

Infrared Thermogram Temperature Trends of Body Extremities of Tharparkar and Karan Fries Cattle during the Extreme Climatic Conditions

Afreed Muhammed N.V., Sohan Vir Singh*, Nikita Bhalakiya, Apeksha Ukey, Gaurav Kumar

ABSTRACT

In order to compare the surface temperature of body extremities of Tharparkar and Karan Fries cattle under extreme climatic conditions during summer and winter season, the present study was carried out under standard managemental conditions. Environmental parameters, including temperature and humidity, were recorded daily, and Temperature Humidity Index (THI) and Black Globe Humidity Index (BGHI) were calculated to assess the level of thermal comfort on cattle. Thermal imaging (Infrared thermography, IRT) of body extremities (muzzle, nose bridge, ear tip and base, fetlock, and knee) were recorded twice weekly during winter (Dec. 2022–Jan. 2023), spring (Feb.–March 2023), and summer (June–July 2023) season. Skin extremities temperature was highest during summer followed by spring and winter season in both the breeds of cattle. Significant ($p < 0.05$) difference was observed in thermal imaging temperatures at different anatomical sites within and between breeds across seasons. Karan Fries exhibited higher fetlock temperature across all seasons and greater ear base temperature variation during winter compared to Tharparkar. Ear tips showed the lowest temperature, with maximum extremity temperature variation during winter, possibly due to arterio-venous anastomoses protecting against frostbite. The huge fluctuations in the temperature of body extremities alter the normal physiology of animals therefore animals should be protected from extreme weather events for normal physiological functions and welfare.

Key words: Arterio-venous anastomoses, Extremities temperature, Skin temperature, Temperature humidity index (THI). Thermal imaging.

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INTRODUCTION

Climate change has led to extreme environmental variations, posing challenges to livestock health and productivity. Thermal stress disrupts physiological homeostasis in cattle (Barros *et al.*, 2015). The thermal comfort zone for adult cattle is 5–25°C (Singh and Upadhyay, 2009). Tropical cattle breeds can cope with temperatures above 26°C or below 5°C, adjusting physiologically, behaviourally, and immunologically to minimize adverse effects (Yadav *et al.*, 2016). Animals maintain stable body temperatures through thermoregulatory responses. When skin surface temperature is below 35°C, the core-to-skin gradient allows effective heat loss mechanisms (Collier *et al.*, 2006).

Infrared thermography (IRT) is a non-invasive technology that measures surface temperature changes, providing insights into livestock health. It detects stress or illness across species, including sheep (Pantoja *et al.*, 2017), water buffaloes (Silva *et al.*, 2018), dairy cows (Gianesella *et al.*, 2018), and beef cattle (Romanello *et al.*, 2018). IRT minimizes infection risks, avoids animal restraint, and assesses stress and welfare (Soerensen and Pedersen, 2015). Surface temperature variations, influenced by ambient conditions, affect heat exchange and adaptation (Collier *et al.*, 2006). Thermoregulatory hotspots like the muzzle, ears, and knees reflect adaptability to environmental stress.

Seasonal analysis of surface temperature using IRT can reveal physiological responses to thermal stress. While the Temperature Humidity Index (THI) assesses heat stress

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globally, studies on extremity temperature trends and the Black Globe Humidity Index (BGHI) are limited. This study on Tharparkar and Karan Fries cattle addresses these gaps, focusing on climate-resilient strategies to protect animals. These breeds' distinct adaptability can improve welfare and productivity under extreme climates.

MATERIALS AND METHODS

The study was conducted at ICAR-NDRI, Karnal, Haryana (29°43' N, 77°20' E; 250 m above sea level), experiencing a tropical climate with temperatures ranging from 0°C to 45°C and 760 mm annual rainfall. The experiment was approved and

carried out according to the established standards of the Institutional Animal Ethics Committee (Reg. 1705/GO/ac/ CPCSEA Dt.3/7//2013) IAEC no.153/16).

Animals, Feeding, and Handling

Twenty each of Tharparkar and Karan Fries cattle were selected from Livestock Research Center, ICAR-NDRI, Karnal, Haryana (India). The age of animals ranged from 1-4 years. All the experimental animals were fed as per the feeding standard of ICAR (2013).

