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Evaluation of Temperature-Humidity Index (THI) thresholds on behavioural responses of heifers under controlled climate condition

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Abstract
The production, reproduction and well-being of livestock are all hampered by heat stress (HS). In tropical humid regions like Kerala, where high temperatures and humidity lead to decreased productivity, the goal of this observational study is to identify the temperature humidity index (THI) threshold on heifer behaviour, which is directly influenced by heat stress and affects the animal welfare. Study conducted in a controlled climate setting with varying temperature and humidity combinations, which examined under THI ranges from 73.14 to 93.88. Results showed a significant difference in the duration of lying and standing postures between the control group (T_1) and all other treatments. Specifically, heifers spent more time standing (188.9 ± 0.20 and 197.3 ± 0.29 minutes) under extreme heat stress conditions, with reduced rumination time (17.65 ± 0.16 minutes). Additionally, increased salivation (18.20 ± 0.13) and higher water consumption were observed under HS conditions. Based on findings of behaviour the threshold level of THI was found to be around 82.92. These findings indicate that behavioural responses are closely linked to HS, providing valuable insights into the responses of heifers in controlled climate environments.

Keywords: Heifers, temperature humidity index, controlled climate, heat stress

1. Introduction
Climate change poses significant challenges for livestock, particularly under heat stress conditions. Among various physiological and blood parameters, behavioral responses have a pronounced impact on animal well-being. In a hot and humid tropical climate like Kerala's, high temperatures and humidity levels can intensify heat stress, leading to substantial behavioral changes. Persistent high humidity limits the effectiveness of sweating and panting, which are the primary cooling mechanisms for cattle, making them more vulnerable to heat-related illnesses. Behavior is the earliest indicator of animal welfare, reflecting an individual's adaptations to environmental conditions and effectively demonstrating the response to interactions between the animal and its surroundings (Etim *et al*., 2013) [5]. One notable behavioral adaptation to heat load is an increase in standing. (Allen *et al*., 2015) [1]. The Temperature Humidity Index (THI) serves as a crucial indicator of heat stress. Consequently, animals adopt various physiological, morphological, and behavioral adaptations to cope with such stress. This study aims to identify the behavioral responses of heifers in controlled environments with different combinations of temperature and relative humidity, calculating THI (LPHSI, 1990) [9]. Using these indices, the study determines the THI threshold for thermal stress specific to Kerala.

2. Materials and Methods
The study was conducted at the Climate Controlled Research Complex, College of Veterinary and Animal Sciences, Mannuthy, Thrissur, Kerala. Eight different combinations of temperature (T) and relative humidity (RH) were used during the experimental period. Six crossbred dairy heifers, all between twelve and eighteen months old, were selected for the study.

The heifers were subjected to a thermoneutral zone (TNZ) with a temperature of 27 °C (T_1) for one week prior to the experiment, for four hours daily (10:00 AM to 2:00 PM). (Yadav *et al*., 2016) [12]. Following this, different combinations of temperature and relative humidity were applied to animals for seven days each, (Hou *et al*., 2021) [7] for four hours daily (10:00 AM to 2:00 PM). The specific combinations with calculated THI were T 30 °C; RH 40% (T_2-76.76), 68 T 30 °C; RH 60% (T_3-79.84), T 30 °C; RH 80% (T_4-82.92), T 35 °C; RH 40% (T_5-82.79), T 69 35 °C; RH 60% (T_6-86.86), T 35 °C; RH 80% (T_7-90.93), T 40 °C; RH 40% (T_8-88.82), and T 70 40 °C; RH 60% (T_9-93.88). Behavioral patterns such as the duration of lying down (minutes), duration of standing (minutes), duration of rumination (minutes), panting (breaths per minute), salivation (minutes), frequency of drinking (nos), volume of water consumed (liters), and frequency of urination (nos) were monitored using continuous surveillance camera recordings (CCTV) during both the experimental period and the TNZ period for four hours per day, when animals are inside the chamber. Additionally, panting scores were calculated according to the procedure described by Gaughan et al. (2008) [6] and are presented in Table 1.

Table. 1: Calculation of panting score

Panting score	Breath characteristics and respiratory rate (RR)
0	No panting, RR <40
1	Slight panting, RR 41-70
2	Fast panting, RR 71-120
3	Open mouth, drooling, RR 121-160
3.5	As for 3 but tongue out slightly
4	As for 3.5 but tongue fully extended, RR>160
4.5	As for 4 but head held down, cattle "breath" from flank

3. Results

Table. 2 presented the behavioral responses across various treatment combinations.There was a significant difference in the duration of lying down and standing between the control group and all treatment groups, with no significant difference observed between T_4 and T_6. Significantly more time was spent on lying posture during T_1, T_2, and T_5, with the least time during T_7, T_8, and T_9. There was more time spent for standing during T_7, T_8 and T_9 compared to other treatments. A significant increase in standing duration started at THI of 76.6 and significant decrease in rumination from THI range of 79.84. Fig. 1 presented the graphical representation on duration of standing, lying down and rumination behaviour between the treatments with THI. For rumination, there was no significant difference between the control (T_1) and treatments T_2, T_6, and T_9, but a significant difference was noted between the control and all other treatments. Comparatively more duration spent for rumination was noted on control and T_2, with least time for rumination on T_9.

