RESEARCH ARTICLE
JIVA 19 (3) December 2021

Received: 28/09/2021
Accepted: 17/11/2021

COMPARISON OF WEATHER PARAMETERS INSIDE AND OUTSIDE THE CATTLE HOUSE AS A CAUSATIVE FACTOR OF THERMAL STRESS UNDER HUMID TROPICS

Ibraheem Kutty C.[1]*, Harikumar S.[2], Shajeesh J.[3]and Bibin Becha B.[4]

Assistant Professors,
Programme coordinator, KVK, Malappuram, Kerala Agricultural University, KCAET campus, Tavanur P.O., Kerala
[2] Dept. of Livestock Production Management, [4]Dept. of Animal Reproduction College of Veterinary and Animal Sciences, Mannuthy, Thrissur
[3]RARS, Kerala Agricultural University, Ambalavayal, Wayanad.
Livestock Research Station, Thiruvazhamkunnu P.O., Palakkad District, Kerala
Kerala Veterinary and Animal Sciences University
**Corresponding author: ibraheemkutty50@gmail.com*

ABSTRACT

Housing conditions playcritical role in regulating the influence of outside weather on animals. The present study was carried out to compare the weather parameters outside and inside the animal houses and the chances of thermal stress (TS). Daily recordings of ambient temperature (AbT), relative humidity (RH) and temperature humidity index (THI) from in house (IH) and outdoor (OD) recordings were compared across months, quarters and half years over a period of one year. Weather parameters showed significant variation between IH and OD recordings with higher AbT and THI inside irrespective of months or seasons, while the pattern of RH variables were opposite with higher values OD than IH. AbT variables were found to contribute significantly more to THI than RH. Besides difference in the highest and lowest of weather parameters across months and seasons, their range of variation was also inconsistent between IH and OD recordings. It is concluded that in spite of regulation by the same environmental factors, the difference in the pattern of IH weather parameters making prone to more TS can be attributed to the housing conditions and calls for better interventions to regulate the IH conditions to minimize TS in animals.

Keywords: Ambient temperature, Cattle house, Climate, Kerala, Thermal stress, Weather

INTRODUCTION

Thermal comfort of animals are

regulated by a balance between heat generation and dissipation(Kumar *et al*. 2019; Mishra and Palai, 2014)so that body temperature is maintained within the normal range prescribed for the species, together with maintenance of all the normal physiological processes with minimal utilization of internal resources (Hansen, 2015). In tropical and sub-tropical regions, high Ambient temperature (AbT) formed the major climatic variable contributing to thermal stress (TS) (Marai *et al*. 2008) and its influence was aggravated by accompanying relative humidity (RH) (Allen *et al.* 2009; Kumari and Pampana, 2015). Other climatic factors contributing TS in animals include intensity and hours of solar radiation, air flow, wind velocity, rainfall and so on (Orihuela, 2000; Mishra *et al*. 2015). All these climatic variables regulate the AbT, and its elevation beyond the thermo-neutral range produces TS, necessitating active heat dissipation mechanisms instead of usual passive transfer (Das *et al*. 2016).

Temperature humidity index (THI) forms a composite measure that simultaneously considers AbT and RH to understand the thermal load contributed by these two variables on to the animal system (Allen *et al.* 2009). However, interaction between various climatic factors decides the net contribution of TS throughout the year. Major determinants of AbT such as rainfall and day length being seasonal in occurrence, comparison of weather parameters across months and seasons will be more useful to understand the combined effect of different variables in producing TS (Marai *et al*. 2008).

Housing conditions plays critical role in regulating the influence of outside weather on to the animals housed inside the barn (Prasad 2014). The pattern and difference of weather parameters between outdoor (OD) and in house (IH) becomes important to understand the possibility of TS caused by the outside weather (Silanikove, 2000). Thus, the present study was carried out with the objective of comparing the weather parameters recorded outside and inside the animal houses, across months, quarters and half years to know the chances of TS in animals under the humid tropical environment.

