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A comparative research on insulating and reflective properties of roof materials after modification on roof surface temperature

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Abstract
An attempt was made to study the difference in surface temperature (both inside and outside) of different roof types during summer at the buffalo farm of LPM, LUVAS, Hisar (Haryana). The experiment was divided into four treatments *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 surface temperature of each roof (both inside and outside) was done at weekly intervals. The overall outside ST at 7:00 AM was significantly higher ($P<0.01$) in T_1 and T_3 as compared to T_2 and T_4. Similarly, the overall outside ST at 2:00 PM differed significantly ($P<0.01$) between the treatments except T_1 and T_3 which did not differ significantly and highest values were seen in T_3 and lowest in T_2, whereas; the overall inside ST was significantly ($P<0.01$) high in asbestos roof as compared to other treatments both at 7:00 AM and 2:00 PM but corresponding values did not differ significantly for T_2, T_3 and T_4 at 7:00 AM and T_3 and T_4 at 2:00 PM. So it can be concluded that different roof types where EPE sheets were used as thermal insulation can reduce the temperature beneath shed upto 7 ^{0}C, while white paint with EPE sheets can lower down the temperature of shed upto 15 ^{0}C.

Keywords: insulating property, Infrared thermometer, reflecting property, surface temperature and roof modification

Introduction
Livestock production and agriculture are intrinsically linked, each being dependent on the other, and both crucial for overall food security. Livestock has been an integral component of traditional agriculture for centuries on record (constituting 28% of the country's agricultural output). India possesses 58% (108.7 million) of the world buffalo population (19th Livestock census, 2012) [1]. It contributes more than half of the total milk (51.06%) produced in the country (during 2014-15) and continues to be the backbone of the dairy industry. But in a tropical country like India, characterized by high ambient temperature acting as the major constraint on animal productivity, the buffaloes are more prone to heat stress (Jat, 2002) [5] which is defined as any combination of environmental variables that give rise to conditions that are higher than those of the temperature range of the animal's thermal neutral zone (Garcýa-Ispierto *et al.* 2007) [3]. Thatcher *et al.* (1978) [12], Collier *et al.* (1982), and Badinga *et al.* (1985) [2] reported that solar radiation and humidity have been identified as major factors contributing to heat stress. Shed is usually a cost effective means of protecting livestock from the amplifying effect of solar radiation coupled with high air temperature. Roofing provides the main protection against direct solar radiation in animal housing (Shearer *et al.*, 2002) [10]. When any shed material interrupts the direct solar radiation, it gets heated up. If the lower side of material becomes hot, it will then radiate heat to the animal body below (Owen, 1994) [7]. As temperature, humidity, solar radiation and other climatic factors that constitute a specific microclimate around the animals are involved in the heat balance; the health of animals is directly related to modification of such factors in adverse climates. So use of highly reflective materials like white paint and low thermal conductive materials like expanded polyethylene sheets can be assessed in roofs to decrease the heat stress in the underneath area.

Material and Methods
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 modified by using different materials to record the surface temperature of roof (both outside and inner side). 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. Infrared thermometer (Phoenix HT-826) was used to record the temperature of the roof surface at 7:00 AM and 2:00 PM weekly.

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) [9]. The data was analyzed using "SPSS" software (version-17).

Results

Roof surface temperature (ST) (^{0}C) of different sheds

Overall roof surface (outerside and inside) temperature of different sheds at 7:00 AM as well as 2:00 PM (fig. 4.3) has been presented in table-1. At 7:00 AM overall outside ST during the experimental period was 33.15±0.40, 31.17±0.24, 33.11±0.37 and 31.23±0.30 and corresponding value at 2:00 PM was 57.17±0.95, 49.47±0.53, 60.39±1.20 and 53.37±0.81 with average values; 45.50±0.30, 40.54±0.32, 46.51±1.01 and 42.54±0.45 in T_1, T_2, T_3 and T_4, respectively. Whereas overall inside ST was 33.52±0.37, 31.78±0.22, 31.32±0.18 and 31.23±0.17 at 7:00 AM and 55.52±1.02, 48.53±0.56, 41.51±0.49 and 40.67±0.40 at 2:00 PM with average values; 44.69±0.49, 40.26±0.38, 36.43±0.31 and 35.98±0.26 in T_1, T_2, T, T_3 and T_4, respectively.

The perusal table reveals that inside and outside roof surface temperature values were almost the same at 7:00 AM. Sometimes the inside temperature was even higher than the outside temperature that may be due to insufficiency in the escape of heat of animals absorbed during night. Further, both the overall outside and inside ST differ significantly (P<0.01) between the groups both at 7:00 AM and 2:00 PM. Overall Surface temperature (^{0}C) of roofs (outer side and inner side) at 2:00 PM has been demonstrated in fig.-1. The overall outside ST at 7:00 AM was significantly higher (P<0.01) in T_1 and T_3 as compared to T_2 and T_4. Similarly, the overall outside ST at 2:00 PM differed significantly (P<0.01) between the treatments except T_1 and T_3 which did not differ significantly and highest values were seen in T_3 and lowest in T_2.

