Indian Journal of Animal Sciences **88** (8): 949–954, August 2018/Article

Effect of modified housing on growth and physiological performance of crossbred dairy calves during the summer

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Received: 6 March 2018; Accepted: 17 May 2018

ABSTRACT

The present study was conducted on crossbred (Vrindavani) cattle calves to evaluate the effect of modified housing using different roofing materials on growth and physiological performance of calves during the summer. Calves (24; 6–8 months old) were randomly selected and allocated in 4 groups, viz. control (C): corrugated cemented sheet (CCS) as roofing material, T1: the CCS roof was painted black inside and white outside, T2: polycarbonate plastic sheet as roof; and T3: polycarbonate roof with adjustable height. Overall the average temperature of shed was significantly lower in T1 (24.89±0.08) followed by T3 (27.30±0.10), T2 (28.28±0.04) and C (29.46±0.16). Overall average relative humidity (%) was significantly lower in T3 (62.38±0.30) as compared to T1 (64.54±0.14), T2 (65.68±0.23) and C (66.30±0.30). Overall average temperature humidity index was significantly lower in T1 (76.32±0.30) followed by T3 (76.50±0.16), T2 (77.91±0.05) and C (78.74±0.25). Total body wt gain (kg) was significantly higher in T3 (35.67), followed by T1 (34.83), T2 (34.1) and C (28.16). Overall rectal temperature (°C) and respiration rate (per minute) in afternoon was significantly higher in control as compared to all other treatment groups. It may be inferred that the micro-environment was more conducive in T1 and T3 than control; hence the reflective paints on roof and adjusted higher height of polycarbonate roof may be the desirable choice for animal housing in view of mitigating heat stress during the summer.

Key words: Adjustable height, Corrugated cemented sheet, Livestock housing, Painted roof, Polycarbonate roofing

High yielding animals mainly the crossbred cattle are more sensitive to heat stress and climatic extremes in northern plains of India. Longer periods of high environmental temperature coupled with high relative humidity compromise the ability of the dairy animals to dissipate excess body heat (Marai *et al.* 2009). Housing design and the materials used for roofing play important roles in modifying the microclimate and reducing the radiant heat load inside the shed (Vanlaer *et al*. 2014). Most commonly used roofing materials include thatch, clay tiles, reinforced cement concrete (RCC), galvanized iron (GI) sheets, tin, asbestos and plastic sheets, which reduce solar radiation on the sheltered animal with different efficiencies. Now-a-days polycarbonate sheets as roofing materials are being used in many agro-industries and commercial buildings by virtue of its light weight, easy portability and installation. These materials can prevent animals from negative effect of ultraviolet rays and are found to be resistant to heat and rain (Sanjay and Prabha Chand 2008). Being lighter in nature it can also be used in livestock shed with adjustable height based on requirement. Simultaneously, some reflective paints can also be used in animal houses for reducing the heat load inside the shed. Paints when applied on roof top reflect solar radiation and thus help in reducing heat load under the roof (Thomas and Sastry 2012). From the perusal of literature, there is lack of information on use of these reflective roofing materials in livestock housing. Housing modification in animal sheds using polycarbonate sheets as roofing materials with height adjustment may provide better micro-environment and consequently enhanced performance. Alternately, animal housing with reflective paint on corrugated cemented sheet roof may also provide comfortable shelter. Therefore, keeping all the facts in view, the present study was carried out to evaluate the effect of different roofing materials and adjustable height of roof on growth and physiological performance of growing crossbred calves.

MATERIALS AND METHODS

The present study was conducted on crossbred (Vrindavani) cattle calves maintained at the cattle and buffalo farm, IVRI, Izatnagar, to evaluate the effect of modified housing using different roofing materials on growth and physiological performance during the summer (April 2017 to June 2017). The Institute is located at an

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altitude of 169 m above mean sea level, at the latitude of 28.22°N 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%. Calves (24; 6–8 months old) were randomly selected and allocated in 4 groups, viz. control (C); corrugated cement sheet was used as roofing material. Treatment 1 (T1): painted black inside the roof and white on the upper exposed surface of the roof; treatment 2 (T2): Polycarbonate sheet as roofing material; treatment 3 (T3): Polycarbonate sheet as roofing material with adjustable height. Height at eaves was kept 3 m and the height at centre was 4 m (for hot-dry period). The roof was arranged like a ridge system of ventilation for hot air in shed to pass from the roof itself. A gap of two feet was provided for ridge ventilation with one side of roof overhanging the other. The animals were maintained under iso-managerial conditions of management, feeding with intensive system and housed in a well ventilated brick cemented loose house with non-slippery floor open byre with standard space as per Indian Standard. The calves were offered green and dry fodder along with concentrate as per the standard practices in all the groups.

