Impact of roof modification on the growth performance, body condition score and economics of lactating Murrah buffaloes in loose housing system

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Abstract

The Murrah breed of buffalo is essential to the agricultural economy of the Indian subcontinent, especially in terms of milk production. However, heat stress remains a major challenge for buffaloes, particularly lactating Murrah buffaloes, affecting their growth, health, and productivity. This study looked at how changes in the environment, like using glass wool and white-painted EPE sheets, affected the growth, health, and cost-effectiveness of raising lactating Murrah buffaloes in a hot climate. Three housing treatments were tested: T_1 (control, asbestos roof), T_2 (glass wool + white painted roof), and T_3 (EPE sheet + white painted roof). Temperature, Relative Humidity and THI was significantly in T_2 followed by T_3 treatment as compared to the control group. The results showed non-significant change in body weight, but buffaloes in T_2 and T_3 showed significantly higher ADG and AWG as compared to control group. Body condition scores (BCS) were significantly elevated in T_2 and T_3 relative to T_1, indicating enhanced feed efficiency and health. T_1 exhibited the lowest cost per buffalo however, T_2 and T_3 proved to be more cost-effective regarding cost per kg weight gain, despite requiring a higher initial investment. The findings indicate that microclimatic modifications, including insulated and reflective roofing systems, can improve buffalo welfare and productivity by alleviating heat stress, resulting in enhanced weight gain and better body condition. This research highlights the significance of environmental management in enhancing the health and economic efficiency of lactating buffaloes in hot and humid climates.

Keywords: Murrah buffaloes; Heat stress; roof modifications; BCS; Growth; Economics

Introduction

Buffaloes are contributing significantly to milk production in developing countries under harsh climatic conditions (Elsayed et al., 2021; Gautam et al., 2021). The Murrah breed of buffalo is essential to the agricultural and rural economies of the Indian subcontinent, serving multiple purposes through its contributions to milk production, meat, and draft power. Dairy buffalo farming plays a crucial role in India's economy, representing approximately 50% of the nation's total milk production. Murrah buffaloes are esteemed for their exceptional milk production, and their adaptability to various environmental conditions renders them a significant genetic resource, both nationally and globally. This breed is primarily located in the northern Indian states of Haryana, such as Bhiwani, Hisar, Rohtak, and Jind, and its genetics have been integrated into buffalo populations in countries including China, Brazil, Egypt, and Bangladesh (Kumar, 2015; Dhillod et al., 2018). India's buffalo population stands at 109.85 million, representing about 20.45% of the total livestock population, with the industry experiencing a growth rate of 1.06%**,** according to the 20th Livestock Census. Heat stress poses a considerable challenge for buffaloes, especially for lactating Murrah buffaloes. Heat stress adversely affects physiological functions, decreases feed intake, and compromises reproductive performance, leading to significant consequences for growth and productivity. The Temperature-Humidity Index (THI) serves as a metric for evaluating heat stress by quantifying the interplay between temperature and humidity in relation to animal comfort. Multiple studies indicate that heat stress negatively affects the growth and health of buffaloes. The climatic conditions of a particular region, like air temperature and relative humidity, influence the animal's health and growth potential and adverse conditions may result in heat stress (Kumar et al. 2025). Verma et al. (2022) and Barman et al. (2017) showed that changes in the environment, like using darker roofs and plastic shading, can improve the average daily gain (ADG) of buffaloes, highlighting the benefits of controlling environmental conditions. Kumar et al. (2022) observed a 15% reduction in weight gain in buffaloes exposed to THI values exceeding 80, whereas Sharma et al. (2023) reported a 10–12% decline in ADG under elevated THI conditions. Insulated and reflective roofing systems effectively reduce heat stress and enhance buffalo growth (Yadav et al., 2023). Heat stress results in a reduction of Body Condition Score (BCS), an essential measure of animal health and productivity. Mahan and Mader (2004) and Mohan et al. (2006) documented a decline in body condition score (BCS) attributed to reduced feed intake and metabolic stress in high-temperature environments. Cooling strategies, including shading and misting, have demonstrated effectiveness in mitigating heat stress and improved BCS (Gao et al., 2019; Kakar et al., 2020). Research has also examined the economic impact of various housing systems for buffaloes. Singh (2000) found that the cost per kg gain in body weight for Murrah buffalo heifers was lowest with thatched roofs (₹23.49), whereas higher costs were linked to asbestos and aluminum foil roofing systems. Amit et al. (2021) documented variations in costs associated with heifer rearing, noting the highest rearing cost for thatched roofs at ₹4662.60, while the lowest cost per kg weight gain was ₹123.35 within the same treatment. The findings highlight the necessity of evaluating both costs and benefits associated with various microclimatic modifications to enhance buffalo rearing practices.