Recording of Climatic Variables

Environmental parameters such as minimum (T_{\min}) and maximum (T_{\max}) temperature, wet and dry bulb (T_{wb} , T_{db}) temperature, black globe temperature (T_{bg}), relative humidity (RH), wind velocity etc were recorded at biweekly interval in morning and afternoon. The temperature humidity index

(THI) and black globe humidity index (BGHI) was calculated using the following equations.

$$THI = 0.72 (T_{db} + T_{wb}) + 40.6 \text{ (NRC, 1971)}$$

$$BGHI = BGT + (0.36 \times T_{db}) + 41.5 \text{ (Buffington et al., 1981)}$$

Where, T_{db} = Dry bulb temperature ($^{\circ}\text{C}$), T_{wb} = Wet bulb temperature ($^{\circ}\text{C}$), BGT= Black globe temperature ($^{\circ}\text{C}$)

Infrared Thermography

The infrared thermography of Tharparkar and Karan Fries cattle was performed weekly twice from a distance of 2-3 feet from animals during different seasons. The temperature of multiple body locations (muzzle, eye, ear tip etc.) was measured twice a week during all the seasons using Infrared camera (Therma CameraTH SC2000, FLIR Systems, Inc., Wilsonville, OR, USA). Images were recorded as JPEG files and stored in card within camera. Images were interpreted using the software (FLIR Tools. Ink).

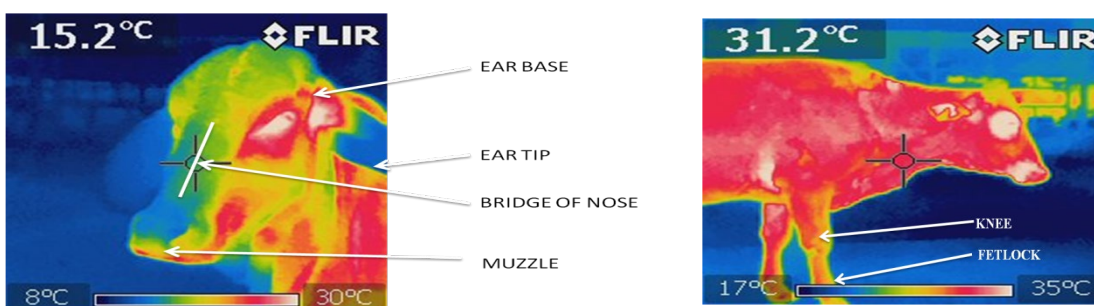


Fig. 1: Infrared thermography images of different body parts of the animal body

RESULTS AND DISCUSSION

Environmental Parameters

The seasonal means of various meteorological parameters studied are presented in Table 1. The T_{\max} ranged from 8.6 $^{\circ}\text{C}$ to 20.7 $^{\circ}\text{C}$ (mean 14.63 $^{\circ}\text{C}$) in winter, 24.6 $^{\circ}\text{C}$ to 29.6 $^{\circ}\text{C}$ (mean 27.28 $^{\circ}\text{C}$) in spring, and 32.3 $^{\circ}\text{C}$ to 42.5 $^{\circ}\text{C}$ (mean 37.69 $^{\circ}\text{C}$) in

summer season. T_{\min} ranged from 3.1 $^{\circ}\text{C}$ to 11.7 $^{\circ}\text{C}$ (mean 7.88 $^{\circ}\text{C}$) in winter, 10.6 $^{\circ}\text{C}$ to 16.6 $^{\circ}\text{C}$ (mean 13.60 $^{\circ}\text{C}$) in spring, and 18.9 $^{\circ}\text{C}$ to 26.5 $^{\circ}\text{C}$ (mean 21.63 $^{\circ}\text{C}$) in summer. THI and BGHI averaged 56.60 and 57.94 in winter, 70.64 and 73.45 in spring, and 82.96 and 88.69 in summer. These meteorological parameters highlighted the significant seasonal variations in climatic stress.

