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Effect of shade materials on rectal temperature, respiration rate and body surface temperature of crossbred calves during rainy season

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ABSTRACT

An attempt was made to study the effect of different shade materials on body surface temperature, rectal and respiration rate in *Vrindavani* calves during the rainy season. Crossbred calves (18) were divided into 3 group, viz. thatch shading roof with plastic covering (T1), agro-net shading roof- 60% light diffusion (T2), and asbestos with canvas shading roof (T3). The recording of macro and microclimate as well as the entire physiological parameters, viz. rectal temperature, respiration rate and body surface temperature were recorded at 9:00 and 2:00 PM for 2 consecutive days at every fortnight interval. The microclimate, viz. maximum and minimum, RH, THI and surface temperature of roof was lower in T2 group. The physiological parameters values were significantly lower in T2 group. It can be concluded that in rainy season agro-net helped to protect calves from the hot and humid condition.

Key words*:* Body surface temperature, Crossbred calves, Rectal temperature, Respiration rate, Shade materials

In Indian climate the extended periods of high ambient temperature coupled with high relative humidity compromise the ability of dairy calves to dissipate excess body heat. Calves with elevated body temperature exhibit lower DMI and growth with less efficiency, reducing profitability for dairy farms in hot, humid climates. Radiation energy flow on animal is 685 kcal/m²h, but actually only 340 kcal/m²h is from the direct solar radiation and rest is by reflection by floor, dust, wall etc. (Thomas and Sastry 2007). As per NRCC (2007) the crossbreds are affected more than indigenous livestock. Physiological responses like rectal temperature, respiration rate and surface body temperature reflect the degree of stress imposed on animals by climatic parameters and are used to assess the ability of an animal to withstand the rigors of climatic stress under warm conditions (Legates *et al*. 1991, Sethi *et al*. 1994). Placing a simple shade over an animal exposed to a hot environment and direct solar radiant energy from the sun cuts the radiant heat load on that animal by about 45% (Blackshaw and Blackshaw 1994). Solar radiation is a major factor in heat stress and increases heat gain by direct as well as indirect means (Shearer *et al.* 2002).

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Different shade materials are used over the manger to protect from direct solar radiation in the open paddock; and type of roof material generally decides the micro climate in the covered area. There are many ways to provide shade, but little is known about the importance of various design features of shade (e.g. blockage of solar radiation, shade amount/animal, etc.). Keeping the importance of housing in tropical country and to exploit positiveness of each roofing material different combination had been tried in this study.

MATERIALS AND METHODS

Location and climatic condition: The present study was conducted at the institute. The institute is located at an altitude of 169 meters above mean sea level, at 28°22' latitude and 79.24° E longitudes. The climate of the place touches both the extremes of hot (approximately 45° C) and cold (approximately 5° C) and relative humidity (RH) ranges between 15 and 99%. Average annual rainfall ranges from 90 to 120 cm, most of which is received during July to September.

Experimental calves: Vrindavani crossbred calves (18) were selected after 3 days of their birth (after colostrum feeding) on staggering basis. Thereafter, the calves were not allowed to suckle the dams and were artificially milk fed separately. Six calves were allocated to each of the following treatments keeping average birth weight and sex into consideration. Each group was kept at different places which had covered area as well as open area. However, different shade material was used for covered area under each treatment.

Experimental design

- T1 (thatch with polythene shading roof): Layer of paddy straw of four inch thickness over which plastic material was tied.
- T2 (agro-net shading roof): Green and black knitted fabric made out of 100% high density polyethylene with ultra violet stabilized having 60% light diffusion.
- T3 (asbestos with canvas shading roof): Asbestos sheet on which canvas were laid over outer surface ensuring 2–3 inch gap between them.

Long axis of the paddock was oriented east-to-west. Different shade materials were used to make covered area measuring 1.5 m × 1 m (excluding manger) for each treatment groups. The open paddock measuring 2 m × 1 m was made using welded wire mesh. The calves were let loose in the above mentioned area. Height of shed at eaves was 2.5 m and had brick on edge floor.

Feeding and health management for the experimental animals: The calves remained with dams for two days after calving. On third day, calves were shifted to the treatment groups and maintained as per the standard recommendation i.e. from 4–28 days of age 1/10th of body weight, from 29–42 days 1/15th and from 43–56 days 1/20th of body weight, the whole milk was fed to individual calves. The desired quantity of milk was offered by pail method and left over was also recorded.

Green fodder and calf starter were offered from first week onwards. The common green fodder supplied was berseem/maize/jowar. Calf starter prepared by Feed Technology Unit was utilized for the experiment consisting of crushed maize, soybean oil cake, wheat bran, mineral mixture and common salt. All the calves were reared under strict management and proper hygienic conditions throughout the period of the study.