To reduce heat stress and lower the shed temperature, researchers used a variety of roofing materials such as thatch, agro net, polystyrene sheets, EPE sheets, and polypropylene. While glass wool and EPE sheets have good insulation properties, there is a lack of research comparing the combined ceiling insulation and roof paint strategies under field conditions and their effects on measurable dairy animal performances in loose housing systems. The objective of this study is to understand the effects of microclimate alterations on temperature, relative humidity, THI, growth performance, body condition score and the economic returns associated with lactating Murrah buffaloes kept in a loose housing system.

Materials and methods

The study conducted at the Buffalo farm of the Department of Livestock Production Management, College of Veterinary Sciences, Lala Lajpat Rai University of Veterinary and Animal Sciences, Hisar, a semi-arid region with a subtropical climate, the experiment spanned from August to November 2024. Eighteen post-colostrum lactating Murrah buffaloes were selected and divided into three treatment groups, each consisting of six animals housed in a loose housing system. The treatments included T_1 (control) with concrete flooring and corrugated asbestos sheet roofing; T_2 with concrete flooring, glass wool insulation (50mm) as false ceiling on asbestos sheet roofing, and a white-paint on upper side of roof; and T_3 with concrete flooring, expanded polyethylene (70mm) as false ceiling on asbestos sheet roofing, and a white-paint on upper side of roof. For each treatment, 6 lactating Murrah buffaloes were housed in an experimental shed measuring 25 m^2 with a closed space underneath and 50 m^2 with an open area.

Microclimate

Temperature and Relative humidity (RH):- Digital Indoor hygrometer thermometer and Dry bulb thermometer were hanged in shed to record temperature and humidity of each shed on fortnightly basis. Temperature Humidity Index (THI): THI was calculated from environmental variables using the following equation (NRC 1971):

$$(1.8 \times T_{db} + 32) - \{(0.55-0.0055 \times RH) \times (1.8 \times T_{db}-26.8)\}$$

Where, Tdb = dry bulb temperature (°C); RH = relative humidity (%).

Growth Performance

Electronic weighing bridge was used for weighing of Murrah buffaloes at fortnightly intervals. Body weights utilized to know average daily gain and average weight gain.

- Average daily gain = total weight gain/ 90 Days
- Average weight gain over experimental period= body weight at the end of experiment – body weight at beginning of experiment.

Body condition score

Body condition score (BCS) was estimated by using 1-5 scale by using 0.25 increments BCS chart developed by Anitha et al. (2011) on monthly interval. Following points were taken into consideration for recording the body condition score (BCS) of the animals.

i) Vertebral column (chine, loin and rump)-flesh covering at the spinous processes of these regions.
ii) Spinous processes- their prominence and sharpness.
iii) Transverse processes of loin region- prominence and sharpness.
iv) Pin and hook bone- prominence and sharpness.
v) Tail head region-prominence of depression i.e. between backbone and pins and between pin and hook bones.
vi) Ribs- their flesh covering.

Economics

The economic evaluation included the costs of feed, materials for shed modifications (white paint, glass wool, EPE sheets, and labor), and total expenditures, with the cost per kilogram. Total feed costs were calculated by multiplying the amount of green fodder, dry fodder, and concentrate consumed by experimental buffaloes in each shed for the whole experimental period by their market price. The cost of material was calculated by including the amount of insulating material used for modification and the white paint used for the upper side of the roof. So, the total cost of each shed was calculated by adding the total feed cost, the cost of material, and the labor cost used to prepare the modified sheds. Cost per kilogram of weight gain is calculated by dividing the total cost by the average weight gain.

