Research paper

Seasonal dynamics of physiological response in Sahiwal cows adapted to hot-arid climate of Rajasthan state

Gayatri Gujar[1,2], Prince Vivek[1], VK Choudhary[2], Monika Sodhi[1], Amandeep[1], Nampher Masharing[1], Manish Tiwari[1] and Manishi Mukesh[1]*

[1]*ICAR-National Bureau of Animal Genetic Resources, Karnal-132001 (Haryana) India*
[2]*Rajasthan University of Veterinary and Animal Sciences, Bikaner, (Rajasthan) India*

ABSTRACT

A total of 50 Sahiwal cows totalling to a cumulative of 400 physiological observations, reared in the hot-arid region of Bikaner district in Rajasthan were evaluated for seasonal effects on their physiological response. All the evaluated physiological parameters *viz* rectal temperature (RT), respiration rate (RR), pulse rate (PR), skin temperature (ST) at ventral (VT), dorsal (DT) and lateral (LT) points of cows revealed a seasonal effect, however the changes were not pathological nor very adverse. The maximum values for all parameters under study were recorded during the afternoon time points in summer and hot-humid seasons, showing a positive effect of THI on these parameters.

Keywords: physiological response, temperature-humidity index, Sahiwal cows, hot arid

***Corresponding author**: mmukesh_26@hotmail.com

INTRODUCTION

Livestock production is an important sector of the agricultural economy of the country, contributing significantly to the income and employment in rural India. Livestock rearing not only provides income, but acts as an insurance against crop failure and other hardships that may arise due to the changing climatic scenario. India is going through a phase of climate change, being witnessed in the erratic and extreme weather events that has been occurring in the past decade, the temperature has also been on a rise during the last decade (figure 1). Various models have predicted that the environmental temperature in India is expected to rise by 0.5°C by the year 2030, and by the end of this century this may go up to 2-4°C with maximum increase predicted to be in the northern part of India (Shukla, 2003). This will jeopardize the heavily climate dependent agriculture and livestock sector of India, having wide ramifications for the rural population. The effect of thermal stress on cattle has been evaluated since time immemorial, with an eye on devising thermal stress alleviation measures. The tropical set up of India characterized by high temperature associated with high humidity adds to the heat load in dairy animals, adversely impacting their productivity. The thermal stress that is exacerbated by increasing global warming, necessitates further look into the heat stress response and associated pathways, that will aid in selection of thermotolerant animals, which is the main pillar of climate resilient livestock production.

India is blessed with an assortment of cattle diversity, with its 50 registered native breeds and several exotic and crossbred cattle, India has world's second largest cattle inventory with 12.88% of cattle (World Cattle Inventory: Ranking of Countries, USDA, 2020) and 193.46 million cattle population (20th livestock census). Out of these, 53.46 million are classified as cross bred or exotic cattle while 145.91 million falls under the category of native/non-discriminate cattle. The 50 recognized native cattle breeds (*Bos indicus*) are well adapted to withstand the harsh climate and still perform efficiently. The better adaptability of indicine milch breeds like Sahiwal, Gir, Red Sindhi, Tharparkar, Rathi, Red Sindhi to the heat stress conditions while maintaining their productivity, makes them a valuable model for studying heat stress response. Among the mechanisms used to elucidate heat stress adaptations in cattle, the physiological responses are the principal benchmark used to identify a heat stressed animal. However, the studies conducted in the past has been mostly centered around comparing the physiological responses between two temperature or temperature humidity index (THI) thresholds or by subjecting animals to extended periods of heat stress in a controlled set up. In recent years, the studies are being gradually redirected towards a more integrated approach of evaluating physiological response in a natural environment, and the seasonal modulations made by animal's body for acclimatization that reflects their adaptational evolution. The recent approaches are more inclusive of a natural response rather than the earlier cases where animal was subjected to experimental procedure to elicit stress response, which often led to misinterpretation of the effect on animal and subsequent response.

The erosion of indigenous genetic pool of animals in India has regrown the interest in evaluating the indigenous livestock breed with a renewed interest, to conserve and

to integrate them further into the production systems of this country. In their adaptation to thermal stress, disease resistance and maintaining productivity under prolonged period of heat stress, the indicine breeds trumps taurine cows significantly. This study was an effort to evaluate the seasonal changes in physiological response of Sahiwal cows reared in the extremely hot climatic conditions of Rajasthan. The homeothermic response of an animal makes it imperative that there will be fluctuations in physiological responses as the animal's microclimate changes. The evaluation of seasonal variations will throw more insights into the physiological changes mounted by an animal as it encounters changes in the microclimate across different seasons.