Environmental observations: Macro and micro climatic condition was recorded daily at 9:00 AM and 2:00 PM. Daily recording of temperature (maximum and minimum) was measured by maximum and minimum thermometer and relative humidity (RH) by psychometric chart with the help of dry and wet bulb reading which was hanged by thread in covered area underneath the roof. Temperature humidity index (THI) was calculated as per McDowell (1972) using the following formula.

THI= 0.72 (wet bulb temperature + dry bulb temperature) +40.6

Physiological variables: Physiological variables such as rectal temperature, respiratory rates and body surface temperature (ST) of calves was recorded at fortnightly intervals for two consecutive days at 9:00 AM and 2:00 PM. Rectal temperature was recorded by using a digital clinical thermometer. Respiration rate was counted from a distance by observing flank movements and expressed as counts per minute. Body ST was recorded from infrared digital thermometer keeping it 2–3 inch away from the desired surface.

Statistical analysis: The data obtained from the study were analyzed as per Snedecor and Cochran (1994).

RESULTS AND DISCUSSION

Environmental observation

Macro climate during rainy season: The macro climatic conditions were more stressful during the experimental period (Table 1). The overall mean THI was above comfortable range (>72), during the course of study, (84.55±0.19), however, maximum THI observed during first fortnight was due to high ambient temperature. It was estimated that an average THI between 35 and 72 enhanced the milk yield of high producing Holstein dairy animals throughout the year. However, the THI tolerance varied in Criollo and in European dairy and beef type cattle depending on acclimatization and acclimation (Johnson *et al.* 1962, 1965, West 2003) genetic adaptability and level of feeding (Olbrich *et al.* 1971).

Micro climate during rainy season

Minimum and maximum (°C) temperature of micro climate: Both at 9:00 AM and 2:00 PM T2 showed lowest temperature and differ significantly (P<0.05) with other groups (Table 2). The minimum temperature was more in T1 and T3 could be attributed to ineffective loss of absorbed heat and poor ventilation by the shade material used in respective group. Roy and Chatterjee (2010) reported that polythene sheet roof had the lowest minimum and higher

Table 1. Mean±SEM Macro climate during rainy season

Fortnights	Solar radiation (W/m^2)	Wind speed (m/sec)	Ambient temperature (°C)			Relative humidity (%)			Temperature humidity index (THI)		
			Minimum	Mean	Maximum	9:00 AM	2:00 PM	Mean	9:00AM	2:00 PM	Mean
I	183.00±12.44	0.77±0.08	28.24±0.22	32.56±0.51	37.32±0.81	68.80±2.13	60.51±1.68	64.66±1.54	86.30±0.43	92.32±0.48	89.31±0.41
II	146.47±14.79	0.38±0.10	26.20±0.31	29.19±0.55	32.63±0.82	85.00±1.40	81.18±2.33	83.09±1.38	81.62±0.53	84.16±1.02	82.89±0.73
III	115.53±8.67	0.27±0.05	26.13±0.24	28.02±0.26	31.21±0.48	85.33±1.31	82.12±2.80	83.73±1.55	82.62±0.46	85.00±0.90	83.81±0.60
IV	167.87±9.92	0.39±0.09	26.07±0.19	28.88±0.26	32.72±0.28	85.75±1.92	74.78±2.46	80.27±1.84	82.41±0.41	85.34±0.54	83.87±0.42
V	130.60±13.86	0.33±0.04	25.13±0.25	27.39±0.34	30.70±0.50	86.87±1.22	77.85±2.44	82.36±1.58	81.98±0.55	84.66±0.78	83.32±0.62
VI	149.33±16.05	0.61±0.14	25.11±0.40	27.64±0.57	31.08±0.80	80.57±1.81	70.13±2.52	75.35±1.81	82.50±0.52	85.67±0.63	84.09±0.56
Overall	148.80±5.06	0.46±0.03	26.15±0.13	28.95±0.17	32.61±0.25	82.05±0.53	74.43±0.50	78.24±0.79	82.90±0.18	86.19±0.25	84.55±0.19

Mean bearing different superscript differ significantly (P<0.05) row wise.

maximum temperature as compared to GI sheet, and tile roof shade structure in rainy season, whereas Jat *et al*. (2005) reported significantly (P<0.01) lower maximum temperature in thatch and mud plaster roof house than loose house with asbestos sheet shade and barn house, and also reported nonsignificant difference between morning and evening temperature between different shade structure. Similarly, Sharma and Singh (2002) reported higher minimum and maximum temperature in August in loose housing system while in closed housing minimum temperature was higher in July, September and November. Singh *et al.* (1989) observed significantly higher (P<0.05) mean maximum temperature (45.02±0.59) and lower mean minimum temperature (24.37±0.22) in literoof as compared to thatch and asbestos round the season.

