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# Comparison of Behavioural Response of Crossbred Dairy Cows in Distinct Type Barns Across Four Different Seasons in the Tropical Humid Climate of Kerala

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## ABSTRACT

The study was conducted across four different seasons during March, 2023 to February, 2024 at Cattle Farm, University Livestock Farm and Fodder Research and Development Scheme, Mannuthy, Kerala, India to analyse the effect of housing modification on thermal stress response in crossbred dairy cows based on the behavioural changes in tropical humid climate of Kerala. Treatments included $T_1$ (North-south oriented barn), $T_2$ (East-west oriented barn) and $T_3$ (East-west oriented barn with roof modification). Eighteen crossbred dairy cows were allotted randomly into three treatments with six animals each. The results highlighted significantly higher Equivalent Temperature Index in $T_1$ and $T_2$ compared to $T_3$ barn at the different diurnal time points across all seasons. Standing time was significantly higher in $T_1$ animals (893.00±10.65, 742.00±1.53 and 826.50±1.29 min day$^{-1}$) compared to $T_2$ (861.33±2.26, 690.67±1.69 and 630.17±0.65 min day$^{-1}$) and $T_3$ (782.67±2.22, 732.5±1.34 and 725.50±1.38 min day$^{-1}$) in pre-monsoon, south-west monsoon and post monsoon season respectively. Significantly higher feeding bouts were observed in $T_1$ animals compared to $T_2$ and $T_3$ in all seasons, whereas seasonal comparison showed higher feeding bouts during southwest monsoon (51.50±3.31, 46.00±1.37 and 47.67±2.97 bouts day$^{-1}$ in $T_1$, $T_2$ and $T_3$ respectively) and post monsoon (56.00±1.46, 52.33±2.26 and 44.17±2.24 bouts day$^{-1}$ in $T_1$, $T_2$ and $T_3$ respectively) and lowest in pre-monsoon season. Drinking bouts were significantly higher in $T_1$ animals compared to $T_2$ and $T_3$. Climatic stress was observed inside all three treatments barns throughout study period, but $T_3$ barn performed comparatively better in reducing heat load due to roof modification employed.

**KEYWORDS:** Behavioural response, climatic stress, housing system, roof modification

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***Data Availability Statement:*** Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

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## 1. INTRODUCTION

Housing comfort plays a crucial role in determining the overall well-being, health, and productivity of dairy cows, particularly under intensive management systems. Providing a well-designed and comfortable housing environment ensures that cows experience optimal resting conditions, reduces physical stress, and promotes better welfare (Vanlaer et al., 2014; Verma et al., 2016). In contrast, inadequate housing conditions, such as exposure to excessive heat or uncomfortable resting surfaces, can contribute to a range of health issues for the animals. Among the various stressors affecting dairy cows, heat stress is particularly significant in tropical humid regions such as Kerala, where high ambient temperatures and humidity levels pose a considerable challenge to animal health and productivity (Kumari and Pampana, 2015 and Ibraheem Kutty et al., 2021). Heat stress can lead to profound physiological (Kumar et al., 2017) and behavioral changes (Sinha et al., 2017; Harikumar et al., 2018 and Sahu et al., 2018) in dairy cattle, impacting their growth, immune function, and milk production (Khode et al., 2017; Corazzin et al., 2020 and Herbut et al., 2021). To cope with the heat stress, cows exhibit a range of behavioral adaptations, including a decrease in feed intake, increased water consumption, more frequent defecation and urination, prolonged standing, and active shade-seeking behavior (Dikmen, 2013; Soriani et al., 2013 and Kamal, 2013). These responses are aimed at regulating body temperature and minimizing discomfort but can also contribute to further stress and reduced productivity. Given the substantial impact of heat stress on dairy cows in tropical climates, effective shelter management (Chaudhary et al., 2018) is essential to mitigating thermal stress and enhancing the animal welfare. One of the most critical aspects of shelter management is the orientation of cattle barns, as it directly influences the micro-climatic conditions within the housing system (Das et al., 2015; Angrecka et al., 2017; Jones et al., 2015 and Divya et al., 2021). Factors such as airflow, solar radiation exposure, and heat dissipation are significantly affected by barn orientation, which, in turn, determines the extent to which cows experience thermal comfort (Mishra et al., 2015: Das et al., 2016 and Amit et al., 2021). In tropical environments, optimizing barn design, particularly in terms of orientation and roof modifications (Patil et al., 2014; Kamal et al., 2014; Narwaria et al., 2017; Syed et al., 2024) can greatly reduce heat stress and contribute to improved welfare and productivity of dairy cows. Understanding the behavioral responses of crossbred dairy cows under tie-stall systems is crucial for developing effective housing strategies. By analyzing these behavioral patterns based on climatic variables such ambient temperature, relative and wind velocity, researchers can gain valuable insights into how environmental modifications can enhance comfort and welfare. In that consideration, the present study aims to assess the bio-climatic index i.e Equivalent Temperature Index of barns and different behavioral responses such as, standing and lying down time, feeding and drinking bouts of crossbred dairy cows housed in conventional tie barns with different orientations and one of the east-west oriented barn with roof modification in the tropical humid climate of Kerala under four different seasons. The findings from this study aimed to contribute to the optimization of dairy housing strategies based on spatial orientation and region specific amelioration strategies based on climatic conditions, which in turn ensuring better living conditions for cows while promoting sustainable and efficient dairy farming practices.

