Cool cows and calves: Heat stress mitigation for dairy cattle of all ages

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Outline

1. When do cows begin to experience heat stress?
2. Shade and forced air movement for continental or temperate climates
3. How do we know if the heat abatement is good enough?
4. What about sprinklers?
5. Heat abatement strategies for calves
Temperature Humidity Index (THI)

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<tr>
<th>Air Temperature (°F)</th>
<th>Relative Humidity (%)</th>
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What does THI tell us?

- Environmental index for when cows’ responses change, on average (break point or threshold)
- Many studies have aimed to identify THI thresholds based on milk yield, SCC, mortality
  → THI = 72 or 68 commonly referenced as when heat stress “begins”
- More recent studies evaluated body temp, respiration rate
Limitations of environmental thresholds

1. Other environmental factors also affect heat exchange (wind/air speed, solar radiation/black globe temperature)
2. Farms vary in facilities and management. Ambient conditions alone don’t tell us how well a given farm’s cows will cope.
3. Single sensor in the barn to activate heat abatement systems (often at threshold of 70-75° F) does not capture the variety of microclimates cows experience

4. Cows experience discomfort and seek cooling in “thermoneutral” conditions, below the THI thresholds based on production losses
5. Even within the same environment, individual cows respond differently, depending on:
   - breed, milk production, pregnancy or health status, coat characteristics
   - social status (which could affect access to drinking water, cooler microclimates, heat abatement)
When does heat stress begin?

Ruminal fermentation generates heat…

\[ \text{DMI, milk yield} = \text{adaptive responses to} \] \[ \text{metabolic heat production} \]

and restore thermal balance

Thermoneutrality
(lower critical temperature (LCT) (metabolic heat production is stable) upper critical temperature (UCT))

Homeothermy
hypothesis (core body temperature maintained within normal range) hyperthermia

cooler environment temperature warmer

Van Os (2019); Bianca (1968); Mader et al. (2005); Pennington et al. (1985); De Silva et al. (1981); Gwaziauskas et al. (1983); Spiers et al. (2004); West et al. (2003)
When does heat stress begin?

Thermal comfort begins before the UCT

Thermal comfort: physiological & behavioral defense mechanisms not yet activated

Thermoneutrality
lower critical temperature (LCT) (metabolic heat production is stable) upper critical temperature (UCT)

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Thermal discomfort begins before the UCT

Van Os (2019); Bianca (1968)

Thermal discomfort begins before the UCT

Thermal comfort: physiological & behavioral defense mechanisms not yet activated

Natural early defense mechanisms:
- Vasodilation
- Sweating
- Respiratory rate †, panting
- Behaviors to:
  † heat production
  † heat gain from environment
  † heat dissipation to environment

Van Os (2019); Bianca (1968)
Outline

1. When do cows begin to experience heat stress?
2. Shade and forced air movement for continental climates
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Supplemental heat abatement is needed

- For high-producing dairy cows, their intrinsic mechanisms are often insufficient

- USDA: 94% of U.S. dairy farms provide at least 1 form of supplemental heat abatement:
  - Shade to limit heat gain
  - Fans and/or water spray to help dissipate heat
Public views on pasture vs. indoor housing depend on heat stress abatement provided

Goals: reduce heat gain, promote heat loss

- **Level 1**: Reduce heat gain. Shade is a basic necessity.

- **Level 2**: Promote heat dissipation. Fans and/or water spray.
Shade is critical!

- Shade seeking is part of cows’ natural behavioral repertoire
- Cows highly value shade
  - Prefer it over being in the sun (including unshaded soakers)
  - Motivated to access it
- If shade is lacking, resources for dissipating heat can be counteracted by heat gain


Goals: reduce heat gain, promote heat loss

- **Level 1**: Reduce heat gain. Shade is a basic necessity.
- **Level 2**: Promote heat dissipation. Fans and/or water spray.