Table 1: Average meteorological parameters recorded during the experimental period (December -2022 to June - 2023)

Season	Winter	Spring	Summer
Maximum Temperature ($^{\circ}\text{C}$)	14.63 \pm 0.23	27.28 \pm 0.08	37.69 \pm 0.19
Minimum Temperature ($^{\circ}\text{C}$)	7.88 \pm 0.14	13.60 \pm 0.09	21.63 \pm 0.14
Black Globe Temperature ($^{\circ}\text{C}$)	12.31 \pm 0.19	23.56 \pm 0.21	24.36 \pm 0.13
Dry Bulb Temperature ($^{\circ}\text{C}$)	11.53 \pm 0.18	23.17 \pm 0.20	34.78 \pm 0.25
Wet Bulb Temperature ($^{\circ}\text{C}$)	10.70 \pm 0.15	18.64 \pm 0.12	34.23 \pm 0.22
Relative Humidity (%)	80.07 \pm 0.98	54.34 \pm 0.95	30.59 \pm 0.84
Wind velocity (m/s)	1.45 \pm 0.05	1.97 \pm 0.06	2.03 \pm 0.07
Temperature humidity Index (THI)	56.60 \pm 0.23	70.64 \pm 0.22	82.96 \pm 0.25
Black Globe Humidity Index (BGHI)	57.94 \pm 0.25	73.45 \pm 0.28	88.69 \pm 0.34

Infrared Thermography (IRT)

Muzzle temperature ($^{\circ}\text{C}$)

The average muzzle temperatures of Tharparkar cattle were 22.36 $^{\circ}\text{C}$ in winter, 28.88 $^{\circ}\text{C}$ in spring, and 33.93 $^{\circ}\text{C}$ in summer. For Karan Fries, the values were 24.41 $^{\circ}\text{C}$, 31.30 $^{\circ}\text{C}$, and 33.85 $^{\circ}\text{C}$,

respectively. Significant seasonal differences ($p < 0.05$) in muzzle temperature were observed for both breeds, but no significant breed differences occurred during summer. Karan Fries showed significantly higher ($p < 0.05$) muzzle temperatures than Tharparkar cattle during spring (Table 2), aligning with Banerjee and Ashutosh (2011), who also



reported higher muzzle temperatures in Karan Fries cattle

compared to Tharparkar bulls. Similar trends were noted by Singh and Upadhyay (2009) in Karan Fries and Sahiwal cattle.

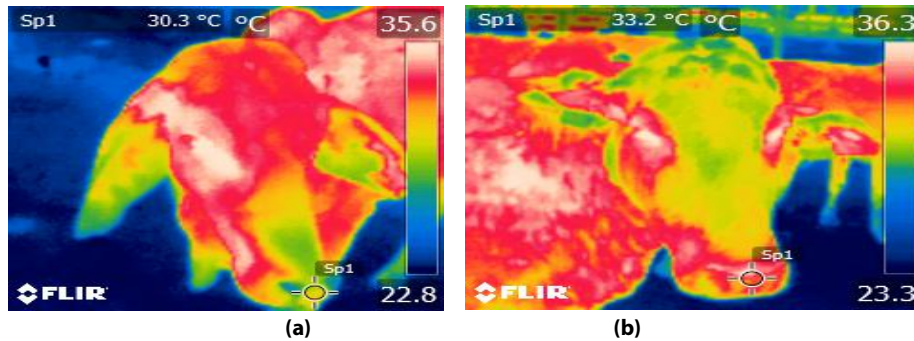


Fig. 2: Muzzle temperature (°C) reading of Tharparkar (a) and Karan Fries cattle (b)

In summer, Karan Fries exhibited slightly lower muzzle temperatures than Tharparkar cattle, likely due to frequent water intake and licking to alleviate heat stress, as observed by George *et al.* (2014) in sheep and cattle. They also reported stronger correlations between eye and rectal/vaginal temperatures in sheep than in cattle due to behavioural differences. Mota-Rojas *et al.* (2021) highlighted muzzle temperature as a useful indicator for remotely assessing health and respiration in dairy cows through thermal imaging.

Ear base temperature (°C)

The ear base mean temperature of Tharparkar cattle was

26.38°C in winter, 33.29°C in spring, and 37.04°C in summer, while for Karan Fries, it was 26.16°C, 33.07°C, and 37.97°C, respectively. Significant seasonal differences ($p < 0.05$) were observed for both breeds (Table 2). Heat stress in cattle due to high ambient temperatures can impact physiological responses. Giro *et al.* (2019) reported moderate to poor correlations between rectal temperature and ear base temperature in Charolais × Zebu cattle. In this study, ear base temperature showed a positive correlation with THI and BGHI. Mayer *et al.* (2016) noted temperature differences of 0.8-0.9°C between vaginal and tympanic ear temperatures in cattle.