Relative humidity (%) of micro climate: The RH was maximum (P<0.05) in T1 followed by T3 and was less in T2 both at 9:00AM and 2:00PM (Table 3. The negative diurnal changes in RH were observed in all the shades during rainy season due to rise in environmental temperature from morning to mid day as routine phenomenon as reported earlier by Kaur and Singh (2004) and supported by Roy and Chatterjee (2010). Agro-net in T2 group did not give any chance for increment in RH between morning and afternoon. Further values were comparatively lower in T2 than T1 and T3, and differ significantly (P<0.01). This might be due to the fact that the moisture resistant characteristic and proper ventilation through their net type structure allows the ground below to dry out. The present findings are also supported by Roy and Chatterjee (2010) who reported significantly higher (P<0.01) RH (>72) in morning and evening in all the shelters (GI sheet, tiles and polythene shade) during rainy season indicating thereby stress on the

Table 2. Mean±SEM of minimum and maximum temperature (°C) of micro climate

Fortnights	Time	Thatch (T1)	Agro-net (T2)	Asbestos (T3)
I	9:00AM	27.93±0.40^{c}	24.47±0.54^{a}	26.17±0.27^{b}
	2:00PM	36.00±0.24^{a}	35.73±0.28^{a}	37.27±0.27^{b}
	Avg.	31.97±0.25^{b}	30.10±0.31^{a}	31.72±0.21^{b}
II	9:00AM	25.73±0.36^{c}	21.73±0.43^{a}	23.27±0.44^{b}
	2:00PM	29.53±1.03	30.33±0.88	31.13±1.01
	Avg.	27.63±0.59	26.03±0.61	27.20±0.67
III	9:00AM	24.80±0.37^{c}	21.40±0.29^{a}	23.40±0.31^{b}
	2:00PM	30.60±0.63	31.07±0.60	31.40±0.63
	Avg.	27.70±0.42^{b}	26.23±0.40^{a}	27.40±0.41^{b}
IV	9:00AM	24.13±0.34^{b}	21.00±0.32^{a}	23.73±0.33^{b}
	2:00PM	32.33±0.35^{a}	32.67±0.42^{a}	34.67±0.41^{b}
	Avg.	28.23±0.27^{b}	26.83±0.32^{a}	29.20±0.33^{c}
V	9:00AM	23.60±0.58^{b}	20.93±0.44^{a}	23.47±0.52^{b}
	2:00PM	30.20±0.48^{a}	31.40±0.63^{a}	33.27±0.49^{b}
	Avg.	26.90±0.50^{a}	26.17±0.51^{a}	28.37±0.46^{b}
VI	9:00AM	23.67±0.27^{b}	21.07±0.43^{a}	23.33±0.37^{b}
	2:00PM	31.93±0.49	32.00±0.79	33.93±0.86
	Avg.	27.80±0.34^{ab}	26.53±0.56^{a}	28.63±0.59^{b}
Overall	9:00AM	24.98±0.17^{c}	21.77±0.11^{a}	23.89±0.17^{b}
	2:00PM	31.77±0.26^{a}	32.20±0.24^{a}	33.61±0.26^{b}
	Avg.	28.37±0.20^{b}	26.98±0.16^{a}	28.75±0.21^{b}

Means bearing different superscript in a row differ significantly: P<0.05.

Table 3. Mean±SEM of relative humidity (%) of micro climate

Fortnights	Time	Thatch (T1)	Agro-net (T2)	Asbestos (T3)
I	9:00AM	80.87±2.40^{b}	50.53±2.02^{a}	78.60±1.79^{b}
	2:00PM	79.35±1.94^{c}	48.43±1.98^{a}	66.46±2.34^{b}
	Overall	80.11±1.53^{c}	49.48±1.64^{a}	72.53±1.70^{b}
II	9:00AM	90.80±1.27^{b}	62.53±0.85^{a}	88.07±1.22^{b}
	2:00PM	89.59±1.44^{b}	62.83±2.41^{a}	83.65±2.43^{b}
	Overall	90.19±1.12^{b}	62.68±1.39^{a}	85.86±1.53^{b}
III	9:00AM	89.75±0.85^{b}	59.76±1.40^{a}	86.72±1.43^{b}
	2:00PM	91.89±0.42^{c}	65.47±2.03^{a}	83.51±2.36^{b}
	Overall	90.82±0.54^{c}	62.61±1.48^{a}	85.11±1.77^{b}
IV	9:00AM	89.77±1.07^{b}	63.13±1.84^{a}	79.52±1.87^{b}
	2:00PM	86.40±1.27^{c}	60.51±1.77^{a}	75.87±1.70^{b}
	Overall	88.08±0.92^{c}	61.82±1.61^{a}	77.69±1.54^{b}
V	9:00AM	91.55±0.40^{c}	67.20±1.60^{a}	80.98±1.26^{b}
	2:00PM	90.03±0.80^{c}	68.02±1.85^{a}	76.87±1.68^{b}
	Overall	90.79±0.51^{c}	67.61±1.46^{a}	78.92±1.22^{b}
VI	9:00AM	88.77±0.95^{b}	67.40±2.62^{a}	82.11±1.79^{b}
	2:00PM	83.27±1.37^{b}	69.83±1.93^{a}	75.01±2.78^{a}
	Overall	86.02±0.93^{c}	68.61±2.10^{a}	78.56±2.11^{b}
Overall	9:00AM	88.58±0.36^{c}	61.76±0.42^{a}	82.67±0.46^{b}
	2:00PM	86.75±0.40^{c}	62.51±0.62^{a}	76.89±0.66^{b}
	Overall	87.67±0.29^{c}	62.14±0.43^{a}	79.78±0.46^{b}