In continental or temperate climates, I would start with mechanical ventilation systems before considering adding water spray… Why?
Lying time decreases with heat stress

- Normally, cows are highly motivated to spend half of the day lying down – common indicator of cow comfort
- Lying time decreases with heat stress
- Soakers (and cooled beds) do not restore lying time
- When there are soakers, cows stand at the feed bunk (without eating) more
  - Standing on concrete and wet flooring → risk factors for lameness

Why does this happen?

- While cows lie down, respiration rate & body temperature ↑
- While cows are standing, respiration rate & body temperature ↓
- Standing exposes more surface area for convective heat loss
Properly calibrated fans allow cows to cool down while getting enough rest.

Air speeds of ≥ 1 m/s (200 ft/minute) at cows’ resting height:

- heat stress responses
- milk yield
- lying time

Reuscher, Cook, Van Os et al. (2023; https://doi.org/10.3168/jds.2023-23364)

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Reuscher, Cook, Van Os et al. (2023; https://doi.org/10.3168/jds.2023-23364)

Fans kept body temperature normal

Maximum daily vaginal temperature (°C)

Means:
- 0.4 m/s (79 ft/min): 39.5°C (103.1 °F)
- 1.7 m/s (335 ft/min): 39.1°C (102.4°F)
- 2.4 m/s (472 ft/min): 39.1°C (102.4°F)

(Similar patterns for respiration rate and skin temperature)

Reuscher, Cook, Van Os, et al. (2023; https://doi.org/10.3168/jds.2023-23364)
Fans protected milk yield

Daily milk yield (kg)

Means:

- 2.4 m/s (472 ft/min)
  - 43.3 kg/d (95.5 lbs/day)
- 1.7 m/s (335 ft/min)
  - 42.7 kg/d (94.1 lbs/day)
- 0.4 m/s (79 ft/min)
  - 41.4 kg/d (91.3 lbs/day)

(Similar patterns for dry matter intake)

Reuscher, Cook, Van Os, et al. (2023; https://doi.org/10.3168/jds.2023-23364)

Critically, fans protected lying time

Daily lying time (hours/day)

Means:

- 2.4 m/s (472 ft/min)
  - 14.3 h/d
- 1.7 m/s (335 ft/min)
  - 13.9 h/d
- 0.4 m/s (79 ft/min)
  - 13.2 h/d

Reuscher, Cook, Van Os, et al. (2023; https://doi.org/10.3168/jds.2023-23364)
A picture is worth 1000 words…

Fans off (control treatment, prevailing winds only)
5 out of 16 cows resting

Fans calibrated to deliver 2.4 m/s (472 ft/min) at cow resting height
14 out of 16 cows resting

Within a facility, individual cows’ lying times can vary

Reuscher, Cook, Van Os, et al. (2023; https://doi.org/10.3168/jds.2023-23364)

Reuscher, Cook, Van Os, et al. (in preparation)
Consistency is key

- Greater variation in air speeds among stalls within a facility → greater variation in cows’ lying times
- Important to provide consistent, sufficiently high air speeds ($\geq 200$ ft/min) across the resting area to promote cow comfort

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What to measure, and why

1. Weather forecast
   ✓ Plan when to monitor the cows

2. Barn microclimate
   ✓ Starting point for when to activate heat abatement systems
   ✓ Context for how well heat abatement is working

3. Cow responses
   ✓ Direct indicator of how well heat abatement is working
   ✓ Is additional intervention needed?

Cow responses: what should we observe?

If the cows are doing the following, they are telling us they are uncomfortable and could benefit from (more) cooling:

- behaviors such as bunching, seeking shade, water, or cooling
- vasodilation (proxy: skin temperature)
- sweating (hard to measure outside of research setting)
- panting, ↑ respiratory rate

Van Os (2019); Bianco (1968)
Panting: a conspicuous indicator

Drooling
Saliva (clear, transparent) comes out of the cow’s mouth; cow is not ruminating; any quantity of visible saliva counts as drooling.

[open mouth]

Tongue Out
Protruding tongue; tongue tip or more crosses the lower teeth and it does not touch any body parts (e.g. not grooming).


