Thermal amplitude effects on dairy calves

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The *zone of thermoneutrality* is the temperature range between which no additional energy is needed to maintain body temperature. We humans abridge that by wearing different clothing, using heating or air conditioning, or staying out of or in the sun. For young dairy calves, that *zone of thermal neutrality* ranges from 15 to 26º C (59 to 79º F) for calves less than 3 weeks of age while for calve past that age the lower critical temperature drops further to 5º C (41º F) according to the 2021 Dairy NASEM. However, this lower critical temperature is subject to several factors: hair coat thickness, matted hair coat, bedding insulation in housing, windiness, humidity, and starter fermentation. The latter is why older calves should have a lower critical temperature as the more and better the fermentation is, the more heat will be produced by that fermentation. Of course, during hot weather, that heat of rumen fermentation becomes a negative factor and causes calves, and cow too, to reduce it by eating less.

The range of temperature change can be another negative factor which has been found to be as, if not, more important than temperature itself (Kertz 2025, Roper et al., 2025). This Brazilian study (Gomes et al., 2026) was done to "evaluate the effects of daily thermal amplitude on physiological parameters, feed intake, ruminal fermentation, apparent nutrient digestibility, health status, and performance of Holstein dairy calves until 28 days of age under controlled climatic conditions, as well as to evaluate residual effects up to 90 days of age."

There were "34 Holstein calves, 13 males and 21 females, all born in a compost barn equipped with a wind tunnel. Calves were enrolled from January to early July 2022 (primarily summer), totaling 6 months for the complete cohort. Only calves from multiparous healthy cows housed in this compost barn during the dry period were included. During the birth period, the average environmental conditions were 23.1°C ± 2.67°C, 80.3% ± 4.13% relative humidity (RH), and a wind speed of 1.3 m/s, resulting in a temperature-humidity index (THI) of 69.7 ± 3.63….

- Colostrum was administered via esophageal tube in 2 stages: the first within 2 hours after birth, providing 10% of the calf's BW standardized to 25% Brix, and the second 6 to 8 hours later, providing an additional 5% of the BW at the same Brix level.
- The calves were randomly assigned into 1 of 2 treatments: (1) control (CON; 6 males and 11 females), maintained at a constant THI of 66 (22°C and 65% RH) for 24 hours; and (2) thermal amplitude (TA; 7 males and 10 females), exposed daily to THI of 66 (22°C and 65% RH) from 0330 to 0630 hours; THI of 84 (32°C and 65% RH) from 0630 to 1530 hours; THI of 66 (22°C and 65% RH) from 1530 to 1830 hours, and THI of 54 (14°C and 65% RH) from 1830 to 0330 hours.
- The trial was conducted from January to October 2022 (primarily summer and winter). Calves entered the climate chamber on the day of birth and remained there until 28 days

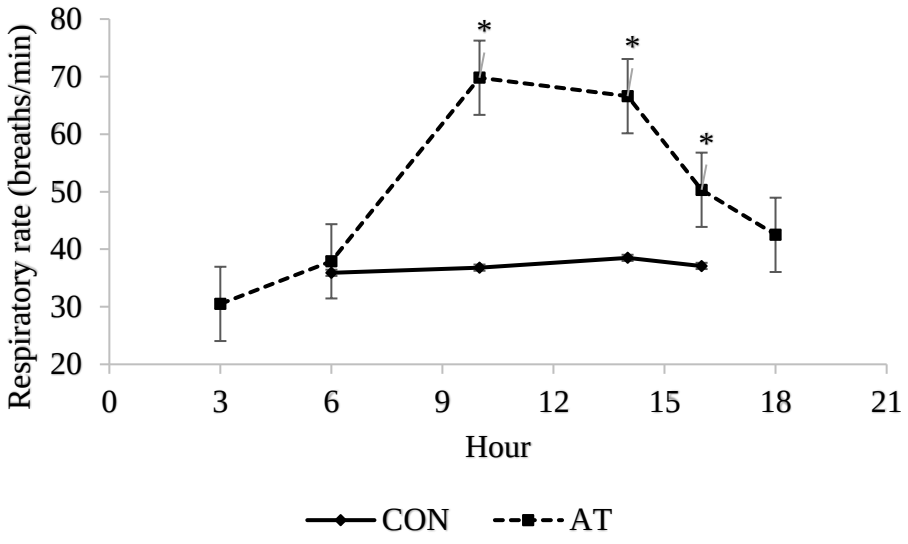
of age (weeks 1–4, exposure period [EP]). Because calvings were distributed across time, it took approximately 1 month to complete enrollment for each chamber group.