## 2. MATERIALS AND METHODS

### 2.1. *Period of study*

The period of study was from March 2023 to February 2024, which covered four different seasons namely Pre-monsoon (March-May), Southwest monsoon (June-September), Post-monsoon (October-November) and Winter (December-February), and this seasonal classification was followed as per Krishnakumar et al. (2009). The study was carried out for a duration of 30 days in each season.

### 2.2. *Location of the study*

The research work was conducted at Cattle Farm, University Livestock Farm and Fodder Research and Development Scheme, Mannuthy under Kerala Veterinary and Animal Sciences University. The farm was located at 10° 31' 50.16" N latitude and 76° 15' 32.04" E longitude, at an altitude of 22.25 m above the mean sea level.

### 2.3. *Selection of experimental animals and treatments*

Eighteen crossbred dairy cows were selected for the study which were in early lactation period during the start of the study. All animals were clinically healthy and free from ailments. Selected experimental animals were allotted randomly into three treatment groups with six animals each in a group. The difference between the treatments were based on the orientation of the long axis of the barns, and modification of the roof, and the details regarding each barn is as follows.

#### 2.3.1. *Treatment 1*

A conventional tie barn with its long axis aligned in north-south orientation. The roof was gable type made up of asbestos sheets and fitted with four wind driven roof ventilators. The floor was that of concrete with a total floor area of 271 sq.m.

*2.3.2. Treatment 2*

A conventional tie barn with its long axis aligned in east-west orientation. The roof was gable type made up of asbestos sheets and fitted with four wind driven roof ventilators. The floor was that of concrete with a total floor area of 243 sq.m.

*2.3.3. Treatment 3*

A conventional tie barn with its long axis aligned in east-west orientation. The roof was gable type made up of asbestos sheets and fitted with four wind driven roof ventilators. The floor was that of concrete with a total floor area of 211 sq.m. Here the upper roof surface was painted with solar reflective white paint (Roofseal Topcoat) and under surface of the roof was painted black (Indigo Magic Black).

*2.4. Recording of micro-climatic data*

Micro-climatic variables related to each barn was collected inside the respective barn. In the interior of each barn ambient temperature (°C) and relative humidity (%) was measured using electronic digital temperature-humidity data logger (testo 174 h) every hour throughout the day during the study. A total of three loggers were used out and installed inside each of the treatment barn at a height of around 2 m from the floor of the respective barn. Inside the barns, wind velocity was measured in the animal standing area of each barn at a height of about 1.5 m from the floor. The climatic variables were recorded at 8.00 AM, 12.00 NOON, 4.00 PM and 8.00 PM in a day during study period.