Temperature of sheds was measured by maximum and minimum thermometer twice daily at forenoon (9:00 am) and afternoon (2:30 pm). Simultaneously the relative humidity (RH) of sheds was measured using dry and wet bulb thermometer twice daily. 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. Inner surface temperature (ST) of roof was recorded by infrared thermometer (ebro, TFI 220) at 9:00 am and 2:30 pm for 3 consecutive days at fortnightly interval. Rectal temperature and respiratory rates of calves were recorded at fortnightly intervals for 3 consecutive days twice a day (9:00 am and 2:30 pm). Rectal temperature (°C) was recorded by using a digital clinical thermometer. Respiration rate (breaths/min) was counted from a distance by observing flank movements and expressed as counts/min. Body weight (kg) of the calves was recorded on fortnightly basis before offering feed and water using digital weighing balance. Dry matter intake (DMI) (kg) from fodder and concentrate was calculated at fortnightly interval for 3 continuous days. Feed conversion ratio (FCR) was calculated as weight gain (kg) per kg of DMI. Water intake (litre/day) was recorded on fortnightly basis. The data obtained from the study were analyzed using standard statistical methods (Snedecor and Cochran 1994).

RESULTS AND DISCUSSION

Macroclimate during the summer: The solar radiation ranged from 182.78±6.18 to 213.27±5.83 W/m^2 during the course of the experiment, whereas wind speed varied from 0.35±0.08 to 0.48±0.06 m/sec. The mean ambient temperature ranged between 25.46±0.88°C to 34.52±0.72°C. The ambient temperature during the experimental period at 9:00 AM ranged between 15.37±0.68°C to 26.95±0.39°C, whereas at 2:30 PM it increased from 35.58±1.17°C to 40.91±0.28°C. The RH during the experimental period at 9:00 AM ranged between 71.67±1.78% to 46.85±2.39%, whereas at 2:30 PM it varied from 49.18±3.17% to 36.91±1.88%. The mean RH during the observation period ranged between 51.38±2.52% and 42.86±1.73%. The THI at 9:00 AM varied between 69.64±0.80 and 84.28±0.42 and at 2:30 PM was ranged between 82.31±0.98 and 89.90±0.35.The macroclimatic conditions were more stressful during last fortnights of the experimental period.

Microenvironment of sheds

Temperature (°C) of sheds: The temperature at 9:00 AM during the first fortnight was 23.37±0.67, 18.67±0.33, 21.53±0.26 and 20.13±0.17°C, which increased to 24.67±0.88, 20.50±0.29, 23.70±0.42 and 22.80±0.20°C under C, T1, T2 and T3 respectively, during the last fortnight, whereas the corresponding values at 2:30 PM during the first fortnight increased from 34.33±0.17, 30.67±0.33, 32.33±0.33 and 31.67±0.33 to 35.67±0.88, 32.83±0.17, 34.27±0.37 and 33.67±0.33, respectively, during last fortnight. The overall minimum temperature at 9:00 AM was 24.11±0.16, 18.46±0.04, 22.84±0.06 and 21.86±0.17°C, whereas at 2:30 PM 34.82±0.25, 31.15±0.04, 33.73±0.07 and 32.74±0.13°C in C, T1, T2 and T3 respectively. The overall average temperature was significantly ($P<0.05$) lower in T1 (24.89±0.08), followed by T3 (27.30±0.10), T2 (28.28±0.04) and C (29.46±0.16). The temperature of sheds at 9:00 AM 2:30 PM were significantly lower ($P<0.05$) in T1 followed by T3, T2 and highest in C, during all the fortnights.

