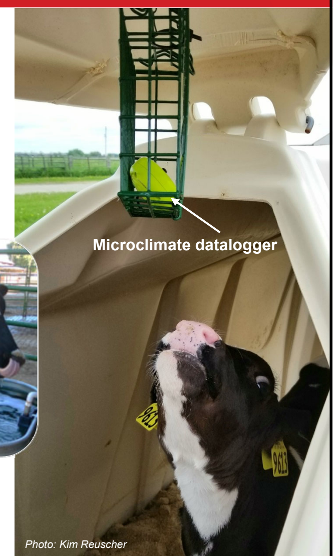
Cool cows and calves:
Heat stress mitigation for dairy cattle of all ages



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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)

Air Temperature (°F)	Relative Humidity (%) 0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
65	61	61	62	62	62	62	62	62	63	63	63	63	63	64	64	64	64	64	65	65	65
70	63	64	64	64	65	65	65	66	66	66	67	67	67	68	68	68	69	69	69	70	70
75	66	66	67	67	68	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75
80	68	69	69	70	70	71	72	72	73	73	74	74	75	76	76	77	78	78	79	79	80
85	70	71	72	72	73	74	75	75	76	77	78	78	79	80	81	81	82	83	84	84	85
90	72	73	74	75	76	77	78	79	79	80	81	82	83	84	85	86	86	87	88	89	90
95	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
100	77	78	79	80	82	83	84	85	86	87	88	90	91	92	93	94	95	97	98	99	100
105	79	80	82	83	84	86	87	88	89	91	92	93	95	96	97	99	100	101	102	104	105
110	81	83	84	86	87	89	90	91	93	94	96	97	99	100	101	103	104	106	107	109	110

https://dairy.extension.wisc.edu/articles/animal-handling-during-heat-stress/

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

Kelly and Bond, 1971; Dikmen and Hansen, 2009; Bohmanova et al, 2007; Vitali et al, 2009; Lambertz et al, 2014; Atkins et al., 2018

Limitations of environmental thresholds

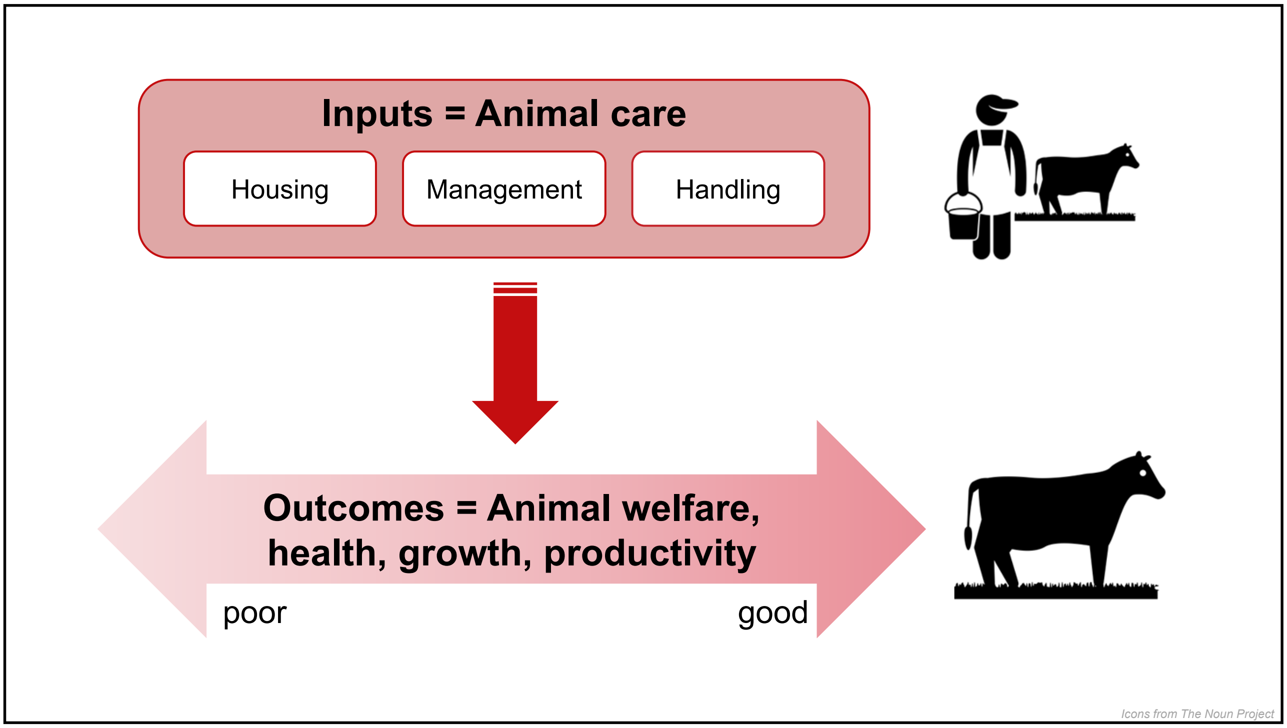
1. Other environmental factors also affect heat exchange (wind/air speed, solar radiation/black globe temperature)
2. Farms vary in facilities and management. Ambient conditions alone don't tell us how well a given farm's cows will cope.
3. Single sensor in the barn to activate heat abatement systems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

Bianca, 1968; Spiers et al, 2004; Gaughan et al, 2008; Legrand et al, 2011; Chen (Van Os) et al, 2013, 2016

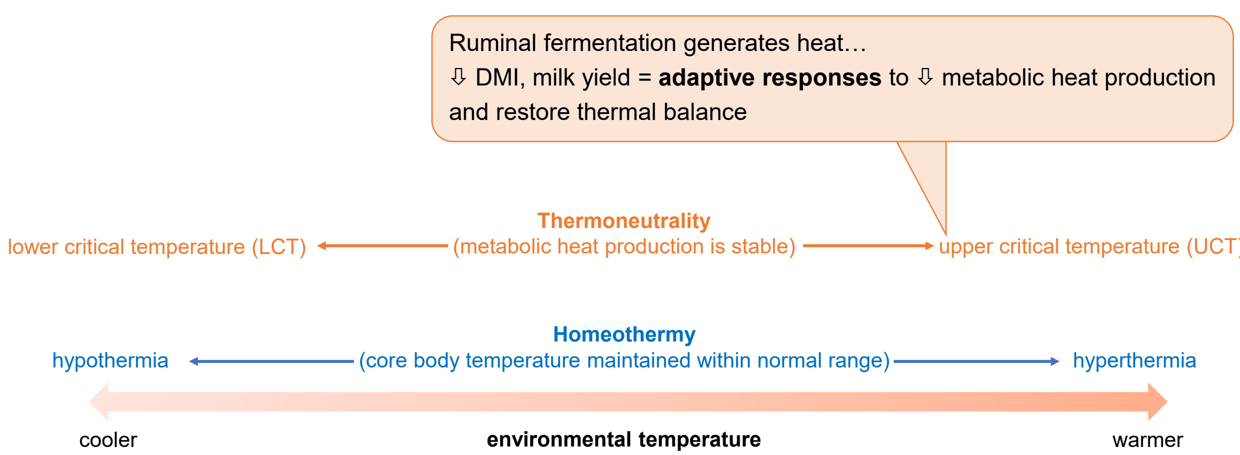
Limitations of environmental thresholds

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)

Bianca, 1968; Spiers et al, 2004; Gaughan et al, 2008; Legrand et al, 2011; Chen (Van Os) et al, 2013, 2016



When does heat stress begin?