- The chamber accommodated up to 9 calves at a time, so calves from each treatment were housed sequentially, with treatment periods alternating throughout the study to minimize temporal bias.
- After completing the EP, calves from both treatments were moved to the same barn for the postexposure period (PEP; 29–90 days of age [weeks 5–13]). This resulted in a staggered but overlapping design: Not all calves were in the chamber or barn simultaneously, but there was a substantial overlap period in the barn when calves from both treatments were co-housed under identical conditions….
- Inside the climate chamber, calves were housed in individual pens (1.78 × 1.14 m) with floors covered by rubber mats and wood shavings as bedding….Maximum, minimum, and average temperatures, as well as RH, were recorded at 0300, 0600, 1000, 1400, 1600, and 1800 hours."
- "During the first 3 days of life, calves received 6 L/day of transition milk from their dams, provided in bottles. From the fourth day onward, they were fed 6 L/day of whole milk, offered in nipple buckets at 0800 and 1430 hours... Weaning was conducted gradually between days 61 and 67 (week 9), with 3 L/day of whole milk offered once daily at 0800 hours. Complete weaning occurred at 67 days of age.
- Water and starter (20% CP; composed of 32.4% soybean meal, 61.6% cornmeal, and 6% mineral premix) were provided ad libitum until day 28 (**Table 1**). From day 28 onward, calves received a TMR consisting of 95% of the same starter used during the EP, and 5% corn silage (DM basis), offered at a maximum of 2.6 kg/day. After weaning, on d 68, corn silage was also offered ad libitum in addition to the TMR.
- Fecal scoring was done daily; blood sampling was done biweekly; rumen sampled via esophageal tube at weeks 2, 4, 8, and 12; and digestibility determined via total collection with 10 calves per treatment for 3 consecutive days from 9 to 12 days and from 23 to 26 days.

Table 1. Nutrient composition on a dry matter (DM) basis fed to calves.

Nutrient	Whole milk	Starter	Corn silage
DM, %	12.7	86.0	30.7
Crude protein, %	22.2	19.2	5.9
Ether extract, %	28.1	2.5	2.8
NDF, %	---	9.2	4.8
Ash, %	5.6	8.3	4.8
Lactose, %	44.1	---	---
Gross energy, Mcal/kg	5.8	4.0	4.2

Figure 1 (Both figures kindly provided by Dr Mariana Magalhaes Campos**).** Measurements) by treatment during the day by hours during THI (temperature heat index) transition.