Panting: a conspicuous, but late indicator

Tresoldi et al. (2016); see also Gaughan and Mader (2014).
Assessing panting

- Focus on a single pen, ideally the highest-producing cows
- Evaluate all the cows in the pen with a quick walk-by scan
- Prioritize cows not eating
- Do not count saliva from rumination

How to report panting

\[
\text{number of cows panting} \times 100 = \% \text{ of cows panting}
\]

Target: 0% of cows panting

- Panting is a later sign of more severe/acute heat stress.
- Seeing cows showing signs of panting is concerning and indicates need for additional intervention.
What if you observe cows panting?

Measure their respiration rates

Assess again after 30 minutes

If no longer panting + RR ↓

Periodically monitor cows if possible. Consider adjusting overall heat abatement systems.

If still panting + RR elevated:

Soak them with water

Respiration rate: an early/sensitive indicator

Rule of thumb: intervene at ≥ 60 breaths per minute

- Threshold / breakpoint has been suggested starting with older studies
- Cows with 24-hour access to fans (Wisconsin) or soakers (California) had RR = 50-54 breaths/min on average
- After being deprived of cooling, cows in California showed a preference for soakers once respiration rate reached 60 breaths/min
- Easy to estimate

Webster (1993); Legrand et al. (2011); Chen (Van Os) et al. (2013, 2016); Atkins et al. (2018); Reuscher et al. (2023)
How many cows ≥ 60 breaths/minute?

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Breaths/minute

11%  30%  30%  36%  82%

“sentinel” animals

average well above 60 breaths/minute
– intervention clearly warranted

The top quartile tells a different story than
the average. From an animal welfare
perspective, intervening earlier is better.
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da Silva, Cook, Van Os et al. (in preparation); see also Chen (Van Os) et al. (2016); Atkins et al. (2018)

Decide how many cows to measure

- Balance accuracy vs. feasibility
- When THI is relatively lower (≤ 68) or higher (>80), unlikely to tell the wrong story
- When THI is in the 70s, sampling more cows → more accurate
- Aim for 20+ randomly selected cows
- If THI is in the 70s, if possible, try to sample 35 cows for better accuracy