The roof painted with white on outer and black inside had significantly ($P<0.05$) lower temperature both in morning as well as afternoon even in hotter days as compared to control. Maximum temperature was observed in C followed by T2. In T3 lower temperature of shed than control was recorded during summer, which may be due to higher height of house and ridge system of ventilation which allowed the hot air accumulated to pass from the roof itself and hence maintained a slightly lower shed temperature. Increasing the height of shed with ridge ventilation might have helped to dissipate heat easily in T3.

The present finding are in agreement with Kamal *et al.* (2014) who recorded higher inner surface temperature of asbestos sheet (45.12±2.50°C) in comparison to thatched roof (34.30±1.57°C) during summer and Jat *et al.* (2005) who reported that higher ($P<0.05$) temperature of asbestos roofed house as compared to thatch and mud plaster roof. Roy and Chatterjee (2010) recorded higher temperature in GI sheet roof (37.72±0.67°C) with brick/mud floor in comparison to tile roof (35.95±1.2°C) with brick floor and brick/jute stick wall during summer. Lowest dry bulb temperature was observed in shelter having RCC roof when compared to asbestos roof shelters and conventional tree shelters (Kaur and Singh 2004). Brown-Brandl *et al.* (2005), in a study with polyethylene shade cloth concluded that more comfortable micro-environment was observed in these sheds. Polystyrene or polyurethane insulation layers had the capability of reducing the load by more than 50% when compared to an identical building roof without insulation (Sanjay and Prabha Chand 2008). Khongdee *et al.* (2010) reported that shade cloth roofing offered a more efficient way to minimize heat stress than that of normal roof.

Relative humidity (%) of sheds: The RH at 9:00 AM during the first fortnight in C, T1, T2 and T3 was 75.17±1.59, 70.00±0.58, 73.00±1.53 and 69.17±1.01%, which altered to 67.60±0.35, 66.07±0.4, 68.70±0.67 and 64.70±0.42% at last fortnight, respectively. Similarly, RH at 2:30 PM decreased from 66.50±1.26, 63.17±0.60, 64.83±0.9 and 62.13±0.13% to 58.53±0.42, 56.13±1.45, 58.33±0.94 and 55.23±1.47% for C, T1, T2 and T3, respectively. The overall RH was 70.37±0.21, 68.48±0.34, 70.26±0.48 and 66.56±0.30, at 9:00 AM and 62.23±0.40, 60.59±0.45, 61.11±0.39 and 58.20±0.74% at 2:30 PM in C, T1, T2 and T3, respectively. Irrespective of treatment RH at 9:00 AM was significantly (P<0.05) higher than at 2:30 PM. The RH at 9:00 AM and 2:30 PM was significantly (P<0.05) higher in C, followed by T2 and T1 and was least in T3 during all the fortnights except third fortnight. The RH under T3 was minimum, which might be due to the fact that this system of housing allowed the floor to become dry quickly and provided proper ventilation during the summer. Present findings on RH in animal housing are in accordance with earlier reports (Sharma and Singh 2002, Kaur and Singh 2004, Kamal *et al.* 2014) who observed higher humidity in asbestos roofed house as compared to thatch, tree and agro-net. Asbestos roofed house had higher temperature and relative humidity than the tile roofed house (Sivakumar *et al.* 2017). However, in contrary Roy and Chatterjee (2010) observed higher RH in plastic shade roof as compared to thatch, GI sheets and tile roof.

Temperature humidity index (THI) of sheds: THI during the first fortnight was 73.77±0.15, 72.53±1.42, 74.47±0.39 and 73.10±0.67, which increased to 77.37±0.27, 76.67±0.67, 77.82±0.61 and75.63±0.33 during the last fortnight under C, T1, T2 and T3 respectively. Similarly, at 2:30 PM the THI increased from 79.63±0.84, 76.33±0.60, 78.17±0.44 and 83.70±0.74, 81.10±0.32, 81.78±0.78 and 80.40±0.31 for C, T1, T2 and T3, respectively. The overall THI at 9:00 AM in C, T1, T2 and T3 was 76.03±0.28, 74.18±0.34, 75.98±0.07 and 74.39±0.39, whereas at 2:30 PM was 81.44±0.23, 78.46±0.33, 79.84±0.09 and 78.61±0.08, respectively. The overall minimum THI (P<0.05) was in T1 and maximum (P<0.05) was recorded in C, followed by T2 and T3 both at 9:00 AM and 2:30 PM. Higher ambient temperature coupled with higher relative humidity (RH), contributed to more stress in dairy cattle. THI was lower in cattle shed with painted roof thus, creates better microenvironment in summer followed by T3, T2 and C. The minimum THI in group T1, T3, T2 as compared to C might be due to less penetration of solar radiation inside all the sheds and higher height of roof in T3.