Statistical analysis

Experimental data were analysed by using the IBM SPSS statistics 20 software package for windows. The data was analysed using the one-way analysis of variance. Significant differences among the treatment's means were determined using Duncan's test as per Snedecor and Cochran (1994). Level of significance was considered at P<0.05.

Results

Temperature (°C), Relative Humidity (%) and Temperature-Humidity Index

The mean values of Temperature (°C), Relative Humidity (%) and Temperature-Humidity Index of different experimental treatment groups across all the study periods are presented in Table 1. The statistical analysis of the data revealed that overall mean values for the entire study period were significantly lower in 25.07°C T_2 and 26.61°C T_3 as compared to 28.05°C T_1 treatment. The overall mean values across fortnights indicated that T_1 (73.22%) exhibited the highest levels, whereas T_2 (71.39%) recorded the lowest, followed by T_3 (72.46%), with significant ($P < 0.05$) differences between T_1, T_2 and T_3 treatments. The overall mean values of THI across all fortnights were significant lower in T_2 (73.86) followed by T_3 (76.21) and highest in T_1 (78.35) treatment. The results indicated that T_2 group that significantly lower THI compared to control (T_1) and T_3 groups.

Growth performance

The average body weights of the experimental buffaloes in various sheds are displayed in Table 2 and Fig. 1. The initial body weights were 484.17 kg for T_1, 463.61 kg for T_2, and 463.61 kg for T_3. During the trial, body weight exhibited a consistent increase across all groups, with no significant differences noted. At the experiment's completion, buffaloes in T_2 (527.25 Kg) and T_3 (527.67 Kg) exhibited greater body weights than those in T_1 (512.44 Kg), although the overall differences were statistically non-significant. The mean values of Average Daily Gain (ADG) **(Figure 2)** and Average Weight Gain (AWG) **(Figure 3)** exhibited significantly (P<0.05) higher values in T2 and T3 groups as compared to T1 group.

Body condition score

The mean values at start of experiment were 3.75, 3.83 and 3.79 in T_1, T_2 and T_3 groups, respectively. The results showed that there was decrease in BCS over progressive periods of experiment. The overall mean values of Body condition score (BCS) of experimental buffaloes were 3.42, 3.66 and 3.58 in treatments groups T_1, T_2 and T_3 groups, respectively as presented in Table 3 and depicted in Fig 4. The statistical analysis of data

Table 1: Mean values of Temperature (°C), Relative Humidity (%) and Temperature–Humidity Index (THI) of experimental sheds with microclimatic modifications in loose house system.

Fortnights		Treatments		
		T_1 (Asbestos roof)	T_2 (Glasswool + White painted roof)	T_3 (E.P.E. Sheet + White painted roof)
At start of experiment	Temperature (°C)	28.70±0.78	26.57±1.01	27.43±1.12
	Relative Humidity (%)	81.93±0.38	81.52±0.02	82.78±0.71
	THI	81.01±1.20	77.61±1.64	79.15±1.87
I	Temperature (°C)	30.02±0.88	27.35±0.81	29.27±0.90
	Relative Humidity (%)	75.32^{c}±0.44	72.68^{a}±0.29	74.01^{b}±0.38
	THI	82.10±1.20	77.66±1.28	80.76±1.46
II	Temperature (°C)	26.23±0.94	24.32±0.94	25.48±0.72
	Relative Humidity (%)	76.60^{b}±0.53	74.68^{a}±0.24	75.05^{a}±0.10
	THI	76.70±1.30	73.40±1.49	75.21±1.14
III	Temperature (°C)	29.30^{b}±0.78	26.17^{a}±0.32	27.92^{ab}±1.01
	Relative Humidity (%)	76.35^{b}±0.56	74.37^{a}±0.11	76.22^{b}±0.35
	THI	80.81^{b}±1.34	75.89^{a}±0.49	78.75^{ab}±1.62
IV	Temperature (°C)	27.85^{b}±0.32	24.58^{a}±0.82	26.45^{ab}±0.81
	Relative Humidity (%)	73.58±0.54	71.95±0.10	73.03±0.64
	THI	78.34^{b}±0.45	73.29^{a}±1.24	76.23^{ab}±1.30
V	Temperature (°C)	26.23^{b}±0.46	23.10^{a}±0.87	24.27^{ab}±0.67
	Relative Humidity (%)	62.47±0.39	60.20±0.25	61.27±1.07
	THI	72.61^{b}±0.68	68.78^{a}±1.21	70.08^{ab}±1.11
VI	Temperature (°C)	28.00^{b}±0.85	23.43^{a}±0.67	25.48^{ab}±0.78
	Relative Humidity (%)	66.32^{b}±0.25	64.30^{a}±0.42	64.88^{ab}±0.65
	THI	76.83^{b}±1.21	70.35^{a}±0.99	73.29^{ab}±1.21
Overall Average	Temperature (°C)	28.05^{b}±0.71	25.07^{a}±0.76	26.61^{ab}±0.86
	Relative Humidity (%)	73.22^{b}±0.35	71.39^{a}±0.16	72.46^{ab}±0.50
	THI	78.35^{b}±1.05	73.86^{a}±1.17	76.21^{ab}±1.38