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Da Silva, Cook, Van Os, et al. (in preparation)
```
Assessing respiration rate

Which cows to measure?
- Focus on a single pen, ideally the highest-producing cows
- Within the pen, focus on stationary cows lying or standing in the stalls
  - Avoid cows who are eating, drinking, walking

Practical tips:
- Record ear tag numbers to avoid double-counting a cow
- It’s ok to start over or move on to a different cow

Interpretation: Is the heat abatement adequate?

- Was the respiration rate for the top quartile of cows ≥ 60 breaths/minute? (i.e., were ≥ 25% of cows breathing at 60 breaths/minute or faster?)
  - If YES: additional heat abatement / adjustments recommended
  - If NO: current heat abatement likely sufficient
What if additional intervention is warranted?

Mechanically ventilated barn or fans over stalls?

No

Adding fans over stalls can promote heat dissipation and improve lying times, DMI, milk yield

Yes

Do all stalls receive ≥ 200 ft/min at 20" high?

No

Start by troubleshooting baffle or fan placement / fan angle, then measure again

Yes

Consider adding feed bunk and/or holding pen soakers, if not already provided

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Misters, Foggers

- **High-pressure** foggers or misters inject the air with **fine** droplets
  - evaporate to lower the temperature of microclimate
  - indirect cooling of cattle
- Works in lower-humidity climates (e.g., southwest)
- When humidity is higher, air has less capacity for water to evaporate (water vapor gradient) to generate latent heat loss

Soakers, Sprinklers, Showers

- **Low-pressure** soakers deliver mostly **coarse** droplets
  - All nozzles output a range of droplet sizes
  - So, smaller droplets evaporate before landing on cows
  - cools the microclimate, just like misters

Chen (Van Os) et al, 2013, 2016; Kendall et al, 2007; Frazzi et al, 2002
Soakers, Sprinklers, Showers

- **Low-pressure** soakers deliver mostly **coarse** droplets
- Wet cows directly → energy from body heat evaporates water
- Enhanced cooling when combined with high-speed air

How **much** to soak? Common rule of thumb – is it right?
**Why is this recommended?**

- Latent heat loss does not rely on a temperature gradient → focus has been on evaporation after the water is turned off

- Dripping water is associated with speculative concerns about mastitis… *but no studies have found a direct link!*
  - SCS and mastitis incidence are higher overall in summer

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**Dripping water *does* help cool cows**

- When water – which is typically cooler than the skin – drips from the body, this removes heat!
- Rapid reductions in skin temp & RR after a single spray (≥1 gallon across 1.5 to 3 minutes)
- Body temperature ↓ after a single 10-12 minute session before the coat began drying

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*Bailey et al., 2012; Flamenbaum et al., 1986; Aggarwal and Upadhyay, 2013; Bernabucci et al., 2010; Lambertz et al., 2014*

*Chen (Van Os) et al., 2015, 2016; Tresoldi et al., 2018; Schütz et al., 2011*
How often to soak at the feed bunk?

- The coat typically takes 14-16 minutes to dry, regardless of whether cows are soaked to the point where water drips off.
- Faster drying in warmer or windier conditions → spray more frequently in warmer conditions.

Therefore, spray every 15 minutes or more frequently for consistent cooling throughout the day.

Use water efficiently

- Enough water should be applied to generate effective cooling.
  - Too little water is not effective, and therefore not efficient!
- After a certain point, applying more water → diminishing returns for cooling.
- In a lower humidity climate, optimal volume ~ 1 gallon per spray application (which can cool 2–3 adjacent cows at feed bunk), at least 4-5×/hour.
- Adjust based on region / responses of cows on specific farms.

Chen (Van Os) et al, 2015, 2016a,b
Are smaller droplets counterproductive?

- Popular belief that small droplets “form insulating barrier” on the coat surface, trapping heat and exacerbating heat stress
- This is likely a misinterpretation of the fact that when droplets evaporate from the coat (or the air), this cools the cow less than when the heat is transferred directly from the skin surface
- Our study did not detect cooling differences among nozzles that output droplets differing 1.2- to 1.5-fold in avg droplet diameter

Soakers can effectively cool cows quickly, but only fans delivering air speeds of $\geq 200$ ft/minute have been shown to promote adequate lying time. Soakers and high-speed air can complement each other.
The future: Precision Livestock / biofeedback

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5. **Heat abatement strategies for calves**
Calves feel the heat too

- Common misconception that heat stress is less of a concern for calves vs. adult, lactating cows