The Equivalent temperature Index inside each treatment barn across four seasons was calculated using the following formula:

$$ETI= 27.88-0.456\times T_a+0.010754\times T_a^2$$
$$-0.4905\times rh+0.00088\times rh^2$$
$$+1.15\times v-0.12644\times v^2$$
$$+0.019876\times T_a\times rh-0.046313\times T_a\times v$$

Where,

Ta=Dry bulb temperature (°C),

rh=Relative humidity

v=Air velocity ($ms^{-1}$)

*2.5. Behavioural response of animals*

Diurnal behavioural patterns such as lying and standing, feeding, drinking and panting were monitored and recorded using continuous surveillance camera. The duration of lying and standing, and frequency of feeding and drinking, and the panting pattern were estimated from the recordings. Three surveillance video cameras were erected on the side wall of the treatment barns to observe animals in each treatment group. 24 h activity was observed by visual inspection of camera recording. A particular behavioural activity was counted and registered if ≥4 numbers of animals in the treatment group of six were involved in that activity.

## 3. RESULTS AND DISCUSSION

*3.1. Equivalent temperature index*

Table 1 sheds the light on changes in ETI across different barns in different seasons. In general, ETI values were higher in treatment barns $T_1$ and $T_2$ and lowest in $T_3$. $T_3$ was significantly lower than $T_1$ and $T_2$ in time points 8 PM and 12 N across all seasons. Whereas, at 4 PM time point in pre-monsoon and winter season, and 8 AM time point during south-west monsoon and winter season the treatments were not significantly different from each other. However, even though not significantly different across all seasons and in all time points, the ETI was lower in $T_3$ barn. According to Baeta et al. (1987) the threshold levels of ETI were <30 means safe, 30 to 34 means caution, 34 to 38 means extreme caution and >38 means danger. All barns experienced caution to danger level across four seasons, which indicated presence of heat load throughout the year. Higher ETI values were observed in pre-monsoon and post-monsoon seasons and significantly lower values than the above two seasons was observed in south-west monsoon and lowest values were observed in winter season. The higher ambient temperature during the pre-monsoon and post-monsoon season, lower ambient temperature and relatively higher humidity during south-west monsoon, and lower ambient temperature coupled with lower humidity during winter season had contributed to this pattern of ETI across seasons. ETI values were calculated by Harikumar (2017) and there also higher ETI values was observed in the pre-monsoon months of March, April and May (37.24, 39.46 and 37.03 respectively) followed by post-monsoon months of October and November (37.44 and 35.37 respectively) and lowest values were recorded during winter months of December, January and February (34, 33.25 and 33.67 respectively). South-west monsoon season was not considered in that study.

*3.2. Standing and lying down duration*

In general, it has been observed that when animals were exposed to increased heat load, an increase in standing time and subsequently decrease in lying down occured, as standing facilitate more evaporative heat loss from body surface and also heat dissipation though convection. Similarly standing would also reduce conductive and radiative heat gain from the ground. Thus, in comparison between the treatments (Table 2), $T_1$ barn animals experienced significantly highest standing time during pre-monsoon, south-west monsoon and post-monsoon season

Table 1: Comparison of diurnal Equivalent Temperature Index (ETI) in the micro-climate between treatments and between seasons