MATERIAL AND METHODS

Location and climate of the study area

The study was carried out at Livestock research station (LRS), Kodamdesar situated in Bikaner, Rajasthan. The site is located at 28°03' N latitude and 73°04 E longitude at an elevation of 203 m above mean sea level. The prevailing climatic conditions is that of prolonged period of extreme heat where temperature goes as high as 50°C during summer and the winters are also very cold with temperature dropping to sub-freezing at times, with hot and cold waves being a common occurrence during summer and winter months. This study was conducted over a period of one year, where data recording was done across four seasons: Summer (May-June); Hot-humid (August-September); Winter (December-January) and, Spring (March-April), starting from June 2019. The temperature and humidity during the duration of this study is provided in the table 1 and figure 2.

Selection and management of animals

All the animals in this study was reared in the cattle yard of LRS, Kodamdesar. Around 50 cows of Sahiwal breed were randomly selected for making physiological observations, being located in the hot-arid region of Bikaner, the animals reared in the LRS are subjected to extremes of both hot and cold temperatures. The animals were housed in a loose housing system with adequate provisions for shade and water in the paddocks. The feeding of animals was carried out as per the ICAR feeding requirements for adult dairy cattle, with *ad libitum* access to clean, hygienic drinking water.

Recording of meteorological and physiological parameters

The prevailing temperature and humidity data of the study area were recorded on a daily basis during the complete duration of this study. The temperature humidity index (THI) was calculated using the formula:

$$THI = (1.8 \times Tdb + 32) - [(0.55 - 0.0055 \times RH) \times (1.8 \times Tdb - 26)]$$ (NRC, 1971)

Where Tdb- dry bulb temperature in °C and RH is relative humidity (%).

All the physiological parameters, rectal temperature (RT), respiration rate (RR), pulse rate (PR), skin temperature (ST) at different points i.e., dorsal temperature (DT), ventral temperature (VT), lateral temperature (LT) and frontal temperature (FT) were recorded at two different time points of morning (7-8 a.m.) and afternoon (2-3 p.m.) across all four seasons.

Rectal temperature (RT)

The RT was measured using a digital thermometer, by gently inserting the pointed end into the rectal mucosa of the cows. The thermometer was kept in the mucosa for 1-2 minutes and the temperature was recorded in °C. In between the recordings, the thermometer was cleaned with a swab soaked in methylated spirit and lubricated well with paraffin.

Respiration rate (RR)

The RR was recorded for each animal from a distance by observing the flank movement, with one inward and one outward flank movement considered as a single breath. The recordings were done as breaths/minute.

Pulse rate (PR)

The PR was recorded by feeling the pulsation in middle coccygeal artery located at the base of tail, by placing the thumb over the artery and holding it for a minute. The

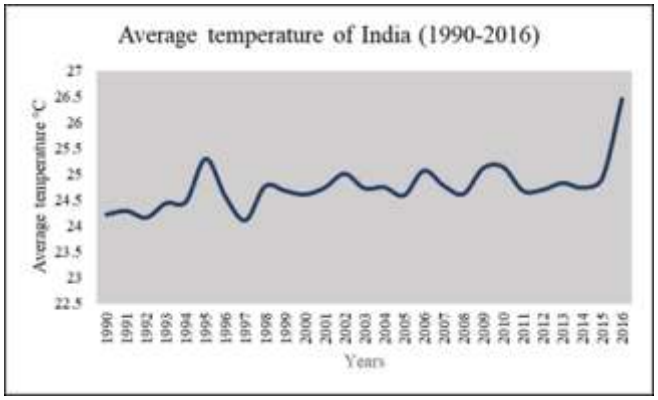

Fig. 1. Average surface temperature of India (1990-2016) (Data source: Indian meteorological department (IMD), New Delhi)