Van Os (2019); Bianca (1968); Mader et al. (2005); Pennington et al. (1985); De Silva et al. (1981); Gwazdauskas et al. (1983); Spiers et al. (2004); West et al. (2003)

When does heat stress begin?

Thermal discomfort 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)

Homeothermy
hypothermia ← (core body temperature maintained within normal range) → hyperthermia

cooler **environmental temperature** warmer

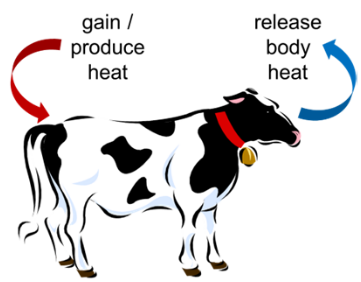
Van Os (2019); Bianca (1968)

Thermal discomfort begins before the UCT

Thermal comfort: physiological & behavioral defense mechanisms
<u>not yet</u> 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)

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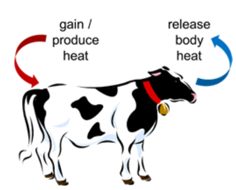
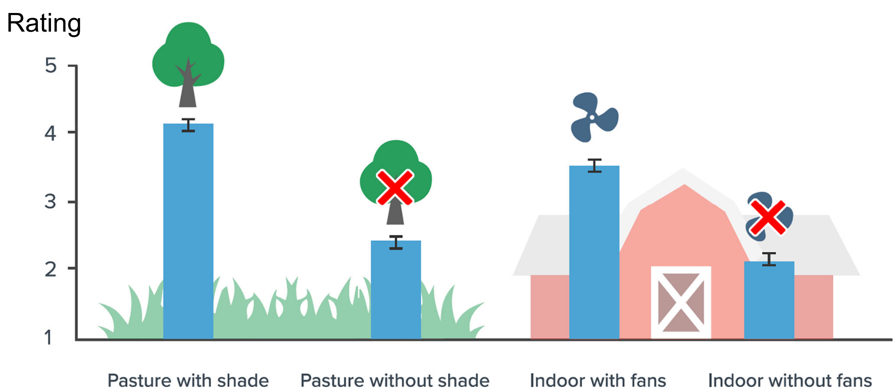
Supplemental heat abatement is needed

- 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



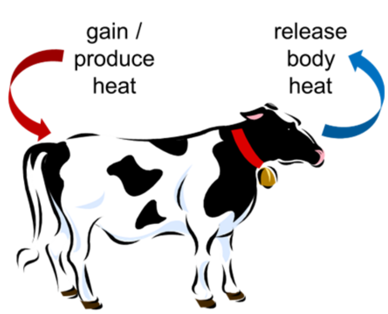
Public views on pasture vs. indoor housing depend on heat stress abatement provided



Cardoso et al. 2018. PLoS ONE:13 e0205352.

Goals: reduce heat gain, promote heat loss

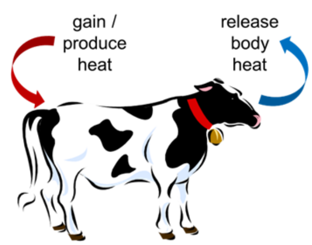
- **Level 1**: Reduce heat gain. Shade is a basic necessity.
- **Level 2**: Promote heat dissipation. Fans and/or water spray.



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 <u>dissipating</u> heat can be counteracted by heat <u>gain</u>



Schütz et al., 2008, 2009, 2011; Tucker et al. 2008

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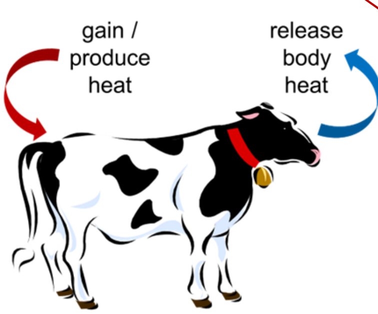
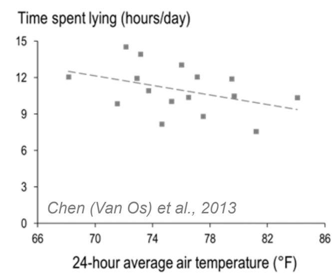


In continental or temperate climates, I would start with mechanical ventilation systems before considering adding water spray… Why?

Lying time decreases with heat stress

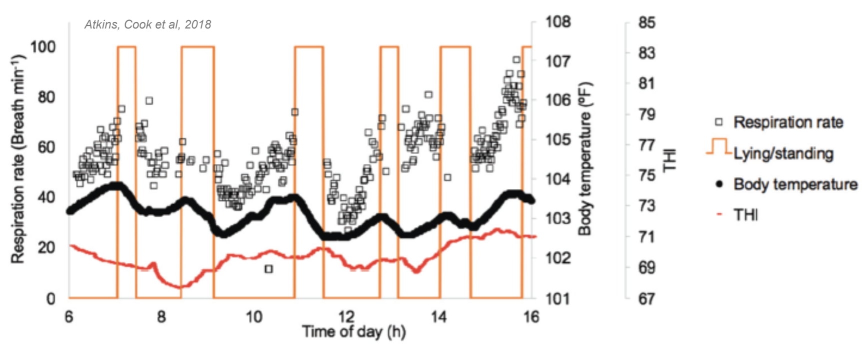
- Normally, cows are highly motivated to spend half of the day lying down
  – common indicator of cow comfort
- Lying time decreases with heat stress
- Soakers (and cooled beds) do not restore lying time
- When there are soakers, cows stand at the feed bunk (without eating) more
  - Standing on concrete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



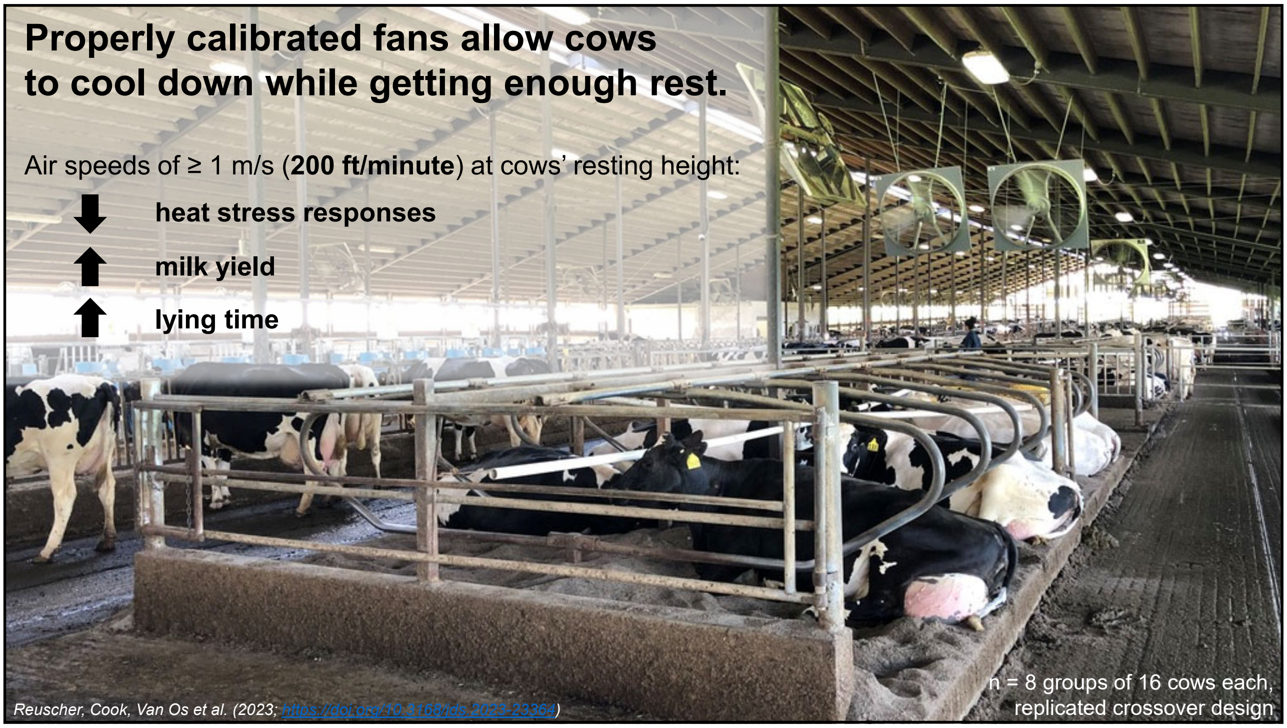
Standing: Schütz et al, 2010; Cook et al, 2007; Chen (Van Os) et al, 2016; Legrand et al, 2011; Zähner et al, 2004; Ortiz et al, 2015; Overton et al, 2002
Lameness: Cook, 2003; Vokey et al, 2001; Somers et al, 2003; Borderas et al, 2004; van Amstel et al, 2004