Respiratory rate (breaths/min)
80
70
60
50
40
30
20
0
3
6
9
12
15
18
21
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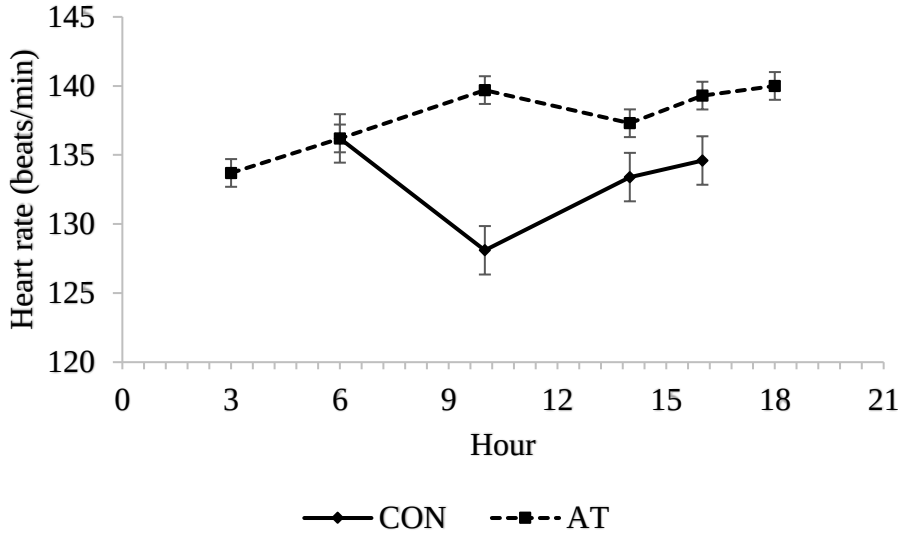
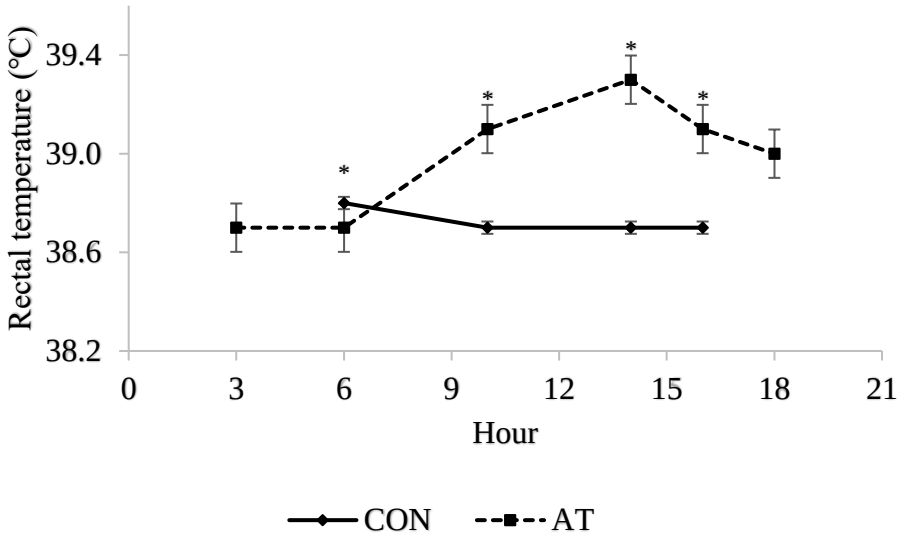
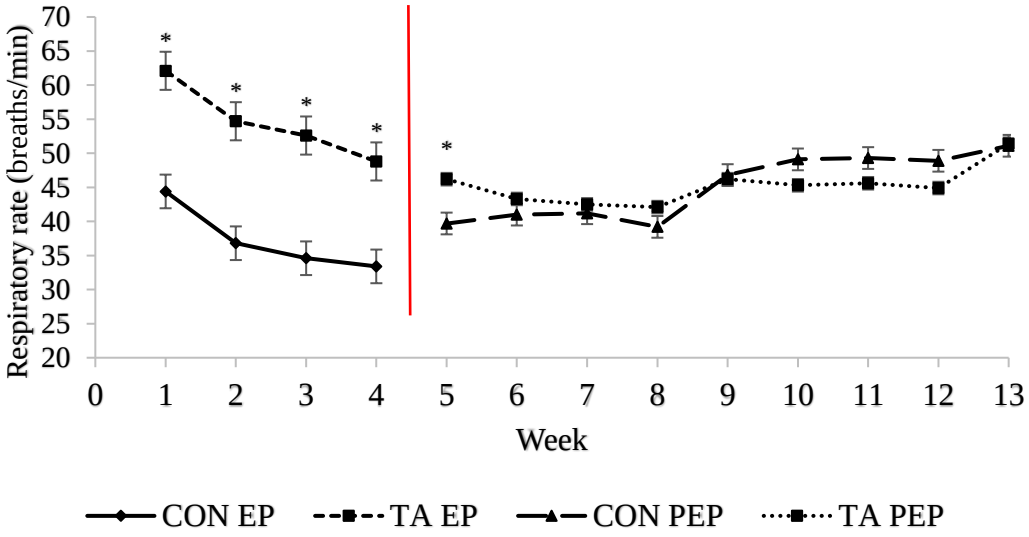
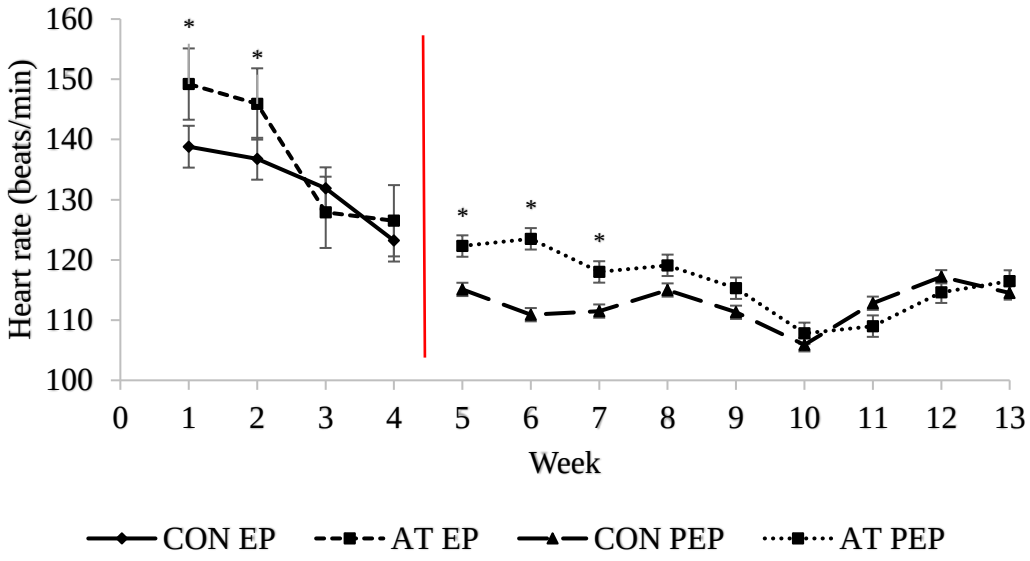