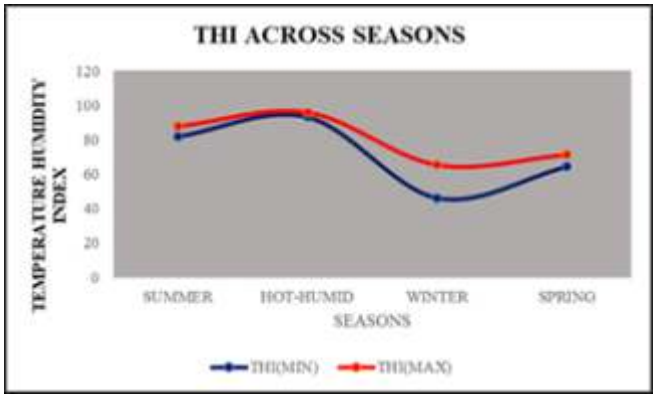

Fig. 2. Prevailing THI of the study area (2019-2020)

observations were made as beats/minute.

Skin temperature (ST)

Skin temperature was recorded at four different points of the body *viz*, frontal, dorsal, lateral and ventral points using a non- contact thermal gun that makes use of infrared thermometry to gauge the ST as FT, DT, LT, and VT. The ST was recorded in °C.

Statistical analysis

The recorded observations were well tabulated and subjected to statistical analysis using statistical package for social sciences (SPSS) version 24 for one-way ANOVA to find the significant differences in parameters between seasons and time period of a day. The results are presented as mean ± SE.

RESULTS

All the recorded physiological parameters, RT, RR, PR, and ST showed an effect of season, with maximum values recorded during the afternoon period in all parameters. The RT was found to be significantly ($P<0.05$) higher during the afternoon periods across four seasons. The highest RT (102.10 ± 0.087°C) was recorded during the afternoon of hot-humid season, followed by summer afternoon, spring afternoon and winter afternoon with values of 102.00 ± .085°C, 101.51 ± 0.074°C, and 101.04 ± 0.105°C, respectively. The RT recorded during the morning time points were 100.46 ± 0.072°C, 100.85 ± 0.056°C, 101.015 ± 0.08°C, and 101.02 ± 0.06°C during winter, spring, summer and hot-humid seasons, respectively. The highest RR was recorded during the afternoon time point during summer (33.95 ± 0.275 breaths/min.), followed by 31.67 ± 0.346 breaths/min., during the afternoon of hot-humid season. The RR recorded during the afternoon time points in winter and spring seasons were 25.62 ± 0.442 breaths/min. and 28.06 ± 0.236 breaths/min., respectively. The highest RR during morning time point was recorded during summer season (28.52± 0.207 breaths/min.), followed by 27.27 ± 0.262 breaths/min., 24.32 ± 0.305 breaths/min., and 23.62 ± 0.257 breaths/min. during hot-humid, spring and winter seasons, respectively.

The RT and RR was significantly higher ($P<0.05$) during summer and hot-humid seasons across both time points of the day, compared to winter season, indicating higher heat load. The PR was highest (66.25 ± 0.423 beats/min.) during the afternoon time point in hot-humid season, followed by the afternoon time point in summer with a value of 65.74 ± 0.356 beats/min, While the PR during afternoon time points during winter and spring seasons were 57.53 ± 0.552 beats/min., and 61.03 ± 0.433 beats/min., respectively. The highest PR during morning time point was recorded during summer season (61.32 ± 0.345 beats/min.), followed by hot-humid, spring and winter seasons, with values of 61.05 ±0.403, 56.32 ± 0.405 and 54.37 ± 0.438 beats/min., respectively. The ST recorded at the ventral, dorsal, lateral, and frontal points of the cows showed an increasing trend with the increase in THI. The ST was found to be significantly higher ($P<0.05$) during summer and hot-humid seasons compared to winter and spring seasons. The VT was found to be 32.53 ±0.134°C and 37.77 ± 0.138°C, 32.03 ± 0.224°C and 37.30 ± 0.098°C, 13.26 ± 0.341°C and 24.75 ± 0.35°C, and 25.67 ±0.327°C and 30.88 ± 0.255°C, during the morning and evening time points in winter, spring, summer, and hot-humid seasons, respectively. While the LT was 33.11 ± 0.134°C and 35.27 ± 0.777°C, 32.17 ± 0.190°C and 37.07 ± 0.178°C, 15.02 ± 0.381°C and 25.23± 0.359°C, and, 24.91 ± 0.435°C and 30.56 ± 0.366°C during the morning and evening time points in winter, spring, summer, and hot-humid seasons, respectively. The DT was found to be 33.22 ± 0.124 and 38.05 ± 0.127, 31.56 ± 0.197 and 37.22 ± 0.119, 11.07 ± 0.381 and 20.67 ± 0.340, and 23.46 ±0.215 and 26.18 ± 0.446, during the morning and evening time points in winter, spring, summer, and hot-humid seasons, respectively. And the FT was 33.02 ± 0.119 and 38.04 ± 0.104, 32.02 ± 0.215 and 37.28 ± 0.097, 11.79 ± 0.396 and 24.29 ± 0.266, and 20.83 ± 0.273 and 26.88 ± 0.311, during the morning and evening time points in winter, spring, summer, and hot-humid seasons, respectively. The mean values of all the physiological parameters has been provided in table 2 and graphically presented in the figures 3,4, 5, and 6 [6(a), 6(b), 6 (c) and 6 (d)].