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



Chen (Van Os) et al., 2016, Cook et al, 2007; Tucker et al, 2008; Jensen et al, 2005; Hillman et al, 2005; Ansell, 1981; Legrand et al, 2011



Properly calibrated fans allow cows to cool down while getting enough rest.

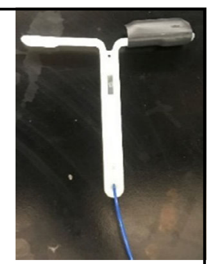
Air speeds of ≥ 1 m/s (**200 ft/minute**) at cows' resting height:

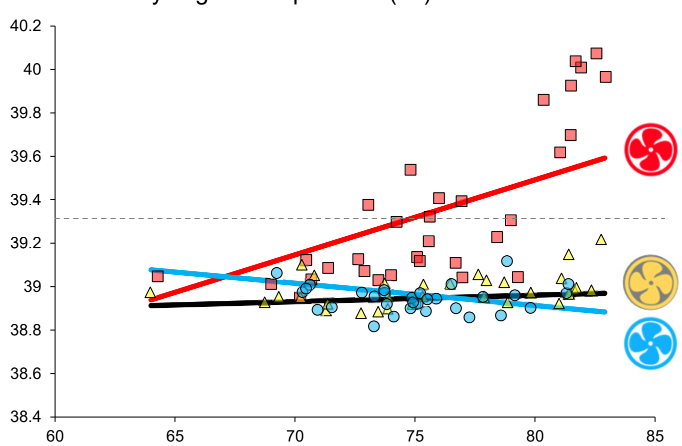
- ⬇ **heat stress responses**
- ⬆ **milk yield**
- ⬆ **lying time**

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

n = 8 groups of 16 cows each, replicated crossover design

Fans kept body temperature normal





Means:

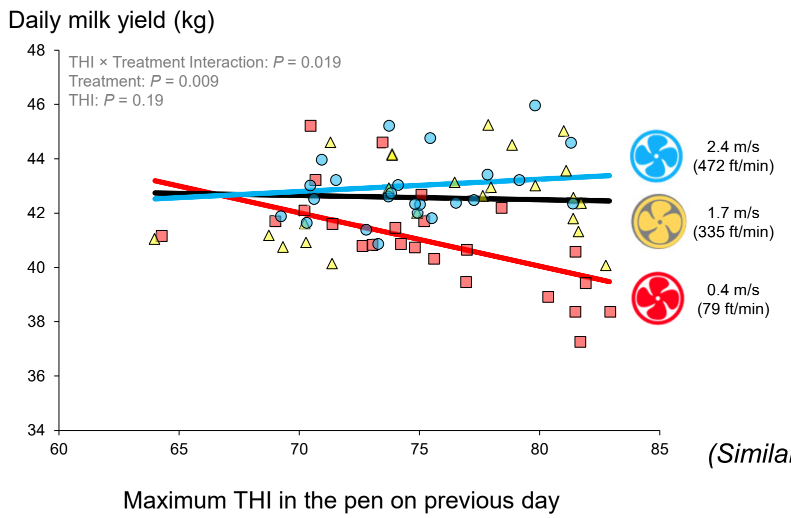
- 0.4 m/s (79 ft/min): 39.5°C (103.1 °F)
- 1.7 m/s (335 ft/min): 39.1°C (102.4°F)
- 2.4 m/s (472 ft/min): 39.1°C (102.4°F)

(Similar patterns for respiration rate and skin temperature)

THI × Treatment Interaction: $P < 0.0001$
Treatment: $P < 0.0001$
THI: $P = 0.030$

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

Fans protected milk yield



Means:

43.3 kg/d (95.5 lbs/day)

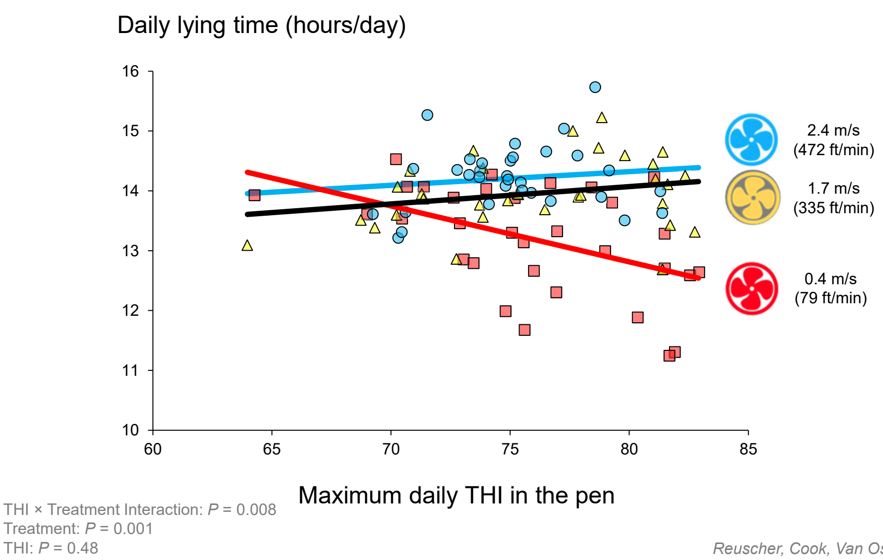
42.7 kg/d (94.1 lbs/day)

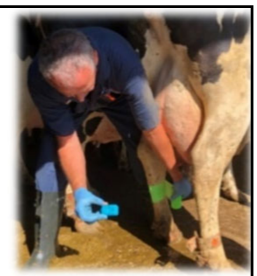
41.4 kg/d (91.3 lbs/day)

(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





Means:

14.3 h/d

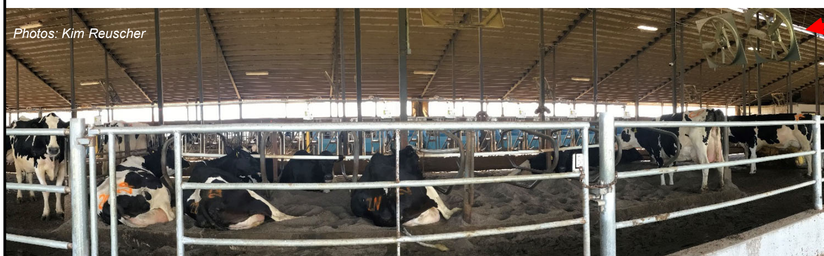
13.9 h/d

13.2 h/d

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

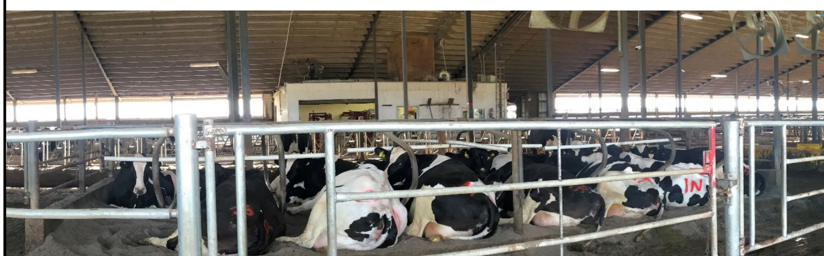
n = 8 groups of 16 cows each,
replicated crossover design

A picture is worth 1000 words…



Fans off (control treatment, prevailing winds only)

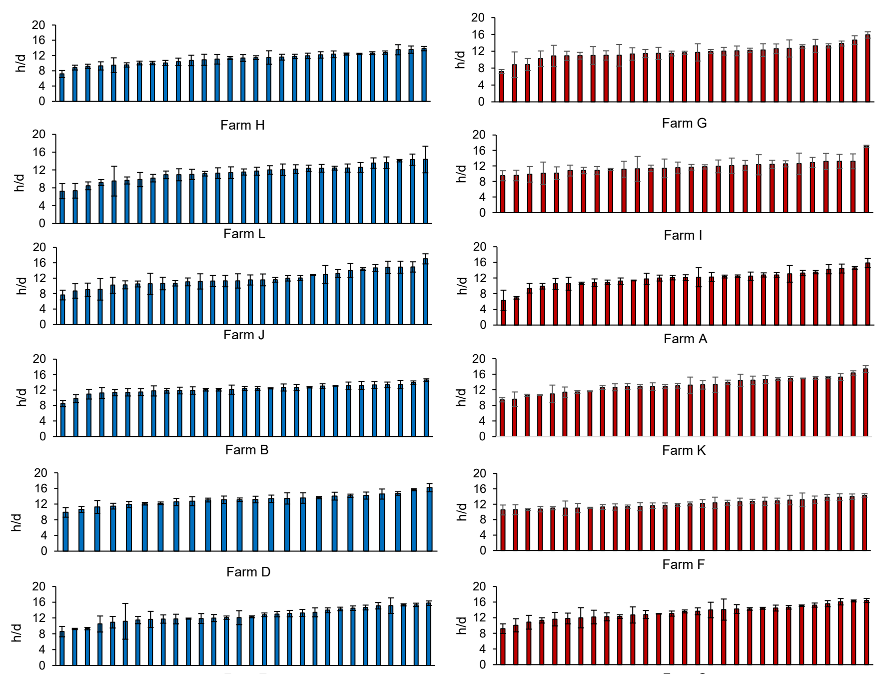
5 out of 16 cows resting



Fans calibrated to deliver 2.4 m/s (472 ft/min) at cow resting height

14 out of 16 cows resting

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

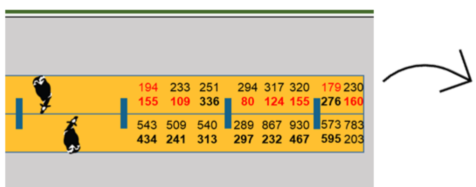


Within a facility, individual cows' lying times can vary

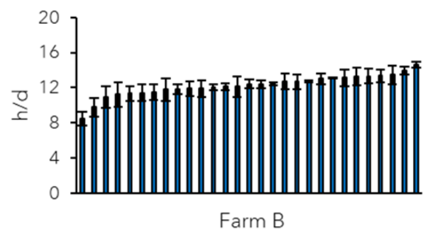
Reuscher, Cook, Van Os, et al. (in preparation)

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 (≥ 200 ft/min) across the resting area to promote cow comfort



variability in stall air speeds



variability in cows' lying times

Outline

1. When do cows begin to experience heat stress?
2. Shade and forced air movement for continental or temperate climates
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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); Bianca (1968)

Panting: a conspicuous indicator

[open mouth]

Drooling

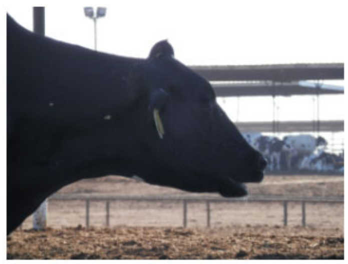
Saliva (clear, transparent) comes out of the cow's mouth; cow is not ruminating; any quantity of visible saliva counts as drooling

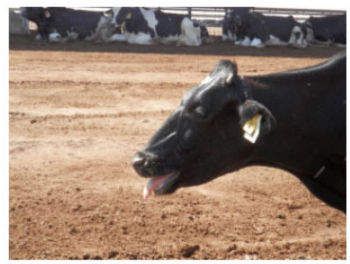
Panting

Open mouth; space between the lips is visible; cow is not ruminating

Tongue Out

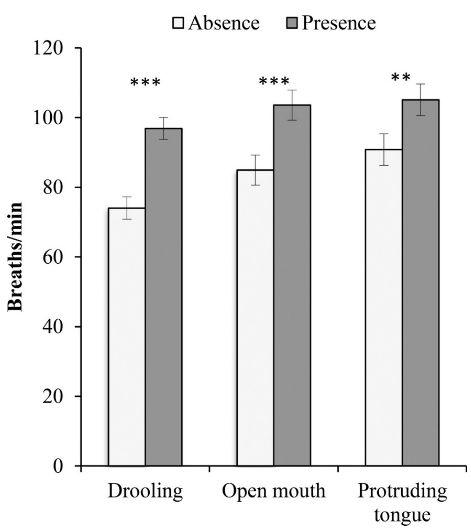
Protruding tongue; tongue tip or more crosses the lower teeth and it does not touch any body parts (e.g. not grooming)