*Means bearing different superscripts in same row differs significantly (P< 0.05)

Table 2: Mean values of Body Weight (Kg), Average Daily Gain (Kg) and Average Weight Gain (Kg) of Murrah buffaloes reared under sheds with roof modification.

Fortnights	Treatments		
	T_1 (Asbestos roof)	T_2 (Glasswool + White painted roof)	T_3 (E.P.E. Sheet + White painted roof)
At start of experiment	484.17±9.93	463.61±15.72	471.33±33.37
I	488.33±9.84	477.11±16.22	482.67±33.10
II	493.50±9.29	487.50±17.11	490.83±31.45
III	498.28±9.12	496.72±17.94	501.11±30.84
IV	502.94±8.90	509.22±19.31	509.75±29.76
V	507.69±8.72	517.75±18.63	519.50±29.04
VI	512.44±8.60	527.25±18.70	527.67±28.12
Average Daily Gain	**0.31^{a}±0.04**	**0.70^{b}±0.11**	**0.63^{b}±0.12**
Average Weight Gain	**28.28^{a}±3.96**	**63.64^{b}±10.1**	**56.33^{b}±10.43**

*Mean s bearing different superscripts in same row differs significantly (P< 0.05)

Table 3: Mean values of Body Condition Score of lactating Murrah buffaloes reared under experimental sheds with roof modification

Fortnights	Treatments		
	T_1 (Asbestos roof)	T_2 (Glasswool + White painted roof)	T_3 (E.P.E. Sheet + White painted roof)
At start of experiment	3.75±0.09	3.83±0.08	3.79±0.07
I	3.54±0.08	3.79±0.08	3.75±0.09
II	3.38^{a}±0.11	3.63^{b}±0.06	3.58^{ab}±0.05
III	3.13^{a}±0.06	3.54^{b}±0.08	3.42^{b}±0.05
IV	3.25^{a}±0.06	3.50^{b}±0.06	3.29^{a}±0.08
V	3.29^{a}±0.04	3.58^{b}±0.05	3.38^{a}±0.06
VI	3.46^{a}±0.08	3.71^{b}±0.04	3.75^{b}±0.06
Overall Average	**3.42^{a}±0.05**	**3.66^{b}±0.04**	**3.58^{b}±0.04**

*Means bearing different superscripts in same row differs significantly (P< 0.05)