Heart rate (beats/min)
145
140
135
130
125
120
0
3
6
9
12
15
18
21
Hour
CON
AT

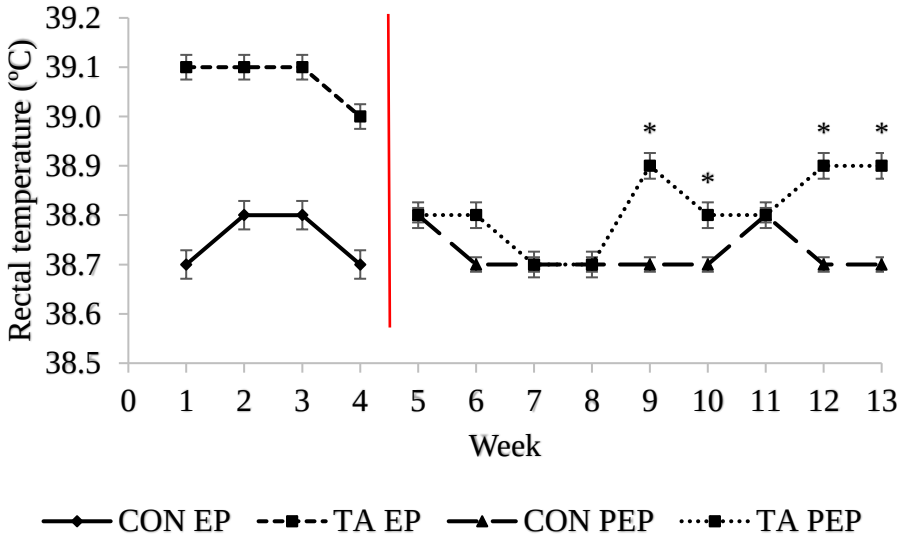


- During the ramp up of temperature during the day, respiration rate greatly increased, as did rectal temperatures while heart rate decreased.
- These hourly measurements show the high degree of heat stress which otherwise may not be evident.