MATERIALS AND METHODS

The study was carried out at Livestock Research Station of Kerala Veterinary and Animal Sciences University at Thiruvazhamkunnu (11°21’ N and 76°21’ E), which is located in Palakkad district of Kerala state, being at the fringes of Western Ghats at an altitude of +35m MSL. Dairy farm of the station having 300 heads of crossbred dairy cattle which were intensively managed as per standard recommendations (ICAR-NIANP, 2013) formed the study settings. The houses were open, with side walls of one meter height and complete walls at both the ends, and consisted of 40 cows housed tail to tail double row system. The asbestos cement roof was gable type slanting towards either sides with five and three meters height respectively at centre and at the eaves.

Weather parameters such as AbT and RH were recorded both IH and OD for a period of one year. IH recording was by using Hobo data logger (HOBO pro V2, Onset Computer Corporation, USA)fixed at the centre of the barnat a height of two meters from the floor and was set for hourly recording. Outdoor weather parameters were collected from the automatic weather station (Campbell Scientific, CR 800 series data logger) situated 50 meters away from the barn. Both the devices were calibrated prior to the study to ensure accuracy of the recordings and the data were retrieved at bimonthly intervals. Different variables such as maximum (Mx), minimum (Mn) and averages of AbT and RH were arrived on daily basis and Temperature humidity index (THI) was calculated based on Livestock Poultry Heat Stress Index (LPHSI) using the formula

$$THI\ (LPHSI) = T - \left(\left(0.55 - \frac{0.55 \times RH}{100}\right) \times (T - 58)\right)$$

Where T - Average temperature (in °F)

RH - Relative humidity (%)

The data were analysed using statistical software (IBM SPSS V. 24.0) for the pattern of variation between IH and OD recordings across months, quarters and half years (based on day length as well as raining intensity) to compare the potential for causing TS in animals. Besides retrieved data of the weather parameters, the difference between daily maximum and minimum of the variables were also compared between IH and OD sources. Four quarters of comparison were corresponding to the seasons established for the locality (Kutty *et al.* 2019; Kutty, 2021) such as North east monsoon, post monsoon, summer and south west monsoon represented by September, October, November (SON), December, January, February (DJF), March, April, May (MAM) and June, July, August (JJA) respectively.

RESULTS AND DISCUSSION

Weather Parameters

AbT and RH of each month obtained from IH and OD recordings and their differences between the sources are shown in Table 1.There were highly significant ($P<0.001$) variations between months with respect to AbT and RH irrespective of the sources as well as the differences between recordings from both

Fig. 1. In house and outdoor recording of ambient temperature across months

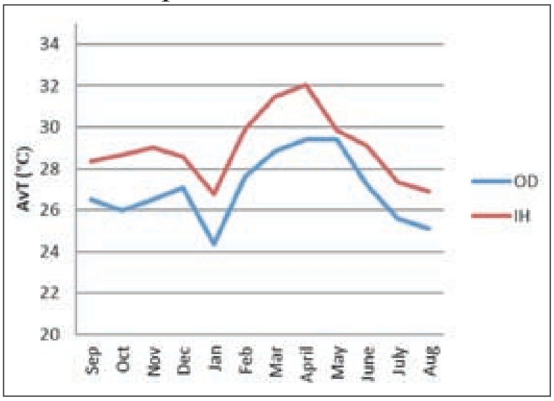


Fig. 2. In house and out door recording of relative humidity across months

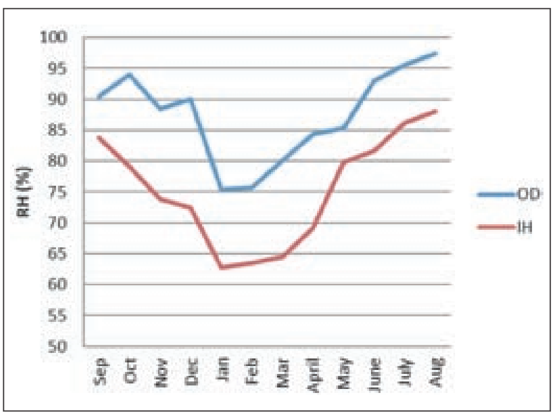
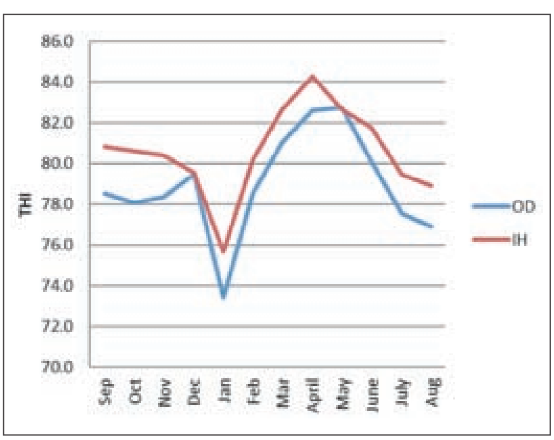