Mean values between 9:00 AM & 2:00 PM differ significantly (P<0.05) within the treatments. Means bearing different superscript in a row differ significantly: P<0.05.

Table 4. Mean±SEM of THI of micro climate

Fortnights	Time	Thatch (T1)	Agro-net (T2)	Asbestos (T3)
I	9:00AM	79.82±0.45^{b}	78.42±0.53^{a}	80.44±0.46^{b}
	2:00PM	84.42±1.72	84.69±0.53	87.18±0.58
	Overall	82.12±0.91^{ab}	81.56±0.49^{a}	83.81±0.46^{b}
II	9:00AM	73.38±0.67^{ab}	72.33±0.84^{a}	74.68±0.63^{b}
	2:00PM	76.91±1.18	77.01±1.12	78.16±0.92
	Overall	75.15±0.85	74.67±0.89	76.42±0.66
III	9:00AM	74.82±0.65^{ab}	73.05±0.79^{a}	76.07±0.59^{b}
	2:00PM	77.97±0.79	76.50±0.87	78.76±0.85
	Overall	76.40±0.62^{ab}	74.78±0.72^{a}	77.42±0.64^{b}
IV	9:00AM	77.18±0.58	76.12±0.69	77.54±0.56
	2:00PM	79.58±0.64	79.05±0.71	80.10±0.79
	Overall	78.38±0.52	77.58±0.62	78.82±0.57
V	9:00AM	75.64±0.67	74.78±0.64	76.22±0.55
	2:00PM	78.42±0.69	77.66±0.92	78.76±0.79
	Overall	77.03±0.64	76.22±0.73	77.49±0.62
VI	9:00AM	77.08±0.72	76.02±0.82	77.99±0.62
	2:00PM	79.43±0.62	79.24±0.88	80.54±0.65
	Overall	78.26±0.66	77.63±0.83	79.26±0.61
Overall	9:00AM	76.32±0.24^{b}	75.12±0.25^{a}	77.16±0.24^{c}
	2:00PM	79.46±0.49^{a}	79.02±0.27^{a}	80.58±0.27^{b}
	Overall	77.89±0.30^{b}	77.07±0.23^{a}	78.87±0.22^{c}

Mean values between 9:00 AM and 2:00 PM differ significantly (P<0.05) within the treatments. Means bearing different superscript in a row differ significantly: P<0.05.

animals (Adam 2006), whereas, Das (2012) observed highest RH in GI sheet roof (80.00±1.90) during rainy season.

Temperature humidity index (THI) of micro climate: At 9:00 AM, THI was significantly more (P<0.05) in T3 followed by T1 and T2 (Table 4), whereas at 2:00 PM, T3 showed significantly more (P<0.05) THI as compared to T1 and T2. It is clear that the morning and evening THI values exceeded critical value of 72 (Johnson 1987) and ranged between 72.33±0.84 to 87.18±0.58 indicating that the crossbred calves in all the shade material were in mild stress (Chase 2008) during rainy season also. However, the THI value was comparatively lower for T2 group calves as compared to T1 and T3 which might be due to less penetration of solar radiation (ultra-violet stabilizer) inside the shed (Singh 2000) and proper heat exchange characteristic of respective shade material.

The present finding is also supported by Khongdee (2008), who concluded that the difference between maximum and minimum THI during the rainy season was lower suggesting that the dairy cows were exposed to heat stress conditions more consistently during the rainy season.