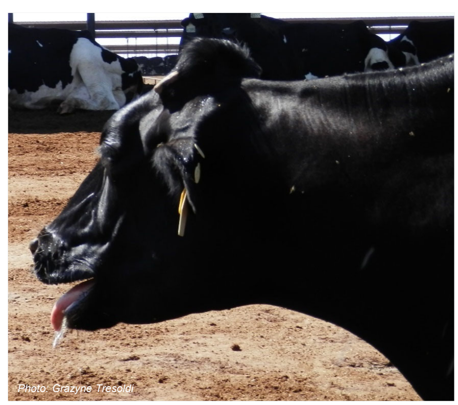




Test yourself: http://tuckerlab.ucdavis.edu/heat-stress.html

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

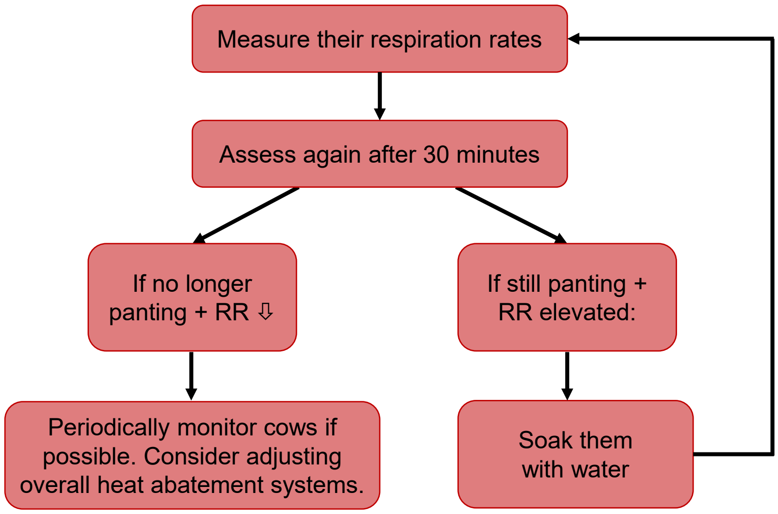
How to report panting

$$\frac{\text{number of cows panting}}{\text{total cows in the pen}} \times 100 = \text{\% of cows panting}$$

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?



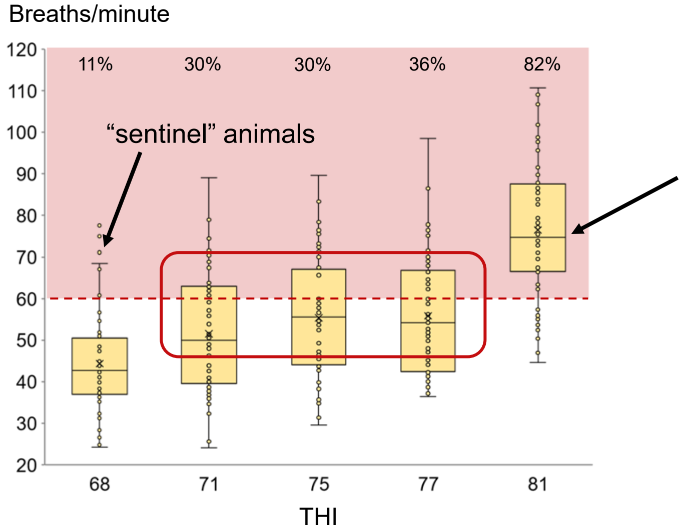
Respiration rate: an early/sensitive indicator

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?



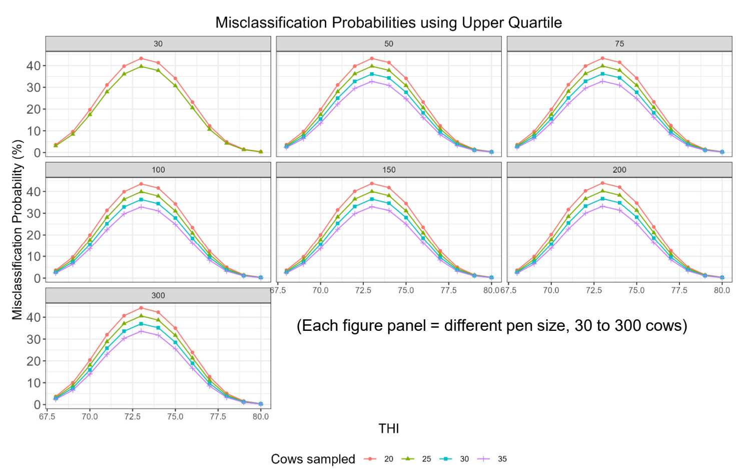
average well above 60 breaths/minute – intervention clearly warranted

The top quartile tells a different story than the average. From an **animal welfare** perspective, intervening earlier is better.

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



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

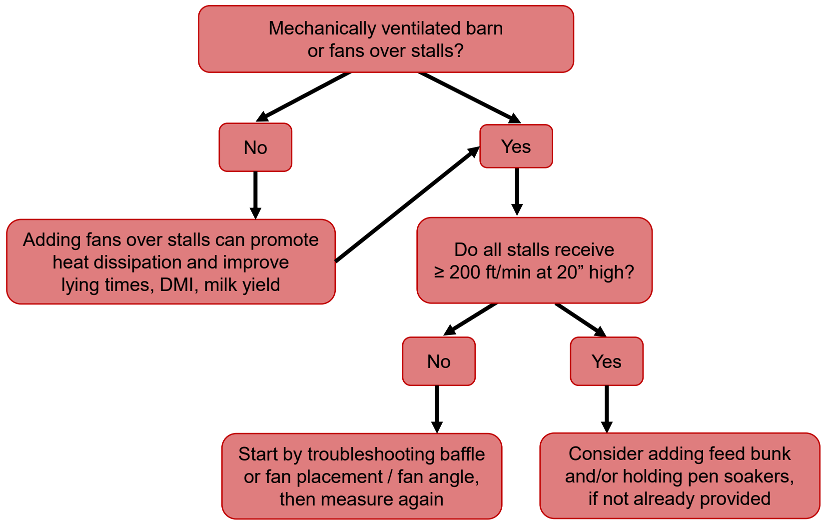
Practical tips:

- 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?



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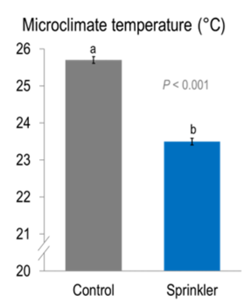
Misters, Foggers

- **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

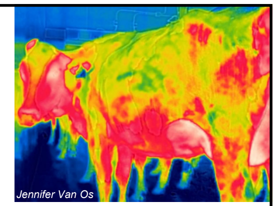
- **Low-pressure** soakers deliver mostly **coarse** droplets
- All nozzles output a range of droplet sizes
- So, smaller droplets evaporate before landing on cows

→ 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

Chen (Van Os) et al, 2013, 2015, 2016; Kendall et al, 2007; Araki et al, 1985; Gaughan et al, 2004

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

Proper degree of wetting cattle
(Photo courtesy of Jeffrey Brose, DVM)

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

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

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

Chen (Van Os) et al, 2015, 2016; Tresoldi et al, 2018; Schütz et al, 2011

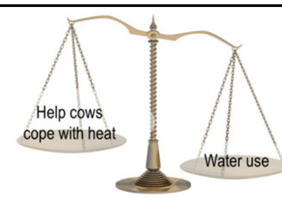
How often to soak at the feed bunk?