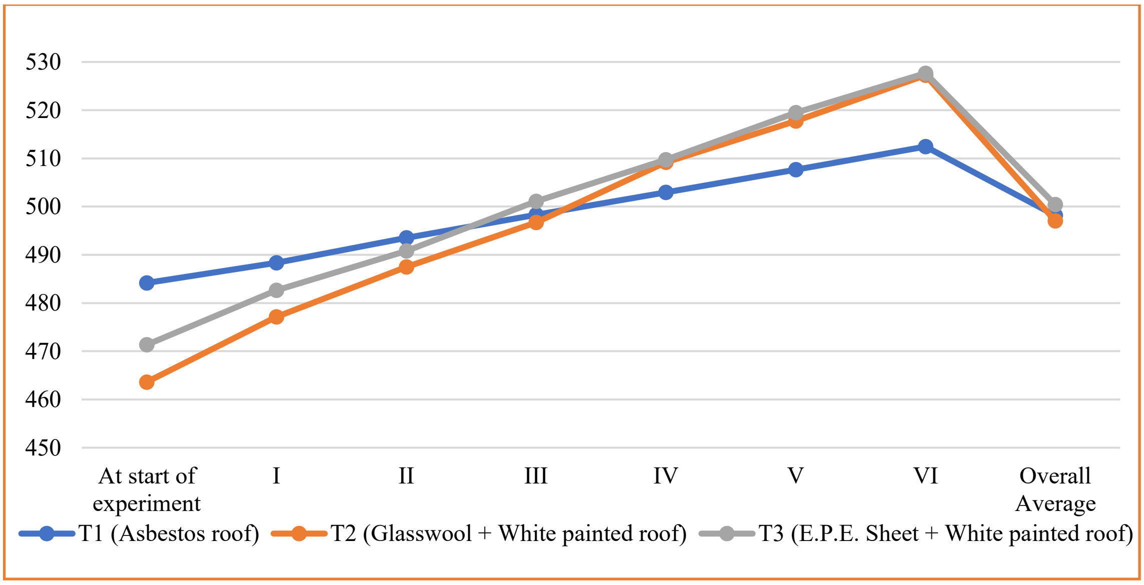

Fig. 1. Mean values of Body Weight (Kg) of lactating Murrah buffaloes reared under experimental sheds with microclimatic modifications in loose house system.