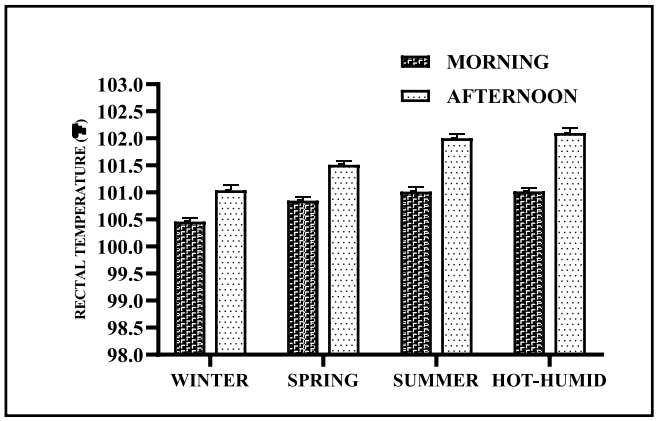

Fig. 3. Rectal temperature (°C) of Sahiwal cows across seasons

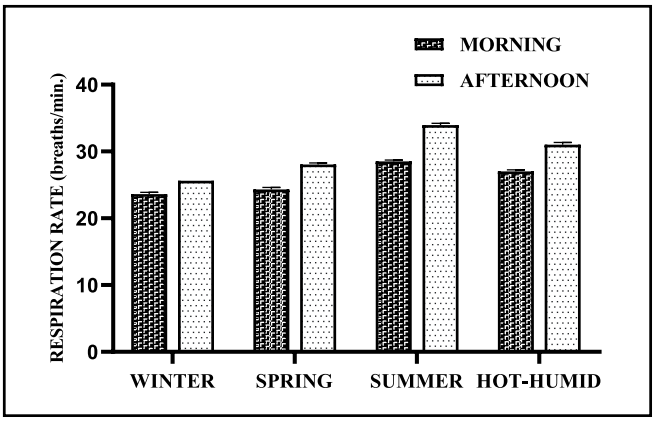

Fig. 4. Respiration rate (breaths/min.) of Sahiwal cows across seasons

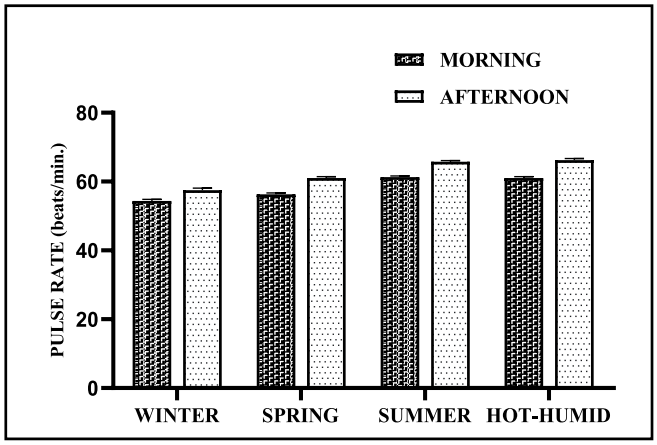

Fig. 5. Pulse rate (beats/min.) of Sahiwal cows across seasons

DISCUSSION

In this study, all the physiological parameters, across seasons, were found to be in the normal physiological range of adult cattle (Radostits, 2006). However, there was a seasonal rhythm apparent in the physiological parameters recorded, with an increasing trend as the temperature/THI increased from winter to hot-humid season. The rectal temperature was found to be highest during the afternoon of summer and hot-humid season, suggesting a higher heat load during these seasons due to very high prevailing THI. When animal is subjected to extended period of high heat load, the animal tries to lose the heat from the body by adjusting its physiological mechanisms, but the persistence of higher ambient temperature compromises the heat dissipation ability. This results in higher core body temperature during hotter months. Further, the RT was found to be higher during the afternoon time point across all seasons, suggesting a diurnal rhythm. Our findings corroborated with that of Bhanet al. (2012);Sailoet al. (2017) and Maibamet al. (2019) who also reported higher RT in Sahiwal cows during hot summer periods. The recorded RR was significantly ($P<0.05$) higher during the afternoon time points of summer and hot-humid seasons. Whenever an animal is subjected to higher heat load for extended period, the pathways of sensible heat loss through conduction and convection gets compromised. As a result, the animal body switches to insensible heat loss through evaporative cooling, and the rise in RR is an indication of the animal body trying to ramp up evaporative cooling even further. When the humidity level is high, even the evaporative cooling fails, raising the body temperature of animals. This is visible in higher RR during summer and hot- humid season afternoon as compared to other three seasons. Similar to our findings, earlier reports of Kordeet al. (2007), Singh et al. (2014) and Al-Kanan, (2016) have also shown rise in RR values in cows with the increase in THI.

The PR of an animal is an important indicator of metabolic and endocrinological shifts inside the animal body during heat stress periods, and has been evaluated periodically to assess the heat stress response in animals. Our study indicated a positive effect of THI on PR, with the highest PR recorded during the afternoon time points of summer and hot-humid seasons. Our findings concurred with the findings of Sengaret al. (2017), Yadav et al. (2016) and Kumar et al. (2017). The higher PR observed during hotter ambience could be attributed to circulatory adjustment as a result of secretion of higher amount of catecholamines in animals that increases the cardiac output in an attempt to dissipate more heat. The ST measured at different sites of animal body was significantly ($P<0.05$) high during summer and hot-humid months, with maximum values recorded during afternoon time points. The ST is highly influenced by the ambient temperature and the intensity of solar radiation (de Lima et al., 2013; Das et al. 1997). As the skin is the principal route of heat exchange to outside, the increased ambient temperature and heat dissipation inadvertently raises the ST, which was evident in our study. The raised ST with increased temperature is consistent with the findings of Jianetal. (2015), Maibamet al. (2017) and Amamou, et al. (2019). Furthermore, the trends in all the physiological parameters under study showed a positive effect of THI, with an apparent increase in physiological parameters.