| Time | Season (S) | Treatment (T) | | | F-value ($p$-value) | | |
|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | T | S | T×S |
| 8 am | Pre-monsoon | $37.80^{aA}\pm0.30$ | $37.32^{aAB}$ 0.29 | $37.11^{aB}\pm0.31$ | $4.534^{*}$ | $259.50^{**}$ | $1.757^{ns}$ |
| | South west monsoon | $35.11^{cA}\pm0.32$ | $34.49^{cA}\pm0.30$ | $34.90^{cA}\pm0.38$ | (0.011) | (<0.001) | (0.107) |
| | Post monsoon | $36.58^{bA}\pm0.31$ | $35.98^{bAB}\pm0.34$ | $35.00^{bB}\pm0.28$ | | | |
| | Winter | $30.65^{dA}\pm0.27$ | $31.02^{dA}\pm0.30$ | $30.51^{dA}\pm0.26$ | | | |
| 12 Noon | Pre-monsoon | $39.31^{aA}\pm0.25$ | $39.20^{aA}\pm0.22$ | $38.69^{aB}\pm0.21$ | $21.24^{**}$ | $157.41^{**}$ | $1.816^{ns}$ |
| | South west monsoon | $38.00^{bA}\pm0.50$ | $37.11^{bA}\pm0.34$ | $36.34^{bB}\pm0.32$ | (<0.001) | (<0.001) | (0.095) |
| | Post monsoon | $39.15^{aA}\pm0.26$ | $39.41^{aA}\pm0.28$ | $37.52^{aB}\pm0.22$ | | | |
| | Winter | $34.75^{cA}\pm0.25$ | $34.91^{cA}\pm0.25$ | $33.84^{cB}\pm0.21$ | | | |
| 4 pm | Pre-monsoon | $38.78^{bA}\pm0.19$ | $38.76^{bA}\pm0.19$ | $38.77^{aA}\pm0.20$ | $7.542^{**}$ | $104.94^{**}$ | $2.991^{**}$ |
| | South west monsoon | $38.61^{bA}\pm0.56$ | $37.10^{cB}\pm0.30$ | $36.81^{bB}\pm0.27$ | (0.001) | (<0.001) | (0.007) |
| | Post monsoon | $40.11^{aA}\pm0.50$ | $40.35^{aA}\pm0.43$ | $38.69^{aB}\pm0.39$ | | | |
| | Winter | $35.05^{cA}\pm0.27$ | $35.51^{dA}\pm0.28$ | $34.72^{cA}\pm0.24$ | | | |
| 8 pm | Pre-monsoon | $37.82^{aA}\pm0.37$ | $38.30^{aA}\pm0.34$ | $37.14^{aB}\pm0.39$ | $19.24^{**}$ | $76.34^{**}$ | $0.879^{ns}$ |
| | South west monsoon | $36.82^{bA}\pm0.37$ | $36.76^{bA}\pm0.37$ | $35.65^{bB}\pm0.35$ | (<0.001) | (<0.001) | (0.511) |
| | Post monsoon | $38.02^{aA}\pm0.42$ | $38.43^{aA}\pm0.48$ | $36.20^{aB}\pm0.44$ | | | |
| | Winter | $33.59^{cA}\pm0.30$ | $34.60^{cA}\pm0.39$ | $32.68^{cB}\pm0.26$ | | | |

**Significant at $p$=0.01 level; ns non-significant; Means having different small letter as superscript differ significantly within a column for each time; Means having different capital letter as superscript differ significantly within a row

except the winter, in which it was second in position of standing time. Inversely, lower lying time was observed in this barn during pre-monsoon and post-monsoon whereas it was second in lying time during south-west monsoon and winter season. $T_2$ barn experienced the lowest standing time and highest lying time in post-monsoon and winter season. Whereas in pre-monsoon and south-west monsoon season it was intermediate in standing time between $T_1$ and $T_3$. $T_3$ barn animals experienced higher standing time in south-west and winter season and lowest in pre-monsoon season and second position in post-monsoon season. Hence in the present study, it was observed that even though significant difference exists between the barns, the pattern of difference between the barns vary according to the seasons. That was even though standing behaviour facilitated more heat dissipation to the surroundings, the climatic variables like relative humidity and wind speed which could significantly influence this heat dissipation also might have played their role, as these variables varied between barns according to their orientation which influenced wind movements. This was also evident in comparing between seasons where during the south-west monsoon when the relative humidity was much higher lowest standing time was observed across the different treatment barns. That was in the highly moisture saturated atmosphere increased standing would not facilitate cutaneous evaporation. The typical difference in the ambient conditions between the barns reflecting on the standing behavior was well evident in the pre-monsoon season, where the standing time in $T_1$ was the highest, $T_2$ next and $T_3$ the lowest. In comparing between the seasons also in both $T_1$ and $T_2$ pre-monsoon showed the highest standing time and the second highest in $T_3$.