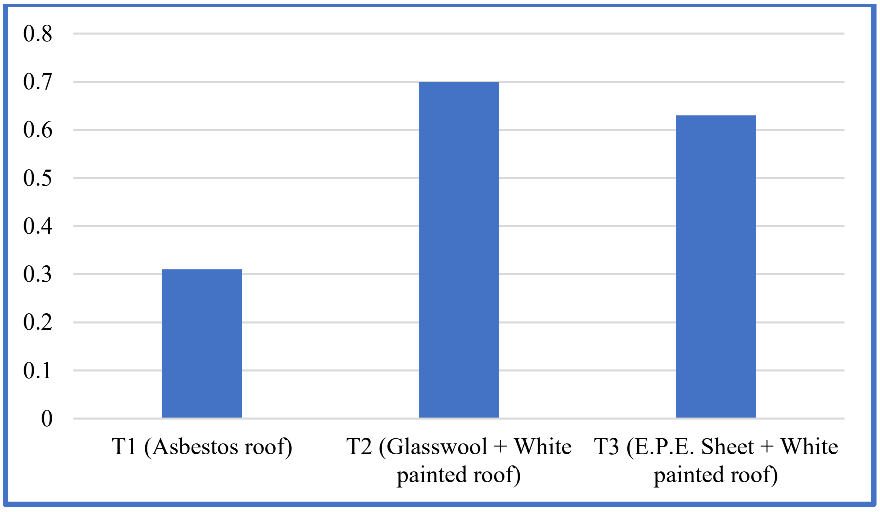

Fig 2. Average Daily Gain

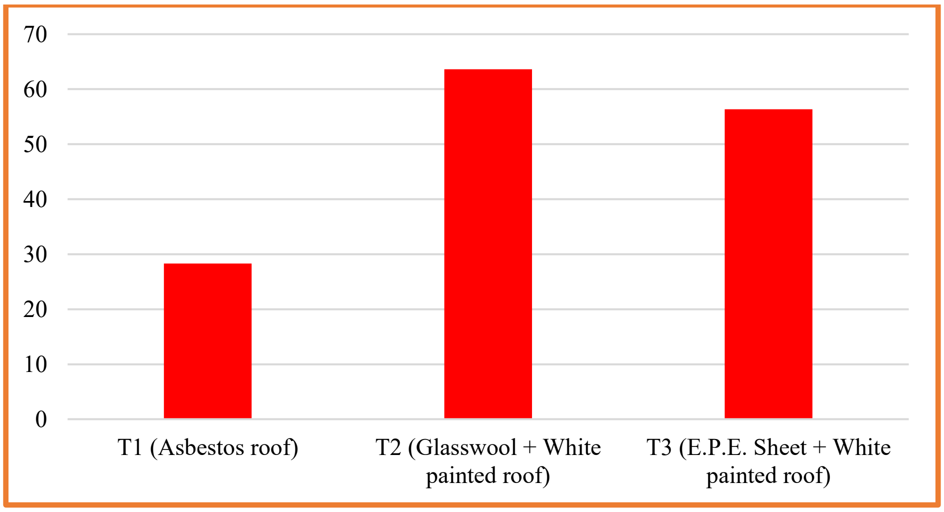

Fig 3. Average Body Weight Gain

Fig 4. Mean values of Body Condition Score of lactating Murrah buffaloes reared under experimental sheds with microclimatic modifications in loose house system.

Table 4: Cost of rearing lactating Murrah buffaloes under experimental sheds in loose house system.

Variables	**Treatments**		
	T_1 (Asbestos roof)	**T_2 (Glasswool + White painted roof)**	**T_3 (E.P.E. Sheet + White painted roof)**
a) Feed Cost (amount of feed consumed x market price x 90 days)	129127.629	135295.2	132773.3
b) Cost of Material (insulating material + white paint)		25500	16500
c) Labour cost		500	500
d) Total Cost (a + b + c)	129127.629	161295.2	149773.3
e) Total Cost/ Buffalo	21521.27	26882.53	24962.21
f) Average Weight Gain (Kg)	28.28	63.64	56.33
g) Cost (Rs)/ Kg Weight Gain	761.006769	422.415671	443.1424

revealed that the BCS were significantly ($P<0.05$) higher in T_2 and T_3 groups as compared to T_1 group. The results indicated that animals in both T_2 and T_3 groups have significantly maintained BCS than control group.

Economics

The economic evaluation of rearing lactating Murrah buffaloes under experimental sheds with microclimatic modifications revealed significant cost differences across treatments were presented in **Table 4**. T_2 (Glasswool + White painted roof) incurred the highest total cost (₹161,295.2), followed by T_3 (E.P.E. Sheet + White painted roof) at ₹149,773.3, and T_1 (Asbestos roof) at ₹129,127.629. Feed costs were the largest expenditure, with T2 having the highest feed cost, followed by T_3 and T_1. Material costs varied, with T_3 being more cost-effective (₹16,500) compared to T_2 (₹25,500), reflecting the higher investment in glass wool insulation. Labor costs were consistent at ₹500 across all treatments. Cost per buffalo was lowest in T_1 (₹21,521.27), while T_2 (₹26,882.53) and T_3 (₹24,962.21) were higher. Despite the higher costs, T_2 and T_3 showed superior weight gains (63.64 kg and 56.33 kg, respectively) compared to T_1 (28.28 kg). The cost per kg weight gain was lowest in T_2 (₹422.42/kg) and T_3 (₹443.14/kg), indicating better cost-effectiveness in these treatments despite higher total costs.