The present findings are comparable with previous reports (Jat *et al.* 2005, Kamal *et al.* 2014) who reported significantly higher (P<0.05) THI at evening than morning hours and concluded that higher THI in loose house covered with asbestos sheet as compared to thatch, mud plastered roof and agro-net roof. Similarly, Patil *et al.* (2014) reported lower values of THI under modified roof shed (thatch + asbestos) as compared to asbestos shed and painted shed in all periods of trial.

Inner surface temperature (°C) of roofing materials

The overall inner surface temperature of roofs at 9:00 AM was significantly (P<0.05) lower in T1 (36.38±0.36) followed by T3 (37.54±0.18), T2 (38.12±0.17) and highest in C (39.58±0.24). The overall inner surface temperature of roofs at 2:30 PM was nonsignificant amongst the groups. The roof painted with white on outer and black inside had lower temperature both in morning as well as afternoon even in hotter days as compared to control. Maximum temperature was observed in C followed by T2. Painted surface reduces the surface temperature via reflecting the radiations while CCS roof absorbs the heat and passes to the animal house. Similarly polycarbonate being heat and UV resistant did not allow heat to pass and thus provide better microclimate as compared to control in T3 and T2.

Body weight (kg) and average daily gain (ADG)

The fortnightly body weight changes of calves during different fortnights in all the 4 groups are presented in Fig. 1. The initial body weight in C, T1, T2 and T3 was 106.50±2.05, 107.00±2.95, 107.17±3.30 and 107.67±3.66 kg, respectively, which was nonsignificant. The fortnightly body weight of calves increased steadily and the final body weight was maximum in T3 group (142.17±1.51 kg) followed by T1 (142.00±2.92 kg) than T2 (141.17±2.79 kg) and C (135.83±3.83 kg). However, the final weight of calves was statistically nonsignificant amongst the groups. Total body weight gain (kg) was significantly (P<0.05) higher in T3 (35.67), followed by T1 (34.83), T2 (34.1) and least in C (28.16). Higher body weight gain in T3 and T1 grouped calves might be due to more DMI and better micro-environment under shade which facilitated the growth of calves in these groups. Whereas, less gain in body weight in C might be due to use of muscle protein as source of energy to regulate excessive heat load.

The ADG during the initial period of experiment was

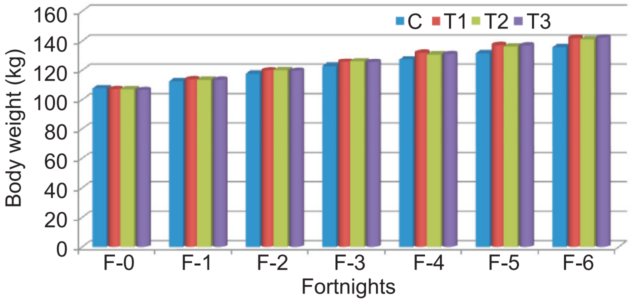

Fig. 1. Body weight of calves under different groups on fortnightly basis.

