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Amit
Veterinary Surgeon, GVH Sanwar, Charkhi Dadri, Haryana, India

Subhasish Sahu
Scientist, Department of LPM, Lala Lajpat Rai University of Veterinary and Animal Sciences, Hisar, Haryana, India

Rakesh Kumar
Veterinary Surgeon, GVH Kimara, Hisar, Haryana, India

Archana Sarangi
Ph.D. Scholar, Department of Animal Physiology and Reproduction Division, CIRB, Hisar, Haryana, India

Spandan Shashwat Dash
M.V. Sc. Scholar, Department of AGB, Lala Lajpat Rai University of Veterinary and Animal Sciences, Hisar, Haryana, India

Devender Singh Bidhan
Associate Professor, Department of LPM, Lala Lajpat Rai University of Veterinary and Animal Sciences, Hisar, Haryana, India

SK Chhikara
Professor and Head, Department of LPM, Lala Lajpat Rai University of Veterinary and Animal Sciences, Hisar, Haryana, India

Man Singh
Assistant Professor, Department of LPM, Lala Lajpat Rai University of Veterinary and Animal Sciences, Hisar, Haryana, India

Corresponding Author
Subhasish Sahu
Scientist, Department of LPM, Lala Lajpat Rai University of Veterinary and Animal Sciences, Hisar, Haryana, India

Effect of roof modifications on microclimatic parameters in alleviating heat stress in dairy shed

Amit, Subhasish Sahu, Rakesh Kumar, Archana Sarangi, Spandan Shashwat Dash, Devender Singh Bidhan, SK Chhikara and Man Singh

Abstract
An attempt was made to study the effect of roof modifications on temperature humidity index during summer at the buffalo farm of LPM, LUVAS, Hisar (Haryana). Experiment was done in four sheds *viz.* T_1 (control): Corrugated asbestos roof; T_2: Corrugated asbestos roof painted white on upper side; T_3: Corrugated asbestos roof having EPE (Expanded polyethylene) sheet on lower side and T_4: Corrugated asbestos roof painted white on upper side and EPE sheet on lower side. The recording of micro climate *viz*. Temperature, relative humidity and temperature humidity index was done at 7:00 AM and 2:00 PM daily. The temperature and THI was significantly ($P<0.05$) higher at 2:00 PM in T_1 whereas; RH values were non-significant among treatments. So it can be concluded that microclimate alterations by roof modifications using EPE sheets as well as white paint helped in better cooling effect due to reduced shed temperature and lower THI during summer as compared to existing asbestos roofs.

Keywords: Macroclimate**,** microclimate, roof modifications, shed temperature

Introduction
In a tropical country like India, thermal stress is a major limiting factor and one of the greatest challenges faced by producers and the livestock, which not only affect the animal bioenergetics but also have adverse effects on production and reproduction of livestock. Thermal stress can be simply defined as a condition that occurs when an animal cannot dissipate an adequate quantity of heat, whether it is produced or absorbed by the body, to maintain body thermal balance. This may prompt physiological and behavioral responses, leading to physiological disorders that negatively affect the productive and reproductive performance of farm animals (West, 2003; Nardone *et al.*, 2006; 2010) [14, 8, 9]. The temperature-humidity index (THI), a combination of temperature and RH, is widely used in hot areas worldwide to assess the impact of heat stress on dairy cows (Fuquay, 1981) [3]. Meteorological variables which influence the ambient temperature significantly are dry bulb temperature, wet bulb temperature, wind velocity and intensity of solar radiation and radiations from surrounding structures in the shed. In tropical and subtropical areas, the high ambient temperature is the major constraint on animal productivity, and the effect of heat stress is aggravated when heat stress is accompanied with high humidity. The heat stress affects the physiological systems governing thermal regulation and the maintenance energy of buffalo during extreme summer. In a warm climate, heat needs to be dissipated to maintain body temperature and normal physiological functions. Therefore, the present work was envisaged to evaluate the effect of roof modifications on temperature humidity index during summer.

