*, 10, 1198697. <https://doi.org/10.3389/fvets.2023.1198697>
3. Giannone, C., Bovo, M., Ceccarelli, M., Torreggiani, D., & Tassinari, P. (2023). Review of the heat stress-induced responses in dairy cattle. *Animals*, 13(22), 3451. <https://doi.org/10.3390/ani13223451>
4. Herbut, P., Hoffmann, G., Angrecka, S., Godyń, D., Corrêa Vieira, F. M., Adamczyk, K., & Kupczyński, R. (2021). The effects of heat stress on the behaviour of dairy cows – a review. *Annals of Animal Science*, 21(2), 385–402. <https://doi.org/10.2478/aoas-2020-0116>
5. Kadzere, C. T., Murphy, M. R., Silanikove, N., & Maltz, E. (2002). Heat stress in lactating dairy cows: A review. *Livestock Production Science*, 77(1), 59–91. [https://doi.org/10.1016/S0301-6226\(01\)00330-X](https://doi.org/10.1016/S0301-6226(01)00330-X)
6. Ouellet, V., Toledo, I. M., Dado-Senn, B., Dahl, G. E., & Laporta, J. (2020). Consequences of maternal heat stress at different stages of embryonic and fetal development on dairy cow progeny. *Frontiers in Animal Science*, 1, 3. <https://doi.org/10.3389/fanim.2020.00003>
7. Rhoads, R. P., Baumgard, L. H., & Suagee, J. K. (2013). Metabolic priorities during heat stress with an emphasis on skeletal muscle. *Journal of Animal Science*, 91(6), 2492–2503. <https://doi.org/10.2527/jas.2012-6120>
8. Warren, H. (2019). Overcoming the effects of heat stress in your dairy cows. *International Dairy Topics*, 20(1), 7–8.
9. West, J. W. (2003). Effects of heat-stress on production in dairy cattle. *Journal of Dairy Science*, 86(6), 2131–2144. [https://doi.org/10.3168/jds.S0022-0302\(03\)73803-X](https://doi.org/10.3168/jds.S0022-0302(03)73803-X)
10. Zhang, X., Yang, Y., Li, Y., Gu, X., Si, J., Zhu, Q., & Zhang, Y. (2025). Heat stress affects dairy cow performance via oxidative stress, hypothalamic–pituitary–adrenal axis, gut microbiota, and multi-dimensional mitigation. *Frontiers in Veterinary Science*, 12, 1686241. <https://doi.org/10.3389/fvets.2025.1686241>