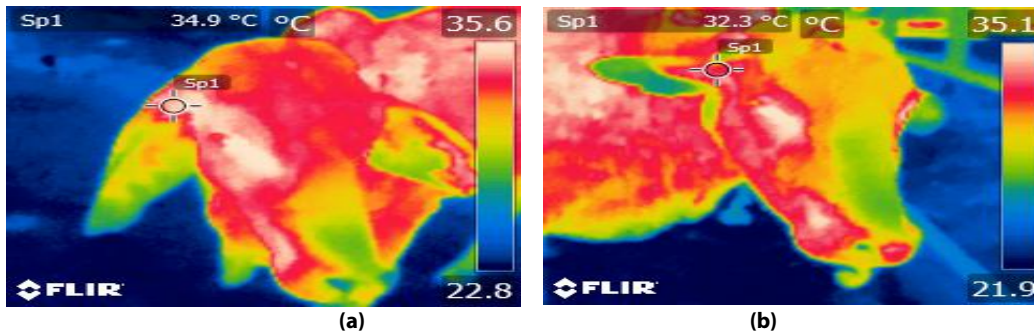


Fig. 3: Ear base temperature (°C) reading of Tharparkar (a) and Karan Fries cattle (b)

Ear base temperatures ranged from 20.6°C to 39.7°C in Tharparkar and 19.6°C to 40.7°C in Karan Fries (Table 3), influenced by environmental factors. Winter temperatures varied more in Karan Fries than Tharparkar, while summer temperatures were significantly higher due to vasodilation for heat dissipation. Jorquera-Chavez *et al.* (2019) demonstrated the effectiveness of remotely measuring cattle temperatures, finding higher correlations for eye temperatures ($r = 0.64-0.93$) than ear base temperatures ($r = 0.33-0.70$). Thermal windows, including the ear base, are critical for heat exchange. Soerensen and Pedersen (2015) identified these regions as having strong correlations with rectal temperature. Tabuaciri *et al.* (2012) found a higher correlation for ear base

temperatures ($r = 0.85$) compared to ear tip temperatures ($r = 0.27$), emphasizing the ear base’s role in thermoregulation.

Ear tip temperature (°C)

The average ear tip temperature of Tharparkar cattle was 15.81°C in winter, 29.59°C in spring, and 36.14°C in summer, showing significant ($p < 0.05$) seasonal variations. Karan Fries exhibited similar trends, with temperatures of 17.18°C, 30.80°C, and 36.16°C, respectively. Temperatures ranged from 7.7°C to 39.6°C in Tharparkar and 8.8°C to 40.7°C in Karan Fries, with a difference of 31.9°C between the highest and lowest values for both breeds (Table 2, 3). Seasonal variations reflect ear tips’ role as key sites for heat exchange due to vascular anatomy and thermoregulation mechanisms.

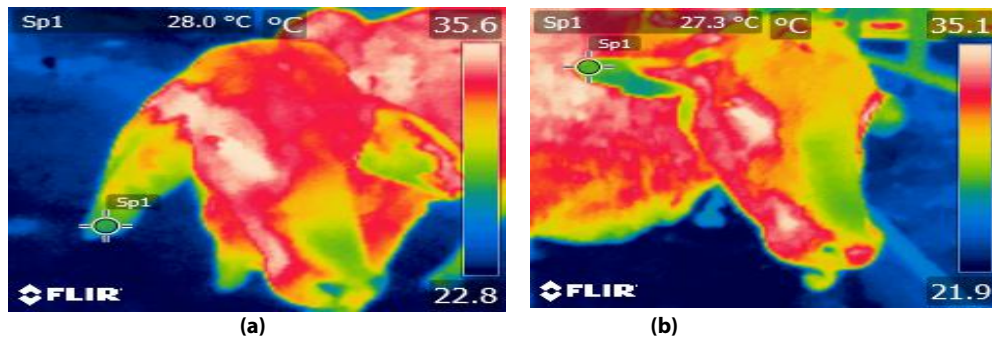


Fig. 4: Ear tip temperature (°C) reading of Tharparkar (a) and Karan Fries cattle (b)