Discussion

Environmental factors affect production potential of Buffaloes (Sharma et al., 2016). The present study investigated the impact of microclimatic alterations, specifically glass wool and EPE sheet with white paint, on microclimate of shed like temperature, relative humidity and THI, buffalo body weight, body condition score (BCS) and economics in tropical climates. The results showed that T2 have significantly lower shed temperature, relative humidity and THI followed by T3 and higher values observed in T1 indicating the efficacy of insulated roofing materials and reflective white paint in reducing heat stress. The findings are consistent with Habeeb et al. (2018), who indicated that THI values exceeding 78 result in severe heat stress, adversely impacting buffalo health. Similarly, Slayi and Jaja (2025) reported that cattle in the treated groups exhibited lower THI values compared to the control group. Glasswool with white paint consistently exhibited lower THI values, thereby shoeing the advantages of insulation and reflective properties. This aligns with the findings of Muhieldeen et al. 2020 which indicate that insulating roof, such as glass wool insulation, can lower inside temperatures by as much as 2°C. The results also back up earlier studies by Sivakumar et al. (2017), and Maurya et al. (2018), which showed that different roofing materials like EPE, thatch, and agro-net had lower temperature, relative humidity and THI values compared to asbestos roofs. While the mean body weight at the end of the experiment showed no significant difference between treatments, both T_2 (Glasswool + White painted roof) and T_3 (E.P.E. Sheet + White painted roof) demonstrated a trend toward improved weight gain, aligning with findings from Vijayakumar et al. (2009) and Verma et al. (2022), who reported similar trends in buffalo heifers under modified sheds. Although microclimatic interventions did not yield statistically significant differences in body weight, the average daily gain (ADG) and average weight gain (AWG) were significantly higher in T_2 and T_3, supporting previous research by Amit et al. (2021) and Verma et al. (2022), which found improved ADG in insulated sheds compared to traditional roofing. Yadav et al. (2023), who reported an 8-12% increase in average daily gain (ADG) resulting from microclimatic modifications. Moreover, the significantly higher BCS in T_2 (3.66) and T_3 (3.58) compared to T_1 (3.42) highlights the importance of heat stress mitigation, with microclimatic modifications showing better feed efficiency and body condition maintenance, as noted by Mohan et al. (2006) and Yadav et al. (2023). The progressive decline in BCS in T_1 further underscores the adverse effects of heat stress, confirming the findings of Petrocchi et al. (2023) and Gupta et al. (2023), who highlighted the role of insulated roofing in improving physiological adaptation and feed intake in heat-stressed buffaloes. Reflective and insulated roofs have demonstrated an increase in BCS by 0.5-0.7 points, thereby enhancing buffalo welfare and productivity (Singh et al., 2023). These results emphasize that microclimatic modifications, such as roof insulation and white-painted surfaces, are crucial strategies for enhancing buffalo welfare, optimizing body weight gain, and improving overall productivity in hot and humid environments, as corroborated by Patel et al. (2023) and Gasco et al. (2021). The present study investigated the cost of rearing lactating Murrah buffaloes under different microclimatic modifications, namely asbestos roofing (T_1), glasswool + white painted roofing (T_2), and E.P.E. sheet + white painted roofing (T_3). The results indicate significant variation in the total costs and cost per kg weight gain across the treatments. T_1, with the asbestos roof, demonstrated the highest cost per kg weight gain (Rs. 761.01), which was notably higher than T_2 (Rs. 422.42) and T_3 (Rs. 443.14), aligning with finding from Singh (2000) and Amit et al. (2021), where lower costs were observed with simpler roofing systems. The increased feed costs, labor, and material costs associated with the advanced roofing materials in T2 and T3 explain the higher total cost in these treatments. The findings indicate that microclimatic modifications, specifically insulated false celling materials and white-painted roofs, effectively reduce THI and enhance buffalo growth and welfare in hot and humid environments.

Conclusion

This study shows how important changes in local climate, especially using insulated and reflective roofs, are for improving the growth, health, and cost-effectiveness of lactating Murrah buffaloes in hot climates. Specifically, T_2 and T_3 groups had much lower Temperature, Relative humidity and Temperature-Humidity Index (THI) than the control group T_1 (asbestos roof), showing better relief from heat stress. While there were no significant differences in the final body weight among the groups, the buffaloes in T2 and T3 have significantly higher average daily and weight gain than those in T1, showing that better microclimate helped to grow faster and better. Additionally, both T2 and T3 displayed improved body condition scores (BCS), indicating higher feed efficiency and general health. Economically, despite the higher initial expenses associated with T2 and T3, these treatments were more cost-effective in terms of cost per kilogram of weight growth, giving them feasible solutions for boosting the productivity of buffalo farming. The results underline the necessity of incorporating microclimatic management measures, such as insulated and reflective roofs, to minimize heat stress and maximize buffalo welfare, growth, and farm profitability in hot and humid environments. We recommend further research to investigate the long-term impacts and cost-benefit analyses of these modifications in various environmental conditions.

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Data availability

The datasets generated during and/or analysed during the current study are available from corresponding author on reasonable request.

Declarations

Ethics approval The study received ethical approval for animal experimentation from the Institutional Animal Ethics Committee (IAEC), India (No. IAEC/LUVAS/30/16)

Conflict of interest The authors confirms no conflicts of interest.

Competing interests No competing interests

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