Fig. 3. In house and out door recording of THI across months



the sources. The months of highest daily average of AbT in ºC were different from IH and OD recordings being April (32.02) and May (29.40), respectively even though the lowest was during January from both the sources. Highest daily average of RH % was during August from both IH (88.02) and OD (97.35) sources and the lowest was (62.85 and 75.45 respectively) during January.

The AbT was more IH than OD, with overall mean difference of 2.03± 0.06 ºC, whereas RH was found to be more outside with a mean difference of 12.08± 0.32 %. Higher AbT inside the shed can be thought of contributed by the heat dissipated from animal body and the higher RH outside the barn can be attributed to better air movements as well as raining and dew formation especially during night hours. Also low RH of IH than OD and *vice versa* can be due to the inverse relationship between the AbT and RH. However, Harikumar (2017) and Divya *et al.* (2021) reported lower AbT and THI inside the barn than outside, which might be due to the difference in the location, structural characteristics of the shed and number of animals housed inside.

Quarterly averages of THI values calculated based on daily AvT and AvRH from IH and OD recordings are shown in Table 2. All the three parameters varied significantly ($P<0.05$) between quarters, except THI recorded OD, which was comparatively high across all the seasons

Table 1. Monthly averages of ambient temperature and relative humidity from in house and outdoor weather recordings and the differencesbetween the two sources

Month and year	In house		Out door		Difference between in house and out door			
					Actual		Per cent	
	AbT (ºC)	RH (%)	AbT (ºC)	RH (%)	AbT (ºC)	RH (%)	AbT (ºC)	RH (%)
SEP	28.35	83.84	26.49	90.45	1.87	-6.61	7.06	-7.20
OCT	28.64	79.08	25.97	93.96	2.67	-14.88	10.34	-15.91
NOV	29.00	73.78	26.51	88.45	2.49	-14.68	9.44	-16.39
DEC	28.55	72.39	27.06	90.05	1.49	-17.66	9.11	-16.88
JAN	26.78	62.85	24.36	75.45	2.43	-12.60	10.01	-16.02
FEB	29.89	63.43	27.62	75.63	2.27	-12.20	8.26	-15.07
MAR	31.48	64.45	28.82	80.11	2.66	-15.66	9.25	-19.55
APR	32.02	69.22	29.41	84.32	2.61	-15.10	8.92	-17.83
MAY	29.86	79.86	29.40	85.39	0.46	-5.53	1.69	-6.43
JUN	29.12	81.69	27.22	92.97	1.90	-11.28	7.01	-12.13
JUL	27.35	86.18	25.58	95.60	1.78	-9.42	7.04	-9.84
AUG	26.89	88.02	25.10	97.35	1.79	-9.33	7.20	-9.58
Mean	29.00**	75.40**	26.96**	87.48**	2.03**	-12.08**	7.94**	-13.56**
F- Value	64.86	92.10	100.77	68.16	10.30	13.38	10.05	14.91

** Significant (P<0.001)

Table 2. Mean values of ambient temperature, relative humidity and THI of four seasons from in house and outdoor weather recordings

Category	Weather parameters	Seasons				F va lue	p value
		SON	DJF	MAM	JJA		
In House	AvT (ºC)	28.66 ^{b}	28.40 ^{b}	31.12 ^{a}	27.78 ^{b}	4.970*	0.031
	AvRH (%)	78.90^{bc}	66.22 ^{a}	71.17^{ab}	85.29 ^{c}	6.694*	0.014
	THI	80.61 ^{ab}	78.47 ^{a}	83.20 ^{b}	80.05 ^{a}	5.091*	0.029
Out Door	AvT(ºC)	26.32 ^{b}	26.34 ^{b}	29.21 ^{a}	25.96 ^{b}	6.093*	0.018
	AvRH (%)	90.95 ^{bc}	80.37 ^{a}	83.27 ^{ab}	95.30 ^{c}	6.243*	0.017
	THI	78.31	77.14	82.14	78.18	4.011^{ns}	0.520