Material and Methods
The materials and various methods adopted for the investigation described in this article are as:

Treatments
The experiment was conducted at the buffalo research centre of Department of Livestock Production and Management, College of Veterinary Sciences, Lala Lajpat Rai University of Veterinary and Animal Sciences (LUVAS), Hisar. Existing buffalo shed of LUVAS with asbestos roofing was taken to explore to modify the microclimate inside the animal shed. Four treatments/modifications were done as follows: T_1 (Control): corrugated asbestos roof, T_2: corrugated asbestos roof painted white on upper side, T_3: corrugated asbestos roof having 70 mm thick heat resistant EPE sheet on lower side, T_4: corrugated asbestos roof painted white on upper side and 70 mm thick heat resistant EPE sheet on lower side.

The floor under the covered area as well as in the open area was cement paved. Inner surface of the walls in the shed was plastered. Corrugated asbestos sheet roof (2.5 to 3 meter high) was differently modified in each treatment. The open area of the shed was enclosed by the wall of height 1.25 meters.

Observations: The following observations were taken during the experiment:

Meteorological data

Meteorological data inside the shed for each treatment group was recorded daily at 7:00 AM and 2:00 PM.

Micro climate

a) **Temperature and Relative humidity (RH):** Digital maximum and minimum thermometer was hung in the covered area underneath the roof to record temperature and relative humidity of each shed on a daily basis at 7:00 AM and 2:00 PM.

b) **Temperature Humidity Index (THI):** Temperature Humidity Index (THI) was calculated on daily basis using the following formula:

$$THI = \frac{0.8 \times \text{Temperature } (^0C) + \text{Relative Humidity}}{100} \times [\text{Temperature } (^0C) - 14.4] + 46.4$$

Statistical Method

The means of data obtained from the studies were compared by one way analysis of variance (ANOVA) as per the methods described by Snedecor and Cochran (1994). The data was analyzed using "SPSS" software (version-17).

Results

Temperature (^{0}C) of microclimate

Fortnightly ambient temperature during the experimental period at 7:00 AM and 2:00 PM under different sheds are presented in table-1. The temperature at 7:00 AM during first fortnight was 27.98±0.54, 28.08±0.51, 27.92±0.57 and 27.92±0.50^{0}C which increased highest in 3rd fortnight to 31.26±0.62, 31.53±0.62, 31.40±0.62 and 31.26±0.63^{0}C under T_1, T_2, T_3 and T_4, respectively. Whereas corresponding value at 2:00 PM increases from 40.39±0.57, 39.35±0.57, 38.55±0.57 and 37.93±0.51 in 1st fortnight to 44.69±0.38, 43.64±0.35, 42.55±0.34 and 41.51±0.34 during 2nd fortnight. The overall temperature at 7:00 AM was 30.07±0.15, 30.12±0.15, 30.01±0.15 and 29.88±0.14^{0}C whereas at 2:00PM was (fig. 4.1) 40.48±0.37, 39.48±0.35, 38.49±0.33 and 37.66±0.33^{0}C in T_1, T_2, T_3 and T_4, respectively.

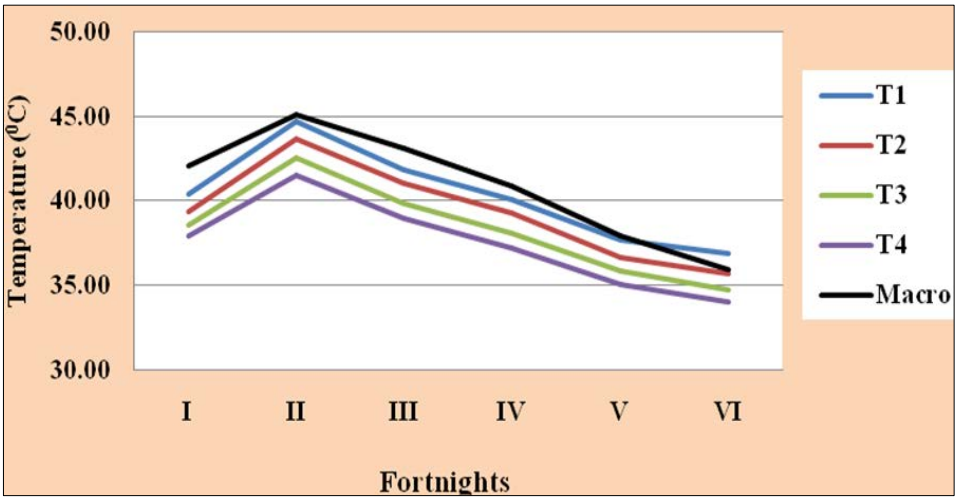

Fig 4.1: Comparison of Temperature (^{0}C) at 2:00 PM in different fortnights among treatments and macroclimate