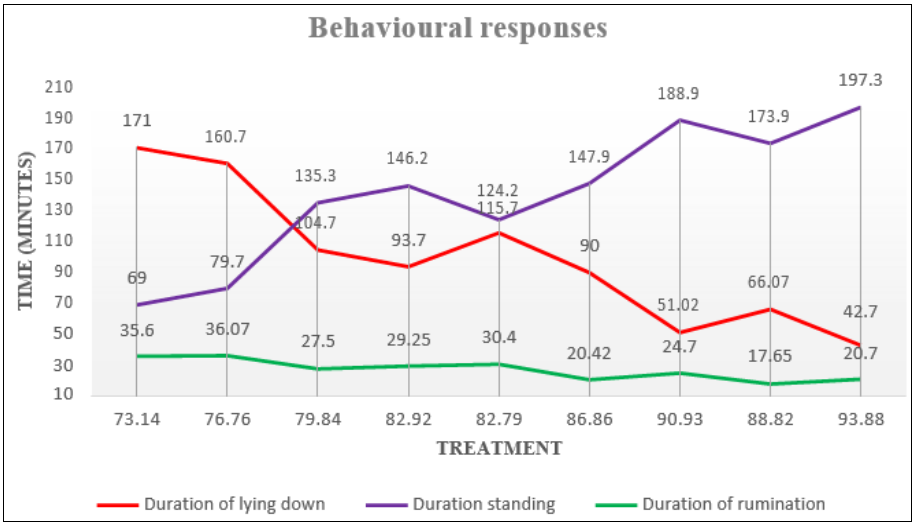

Fig 1: Duration of lying down, standing and rumination among different treatments

For panting, there was no significant difference between the control (T_1) and treatment T_2 and significant difference was noticed on all other treatments. From T_6, significantly higher incidence of panting was observed with least panting on control and T_2, compared to other treatments. Panting in crossbred heifers was found to be score two (Fast panting) (Gaughan *et al*., 2008) [6], when THI exceeded 82.92 (T_4). Based on standing, lying, panting and rumination duration, there was significant changes at THI of 76.76, but a higher range of increased standing and panting started at THI of 82.92, whereas rumination and lying duration decreased at the same level of treatment combination. Salivation differed significantly between the control and all treatments, with T_9 showing the highest levels of salivation. No salivation was observed in the control group, and T_2 had the lowest salivation compared to all other treatments. Present study found that salivation increasing with rising THI. Drinking frequency was higher in T_7 and T_9 compared to other treatments, with the volume of water consumed being the highest at T_7 and T_9, recorded at 22.07 L and 27.67 L, respectively. The frequency of urination was relatively similar across all treatments. On statistical analysis, results indicate strong correlations between THI and behavioural responses. Higher THI was strongly associated with increased standing

duration (r = 0.97), panting (r = 0.95), salivation (r = 0.87), frequency of drinking (r = 0.98), frequency of urination (r = 0.94) and volume of water intake (r = 0.96) and conversely higher THI correlated negatively with duration of lying (r = - 0.97) and rumination (r = - 0.87).