Table 5. Mean±SEM of surface temperature (ST) (°C) of different shade material

Fortnights	Surface	Time	Thatch (T1)	Agro-net (T2)	Asbestos (T3)
I	Roof outside	9:00 AM	77.23±0.84^{c}	40.56±1.95^{a}	64.45±2.78^{b}
		2:00 PM	80.14±0.97^{c}	40.14±1.25^{a}	65.28±0.28^{b}
		Overall	78.68±0.07^{c}	40.35±1.60^{a}	64.86±1.53^{b}
	Roof inside	9:00 AM	40.28±2.78^{ab}	26.39±2.50^{a}	49.03±5.42^{b}
		2:00 PM	43.47±2.64^{b}	28.47±1.25^{a}	55.56±1.12^{c}
		Overall	41.88±0.07^{b}	27.44±1.88^{a}	52.30±3.27^{c}
II	Roof outside	9:00 AM	46.25±17.08	29.14±0.31	39.45±5.56
		2:00 PM	45.14±2.64	30.00±0.56	45.42±5.70
		Overall	45.70±9.87	29.57±0.43	42.43±0.07
	Roof inside	9:00 AM	27.50±0.28^{ab}	24.45±0.28^{a}	30.56±1.95^{b}
		2:00 PM	29.17±0.00^{a}	26.94±2.50^{a}	38.34±1.95^{b}
		Overall	28.33±0.14^{ab}	25.70±1.39^{a}	34.45±1.95^{b}
III	-Roof outside	9:00 AM	62.92±0.42^{c}	30.28±0.84^{a}	45.00±0.00^{b}
		2:00 PM	47.50±0.28^{c}	29.17±1.39^{a}	39.72±0.00^{b}
		Overall	55.21±0.35^{c}	29.72±0.28^{a}	42.36±0.00^{b}
	--Roof inside	9:00 AM	27.36±0.14^{b}	24.45±0.28^{a}	28.61±0.00^{c}
		2:00 PM	29.31±0.14^{b}	24.03±0.42^{a}	36.39±0.00^{c}
		Overall	28.33±0.14^{b}	24.24±0.07^{a}	32.50±0.00^{c}
IV	Roof outside	9:00 AM	55.14±19.31	34.72±2.22	59.72±7.50
		2:00 PM	65.28±14.17	35.14±5.42	56.53±12.36
		Overall	60.21±16.74	34.93±3.82	58.13±9.94
	Roof inside	9:00 AM	29.17±3.06	28.48±0.42	43.06±7.50
		2:00 PM	33.20±3.20	25.83±3.89	44.03±6.53
		Overall	31.19±3.13	27.16±1.74	43.55±7.02
V	Roof outside	9:00 AM	51.81±12.64	29.17±2.78	48.61±12.50
		2:00 PM	51.25±11.25	29.59±2.92	48.34±11.67
		Overall	51.53±11.95	29.38±2.85	48.48±12.09
	Roof inside	9:00 AM	27.09±2.09	24.59±1.81	36.53±9.31
		2:00 PM	29.87±4.31^{b}	23.89±0.56^{a}	40.42±12.64^{c}
		Overall	28.48±3.20	24.24±1.18	38.47±10.97
VI	Roof outside	9:00 AM	52.64±1.53^{b}	35.84±0.84^{a}	60.97±0.97^{c}
		2:00 PM	55.14±1.25^{b}	36.81±0.42^{a}	65.70±0.70^{c}
		Overall	53.89±1.39^{b}	36.32±0.21^{a}	63.34±0.84^{c}
	Roof inside	9:00 AM	32.23±0.56^{b}	25.70±0.70^{a}	50.84±0.84^{c}
		2:00 PM	34.45±1.67	24.03±1.25	50.42±0.98
		Overall	33.33±1.11^{b}	24.86±0.97^{a}	50.63±0.91^{c}
Overall	Roof outside	9:00 AM	57.66±1.69 ^{c}	33.28±0.19 ^{a}	53.03±2.06 ^{b}
		2:00 PM	57.41±0.37 ^{c}	33.48±0.19 ^{a}	53.50±1.14 ^{b}
		Overall	57.54±0.66 ^{c}	33.38±0.19 ^{a}	53.27±0.47 ^{b}
	Roof inside	9:00 AM	30.60±0.14^{b}	25.67±0.58^{a}	39.77±0.74^{c}
		2:00 PM	33.25±0.56^{b}	25.54±0.91^{a}	44.19±0.72^{c}
		Overall	31.92±0.21^{b}(79.94%)	25.60±0.16^{a}(30.39%)	41.98±0.73^{c}(26.89%)

Mean values between 9:00 AM and 2:00 PM differ significantly (P<0.05) within the treatments. Mean bearing different Superscript differ significantly (P<0.05) row wise. Value given in parenthesis indicate % of temperature reduction inside the surface compare to outside.