- 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

Chen (Van Os) et al, 2016; Tresoldi et al, 2018; Kendall et al, 2007; Araki et al, 1985

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

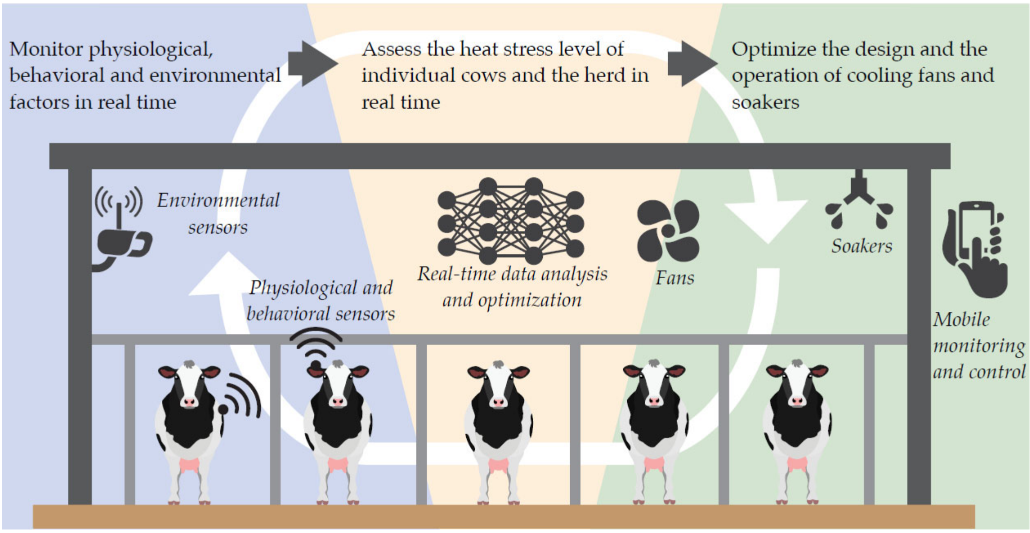
Chen (Van Os) et al, 2015, 2016a,b

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

Chen (Van Os) et al, 2015; Mitlöhner et al, 2001; Armstrong, 1994; Hahn, 1985; Flamenbaum, 1986

The future: Precision Livestock / biofeedback



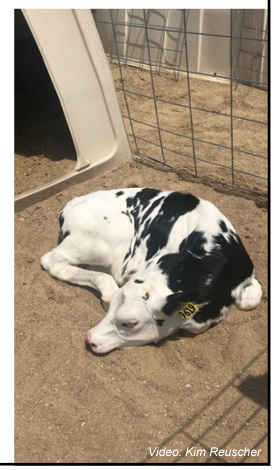
Kim, Choi, Van Os, Brounts (2021-2024 NSF-CPS/USDA grant); Chung, Li, Kim, Van Os, Brounts, Choi (2020)

Outline

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

Calves feel the heat too

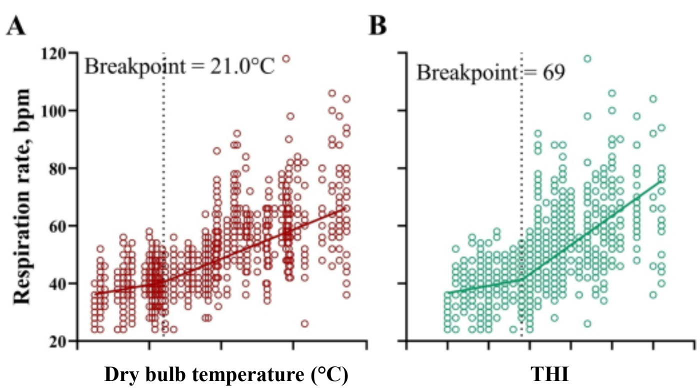
- Common misconception that heat stress is less of a concern for calves vs. adult, lactating cows
- But studies show that heat stress in calves →
  - ↓ starter intake
  - ↓ ADG
  - ↓ serum IgG
  - ↑ morbidity, mortality



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

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

Wisconsin calves in hutches



Average of 40 breaths/minute at the breakpoint

Dado-Senn et al. (2020); Dado-Senn, Laporta, Van Os, et al. (2023)

Heat abatement strategies for calves

	Reduce heat gain	Promote heat loss
Calf barn	Barn roof	Mechanical / active ventilation (forced air movement): fans, tubes
Outdoor hutches	Shade (cloth, trees) Hutch material	Natural / passive ventilation (air exchange): elevate hutches, add openings

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; Kovács et al., 2018; Manriquez et al., 2018; Reuscher et al., 2019; Montevecchio et al., 2022; Dado-Senn et al., 2020, 2022

Passive ventilation can mitigate the heat of 2 calves

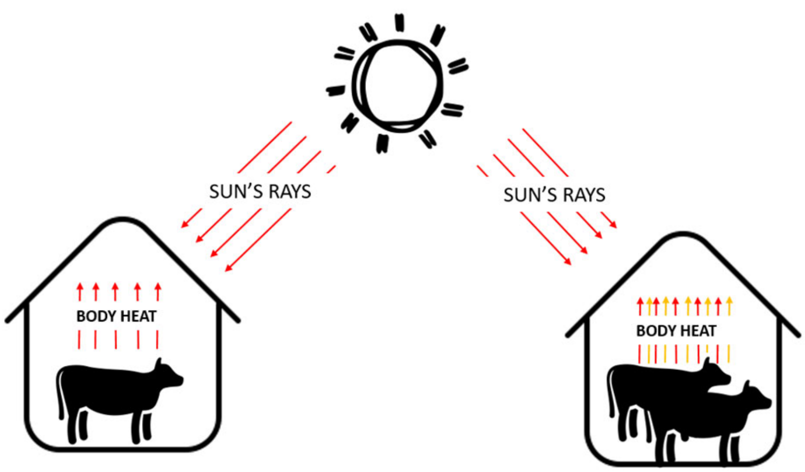
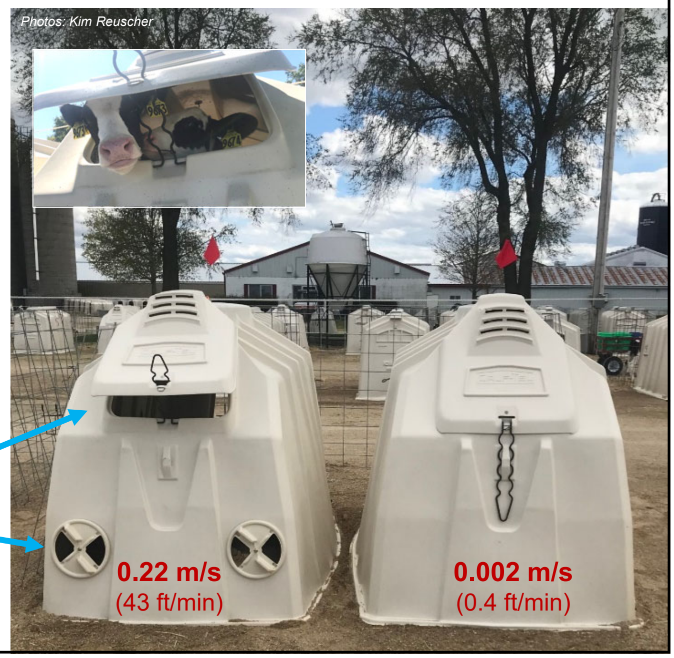


Diagram: Kim Reuscher



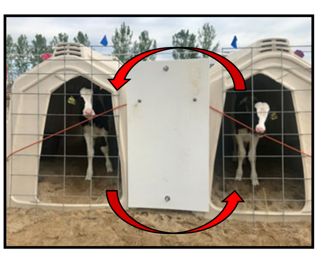
Additional passive ventilation

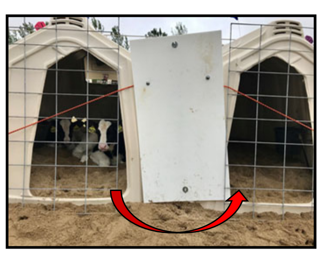
n = 25 pairs (50 calves)