AvT – Daily average temperature, AvRH – Daily average relativehumidity, ^{ns} non-significant (P>0.05)
* Significant(P<0.05), Means with differentsuperscripts varysignificantly between columns

making the variation non significant. Seasonal pattern of AvT, AvRH and THI were more or less similar for IH and OD recordings indicating reflection of the outside weather into the barns as well. Quarterly means of AbT and THI were highest during MAM, the period being summer with longer days. Likewise, highest RH and lowest AbT was during JJA corresponding to the maximum raining of the period. Lowest of RH and THI were during DJF attributable to minimum raining and shorter day length of the period. Highest AbT and THI coincided the

Table 3. Half yearly averages of ambient temperature, relative humidity and THI based on in house and outdoor weather recordings and their differences

	In house			Out door			Difference		
Period (Months)	AbT (ºC)	RH (%)	THI	AbT (ºC)	RH (%)	THI	AbT (ºC)	RH (%)	THI
Short days (Sep to Feb)	28.54	72.56	79.54	26.34	85.67	77.72	2.20	-13.10	1.82
Long days (Mar to Aug)	29.45	78.24	81.78	27.59	89.29	80.27	1.87	-11.05	1.52
Rainy season (Jun to Nov)	28.23	82.10[a]	80.37	26.14	93.13[a]	78.26	2.08	-11.03	2.10
Non-rainy (Dec to May)	29.77	68.70[b]	80.83	27.78	81.82[b]	79.60	1.99	-13.12	1.23
Yearly mean value	29.00	75.40**	80.55	26.96	87.48**	78.77	2.03	12.08	1.78

** highly significant (P<0.01) Values with differentsuperscripts varysignificantly between the rows

Table 4. The difference between daily maximum and minimum of the three weather parameters from in house and outdoor sources across the months

	In house			Out door		
Months	AbT	RH	THI	AbT	RH	THI
SEP	3.76	18.29	4.57	1.61	12.70	2.13
OCT	3.27	24.00	4.02	2.21	14.80	3.64
NOV	3.51	18.48	6.22	3.12	26.09	5.94
DEC	3.72	20.87	4.37	3.37	14.10	6.14
JAN	4.14	17.60	7.47	3.99	28.87	6.25
FEB	3.80	26.78	5.88	3.84	48.18	5.84
MAR	2.93	20.65	7.02	2.77	18.02	4.84
APR	3.62	15.38	4.12	4.12	15.54	6.52
MAY	5.59	23.48	6.67	3.03	13.17	4.30
JUN	5.75	19.85	6.53	4.34	17.00	5.89
JUL	4.34	14.54	5.72	4.50	9.50	7.08
AUG	4.98	15.48	6.53	4.17	9.60	6.71
Mean	4.12	19.62	5.76	3.42	18.96	5.44

period of maximum day length (MAM) and intermittent summer raining, while SON maintained a moderate level with respect to all the three weather parameters.

Monthly pattern of IH and OD recordings of AbT, RH and THI are shown respectively in Figures 1 to 3 for better comparison. Since length of the days and intensity of raining appears to be the major determinants of IH and OD weather parameters, comparison of AbT, RH and THI values from the two sources and their differences, were made across the half years based on day length as well as raining pattern and are shown in Table 3. Both IH and OD recordings of RH showed highly (P<0.01) significant variation between the two half years of rainy and non-rainy seasons, while the variation was not significant for

Table 5. Comparison of the daily minimum and maximum of three weather parameters from the in house and outdoor recordings and their differences across seasons