Table 1. Rectal temperature (°C) of calves

Fortnight	Time	Corrugated cement sheet (C)	Painted roof (T1)	Polycarbonate roof (T2)	Roof with adjustable height (T3)
F1	9:00 AM	38.75 ± 0.13	38.56 ± 0.18	38.67 ± 0.12	38.53 ± 0.04
	2:30 PM	39.20 ± 0.06	39.06 ± 0.08	39.04 ± 0.05	38.94 ± 0.09
	Average	38.98 ± 0.09	38.81 ± 0.11	38.84 ± 0.05	38.74 ± 0.06
F2	9:00 AM	38.82 ± 0.18	38.59 ± 0.07	38.74 ± 0.19	38.54 ± 0.06
	2:30 PM	39.28 ± 0.04^{a}	39.06 ± 0.02^{ab}	39.09 ± 0.12^{ab}	38.91 ± 0.12^{b}
	Average	39.06 ± 0.07	38.83 ± 0.04	38.93 ± 0.13	38.73 ± 0.09
F3	9:00 AM	38.94 ± 0.11	38.88 ± 0.17	38.74 ± 0.14	38.74 ± 0.14
	2:30 PM	39.33 ± 0.12	39.07 ± 0.09	39.13 ± 0.03	39.07 ± 0.03
	Average	39.14 ± 0.12	38.97 ± 0.13	39.00 ± 0.16	38.90 ± 0.07
F4	9:00 AM	38.93 ± 0.03	38.64 ± 0.07	38.87 ± 0.12	38.71 ± 0.12
	2:30 PM	39.40 ± 0.06^{a}	39.12 ± 0.04^{ab}	39.22 ± 0.07^{ab}	39.07 ± 0.09^{b}
	Average	39.17 ± 0.03^{a}	38.88 ± 0.05^{b}	39.05 ± 0.03^{a}	38.89 ± 0.02^{b}
F5	9:00 AM	39.10 ± 0.06	39.00 ± 0.06	39.07 ± 0.18	39.03 ± 0.03
	2:30 PM	39.43 ± 0.07	39.17 ± 0.10	39.37 ± 0.07	39.20 ± 0.10
	Average	39.28 ± 0.02	39.08 ± 0.06	39.22 ± 0.12	39.12 ± 0.07
F6	9:00 AM	39.01 ± 0.06	38.93 ± 0.03	38.83 ± 0.09	38.93 ± 0.03
	2:30 PM	39.43 ± 0.04	39.13 ± 0.13	39.32 ± 0.06	39.27 ± 0.09
	Average	39.22 ± 0.02	39.05 ± 0.05	39.09 ± 0.07	39.10 ± 0.06
Overall	9:00 AM	38.93 ± 0.04	38.77 ± 0.06	38.84 ± 0.02	38.75 ± 0.03
	2:30 PM	39.35 ± 0.03^{a}	39.11 ± 0.03^{b}	39.19 ± 0.01^{b}	39.07 ± 0.03^{b}
	Average	39.14 ± 0.04^{a}	38.94 ± 0.03^{b}	39.01 ± 0.01^{ab}	38.91 ± 0.02^{b}

Means values between 9:00 AM and 2:30 PM differ significantly (P<0.05) within the treatments; means bearing different superscript differ significantly (P<0.05) within row.

0.32±0.02, 0.44±0.01, 0.43±0.01 and 0.47±0.02 kg in C, T1, T2 and T3, respectively, where T3, T2 and T1 were significantly (P<0.05) higher than control. At last fortnight ADG for C, T1, T2 and T3 were 0.27±0.03, 0.31±0.02, 0.34±0.02 and 0.32±0.02, respectively, which was statistically nonsignificant. The overall ADG was significantly (P<0.05) higher in T3 followed by T1, T2 and least in control grouped calves. Patil *et al.* (2008) reported higher weight gain by providing simple thatch shed to the kids in comparison to tin roof, whereas, Shrikant and Kumar (2001) found no significant difference in growth of calves and between ADG in loose house with single wall and loose house with 4' side wall. Singh *et al.* (2008) observed that the asbestos, agro-net grouped kids grew more as compared to their initial body weight in comparison to kids under tree and open sky.

Dry matter intake and feed conversion ratio (*FCR*) *of calves*

The overall total DMI (kg/day) from all sources in C, T1, T2 and T3 is 15.73±0.10, 16.06±0.01, 14.63±0.21 and 15.56±0.20, respectively. Overall total DMI from all sources was significantly (P<0.05) higher in T3 followed by T1 as compared to T2 and least in control.