Figure 2. Physiological parameters measured for control (CON) and thermal amplitude (TA) during the exposure period (EP) and post exposure period treatments.







- Respiration rate and rectal temperature increased the most during the EP but mostly subsided during the PEP.
- Heart rate increased for temperature amplified (TA) calves initially, but then subsided the first 2 weeks.

Table 2. Intakes for calves on Control (Con) and temperature amplified (TA) treatments during exposure period (EP) and post exposure period (PEP).

Item	Control	Temperature amplified
EP, lb/day		
Milk	1.60	1.64
Starter	0.08	0.08
Total DM	1.72	1.64
Water	1.64	2.86

PEP, lb/day		
Milk	1.47	1.48
Starter	2.17	2.29
Corn silage	1.19	1.06
Total DM	2.18	2.36
Water	11.23	13.87

- Milk intake was around the 1.5-1.75 lb per day threshold where above it, it negatively impacts starter intake.
- Given, calves were less than 28 days on treatments, fed a meal starter, and with the higher milk feeding rate, starter intake was quite low.
- Water intake was greater during the EP time most likely due to the temperature fluctuation. The difference was not as great during the PEP time, but still was significantly different. In both EP and PEP times, water intake exceeded the typical 4:1 ratio of water to DM intake (Kertz 2019).

Other measurements:

- No treatment differences on blood components except for greater creatinine and cholesterol during the PEP time.
- Three treatment differences in the 9 blood cytokines measured.
- No treatment differences in rumen pH and VFAs during both EP and PEP times.
- No treatment differences in digestibilities during both EP and PEP times.
- No treatment differences in fecal scores, days with diarrhea, and days with severe diarrhea for either EP or PEP times.
- No treatment differences in birth, 28-day, and 90-day body weights.

This was an incredibly detailed and intense study to do. And post weaning measurements were done out to 90 days of age. Sure, it would have been better to have more calves per treatment, but the intensity of measurements and use of a climate-controlled chamber limited the number of calves which could be accommodated.

The Bottom Line

Creating an upswing in temperature and humidity during the day accentuated increased respiration rate and rectal temperatures. This indicates that it is not only the temperature and humidity at one time point which impacts calves ,but the range experienced during a 24-hour day.

References

Gomes, M. B., S. G. Coelho, L. F. M. Neves, E. M. B. Souza, J. P. Campolina, J. Diavão, A. S. Silva, T. R. Tomich, W. A. Carvalho, and M. M. Campos. 2026. Effect of thermal amplitude on physiological parameters, ruminal fermentation, digestibility, health, and performance of Holstein dairy calves, J. Dairy Sci. 109:3063-3074.

Kertz, Alois F. *Dairy Calf and Heifer Feeding and Management—Some Key Concepts*

*and Practices***.** Outskirts Press, July 31, 2019, 166 pages. **https://outskirtspress.com/dairycalfandheiferfeedingandmanagement**

Kertz, A.F. 2025. Seasonal effects on preweaned calves in the Southeastern United States. *Feedstuffs*, June 10.

NASEM (National Academies of Sciences, Engineering, and Medicine). 2021. Nutrient Requirements of Dairy Cattle. 8th rev. ed. National Academies Press, Washington, DC.

National Animal Health Monitoring System (NAHMS). Daudiy 2014. Dairy Cattle Management Practices in the United Sates. United States Dept. of Agric., Animal Plant and Health Inspection Service, Veterinary Services, February 2016, Fort Collins, CO.

Roper, Ansley M., Ruth M. Orellana Rivas, Jing Gao, Thiago N. Marins, C. G. Savegnago, Thalyane Rodrigues, Victor H. L. R. Melo, Diego Ferreira de Araújo, Juliana Goncalves de Souza, Pedro Melendez, * John K. Bernard, and Sha Tao. 2025. Seasonal effects on growth, digestibility, and metabolism of preweaning dairy calves in the southeastern United States, J. Dairy Sci. 108:4318–4331.