- But studies show that heat stress in calves →
  - ↓ starter intake
  - ↓ ADG
  - ↓ serum IgG
  - ↑ morbidity, mortality

Stott et al., 1975; Kelly et al., 1982; Donovan et al., 1986; Broucek et al. 2008, 2009; Stuff et al., 2008; Hill et al., 2011; Pelta et al., 2016; López et al., 2018; Louie et al., 2018; Wang et al., 2020; Menné et al., 2021; Dado-Senn et al., 2020, 2023

Wisconsin calves in hutches

A Breakpoint = 21.0°C

B Breakpoint = 69

Dry bulb temperature (°C)  Respiration rate, bpm

THI

Average of 40 breaths/minute at the breakpoint

Note: Florida threshold was lower (THI = 65), likely due to lack of overnight relief in the subtropical climate.

Dado-Senn et al. (2020); Dado-Senn, Lapa, Van Os et al. (2023)
Heat abatement strategies for calves

<table>
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<tr>
<th>Calf barn</th>
<th>Outdoor hutch(es)</th>
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<tr>
<td><strong>Reduce heat gain</strong></td>
<td><strong>Promote heat loss</strong></td>
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<tr>
<td>Barn roof</td>
<td>Mechanical / active ventilation (forced air movement): fans, tubes</td>
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<tr>
<td>Shade (cloth, trees)</td>
<td>Natural / passive ventilation (air exchange): elevate huts, add openings</td>
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<tr>
<td>Hutch material</td>
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Stott et al., 1975; Coleman et al., 1996; Lammers et al., 1996; Spain & Spiers, 1996; Hill et al., 2011; Moore et al., 2012; Carter et al., 2014; Peña et al., 2016; Kovacs et al., 2018; Manriquez et al., 2018; Reuscher et al., 2019; Montevettolini et al., 2022; Dado-Senn et al., 2020, 2022

Passive ventilation can mitigate the heat of 2 calves

Diagram: Kim Reuscher
Additional passive ventilation
n = 25 pairs (50 calves)

Photos: Kim Reuscher

Reuscher, Van Os, et al. (2024; https://doi.org/10.3168/jds.2023-24006)

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<th>Week of life</th>
<th>Pre-weaning</th>
<th>Weaning</th>
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Hutch restriction, use

Every 15 minutes

Reuscher, Van Os, et al. (2024; https://doi.org/10.3168/jds.2023-24006)

Photos: Kim Reuscher
Passive ventilation → cooler microclimate

Reuscher, Van Os, et al. (2024; https://doi.org/10.3168/jds.2023-24006)

Week of life: 4 6 9

Hutch internal THI

External daily max THI:

77 ± 4
76 ± 4
74 ± 5

Passive ventilation → cooler microclimate, even with 2 calves inside

Reuscher, Van Os, et al. (2024; https://doi.org/10.3168/jds.2023-24006)

Week of life: 4 6 9

Hutch internal THI

External daily max THI:

77 ± 4
76 ± 4
74 ± 5

Ventilation:  P = 0.003
Week of life: P = 0.008
# of calves × week: P = 0.065
# of calves, other interactions:  P = 0.11
Calves preferred ventilation in wk 6 and 9 of life
Pairs strongly preferred to be together
Conclusions:

- Pair-housed calves prefer to be together
- Calves prefer hutch ventilation, which keeps them cooler

Innovative active ventilation outdoors

Photos: Kim Reuscher
Reuscher, Van Os, et al. (2024; https://doi.org/10.3168/jds.2023-24006)

Dado-Serr, Laporta, Van Os, et al. (2023; https://doi.org/10.3168/jdsc.2023-0390)
**Ventilation (esp. passive) → cooler microclimate**

In passive ventilation treatment, open bedding door may have allowed warm air to escape better.

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**Passive ventilation (PAS)**
Rear hutch windows opened
Air speed = 0.21 m/s

**Minimal ventilation (CON)**
Rear hutch windows closed
Air speed = 0.05 m/s

Previous study: 0.22 vs. 0.002 m/s

**Active ventilation (ACT)**
Solar-powered duct fan
Air speed = 1.74 m/s

Target air speed ≥ 1.0 m/s at resting height to promote mature cow thermoregulation

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n = 12 calves (individually housed)
3 × 3 Latin square
4-d treatment + 3-d rest
starting at 22 ± 6 d of age

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Dado-Senn, Laporta, Van Os, et al. (2023; https://doi.org/10.3168/jdsc.2023-0390); Reuscher, Van Os, et al. (2024; https://doi.org/10.3168/jds.2023-24006); Reuscher, Cook, Van Os, et al. (2023; https://doi.org/10.3168/jds.2023-23364)
Active ventilation from fans: △ △ respiration rate

- no differences in skin or rectal temperature or in sweating rate
- △ rectal surface temperature (9-11 am) with both ventilation treatments

Conclusions:
- Solar-powered fans showed promise for cooling the hutch and the calves
- Follow-up study refined both the ventilation & experimental methods
Take-home messages

- All age classes feel the heat
- Thermal discomfort begins even when “thermoneutral”
- Combine shade + at least 1 resource to promote heat loss (e.g., fans, soakers)
  - Consistent fast-moving air promotes resting behavior
- Observe the animals directly to make sure they are staying cool

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