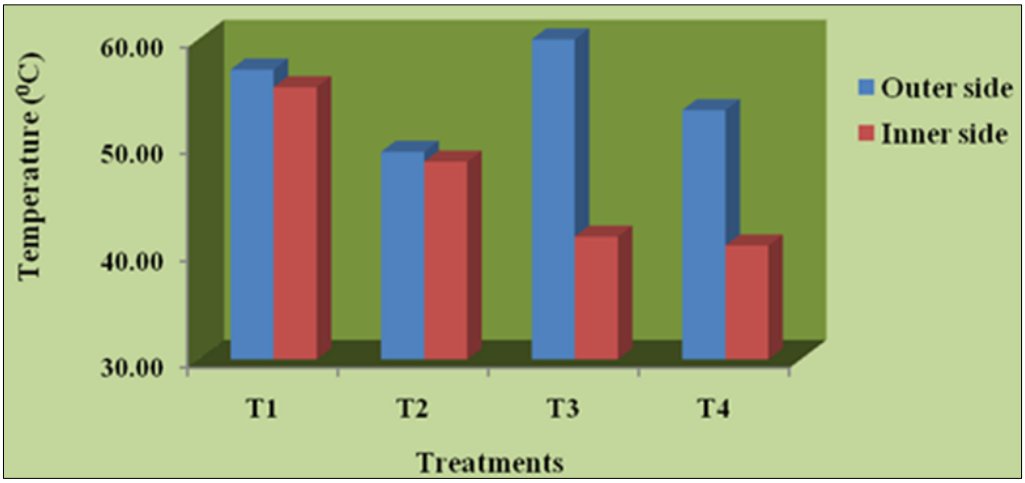

Fig 1: Overall surface temperature of different roofs at 2:00 PM

Table 1: Mean ± SE of roof surface temperature (^{0}C) of different sheds

Fortnight	Surface	Time	Asbestos roof (T_1)	White painted roof (T_2)	EPE sheet roof (T_3)	White painted and EPE sheet roof (T_4)
I	Roof outside	7:00 AM	38.33±2.03	33.00±1.39	37.43±1.78	33.33±2.11
		2:00 PM	55.40±3.06^{ab}	46.76±0.82^{b}	58.02±2.51^{a}	50.28±1.86^{ab}
		Average	47.31±2.27^{a}	39.90±0.65^{b}	47.70±1.61^{a}	41.85±1.39^{ab}
	Roof inside	7:00 AM	38.10±1.84^{a}	33.68±1.12^{ab}	32.38±0.57^{b}	32.48±0.74^{b}
		2:00 PM	54.06±1.16^{a}	47.12±0.85^{b}	42.94±0.61^{c}	42.02±0.94^{c}
		Average	46.24±1.15^{a}	40.41±0.73^{b}	37.55±0.60^{b}	37.23±0.91^{b}
II	Roof outside	7:00 AM	35.54±1.48	32.72±0.87	35.48±1.46	32.50±1.35
		2:00 PM	63.18±1.02^{b}	54.88±0.42^{d}	68.02±0.71^{a}	58.50±0.59^{c}
		Average	49.36±0.71^{a}	43.80±0.53^{b}	51.75±0.82^{a}	45.50±0.73^{b}
	Roof inside	7:00 AM	34.34±1.07	32.06±0.91	32.06±0.57	31.76±0.52
		2:00 PM	60.70±0.86^{a}	53.22±0.42^{b}	45.54±0.56^{c}	44.36±0.53^{c}
		Average	47.52±0.55^{a}	42.64±0.55^{b}	38.80±0.48^{c}	38.06±0.41^{c}
III	Roof outside	7:00 AM	35.32±2.03	33.06±1.45	35.96±2.21	33.72±1.79
		2:00 PM	59.22±2.60^{ab}	51.78±2.00^{b}	65.04±2.86^{a}	57.10±2.50^{ab}
		Average	47.27±2.08	42.42±1.58	50.50±2.28	45.41±1.93
	Roof inside	7:00 AM	35.72±1.96	33.66±1.60	32.50±0.99	32.42±0.95
		2:00 PM	57.68±2.48^{a}	50.24±2.23^{ab}	41.76±2.16^{b}	41.06±2.04^{b}
		Average	46.70±2.01^{a}	41.95±1.84^{ab}	37.13±1.52^{b}	36.74±1.44^{b}
IV	Roof outside	7:00 AM	30.88±1.66	29.98±1.41	30.78±1.90	29.74±1.40