However, the shade of polypropylene had a significantly lower ambient temperature and THI (P<0.05) for 5 h and 5 h 30 min, respectively, a difference most likely due to the reduction in re-radiated heat in the Shaded shed. Pusta *et al*. (2006) reported higher THI (>72) in pasture heifers in the month of rainy season as compared to cows during lactation. Jat *et al*. (2005) recorded higher THI in asbestos in morning (81.52±0.35) and evening (85.71±0.51) as compared to mud plaster and less in thatch during rainy season, whereas, Das (2012) and Roy and Chatterjee (2010) observed higher THI (83.48±0.52) under GI sheet roof.

Surface temperature (ST) (°C) of different shade material: ST both inside and outside was more during first fortnight (Table 5). This could be due to no rainfall during this period. However, corresponding values relatively were less in the subsequent fortnights and remained consistent throughout the experimental period. Such results could be due to intermittent rainfall which happened mostly during night hour. The overall outside ST was significantly higher (P<0.05) for T1 followed by T3 and lowest for T2. However, inside ST was comparatively very less (P<0.05) in T1 as compared to T3. Percentage of temperature reduction inside the surface compared to outside was 79.94, 30.39, and 26.89% for T1, T2 and T3 respectively. The higher difference between outside and inside ST in T1 could be due to intermittent rainfall which happened mostly during night hour led to the absorption of moisture by the straw. Further, the polythene laid on the outer surface use to dry and absorbs heat during the morning hour which resulted to high outside ST.

The ST data clearly indicated that the agro-net was better to reduce the solar radiation by their ultra violet stabilizer characteristic compared to other shade materials. However, according to Spain and Spiers (1996) the inside and outside surface of hutch in both shaded and unshaded area did not differed significantly.

Rectal temperature (°C) of calves: The rectal temperature of calves (Table 6) at 2:00PM was significantly higher (P<0.05) than rectal temperature at 9:00AM in all the groups throughout the experiment with few exception in T1; this might be due to fluctuating solar radiation and wind speed during the course of experiment and the ability of the animal to maintain homoeothermy. The rectal temperature both at 9:00AM and 2:00PM was higher in T3 and T1 grouped calves as compared to T2 grouped calves. The significant rise in rectal temperature in T3 and T1 grouped calves might be due to high THI under the shade and thus inability to eliminate excess heat.

Khongdee *et al.* (2006) reported nearly 1°C less rectal temperature in double shaded polypropylene shade cloth house as compared to single shaded which indicated that shade was successful in reducing heat stress of cows maintained in double shade. Das (2012) observed that the atmospheric temperature and RH had significant (P<0.05) effect but THI had highly significant (P<0.01) effect on the rectal temperature of the calves. It was also observed that rectal temperature, were increased significantly (P<0.05)

Table 6. Mean±SEM of rectal temperature (°C) of calves

Fortnights	Time	Thatch (T1)	Agro-net (T2)	Asbestos (T3)
I	9:00AM	39.73 ± 0.12	$39.44\pm0.11^{*}$	$39.60\pm0.09^{*}$
	2:00PM	39.87 ± 0.10^{b}	$39.53\pm0.12^{a*}$	$39.68\pm0.06^{ab*}$
	Overall	39.80 ± 0.10^{b}	39.48 ± 0.11^{a}	39.63 ± 0.07^{ab}
II	9:00AM	$39.21\pm0.12^{b*}$	$38.94\pm0.06^{a*}$	39.18 ± 0.06^{ab}
	2:00PM	$39.16\pm0.11^{ab*}$	$39.04\pm0.06^{a*}$	39.33 ± 0.06^{b}
	Overall	39.18 ± 0.11^{ab}	38.99 ± 0.05^{a}	39.25 ± 0.06^{b}
III	9:00AM	$39.31\pm0.15^{b*}$	$38.96\pm0.07^{a*}$	39.09 ± 0.04^{ab}
	2:00PM	$39.26\pm0.13^{*}$	$39.03\pm0.08^{*}$	39.24 ± 0.08
	Overall	39.28 ± 0.14^{b}	38.99 ± 0.07^{a}	39.17 ± 0.05^{ab}
IV	9:00AM	39.51 ± 0.09	39.73 ± 0.10	$39.69\pm0.12^{*}$
	2:00PM	39.64 ± 0.11	39.88 ± 0.13	$39.77\pm0.11^{*}$
	Overall	39.58 ± 0.09	39.80 ± 0.11	39.73 ± 0.11
V	9:00AM	39.38 ± 0.13^{a}	39.19 ± 0.11^{a}	39.71 ± 0.06^{b}
	2:00PM	39.73 ± 0.06^{b}	39.44 ± 0.08^{a}	39.89 ± 0.05^{b}
	Overall	39.56 ± 0.09^{b}	39.31 ± 0.08^{a}	39.80 ± 0.05^{c}
VI	9:00AM	39.46 ± 0.09^{a}	39.46 ± 0.08^{a}	39.79 ± 0.07^{b}
	2:00PM	39.60 ± 0.08^{a}	39.56 ± 0.09^{a}	39.94 ± 0.05^{b}
	Overall	39.53 ± 0.08^{a}	39.51 ± 0.08^{a}	39.86 ± 0.05^{b}
Overall	9:00AM	39.43 ± 0.05^{b}	39.28 ± 0.04^{a}	39.51 ± 0.04^{b}
	2:00PM	39.54 ± 0.05^{b}	39.41 ± 0.03^{a}	39.64 ± 0.04^{b}
	Overall	39.49 ± 0.05^{b}	39.35 ± 0.03^{a}	39.58 ± 0.04^{b}