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

	Pre-weaning						Weaning		Weaned
Week of life	1	2	3	4	5	6	7	8	9

Hutch restriction, use





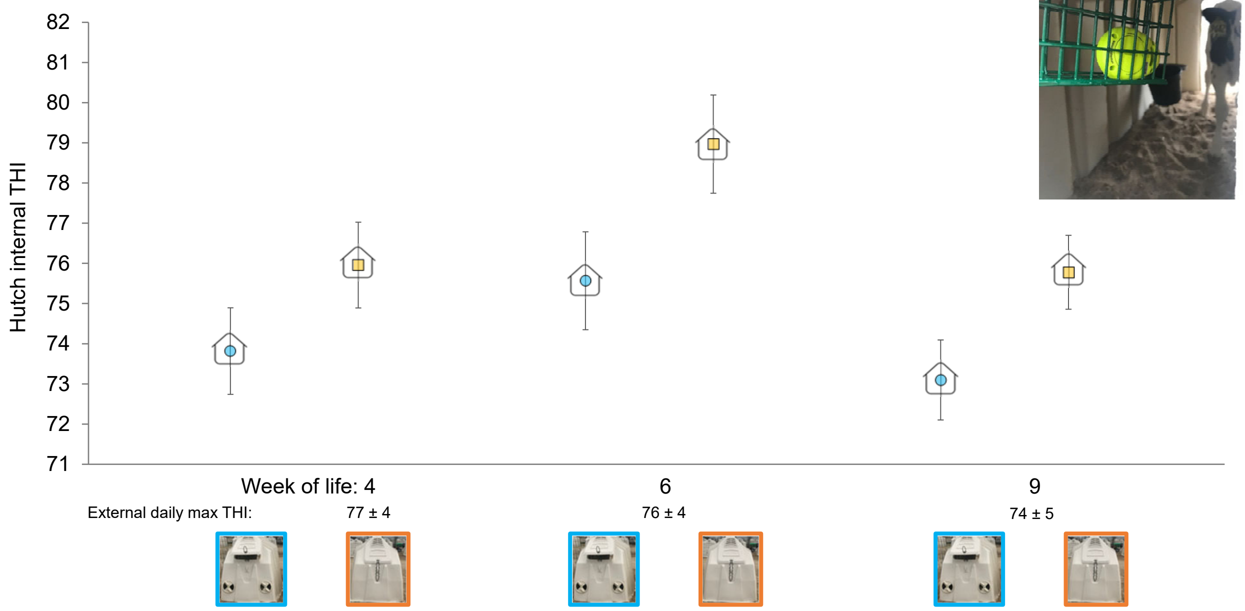
Every 15 minutes

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

Photos: Kim Reuscher

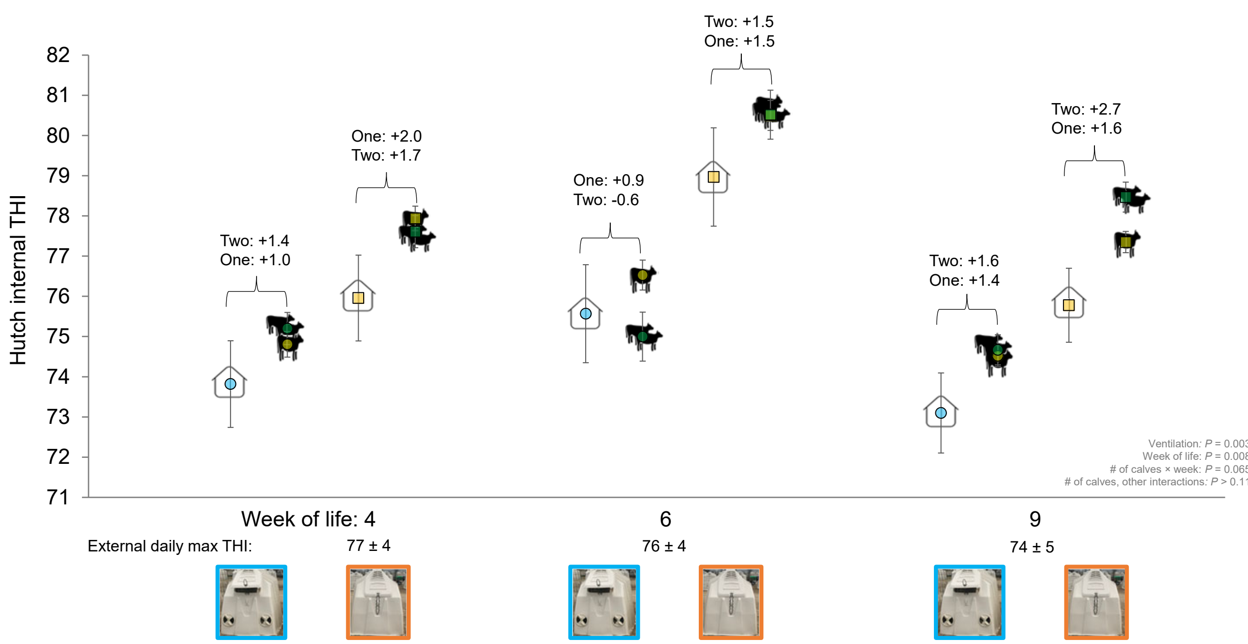
Reuscher, Van Os, et al. (2024; https://doi.org/10.3168/jds.2023-24006)

Passive ventilation → **cooler microclimate**



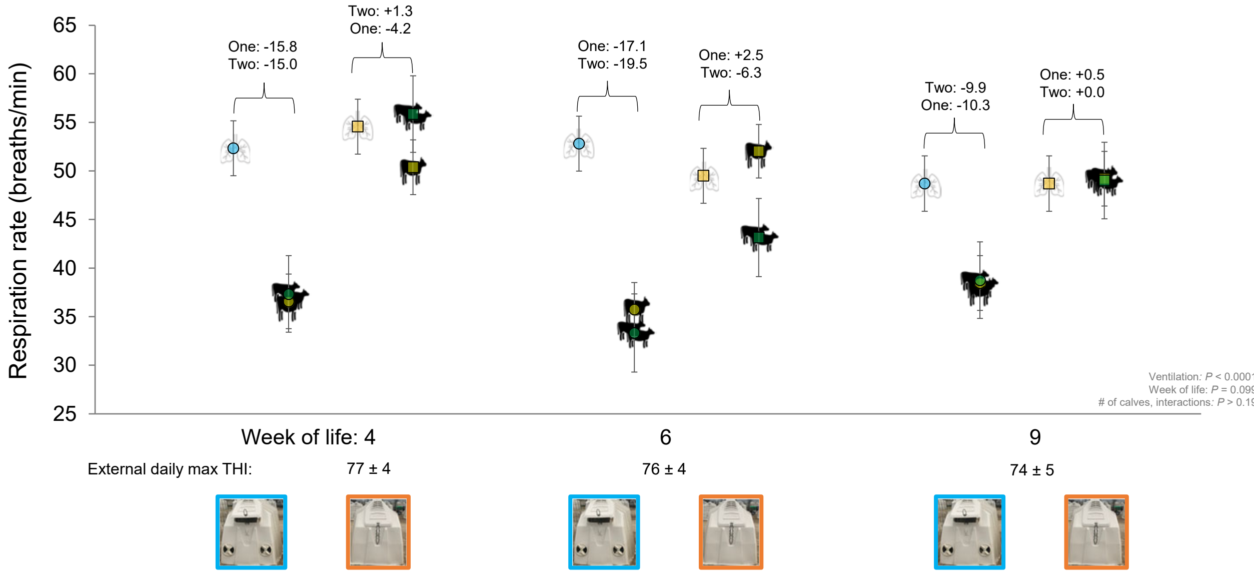
Reuscher, Van Os, et al. (2024; https://doi.org/10.3168/jds.2023-24006)