		2:00 PM	53.50±4.65	47.78±2.59	57.00±6.05	51.70±3.20
		Average	42.78±2.91	39.38±1.83	44.49±3.70	41.20±2.13
	Roof inside	7:00 AM	32.45±1.56	31.70±1.50	31.58±1.10	31.43±0.99
		2:00 PM	52.10±5.04	47.45±2.42	40.65±1.88	39.58±1.42
		Average	42.28±3.09	39.58±1.87	36.11±1.39	35.50±1.14
V	Roof outside	7:00 AM	30.36±1.52	29.62±0.90	29.98±1.20	29.64±1.05
		2:00 PM	49.85±2.70	43.53±2.29	53.10±2.85	46.80±2.75
		Average	40.01±2.31	36.53±1.72	39.03±2.95	38.13±2.04
	Roof inside	7:00 AM	30.04±0.93	29.34±0.68	29.56±0.45	29.54±0.41
		2:00 PM	49.70±1.78^{a}	43.50±1.88^{ab}	37.25±2.02^{b}	36.68±2.05^{b}
		Average	39.81±1.49^{a}	36.38±1.37^{ab}	33.41±1.29^{b}	33.13±1.27^{b}
VI	Roof outside	7:00 AM	29.70±0.61	29.00±0.41	30.00±0.71	28.82±0.43
		2:00 PM	60.50±1.44^{a}	50.98±0.97^{b}	60.04±0.45^{a}	54.96±0.80^{b}
		Average	45.10±0.42^{a}	39.99±0.29^{c}	45.02±0.18^{a}	41.89±0.19^{b}
	Roof inside	7:00 AM	31.08±0.69	30.58±0.30	30.06±0.28	30.02±0.24
		2:00 PM	57.90±1.54^{a}	48.88±0.78^{b}	40.12±0.24^{c}	39.46±0.24^{c}
		Average	44.49±0.43^{a}	39.73±0.25^{b}	35.09±0.15^{c}	34.74±0.15^{c}
Overall	Roof outside	7:00 AM	33.15±0.40^{a}	31.17±0.24^{b}	33.11±0.37^{a}	31.23±0.30^{b}
		2:00 PM	57.17±0.95^{a}	49.47±0.53^{c}	60.39±1.20^{a}	53.37±0.81^{b}
		Average	45.50±0.30^{a}	40.54±0.32^{b}	46.51±1.01^{a}	42.54±0.45^{b}
	Roof inside	7:00 AM	33.52±0.37^{a}	31.78±0.22^{b}	31.32±0.18^{b}	31.23±0.17^{b}
		2:00 PM	55.52±1.02^{a}	48.53±0.56^{b}	41.51±0.49^{c}	40.67±0.40^{c}
		Average	44.69±0.49^{a}	40.26±0.38^{b}	36.43±0.31^{c}	35.98±0.26^{c}

Means bearing different superscripts in a row differ significantly (P<0.01)

The overall inside ST was significantly (P<0.01) high in asbestos roof as compared to other treatments both at 7:00 AM and 2:00 PM but corresponding values did not differ significantly between T_2, T_3 and T_4 at 7:00 AM and among T_3 and T_4 at 2:00 PM, respectively. Higher percentage of temperature reduction in T_3 and T_4 shed clearly indicates that these sheds were better to reduce the solar radiation. Asbestos sheet and white paint at 2:00 PM reduced the temperature load up to 1-2 ^{0}C, however; there was a difference of 7 ^{0}C between T_1 and T_2 on the inner side. Both of these were not so effective as compared to T_3 and T_4 which reduced the temperature load up to 19 ^{0}C and 12 ^{0}C, respectively indicating the highly superior thermal insulation power of EPE sheet. Further, there was a difference of 12-15 ^{0}C in the inner side ST between asbestos sheet and EPE sheet during daytime.

The results were in agreement with Sarmento *et al.* (2005) [8] who concluded that white color on the outer surface of the roof reduces the temperature of the inner surface of the shed up to 9.0 °C in the hottest times of the day. Kamal *et al.* (2014) [6] found that the outside ST was significantly higher (P<0.05) than the inner surface in all the shade materials with highest values for asbestos and lowest for agro-net. However, Spain and Spiers (1996) [11] concluded that the inside and outside surface of the hutch in both shaded and unshaded areas did not differ significantly.

Conclusion

So it can be concluded that EPE sheets and white paint can be used to reduce the temperature in the underneath area as compared to existing asbestos roofs. Use of white painted reduces the temperature to a lower extent as compared to EPE sheet sheds which indicates that white painted roof was also insufficient however; the conditions were more favourable as compared to conventional asbestos roof.

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