Mean bearing different superscript differs significantly (P<0.05) row wise. *Nonsignificant between 9:00 AM and 2:00 PM within the treatments.

by 0.13, 0.01 and 0.25 °C with the unit increase of air temperature, RH and THI.

Respiration rate (per minute) of calves: The respiration rate (per minute) at 9:00 AM in all the shade materials throughout the experiment (Table 7). Respiration rate at 9:00 AM were significantly higher (P<0.05) in T3 followed by T1 whereas at 2:00 PM respiration rate was significantly higher (P<0.05) only in T3. However, at both 9:00AM and 2:00 PM respiration rate for T2 grouped calves was significantly low (P<0.05), which showed better micro environment provided by the respective shade material.

The higher respiration rate in T3 and T1 might be attributed to more heat load which gets rid off by increased pulmonary evaporative cooling through respiratory channel (Gangwar *et al*. 1980).

Das (2012) reported that respiration rate increased significantly (P<0.05) by 2.48 to 8.62/min with the unit increase in air temperature, RH and THI. Khongdee *et al.* (2008) concluded that RR in cattle 20 breaths/min indicated cool conditions and 80 breath/min indicated very warm conditions. They also observed that the cows in the double shade house (polypropylene shade cloth) had lower respiration rate than that of their counter parts cows in the adjacent single shade animal house and is consistent with the findings of other studies (Johnson 1987, West 2003, Khongdee *et al.* 2006). Increased RR or panting by cows, although not as effective as sweating for evaporative cooling, but it is needed to maintain homeothermy during exposure to increased heat load (Ingram and Mount 1975).

Surface temperature (ST) (°C) at different body locations

Table 7. Mean±SEM of respiration rate (per minutes) of calves

Fortnights	Time	Thatch (T1)	Agro-net (T2)	Asbestos (T3)
I	9:00AM	23.58±0.66^{b}	20.83±0.34^{a}	23.58±0.29^{b}
	2:00PM	31.67±0.43^{a}	32.17±0.56^{a}	48.42±0.87^{b}
	Overall	27.63±0.44^{a}	26.50±0.25^{a}	36.00±0.47^{b}
II	9:00AM	25.17±0.42^{b}	20.83±0.39^{a}	26.83±0.49^{c}
	2:00PM	31.25±0.66^{a}	31.25±0.65^{a}	48.33±0.75^{b}
	Overall	28.21±0.26^{b}	26.04±0.35^{a}	37.58±0.37^{c}
III	9:00AM	25.08±0.57^{b}	21.92±0.40^{a}	26.58±0.42^{c}
	2:00PM	32.92±0.51^{a}	31.42±0.92^{a}	48.25±0.82^{b}
	Overall	29.00±0.35^{b}	26.67±0.47^{a}	37.42±0.46^{c}
IV	9:00AM	24.67±0.77^{b}	21.92±0.29^{a}	27.25±0.48^{c}
	2:00PM	32.42±0.56^{a}	31.92±0.71^{a}	47.58±0.63^{b}
	Overall	28.54±0.47^{b}	26.92±0.40^{a}	37.42±0.29^{c}
V	9:00AM	25.92±0.51^{b}	22.33±0.36^{a}	27.17±0.55^{c}
	2:00PM	32.00±0.59^{a}	31.50±0.71^{a}	47.50±0.58^{b}
	Overall	28.96±0.50^{b}	26.92±0.34^{a}	37.33±0.49^{c}
VI	9:00AM	28.67±0.97^{b}	21.92±0.34^{a}	28.50±0.63^{c}
	2:00PM	32.92±0.68^{b}	30.67±0.62^{a}	48.08±0.45^{c}
	Overall	30.79±0.64^{b}	26.29±0.34^{a}	38.29±0.34^{c}
Overall	9:00AM	25.51±0.31^{b}	21.63±0.27^{a}	26.65±0.35^{c}
	2:00PM	32.19±0.44^{a}	31.49±0.64^{a}	48.03±0.54^{b}
	Overall	28.85±0.26^{b}	26.56±0.31^{a}	37.34±0.27^{c}

Mean values between 9:00 AM & 2:00 PM differ significantly (P<0.05) within the treatments.Mean bearing different Superscript differ significantly (P<0.05) row wise.