The perusal of table revealed that the overall temperature at 7:00 AM was lower in T_4 as compare to other treatment groups however the difference was non-significant, whereas temperature at 2:00 PM was significantly higher (P<0.05) in T_1 followed by T_2, T_3 and T_4, however the difference was non-significant between T_3 and T_4. Similarly, overall average temperature differed significantly between T_1 and T_4 however the difference was non-significant between T_1 and T_2, T_2 and T_3. Conventional asbestos sheet used in T_1 might be unable to cut down the heat load falling on it through radiations as compared to other treatments, obviously it is heated up and heat is passed to micro-environment in shed which corroborates with Macfarlane (1981) [7], whereas, T_2 might had lesser protection against direct sunlight as compared to T_3 and T_4 groups shed. T_3 and T_4 sheds were able to keep the mean temperature at 2:00 PM lower in comparison to other groups indicating that the EPE sheet underneath the asbestos used in T_3 and T_4 had superior protective capacity due to thermal insulation.

The present findings are in agreement with Singh (2000) [11] who observed that the mean maximum temperature was significantly (P<0.01) lower in aluminium foil pasted roof and thatch roof in comparison to asbestos roof and white painted roof. Jat *et al.* (2005) [5] also reported that the maximum temperature in thatch and mud plaster roof was significantly (P<0.05) lower than asbestos sheet. Similarly, Roy and Chatterjee (2010) [10] found lower maximum temperature in sheds having tile roofs as compared to GI sheet and polythene sheet. Kamal *et al.* (2014) [6] also indicated that the overall minimum temperature was significantly lower (P<0.05) in agro-net as compared to other shade materials (asbestos, tree and thatch roof) during all the fortnights, whereas maximum temperature was significantly higher (P<0.05) in asbestos, followed by tree and lowest in agro-net shade, followed by thatch roof.

Table 1: Mean ± SE of Temperature (^{0}C) of microclimate

Fortnight	Time	Asbestos roof (T_1)	White painted roof (T_2)	EPE sheet roof (T_3)	White painted and EPE sheet roof (T_4)
I	7:00 AM	27.98±0.54	28.08±0.51	27.92±0.57	27.92±0.50
	2:00 PM	40.39±0.57^a	39.35±0.57^{ab}	38.55±0.57^b	37.93±0.51^b
	Average	33.91±0.49	33.45±0.49	32.95±0.54	32.66±0.46
II	7:00 AM	29.93±0.42	30.18±0.44	30.17±0.39	30.01±0.39
	2:00 PM	44.69±0.38^a	43.64±0.35^b	42.55±0.34^c	41.51±0.34^d
	Average	37.31±0.26^a	36.91±0.27^{ab}	36.36±0.24^{ab}	35.76±0.24^b
III	7:00 AM	31.26±0.62	31.53±0.62	31.40±0.62	31.26±0.63
	2:00 PM	41.81±0.72^a	41.05±0.68^a	39.87±0.64^{ab}	38.99±0.63^b
	Average	36.94±0.61	36.69±0.55	36.05±0.54	35.55±0.55
IV	7:00 AM	30.61±0.56	30.66±0.57	30.49±0.54	30.33±0.54
	2:00 PM	40.11±1.20	39.26±1.22	38.12±1.12	37.22±1.13
	Average	35.88±0.90	35.18±0.90	34.52±0.82	33.99±0.84
V	7:00 AM	30.57±0.40	30.40±0.40	30.35±0.39	30.16±0.38
	2:00 PM	37.73±1.14	36.67±1.09	35.85±1.03	35.10±1.00
	Average	34.05±0.71	33.44±0.68	33.00±0.67	32.55±0.64
VI	7:00 AM	29.86±0.35	29.63±0.33	29.54±0.31	29.44±0.32
	2:00 PM	36.94±0.72^a	35.68±0.69^{ab}	34.75±0.63^b	34.00±0.62^b
	Average	33.43±0.36^a	32.65±0.37^{ab}	32.16±0.35^b	31.74±0.36^b
Overall	7:00 AM	30.07±0.15	30.12±0.15	30.01±0.15	29.88±0.14
	2:00 PM	40.48±0.37^a	39.48±0.35^b	38.49±0.33^c	37.66±0.33^c
	Average	35.29±0.25^a	34.77±0.23^{ab}	34.23±0.22^{bc}	33.74±0.22^c