	Season	Minimum				Maximum			
		In house	Out door	Actual Difference	Difference in Per cent	In house	Out door	Actual Difference	Difference in Per cent
Temp. ºC	SON	26.37	24.76	1.61	6.50	30.23	27.88	2.35	8.44
	DJF	24.89	22.66	2.23	9.85	31.43	29.25	2.18	7.45
	MAM	26.82	26.97	-0.16	-0.57	33.51	31.22	2.29	7.32
	JJA	24.17	22.89	1.28	5.60	31.88	29.27	2.61	8.93
Rel. Hum. (%)	SON	65.57	67.61	-2.04	-3.01	91.40	99.50	-8.10	-8.14
	DJF	46.69	44.12	2.57	5.82	87.56	94.50	-6.94	-7.34
	MAM	53.95	71.88	-17.93	-24.95	91.17	93.10	-1.93	-2.07
	JJA	73.23	83.00	-9.77	-11.77	96.28	100.00	-3.72	-3.72
THI	SON	76.23	74.65	1.58	2.12	82.81	80.59	2.22	2.76
	DJF	72.29	70.60	1.69	2.39	82.87	81.31	1.56	1.92
	MAM	78.52	78.87	-0.35	-0.45	86.89	85.59	1.30	1.52
	JJA	75.15	73.20	1.95	2.66	84.77	82.63	2.14	2.59

AbT and THI. At the same time, none of the weather parameters showed significant variation between the two half years of longer and shorter day lengths. This gives the indication that raining pattern forms the major determinant of weather parameters rather than day length in the region (Kumar, 2013; Rao, 2013), mainly attributable to the occurrence of intense raining during the second half of long day period suppressing the AbT elevation to the lowest level among the four seasons (Kutty *et al*. 2019, Kutty, 2021).

Mx and Mn values of weather parameters attained each day are very important in deciding the thermal comfort of animals (Maurya *et al.* 2005; Prasad *et al.* 2013). Hence monthly averages of daily Mx and Mn values of AbT, RH and THI were compared between IH and OD recordings. Lowest of MxT in ºC attained was during January from both IH (29.03) and OD (26.65) recordings, while the highest was during April (33.51) and May (31.22) respectively. AbT being the major contributor of TS, MxT of each day determines the extent of TS affecting the animal (Maurya*et al.* 2005). However the monthly pattern of MxT was different between IH and OD sources, attributable to the modifications by the housing conditions as reported by Harikumar (2017) and Prasad (2014).Corresponding to MxT, MnT of OD also had its lowest during January (22.66) and highest in May (28.19). However for IH, lowest and highest of MnT was during Aug (24.17) and March (30.17) respectively showing a different pattern. Since MnT attained each day forms major determinant of thermal comfort under the tropical climate (Sonmez *et al.* 2005), the difference of MnT between IH and OD recordings is more important to consider from the animal welfare perspective.

The difference of monthly means of MxT between IH and OD recordings was ranging from the lowest of 1.19 ºC during May to 2.83 ºC during September (Mean 2.24ºC) and the difference was more than 2ºC during nine months. Similarly monthly means of MnT was also more IH during 11 months with a difference of 0.68 ºC during September to 2.91 ºC during April (mean 1.81 ºC). However, during May the difference in IH temperature was less than OD (-1.38 ºC), which was attributable to more thermal radiations outside due to the heating of surroundings, while the roof and side walls of the barns contributed to reduce IH temperature, in agreement with the report of Das *et al.*, 2016. Thus, AbT in terms of daily mean, maximum and minimum were more IH compared to OD (except in one month), indicating inadequacy of heat dissipation from the barns especially during afternoon hours.

Monthly means of MxTHI and MnTHI values from IH and OD recordings and their differences showed almost same pattern as that of AbT. Mean of MxTHI value OD was highest during May (85.59) and lowest in Jan (76.85), while IH the highest was during March (86.89) and lowest during Jan itself (79.76). MnTHI was highest during May (81.29) from OD and APR (81.85) for IH recordings corresponding to the pattern of AbT, while the lowest mean of MnTHI was during Jan from both OD (70.60) and IH (72.29 sources. Except in May, Similar to AbT, THI was more IH during all the months with mean difference of 1.95 and 1.81 respectively for Mx and Mn THI. During May, MxTHI and MnTHI of IH recordings were less respectively by 0.40 and 2.77 units than OD values, and is attributable to the AbT pattern of May as mentioned earlier.