Table 8. Mean±SEM of mean body Surface temperature (ST) (°C) at different body locations of calves

Body location	Time	Thatch (T1)	Agro-net (T2)	Asbestos (T3)
Forehead	9:00AM	36.54±0.35	36.62±0.36	36.06±0.27
	2:00PM	38.79±0.29	39.09±0.43	38.77±0.40
Neck	9:00AM	35.86±0.42	35.75±0.40	35.64±0.38
	2:00PM	38.15±0.32	38.27±0.28	37.92±0.30
Shoulder	9:00AM	36.61±0.31	36.50±0.30	36.08±0.25
	2:00PM	38.36±0.27	38.61±0.36	37.94±0.28
Fore-limb	9:00AM	34.94±0.31	35.03±0.31	34.27±0.30
	2:00PM	37.21±0.32^{b}	37.51±0.35^{b}	36.08±0.27^{a}
Knee	9:00AM	34.25±0.38	33.26±0.37	33.97±0.28
	2:00PM	36.69±0.31	36.54±0.38	35.87±0.32
Fore-digits	9:00AM	33.16±0.36^{b}	32.24±0.36^{ab}	31.87±0.32^{a}
	2:00PM	36.21±0.30^{b}	35.93±0.36^{b}	34.46±0.36^{a}
Back	9:00AM	37.59±0.37	37.55±0.40	37.09±0.39
	2:00PM	38.77±0.39	39.41±0.40	38.92±0.38
Thigh	9:00AM	36.30±0.40^{b}	35.58±0.37^{ab}	35.04±0.32^{a}
	2:00PM	38.25±0.35^{b}	37.43±0.33^{b}	36.39±0.34^{a}
Hind-limb	9:00AM	35.65±0.40^{b}	33.75±0.35^{a}	34.86±0.31^{b}
	2:00PM	37.83±0.36^{c}	36.41±0.30^{b}	35.51±0.22^{a}
Hock	9:00AM	34.32±0.38	33.78±0.38	34.02±0.37
	2:00PM	37.11±0.37^{b}	36.37±0.29^{b}	34.87±0.33^{a}
Hind-digits	9:00AM	33.44±0.36^{b}	32.28±0.30^{a}	31.95±0.35^{a}
	2:00PM	36.86±0.29^{b}	35.53±0.27^{a}	35.04±0.26^{a}
Overall	9:00AM	35.33±0.29	34.76±0.27	34.62±0.21
	2:00PM	37.66±0.26^{b}	37.37±0.26^{b}	36.53±0.21^{a}

All mean values between 9:00 AM & 2:00 PM differ significantly (P<0.05) within the treatments.Mean bearing different Superscript differ significantly (P<0.05) row wise.

of calves: The body ST at different sites were low (P<0.05) at 9:00 AM and about 2–5 °C higher at 2:00 PM throughout the experiments (Table 8). The mean ST measured at different sites of the calf body fortnightly suggested that the maximum body ST on back region followed by forehead, neck, shoulder, thigh, forelimb and hindlimb whereas minimum in knee, fore-digits, hock and hind-digits region among all the body parts. This might be attributed to portion of body surface area exposed to solar radiation.

The body ST in T3 group calves were significantly (P<0.05) lower at all the different body locations in comparison to T1 and T2 throughout the experiment, in spite of high THI inside the shade.

This might be due to increased sweating (Hansen 2004) which led to cooling of the skin surface resulting in low surface body temperature in T3 grouped calves. Whereas, under T1 and T2 the sweating would not have started to cool the ST and high temperature could have increased the temperature of hairy skin coat only. The ability of an animal to withstand the rigor of climatic stress under warm conditions is assessed physiologically by changes in body ST (RR; Amakiri and Funsho 1979, Legates *et al*. 1991, Nienaber *et al*. 2003). It is well known that environmental temperature affects skin ST (Arp *et al.* 1983, Chaiyabutr *et al*. 1987, Piccione *et al*. 2003) and different body locations differ in their ability to dissipate heat. Therefore, ST variation at different locations under different shade material was obvious as in the present study. According to Singh and Singh (2006) the changes in skin temperature at various sites indicated that temperature of skin surface not only varies with the change in the environmental temperature but also varied in different parts of the body at a particular period of time.

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