Means bearing different superscripts in a row differ significantly (P<0.05)

Relative Humidity (%) of microclimate

The RH at 7:00 AM and 2:00 PM in the fortnightly interval during the experimental period is presented in table-2. The RH at 7:00 AM during the first fortnight was 52.31±2.70, 52.46±2.79, 51.38±2.69 and 50.69±2.55% which increased to 82.71±2.16, 84.07±2.09, 83. 21±2.05 and 82.50±2.26% in last fortnight for T_1, T_2, T_3 and T_4, respectively. Similarly, RH at 2:00 PM increased from 13.71±1.73, 13.71±1.72, 14.57±2.01 and 14.43±1.87% in 2nd fortnight to 55.64±4.11, 59.45±4.11, 62.45±3.85 and 61.18±3.90% in last fortnight for T_1, T_2, T_3 and T_4, respectively. The overall RH was 65.00±1.13, 65.03±1.24, 64.56±1.23 and 63.96±1.16 at 7:00 AM and 33.36±2.02, 34.97±2.06, 36.84±2.04 and 36.01±2.00% at 2:00 PM with average values 48.26±2.01, 48.98±2.08, 49.65±2.06 and 49.02±2.06% in T_1, T_2, T_3, and T_4, respectively.

Table 2: Mean ± SE of Relative Humidity (%) of microclimate

Fortnight	Time	Asbestos roof (T_1)	White painted roof (T_2)	EPE sheet roof (T_3)	White painted and EPE sheet roof (T_4)
I	7:00 AM	52.31±2.70	52.46±2.79	51.38±2.69	50.69±2.55
	2:00 PM	19.14±1.93	18.64±1.95	20.07±2.08	20.07±1.91
	Average	35.75±2.06	35.54±2.10	35.83±2.14	35.33±2.05
II	7:00 AM	39.07±3.22	36.36±3.39	35.86±3.56	37.29±3.32
	2:00 PM	13.71±1.73	13.71±1.72	14.57±2.01	14.43±1.87
	Average	26.39±2.33	25.04±2.44	25.21±2.66	25.86±2.48
III	7:00 AM	62.07±3.44	61.40±3.70	61.20±3.60	60.60±3.40
	2:00 PM	29.80±2.09	32.10±2.05	34.30±2.10	32.60±2.30
	Average	44.10±2.22	44.80±2.47	45.85±2.51	44.75±2.41
IV	7:00 AM	69.64±3.97	69.64±4.13	70.21±3.99	69.50±3.99
	2:00 PM	39.55±6.44	42.55±6.62	45.18±6.53	43.18±6.53
	Average	52.91±5.30	54.36±5.52	55.95±5.37	54.64±5.37
V	7:00 AM	80.53±1.63	82.40±1.70	81.60±1.64	79.60±1.92
	2:00 PM	52.64±5.55	55.18±5.17	56.73±5.27	56.18±5.59
	Average	66.91±3.27	69.18±2.99	69.50±3.02	68.32±3.37
VI	7:00 AM	82.71±2.16	84.07±2.09	83.21±2.05	82.50±2.26
	2:00 PM	55.64±4.11	59.45±4.11	62.45±3.85	61.18±3.90
	Average	70.05±2.93	72.70±2.87	73.60±2.75	72.75±3.02
Overall	7:00 AM	65.00±1.13	65.03±1.24	64.56±1.23	63.96±1.16
	2:00 PM	33.36±2.02	34.97±2.06	36.84±2.04	36.01±2.00
	Average	48.26±2.01	48.98±2.08	49.65±2.06	49.02±2.06