Sahu et al. (2019) at Kalyani, West Bengal observed behaviour and welfare of crossbred Jersey cows under two housing system i.e., control group under existing shed of concrete floor and asbestos roof and treatment group under thatched ceiling and sand flooring. They observed significantly higher standing time in control group compared to treatment group in both summer (379.17±11.26 vs 264.10±13.42) and winter season (395.27±13.87 vs 271.71±12.24), whereas, significantly lower overall lying time (resting position) was observed in control group (634.7±9.39) compared to treatment (683.51±16.50). Though the present study agreed with the observation of this study on summer season it was different in case of winter season. In that study between season comparison showed significantly higher standing time in winter season compared to summer in both control and treatment group and inversed to that apparently lower lying position was observed in both the groups during winter season, which was contradictory to

Table 2: Comparison of standing and lying down time between treatments and between seasons

| Behaviour | Season (S) | Treatment (T) | | | F-value ($p$-value) | | |
|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | T | S | T×S |
| Standing (min day$^{-1}$) | Pre-monsoon | $893.00^{aA}\pm10.65$ | $861.33^{aB}\pm2.26$ | $782.67^{bC}\pm2.22$ | $639.35^{**}$ (<0.001) | $888.73^{**}$ (<0.001) | $422.41^{**}$ (<0.001) |
| | South west monsoon | $742.00^{cA}\pm1.53$ | $690.67^{cB}\pm1.69$ | $732.5^{cA}\pm1.34$ | | | |
| | Post monsoon | $826.50^{bA}\pm1.29$ | $630.17^{dC}\pm0.65$ | $725.50^{cB}\pm1.38$ | | | |
| | Winter | $717.33^{dB}\pm0.96$ | $663.00^{cC}\pm1.41$ | $841.33^{aA}\pm1.02$ | | | |
| Lying (min day$^{-1}$) | Pre-monsoon | $547.00^{dC}\pm10.65$ | $578.67^{dB}\pm2.26$ | $657.33^{bA}\pm2.22$ | $639.35^{**}$ (<0.001) | $888.73^{**}$ (<0.001) | $422.41^{**}$ (<0.001) |
| | South west | $698.00^{bB}\pm1.53$ | $749.33^{cA}\pm1.69$ | $707.50^{aB}\pm1.34$ | | | |
| | Post monsoon | $613.50^{cC}\pm1.29$ | $809.83^{aA}\pm0.65$ | $714.50^{aB}\pm1.38$ | | | |
| | Winter | $722.67^{aB}\pm0.96$ | $777.00^{bA}\pm1.41$ | $598.67^{cC}\pm1.02$ | | | |

$^{**}$Significant at $p$=0.01 level; $^{*}$Significant at $p$=0.05 level; ns: non-significant; Means having different small letter as superscript differ significantly within a column for each behaviour; Means having different capital letter as superscript differ significantly within a row

the present study and expected behavioural pattern and this might be due to the varied climatic factors in that locality during that season. In a study on behavioural pattern conducted by Jat and Yadav (2010) in Hisar, Haryana on buffalo calves during winter season under four different housing system, they observed no significant difference for standing time and resting time between $T_1$: Asbestos sheet, $T_2$: Thatched roof cum asbestos, $T_3$: Mud plaster roof and $T_4$: Closed barn (Standing time: 720.95±39.920, 639.35±27.799, 726.10±35.892, 665.90±43.196 and Resting time: 719.05±39.916, 800.65±27.799, 713.90±35.892, 774.10±43.197 respectively). In the arid region of Rajasthan during summer, Lamba et al. (2022) observed significantly higher resting time for the Sahiwal calves housed under thatched roof and agro net roof compared to plain asbestos roof and significantly higher standing time was observed under asbestos roof followed by agro net roof and then thatched roof. Sinha et al. (2017) at Karnal studied on a behavioural aspect of crossbred cows under modified housing system in hot-humid season. They observed significantly higher lying time (596.95±5.36 vs 520.32±6.67 min day$^{-1}$) and significantly lower standing time (521.24±9.55 vs 599.25±9.79 min day$^{-1}$) in modified shed (Asbestos sheet roof of height: 15 ft and width: 20 ft, sand flooring, foggers and fans) compared to existing shed (Asbestos sheet roof of height: 12 ft and width: 10 ft, concrete flooring). Harikumar (2017) at Thumburmuzhy, Kerala in crossbred cows observed significantly higher lying time (min day$^{-1}$) and significantly lower standing time (min day$^{-1}$) for the cows housed under automatic wetting and fan compared to control in high THI period (725.18±5.9 vs 657.29±5.9, 640.17±5.03 vs 693.23±5.03 respectively). In the same study when comparison between the season was done, all treatment group animals showed significantly lower lying time (min day$^{-1}$) in high THI, summer season (673.64±2.98) compared to medium THI, post-monsoon (743.06±3.12) and low THI, winter (762.91±3.8), and significantly higher standing time (min day-1) in summer (675.75±2.52) followed by post-monsoon (632.44±3.47) and then winter season (581.17±3.3). Thus, it could be observed that much of the studies agreed to the role of increased standing time in heat dissipation during hotter season and how thermal alleviation measures by housing could significantly lower the standing time facilitating more resting for the animal.