Conversely, monthly averages of MxRH and MnRH was more OD than IH with mean differences of 9.63 % and 10.34 % respectively. Lowest of MxRH attained was during January with 84.50 % OD and 70.53 % IH. On the higher side MxRH of OD reached saturation (100 %) during June, July and August attributable increased raining of the period. MxRH recorded IH was also high during those three months, with the highest of 96.28 % during August. The pattern of MnRH was lowest for OD during February (44.12%) and highest during July (90.50%), while IH, lowest and highest were 46.69% and 80.81% during February and August respectively. Monthly means of MnRH from both IH and OD varied widely across the year with the highest of almost double compared to the lowest recording.

The difference between MxT and MnT of each day indicates the extent of temperature variation exposed to the animal and contributes greatly to TS (Maurya *et al.* 2005). Differences between daily maximum and minimum of the three weather parameters from OD and IH sources across months are shown in table No 4. Overall mean differences were more IH than OD for AbT and THI across months, while the difference of RH was more OD than IH. The variation between IH and OD were highly significant ($P<0.001$) with respect to the difference of maximum and minimum of all the three weather parameters.

The lowest of daily variation of AbT was during March and September from IH and OD respectively and the highest variations were during August and July respectively, indicating a difference in the pattern between IH and OD recordings. THI variation was lowest during October and September and highest during January and July respectively for IH and OD sources. The difference in the pattern of THI variation from that of AbT can be attributed to the influence of RH, which was having a different pattern with the lowest and highest during July and February respectively from both the sources, and was corresponding to the months of highest and lowest rainfall in the region(Kumar, 2013; Rao, 2013).

The attainment of highest and lowest values of different weather parameters and their differences were not consistent across months between IH and OD recordings. Even though these variables were regulated by more or less same environmental factors, the difference in their pattern can be attributed to the influence of housing conditions (Prasad, 2014). Since weather parameters were mostly regulated by day length (Gaughan, *et al.* 2013) and rainfall of the locality (Rajoriya *et al.*2014), having unique pattern across seasons, IH and OD weather parameters were compared between corresponding quarters. Accordingly quarterly averages of daily Mn and Mx values of the three weather parameters from IH and OD as well as their differences in actual terms as well as percentage are shown in table No 5.

During all the seasons, MxT and MxTHI recorded IH was consistently above the OD values by a mean difference of 2.36 ºC (8.03%) and 1.81 (2.20 %) respectively, while MxRH (%) of IH recording across the seasons showed a consistent reduction by around 5.17 (5.32 %) than OD values. At the same time, the difference of daily minimum values ofall the three weather parameters between IH and OD recordings showed different patterns across seasons. During MAM, daily minimum values of AbT (°C), RH (%) and THI were lesser inside the barn by 0.16, 17.93 and 0.35 respectively. The differences were highly significant (P<0.001) and is attributed to the influence of moist floor of the barn facilitating evaporative cooling, enhanced by the influx of dry air during the summer season. In contrast, during DJF, minimum values of all the three parameters were more inside the shed than outside attributable to cooler weather conditions and low RH outside (Kilgoura *et al*. 2012), as against lesser RH inside during all other seasons. During SON and JJA, the patterns of the minimum and maximum values of the parameters were similar.

SUMMARY

All the weather parameters such as AbT, RH and THI varied significantly between IH and OD recordings. AbT in terms of daily mean, maximum and minimum were more IH compared to OD, indicating inadequacy of heat dissipation from the barns especially during afternoon hours. While THI of IH and OD showed similarity with AbT, RH variables showed monthly and seasonal pattern opposite to that of AbT with higher values OD than IH. Even though weather parameters of both IH and OD were regulated by more or less same environmental factors, the difference in their pattern indicates the need for better housing interventions to enhance the thermal comfort of animals

ACKNOWLEDGMENT

The authors are thankful to Dr. Thirupathy, Dr. Pramod S, Dr Lasna Sahib of LRS Thiruvazhamkunnu for their valuable help during the course of the study. This paper is part of the PhD thesis submitted to Kerala Veterinary and Animal Sciences University, Pookode, Wayanad.

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