Passive ventilation → **cooler microclimate**, even with 2 calves inside

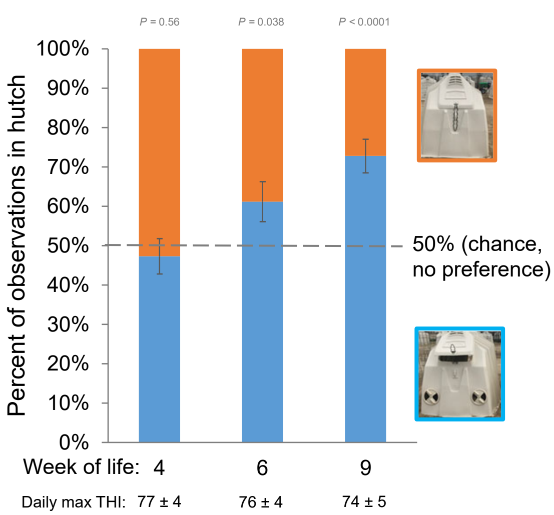


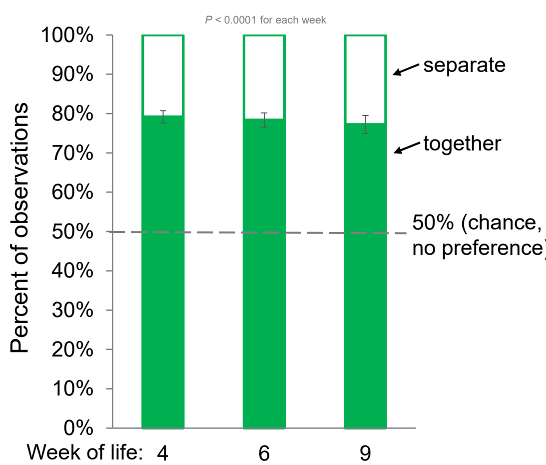
Reuscher, Van Os, et al. (2024; https://doi.org/10.3168/jds.2023-24006)

Passive ventilation ⇩⇩ **respiration rate**



- Calves **preferred ventilation** in wk 6 and 9 of life
- Pairs strongly **preferred to be together**





Same pattern overall and inside each hutch type

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

Conclusions:

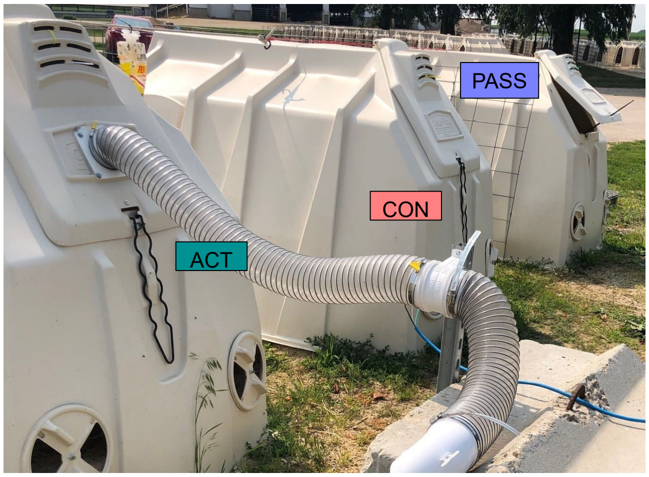
- Pair-housed calves prefer to be together
- Calves prefer hutch ventilation, which keeps them cooler

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

Innovative active ventilation outdoors

LAPORTA LABORATORY @UW-MADISON

Dado-Senn, Laporta, Van Os, et al. (2023; https://doi.org/10.3168/jdsc.2023-0390)



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

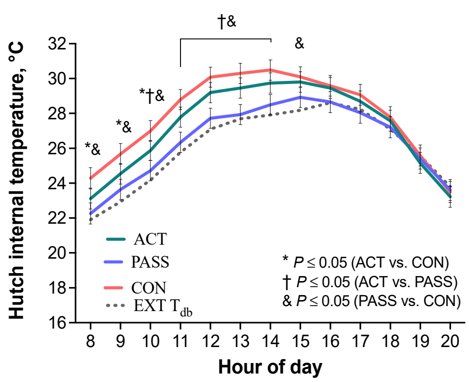
Active ventilation (ACT)
Solar-powered duct fan
Air speed = **1.74 m/s**

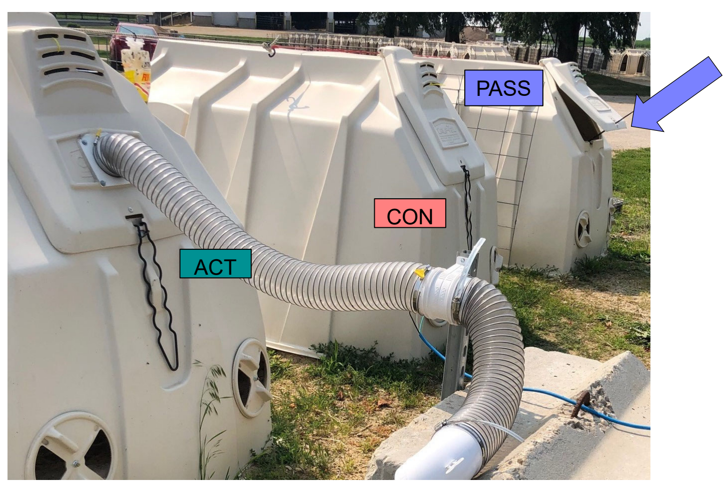
Target air speed ≥ 1.0 m/s at resting height
to promote mature cow thermoregulation

n = 12 calves (individually housed)
3 × 3 Latin square
4-d treatment + 3-d rest
starting at 22 ± 5 d of age

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)

Ventilation (esp. passive) → **cooler microclimate**

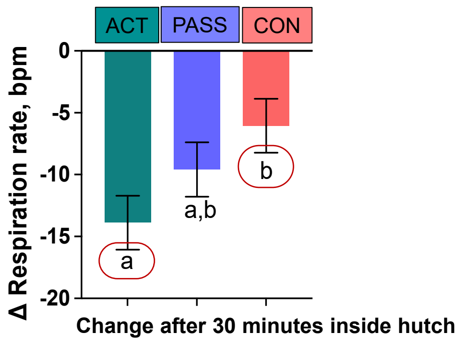




In passive ventilation treatment, open bedding door may have allowed warm air to escape better

Dado-Senn, Laporta, Van Os, et al. (2023; https://doi.org/10.3168/jdsc.2023-0390)

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

Dado-Senn, Laporta, Van Os, et al. (2023; https://doi.org/10.3168/jdsc.2023-0390)

Conclusions:

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

Dado-Senn, Laporta, Van Os, et al. (2023; https://doi.org/10.3168/jdsc.2023-0390); Larsen, Laporta, Van Os, et al. (2023 American Dairy Science Association)

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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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DAIRY INNOVATION HUB

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