Means bearing different superscripts in a row differ significantly (P<0.05)

The perusal of the table reveals that there was no significant difference in RH among the treatments. However, the relative humidity level was higher in the morning as compared to afternoon during all the fortnights. This may be due to high ambient temperature during day time which leads to more evaporative loss of moisture and drying of the floor of the shed. The present findings corroborates with Roy and Chatterjee (2010) [10] who observed higher RH (minimum) in plastic shade roof as compared to thatch, GI sheets and tile roof. Whereas, Barman (2016) [2] concluded that both morning as well as evening RH was significantly (P<0.05) high in iron sheet, followed by asbestos as compared to thatch roof.

Temperature Humidity Index (THI) of microclimate

The THI recorded fortnightly at 7:00 AM and 2:00 PM during the experimental period under different sheds are presented in table-3. THI during first fortnight was 75.77±0.54, 75.93±0.51, 75.55±0.58 and 75.48±0.57 which increased to 83.81±0.44, 83.83±0.48, 83.63±0.45 and 83.08±0.42 during fifth fortnight under T_1, T_2, T_3 and T_4, respectively. Similarly, at 2:00 PM (fig. 4.2) the THI increased from 83.59±0.42, 82.43±0.45, 81.98±0.46 and 81.38±0.38 to 88.25±0.53, 87.49±0.57, 86.72±0.49 and 85.58±0.53 for T_1, T_2, T_3 and T_4, respectively. The overall THI values at 7:00 AM in T_1, T_2, T_3 and T_4 were 80.59±0.21, 80.63±0.21, 80.41±0.20 and 80.18±0.20, respectively whereas at 2:00 PM were 86.81±0.18, 86.06±0.17, 85.38±0.15 and 84.23±0.15, respectively with average values; 83.55±0.22, 83.18±0.22, 82.73±0.20 and 82.03±0.20. The THI values at 7:00 AM were always lower than THI at 2:00 PM among the treatment groups.

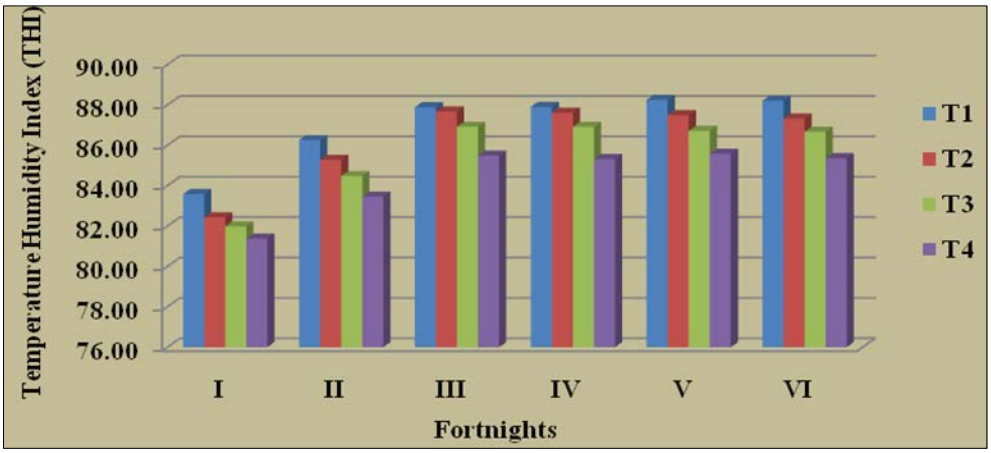

Fig 4.2: Comparison of THI values at 2:00 PM in different fortnights among treatments

The perusal table revealed that there was no significant difference in morning THI value between the treatments; however afternoon values of THI were significantly (P<0.05) low in T_4 as compared to T_1, T_2 and T_3. This may be due to significantly (P<0.05) lower temperature at 2:00 PM in T_4 as compared to T_1, T_2 and T_3. Minimum THI in group T_4 as compared to other sheds might be due to less penetration of solar radiation inside the shed.