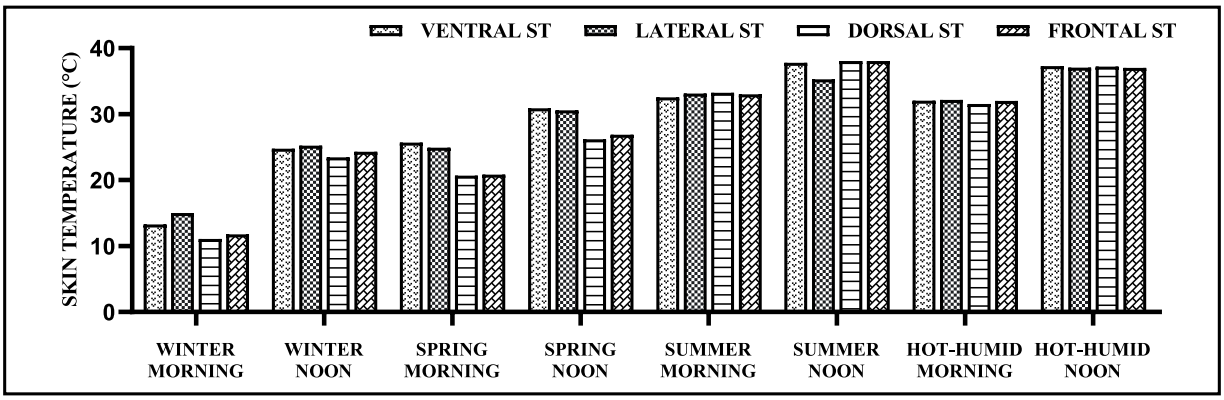

Fig. 6. Skin temperature (°C) of Sahiwal cows across seasons

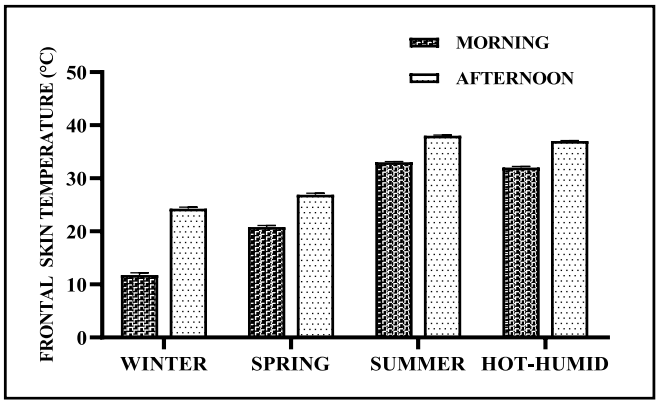

Fig. 6 (a). Frontal skin temperature (°C) of Sahiwal cows across seasons

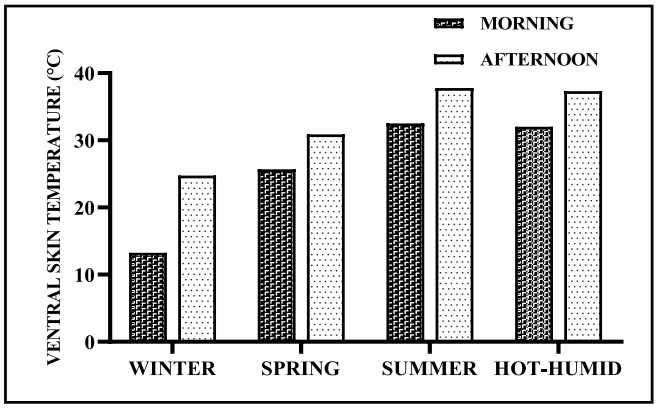

Fig. 6 (b). Ventral skin temperature (°C) of Sahiwal cows across seasons

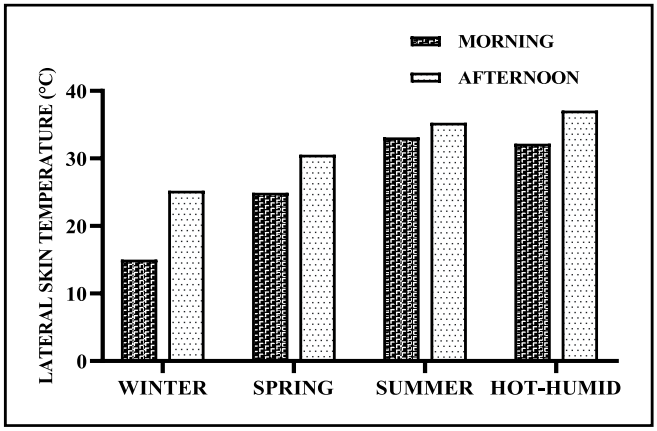

Fig. 6 (c). Lateral skin temperature (°C) of Sahiwal cows across seasons

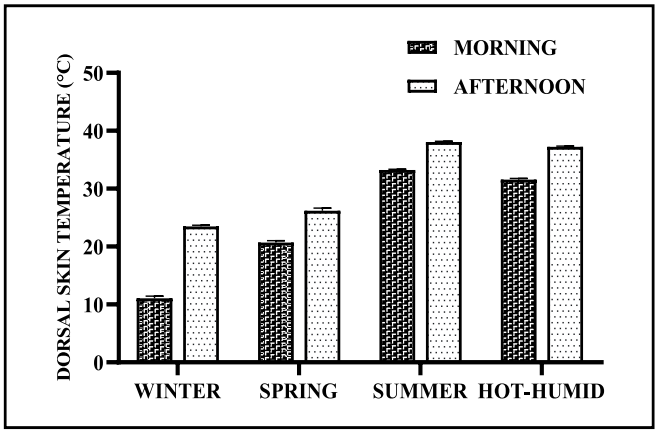

Fig. 6 (d). Dorsal skin temperature (°C) of Sahiwal cows across seasons

CONCLUSION

Our study revealed a seasonal rhythm in the physiological parameters of Sahiwal cows, however even at very high THI, the physiological parameters were maintained within the normal physiological range described for cows. This further affirms the established fact that indicine cattle breeds have superior thermotolerance ability. Further, cellular and gene level studies is being carried out by our group to evaluate the underlying mechanisms that confers the thermotolerance ability in indicine breeds which will help in better understanding of heat stress response in indicine cattle.