### 3.3. *Feeding and drinking bouts*

The first reaction to elevated temperature inducing thermal stress was decrease in feed intake, as the heat increment of feed intake acted as a source of heat production in ruminants. In comparison on feeding performance between barns (Table 3), higher feeding bouts was observed in the $T_1$ barn in all the seasons compared to $T_2$ and $T_3$, indicating the higher metabolic activity of the animals housed in $T_1$ barn compared to the other two barns. Though $T_3$ barn was more thermally alleviating compared to the $T_1$ barn, a contrast to what was expected in feeding is observed in that barn with lower feeding time. This contrasting pattern in feeding indicate that the housing modification attempted in the present study was not sufficient enough in all means to alleviate thermal stress and with regard to feeding the animal factors also tend to play. This was also evident in case of drinking behaviour where significantly higher drinking bouts was observed in $T_1$ barn compared to $T_2$ and $T_3$ barn in pre-monsoon and post-monsoon season, whereas in the other two seasons there was no significant difference between them. However, in the case of seasonal comparison, feeding was significantly lowest in the hotter pre-monsoon season, whereas it was highest in south-west monsoon and post-monsoon season and intermediate

Table 3: Comparison of feeding and drinking bouts between treatments and between seasons

| Behaviour | Season (S) | Treatment (T) | | | F-value ($p$-value) | | |
|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | T | S | T-S |
| Feeding (bouts day$^{-1}$) | Pre-monsoon | $32.17^{cA}$±1.01 | $29.83^{cB}$±2.01 | $30.00^{cB}$±0.97 | $8.642^{**}$ (<0.001) | $56.45^{**}$ (<0.001) | 1.531 (0.184) |
| | South west monsoon | $51.50^{aA}$±3.31 | $46.00^{aB}$±1.37 | $47.67^{aB}$±2.97 | | | |
| | Post monsoon | $56.00^{aA}$±1.46 | $52.33^{aB}$±2.26 | $44.17^{aB}$±2.24 | | | |
| | Winter | $46.83^{bA}$±2.01 | $41.50^{bB}$±2.08 | $41.00^{bB}$±1.79 | | | |
| Drinking (bouts day$^{-1}$) | Pre-monsoon | $69.67^{aA}$±1.59 | $56.83^{aB}$±1.70 | $49.33^{aB}$±2.04 | $21.501^{**}$ (<0.001) | $44.873^{**}$ (<0.001) | $2.545^{*}$ (0.029) |
| | South west$^{(ns)}$ | $41.33^{c}$±1.20 | $36.83^{b}$±1.28 | $38.17^{b}$±1.35 | | | |
| | Post monsoon | $49.67^{bA}$±2.73 | $38.83^{bB}$±3.21 | $35.50^{bB}$±2.05 | | | |
| | Winter$^{(ns)}$ | $42.50^{c}$±1.73 | $38.50^{b}$±4.90 | $36.00^{b}$±3.06 | | | |

$^{**}$Significant at $p$=0.01 level; $^{*}$Significant at $p$=0.05 level; ns non-significant; Means having different small letter as superscript differ significantly within a column for each behaviour; Means having different capital letter as superscript differ significantly within a row

during winter. Increased feeding bouts was observed in the south-west and post-monsoon season with higher relative humidity that which increases the moisture content of the fodder grass provided and hence to meet the dry matter requirement animal tends to eat more that may increase the feeding bouts. In case of drinking behaviour the highest drinking bouts was observed in the hotter pre-monsoon season without significant difference between them in case of the other three seasons.