Table 3: Mean ± SE of Temperature Humidity Index (THI) of microclimate

Fortnight	Time	Asbestos roof (T_1)	White painted roof (T_2)	EPE sheet roof (T_3)	White painted and EPE sheet roof (T_4)
I	7:00 AM	75.77±0.54	75.93±0.51	75.55±0.58	75.48±0.57
	2:00 PM	83.59±0.42^{a}	82.43±0.45^{ab}	81.98±0.46^{b}	81.38±0.38^{b}
	Average	79.35±0.39^{a}	78.86±0.40^{ab}	78.45±0.43^{ab}	78.12±0.35^{b}
II	7:00 AM	76.50±0.90	76.40±0.95	76.29±0.92	75.84±0.80
	2:00 PM	86.26±0.39^{a}	85.28±0.39^{ab}	84.48±0.37^{bc}	83.46±0.32^{c}
	Average	81.38±0.58	80.84±0.62	80.39±0.60	79.89±0.57
III	7:00 AM	81.64±0.58	81.88±0.54	81.67±0.55	81.61±0.56
	2:00 PM	87.89±0.31^{a}	87.68±0.32^{ab}	86.92±0.32^{b}	85.49±0.29^{c}
	Average	85.00±0.44	85.00±0.45	84.55±0.46	83.72±0.44
IV	7:00 AM	81.94±0.48	81.98±0.45	81.85±0.45	81.86±0.32
	2:00 PM	87.91±0.41^{a}	87.62±0.42^{a}	86.91±0.42^{b}	85.32±0.41^{b}
	Average	84.98±0.44^{a}	84.84±0.46^{a}	84.42±0.45^{ab}	83.46±0.47^{b}
V	7:00 AM	83.81±0.44	83.83±0.48	83.63±0.45	83.08±0.42
	2:00 PM	88.25±0.53^{a}	87.49±0.57^{b}	86.72±0.49^{ab}	85.58±0.53^{b}
	Average	85.91±0.42^{a}	85.57±0.48^{a}	85.07±0.45^{ab}	84.23±0.41^{b}
VI	7:00 AM	83.04±0.52	82.86±0.46	82.58±0.44	82.39±0.53
	2:00 PM	88.21±0.36^{a}	87.33±0.33^{ab}	86.67±0.32^{b}	85.36±0.33^{c}
	Average	85.88±0.37^{a}	85.29±0.30^{ab}	84.82±0.30^{bc}	84.06±0.35^{c}
Overall	7:00 AM	80.59±0.21	80.63±0.21	80.41±0.20	80.18±0.20
	2:00 PM	86.81±0.18^{a}	86.06±0.17^{b}	85.38±0.15^{c}	84.23±0.15^{d}
	Average	83.55±0.22^{a}	83.18±0.22^{ab}	82.73±0.20^{b}	82.03±0.20^{c}

Means bearing different superscripts in a row differ significantly (P<0.05)

Our findings corroborated with earlier workers (Singh, 2000 and Jat *et al.*, 2005) [11, 5] who found significantly higher (P<0.05) THI values at evening than morning hours and concluded that higher THI in conventional asbestos roofs, whereas; lower maximum temperature and less THI values in thatch and mud roof house created better microclimate. Similarly, Kamal *et al.* (2014) [6] observed that THI values were significantly (P<0.05) lower in morning than evening in all the treatments and differ significantly (P<0.05) among the treatments in both morning and evening with minimal values in agro-net. Sinha *et al.* (2017, a) [12] concluded that THI values were significantly (P<0.05) lower in modified sheds as compared to existing sheds.

Conclusion

Use of EPE sheets on the inner side of the existing sheds

altered the microclimate of the shed indicating highly superior thermal insulation power of the EPE sheet thus reduced heat stress. Conventional asbestos roof was unable to cut down the heat load falling on it through radiations, thus it could not provide proper microclimatic temperature. White painted roofs might have lesser protection against direct sunlight as compared to those in EPE sheet sheds during summer however; the conditions were more favourable as compared to conventional asbestos roofs.

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