The overall FCR was significantly (P<0.05) lower in T2 (6.67±0.09), T3 (6.71±0.06) followed by T1 (6.80±0.03) as compared control (8.24±0.08). FCR was better in T3, T1 and T2 as compared to C grouped calves during experimental period. Heat gain from the environment might have been more for the calves kept in C during hot conditions, and as a result, more dietary energy would have been utilized for the maintenance of homeothermy, thus reducing the FCR to some extent. The decrease in DMI in C and T2 in comparison to T3 and T1 may be due to direct effect of elevated temperature, which reduced the gut motility, rumination, luminal concentrations and depressed appetite. When exposed to an increased heat load, DMI in cattle get reduced, thus reduction in their metabolic rate (Leonard *et al.* 2001), which reduces the metabolic heat load. As expected, DMI in the current study was affected by hot environmental conditions. The use of shade reduced the effects of hot weather on cattle and can consequently reduce the impact of the hot conditions on DMI (Brown-Brandl *et al.* 2005, Gaughan *et al.* 2010). The present findings are in agreement with Kamal *et al.* (2014) who reported lesser DMI by asbestos grouped calves as compared to agronet and thatch. Similarly Chauhan *et al.* (2011), Yazdani and Gupta (2000) and Jat *et al.* (2005) reported significantly (P<0.05) higher DMI by calves kept under thatch and RCC shed in comparison to calves under tree shed. Improved DMI and ADG for shaded compared with unshaded heifers were reported by Mitlohner *et al.* (2001).

Water intake (*L/day*) *of calves*

The water intake (litre/day) of calves in C, T1, T2 and T3 during first fortnight was 77.5±0.63, 73.5±0.95, 75.44±0.14 and 72.44±0.45, respectively, which increased to 86.47±0.63, 81.17±0.95, 82.40±0.14 and 81.07±0.45 in last fortnight, respectively. The calves in control group consumed more (P<0.05) water followed by T2, T3 and

Table 2. Respiration rate (/min) of calves

Fortnight	Time	Corrugated cement sheet (C)	Painted roof (T1)	Polycarbonate roof (T2)	Roof with adjustable height (T3)
F1	9:00 AM	27.17 ± 0.60	24.30 ± 0.71	25.70 ± 0.51	24.93 ± 0.58
	2:30 PM	31.07 ± 0.75	29.50 ± 0.29	29.23 ± 0.28	30.33 ± 0.88
	Average	29.07 ± 0.57	26.92 ± 0.23	27.47 ± 0.38	27.63 ± 0.70
F2	9:00 AM	26.73 ± 0.92 [a]	23.61 ± 0.50[b]	23.92 ± 0.50[b]	25.33 ± 0.41 [ab]
	2:30 PM	32.27 ± 0.37 [a]	27.33 ± 0.34 [b]	28.03 ± 0.67 [b]	28.63 ± 0.68 [b]
	Average	29.97 ± 0.51 [a]	25.47 ± 0.24 [b]	25.97 ± 0.27[b]	26.98 ± 0.52[b]
F3	9:00 AM	26.47 ± 0.97	25.12 ± 0.84	25.48 ± 1.12	24.85 ± 0.94
	2:30 PM	31.00 ± 0.13	29.60 ± 1.12	28.97 ± 1.21	29.40 ± 1.17
	Average	28.73 ± 0.47	27.36 ± 0.41	27.23 ± 0.20	27.14 ± 0.62
F4	9:00 AM	25.30 ± 0.44 [a]	23.27 ± 0.40 [b]	23.40 ± 0.80 [b]	22.57 ± 0.81 [b]
	2:30 PM	30.93 ± 0.52 [a]	27.00 ± 1.15 [b]	28.17 ± 0.94 [b]	27.34 ± 0.16 [b]
	Average	28.12 ± 0.06 [a]	25.13 ± 0.38 [b]	25.78 ± 0.86 [b]	24.95 ± 0.48 [b]
F5	9:00 AM	26.47 ± 0.44 [a]	23.80 ± 1.15[b]	24.60 ± 1.39[ab]	21.97 ± 1.74 [b]
	2:30 PM	29.47 ± 0.74 [a]	27.54 ± 0.31[ab]	27.81 ± 0.90[ab]	25.43 ± 0.38 [b]
	Average	27.97 ± 0.38 [a]	25.67 ± 0.72 [b]	26.20 ± 0.35 [b]	23.70 ± 1.09 [c]
F6	9:00 AM	23.95 ± 1.27 [a]	20.90 ± 0.62 [b]	21.69 ± 1.27 [ab]	19.87 ± 1.23 [b]
	2:30 PM	28.57 ± 0.38 [a]	26.76 ± 1.95 [b]	28.30 ± 0.35 [a]	27.80 ± 1.35 [ab]
	Average	26.88 ± 0.22 [a]	23.85 ± 0.70[b]	24.99 ± 0.61 [ab]	23.83 ± 1.32 [b]
Overall	9:00 AM	25.99 ± 0.31 [a]	23.51 ± 0.40 [b]	24.13 ± 0.25 [b]	23.25 ± 0.03 [b]
	2:30 PM	30.76 ± 0.23 [a]	27.96 ± 0.46 [b]	28.42 ± 0.16 [b]	28.16 ± 0.08 [b]
	Average	28.37 ± 0.26 [a]	25.73± 0.20 [b]	26.27 ± 0.05 [b]	25.71 ± 0.05 [b]