ACKNOWLEDGMENTS

The authors duly acknowledge the financial support received under ICAR-National Fellow Scheme.

REFERENCES

20th Livestock Census. 2019. All India report: ministry of agriculture, department of animal husbandry, dairying & fisheries, Krishi Bhawan, New Delhi, India.

Al-Kanaan, AJJ. 2016. Heat stress response for physiological traits in dairy and dual purpose cattle populations on phenotypic and genetic scales (Doctoral dissertation). Ph.D thesis submitted to The Faculty of Organic Agriculture, The University of Kassel, Germany.

Amamou H, Beckers Y, Mahouachi M and Hammami H. 2019. Thermotolerance indicators related to production and physiological responses to heat stress of Holstein cows. Journal of thermal biology82: 90-98.

Bhan C, Singh SV, Hooda OK and Upadhyay RC, Beenam and Mangesh V. 2012. Influence of temperature variability on physiological, haematological and biochemical profile of growing and adult Sahiwal cattle. Journal of Environmental Research and Development7: 986-994.

Das SK, Upadhyay RC and Madan ML. 1997. Changes in skin temperature and physiological reactions in Murrah buffalo during solar exposure in summer. Asian-Australasian Journal of Animal Sciences10 (5): 478-483.

De Lima V, Piles M, Rafel O, López-Béjar M, Ramón J, Velarde A and Dalmau A. 2013. Use of infrared thermography to assess the influence of high environmental temperature on rabbits.Research in Veterinary Science95(2): 802-810.

Jian W, Ke Y and Cheng L. 2015. Physiological responses and lactation to cutaneous evaporative heat loss in *Bos indicus*, *Bos taurus*, and their crossbreds. Asian-Australasian journal of animal sciences28 (11):1558.

Korde JP, Singh G, Varshney VP and Shukla DC. 2007. Effects of long-term heat exposure on adaptive mechanism of blood acid-base in buffalo calves. Asian-Australasian journal of animal sciences20 (5), pp.742-747.

Kumar J, Kumar M, Madan A, Singh Y, Yadav Brijesh and Anand M. 2017.Effect of season on physiological parameters and production profile of Hariana and Sahiwal cattle.Haryana Veterinarian56 (1):69-71.

Maibam U, Hooda OK, Sharma PS, Singh SV, Mohanty AK and Upadhyay RC. 2017. Seasonal variation in HSP70 expression and oxidative stress in skin of zebu (Tharparkar) and crossbred (Karan Fries) cattle under tropical climate. Biological Rhythm Research48(4): 647-661.

National Research Council, 1971.A guide to environmental research on animals.National Academies.

Radostits OM, Gay CC, Hinchcliff KW and Constable PD. 2007.A textbook of the diseases of cattle, horses, sheep, pigs and goats.Veterinary medicine10:2045-2050.

Sailo L, Gupta ID, Das R and Chaudhari MV. 2017. Physiological response to thermal stress in Sahiwal and Karan Fries cows. International Journal of Livestock Research7(5):275-283.

Sengar GS, Deb R, Singh U, Raja TV, Kant R, Sajjanar B, Alex R, Alyethodi RR, Kumar A, Kumar S and Singh R. 2018. Differential expression of microRNAs associated with thermal stress in Frieswal (*Bos taurus* x *Bos indicus*) crossbred dairy cattle. Cell Stress and Chaperones23(1), pp.155-170.

Singh M, Sehgal JP, Khan JR and Sharma HD. 2014.Effect of different seasons on feed efficiency, plasma hormones and milk production in lactating cows.Parity3(3.42): 3-10.

Shukla PR. 2003.Climate change and India: vulnerability assessment and adaptation. Universities Press. Orient Blackswan.ISBN 8173714711, 9788173714719 Chapter 3.

World Cattle Inventory: Ranking of Countries retrieved from https://beefmarketcentral.com/story-world-cattle-inventory-ranking-209-countries-fao-0-127843

Yadav B, Singh G and Wankar A. 2017.The use of infrared skin temperature measurements for monitoring heat stress and welfare of crossbred cattle.Indian Journal of Dairy Science70(1):127-131.