Table 2: Behavioural responses of different treatment combinations

Behavioural response	Treatments with THI								
	T_1 (TNZ) (73.14)	T_2 (76.76)	T_3 (79.84)	T_4 (82.92)	T_5 (82.79)	T_6 (86.86)	T_7 (90.93)	T_8 (88.82)	T_9 (93.88)
Duration of lying down (min)	171.0±2.6a	160.7±0.8b	104.7±0.66c	93.7±0.68d	115.7±0.39e	90.0±0.42d	51.02±0.20f	66.07±0.38g	42.7±0.29h
Duration of standing (min)	69.00±2.6a	79.70±0.8b	135.3±0.66c	146.2±0.68d	124.2±0.39e	147.9±0.42d	188.9±0.20f	173.9±0.38g	197.3±0.29h
Duration of rumination (min)	35.6±0.5a	36.07±0.6a	27.5±0.25b	29.25±0.34c	30.4±0.36d	20.42±0.25e	24.7±0.15f	17.65±0.16g	20.7±0.10e
Panting (breaths/min)	31.55±0.6a	31.5±0.4a	44.01±0.24b	53.12±0.72c	46.5±0.60d	58.47±0.54e	89.49±0.48f	78.66±0.58g	106.9±1.30h
Salivation (min)	0.0a	0.5±0.2ab	1.25±0.25c	1.50±0.28ce	1.00±0.0bce	2.50±0.28f	15.62±0.14g	11.6±0.24h	18.2±0.13i
Frequency of drinking (nos)	2.50 ± 0.2^{a}	3.25 ± 0.47^{ab}	4.25 ± 0.47^{b}	6.75 ± 0.47^{c}	5.50 ± 0.64^{d}	6.75 ± 0.47^{ce}	8.25 ± 0.25^{f}	7.50 ± 0.28^{ef}	8.75 ± 0.25^{f}
Volume of water consumed (L/4hrs)	6.35 ± 0.19^{a}	8.35 ± 0.30^{b}	13.22 ± 0.27^{c}	14.22 ± 0.16^{d}	11.80 ± 0.10^{e}	16.20 ± 0.14^{f}	22.07 ± 0.25^{g}	17.32 ± 0.25^{h}	27.67 ± 0.25^{i}
Frequency of urination (nos)	3.25 ± 0.47^{a}	2.75 ± 0.47^{a}	4.25 ± 0.25^{ac}	4.50 ± 0.28^{cd}	4.75 ± 0.47^{cd} e	5.25 ± 0.25^{cd} ef	5.50 ± 0.50^{def}	5.25 ± 0.47^{cd} ef	5.75 ± 0.47^{ef}

Means with different superscripts (a-i) in row differ significantly ($p<0.05$)

4. Discussion

Standing and lying down are crucial behavioral indicators that change during heat stress. The duration of lying down significantly differed between the control group (T_1) and all other treatments. Animals in T_1 (TNZ) and T_2 spent more time lying down compared to other treatment combinations, indicating reduced thermal stress in these specific treatments. Conversely, animals spent more time standing under heat stress conditions, particularly in treatments T_4, T_6, T_7, T_8, and T_9. However, during T_5, where humidity was the lowest, there was slightly less time spent standing compared to other heat-stressed conditions. Cows that were under heat stress tended to stand for longer periods of time, which improves heat loss and maintains thermal balance (Nordlund *et al*., 2019) [10]. More standing time was explained as having the potential to increase respiration efficiency, or maximize effective surface area for sensible and insensible heat dissipation from body surfaces (Anderson *et al*., 2013) [2]. Kim *et al*., 2019 [8] observed that while ruminating time reduced at higher THI, there was a drop in the amount of time spent lying down when the THI ranged from 74.22 to 87.72, as compared with 70.01. In this study, it was noted that the decreased lying time when the THI ranged from 79.84 to 93.88 and for rumination, there was similar findings of decrease was found in THI 79.84. Bar *et al*., 2019 [4] stated that increased activity, whether it be in the body's core or its periphery, was essentially provoked the panting. This implied that when it was hot outside, cattle start to pant before their body temperature increased. Whereas, Gaughan *et al*. (2008) [6] found that animals exposed to high air temperatures in controlled environment showed a delay in panting. In the present study, panting was higher with panting score 2, where the THI exceeded from 82.92 and this study evident that panting was observed, before the core body r60 per cent with THI of 86.86) and T_9 (40oC; RH 60 per cent with THI 93.88), salivation beganises. In T_6 (35oC; RH 60 per cent with THI of 86.86) and T_9 (40oC; RH 60 per cent with THI 93.88), salivation began to increase and peaked. This results was supported by (Prasad, 2014) [11], who reported that higher salivation response indicated higher stress level experienced by cattle in high stress zones in Kerala. According to (Yadav *et al*., 2019) [13], that there was a notable increase in water consumed among crossbred cattle exposed to heat stress condition, with an average of approximately 24 L/day. In the present study, it was noted that the water intake was increased during heat stressed conditions at T_6, T_7, T_8 and T_9, where the mean volume of water consumed was approximately 16.2 L, 22 L, 17.3 L and 27.6 L respectively. Tharparkar and Karan fries (KF) heifers that were stressed by heat showed higher water consumption, according to Banerjee and Ashutosh (2011) [3]. In particular, the water capacity of the KF heifers was around 29 L, whereas the Tharparkar heifers had about 31 L approximately.

5. Conclusion

This study evaluated the THI threshold on behavioural responses of heifers in Kerala. The study concluded that, there was a more standing time observed which associated with heat stressed conditions and vice versa of more lying posture during thermoneutral zone and other treatment combinations were humidity was least. Rumination was less when exposed to heat stressed environment. Under the controlled chamber, om findings of behaviour the threshold level of THI was found to be around 82.92 and the study helps to assess the THI threshold for behavioural responses, which directly showed that even when animals experiencing high air temperature, humidity plays a major role, and further appropriately improves the understanding of the responses of heifers in hot and humid tropical region like Kerala.

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7. Conflict of Interest

Not available

8. Financial Support
Not available

9. References

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