Means values between 9:00 AM and 2:30 PM differ significantly ($P<0.05$) within the treatments; means bearing different superscript differ significantly ($P<0.05$) within row.

T1. Similar trend followed throughout the experiment.

Feed with relatively high moisture content decreases the quantity of drinking water required. The less water intake in T3 and T1 grouped calves may be due to more intake of fodder during experimental period in spite of high environmental temperature, indicating comfortable micro-environment under respective shade material as compared to other shade materials. Water intake in calves increased as heat load increased. Yazdani and Gupta (2000) found lower ($P<0.05$) voluntary water intake in thatch group. Chauhan *et al.* (2011) found significantly ($P<0.01$) higher water intake in summer by Kankrej cow under RCC shed than thatched and tree. Asbestos roofed shed cows drank more ($P<0.05$) water (litre/day) than those in thatched asbestos roof shed and white painted roof shed in hot and humid season of Konkan region (Patil *et al.* 2014).

Physiological parameters

The fortnightly rectal temperature and respiration rate are presented in Tables 1 and 2, respectively. Overall rectal temperature at 2:30 PM was significantly ($P<0.05$) higher in control as compared to all other groups whereas at 9:00 AM no significant difference was found within the groups.

Overall respiration rate during morning and afternoon was significantly ($P<0.05$) higher in control group as compared to the other groups. The rectal temperature and respiration rate of calves at 2:30 PM was significantly ($P<0.05$) higher than rectal temperature at 9:00 AM in all the groups throughout the experiment.

The increase in rectal temperature is gradually observed, after exposure to the solar radiation. The significant rise in rectal temperature in control grouped calves might be due to heated CCS during experimental period. Inability to dissipate excess heat might be the reason for increased rectal temperature. When animals were exposed to rising air temperature the first response observed was an increase in respiration rate. The change in respiration rate was observed to be related with discomfort and it was mainly due to exposure to greater intensity of solar radiation. The present findings are in agreement with Patil *et al.* (2014) who reported higher rectal temperature and respiration rate in crossbred cows in the asbestos roof shed in comparison to white painted roof shed and thatched asbestos roof shed. Khongdee *et al.* (2010) reported lower mean rectal temperature and respiration rate in shade cloth than that of the cows housed under normal roofing. Similarly, Brown-Brandl *et al.* (2005) also reported reduced body temperature, respiration rate and lowered open-mouthed breathing under shed. Schutz *et al.* (2010) reported increased respiration rate under different treatments of shading.

From the study, it is concluded that corrugated cement sheet painted with sun reflective white on top surface and black on inner surface provided better microenvironment in animal housing than plain corrugated cemented sheet roofing. Alternately the performance of calves under polycarbonate roofing with adjustable height was better than simple polycarbonate as well as cement sheet roofing sheds. The polycarbonate roofing with height adjustment and sun reflective paints may be very effective materials to mitigate summer stress in the crossbred dairy animals.

ACKNOWLEDGEMENTS

The authors are thankful to the Director and all Joint Directors, ICAR-IVRI, Izatnagar, for providing the necessary infrastructural facilities for carrying out the experiment.

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