Studying on Vrindavani calves at Izatnagar, Kamal et al. (2014) observed that in summer, calves spent significantly higher feeding time (min 7 h$^{-1}$) housed under agro-net (85.48±0.75) followed by tree (81.33±0.64), thatch (77.12±1.81) and then asbestos (75.93±1.34), and he also observed significantly higher drinking behaviour (min 7 h$^{-1}$) in calves housed in under asbestos (13.67±0.44) compared to tree (11.21±0.50), thatch (10.29±0.64) and agro-net (9.71±0.31). Again, in the same study area Narwaria (2020) studied the effect of false ceiling on behavioural changes in Vrindavani calves during summer and observed significantly higher feeding time (min 12 h$^{-1}$) for calves housed under false ceiling of EPE sheet (130.50±1.85) and Thatch (132.40 ±1.92) compared to under plain asbestos roof (119.58±1.45). Conversely, he observed higher drinking behaviour (min 12 h$^{-1}$) under asbestos (6.13±0.26) followed by EPE sheet (5.81±0.19) and Thatch (5.63±0.15). In a study on behavioural pattern conducted by Jat and Yadav (2010) in Hisar, Haryana on buffalo calves during winter season under four different housing system, significantly higher feeding time (min day$^{-1}$) was observed in the animals housed under closed barn with proper ventilation (315.00±9.927), asbestos with thatch (308.50±7.639) and asbestos with mud plaster (304.45±7.190) compared to plain asbestos (284.45±6.438). In the arid region of Rajasthan during summer, Lamba et al. (2022) observed significantly higher feeding time for the Sahiwal calves housed under thatch (71.17±0.87) followed by agro-net (67.67±0.98) and lower feeding time under plain asbestos (64.5±0.99). Conversely, they observed significantly higher drinking behaviour under asbestos (18.50±1.056) compared to lower in agro-net (15.00±0.51) and thatch (13.67±0.33). Sinha et al. (2017) at Karnal observed significantly higher eating time (336.65±3.80 vs 321.85± 4.32 min day$^{-1}$) and significantly lower feeding bouts (8.61±0.20 vs 9.63±0.32 number day$^{-1}$) for the crossbred cows housed in modified shed roof height of 15 ft and width of 20 ft; compared to existing shed roof height of 12 ft and width of 10 ft. Sahu et al. (2019) at Kalyani, West Bengal observed behaviour of crossbred Jersey cows under two housing system i.e control group (concrete floor and asbestos roof) and treatment group (thatched ceiling and sand flooring). They observed that overall eating time was significantly higher in treatment group compared to control group (346.41±14.73 vs 287.78±7.87), they observed eating time was more in winter season compared to summer in both treatment group (368.48 ±19.93 vs 330.97±20.59) and control group (310.08±11.31 vs 262.57±8.31). Whereas, no significant difference between seasons and between treatments was observed for drinking behaviour. A study by Allen et al. (2015) identified that cattle experiencing heat stress exhibited increased periods of standing bouts and a greater water intake. Madke et al. (2010) under three different housing system i.e $G_1$: Concrete flooring, $G_2$: Concrete flooring, rubber mat bedding and thatched roof and $G_3$: Concrete flooring (in hot-dry and hot-humid season and straw bedding in winter) and thatched roof, observed significantly lower drinking behaviour for the animals housed in $G_3$ compared to $G_1$ and $G_2$ in hot-dry ($G_3$: 5.04±0.03<$G_1$; 5.38±0.04<$G_2$; 5.40±0.07), hot-humid

($G_3$: 2.91±0.06<$G_2$; 3.14±0.06<$G_1$; 3.24±0.08) and winter ($G_3$: 2.71±0.02<$G_2$; 2.57±0.03<$G_3$; 3.64±0.05). They also observed significantly higher drinking behaviour in hot-dry season followed by hot-humid and winter season.

## 4. CONCLUSION

Roof modifications in the $T_3$ barn, including solar-reflective and black paint, effectively reduced heat stress, improving cows' thermal comfort and behavior, particularly during high heat stress periods (pre- and post-monsoon). Cows in the $T_3$ barn showed reduced standing time and improved comfort, unlike those in $T_1$ barns, who spent more time standing. These findings emphasized the importance of optimizing barn orientation and roof design to enhance cow welfare, reduce heat stress, and improve productivity in tropical dairy farming.

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