In winter, ear tip temperatures ranged from 7.7°C to 33.6°C in Tharparkar and 8.8°C to 32.4°C in Karan Fries, with variations of 25.9°C and 23.6°C, respectively. Cold stress triggers vasoconstriction to conserve heat but may lead to the Huntington Reflex (Cold-Induced Vasodilation) to prevent frostbite and maintain tissue integrity. About 10% of winter observations recorded ear tip temperatures above 25°C, indicating this dynamic response. Daanen and Ducharme (1999) documented a similar reflex in monkeys. During spring, temperatures ranged from 18°C to 38.1°C in Tharparkar and 20.9°C to 35.1°C in Karan Fries. In summer, temperatures ranged from 30°C to 39.6°C and 28.9°C to 40.7°C, respectively (Table 3). Increased blood flow to ear tips during heat stress aids in dissipating body heat through radiation and convection, facilitated by dense blood

vessel networks near the skin (Mota-Rojas *et al.*, 2021). This thermoregulatory adaptation highlights the ear tips' role in managing extreme temperatures.

Bridge of nose temperature (°C)

The bridge of the nose temperature of Tharparkar cattle averaged 18.94°C in winter, 29.25°C in spring, and 35.91°C in summer, showing significant ($p < 0.05$) seasonal variations. Karan Fries exhibited similar trends with mean temperature of 19.63°C, 30.47°C, and 36.32°C, respectively. During winter, temperatures ranged from 11.2°C to 33.3°C in Tharparkar and 12.8°C to 33.3°C in Karan Fries, while in summer, values ranged from 28.9°C to 39.9°C and 29.4°C to 40.3°C, respectively (Table 2, 3).

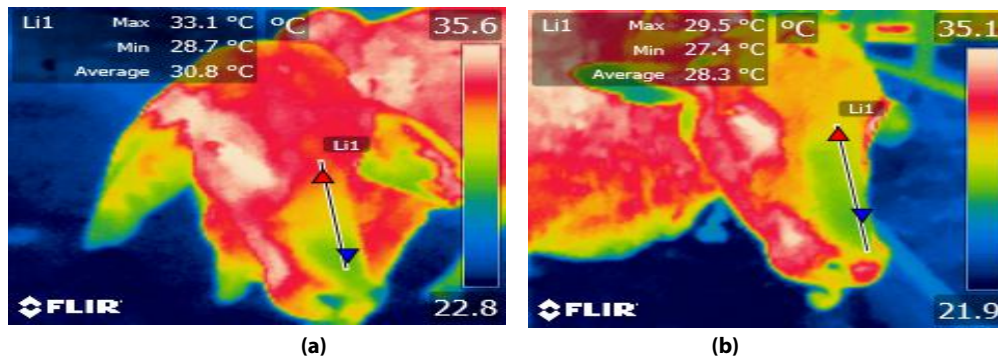


Fig.5: Bridge of Nose temperature (°C) reading of Tharparkar (a) and Karan Fries cattle (b)

The lowest and highest temperatures during winter and summer suggest that cold stress impacts Tharparkar cattle more, while heat stress is more challenging for Karan Fries. The bridge of the nose plays a critical thermoregulatory role, with vasodilation aiding heat dissipation and vasoconstriction conserving heat during cold stress.

Fetlock and Knee temperature (°C)

The mean fetlock temperature of Tharparkar cattle was 15.73±0.19°C in winter, 26.32±0.24°C in spring, and 34.28±0.18°C in summer, showing significant ($p < 0.05$) seasonal variations. For Karan Fries, the respective fetlock

temperatures averaged 17.72±0.23°C, 28.06±0.19°C, and 35.13±0.14°C, also with significant ($p < 0.05$) seasonal differences (Table 2). Karan Fries exhibited higher fetlock temperatures across all seasons, likely due to their higher metabolic rate. Temperature ranged from 10.5°C to 39°C in Tharparkar and 11°C to 39.2°C in Karan Fries, with greater winter variation attributed to the Huntington Reflex. This protective mechanism, observed in mammals (O'Brien, 2005), alternates between vasoconstriction and vasodilation during prolonged cold exposure to maintain tissue integrity. Daltro *et al.* (2017) similarly noted increased foot temperature under thermal stress in cattle using infrared thermography.



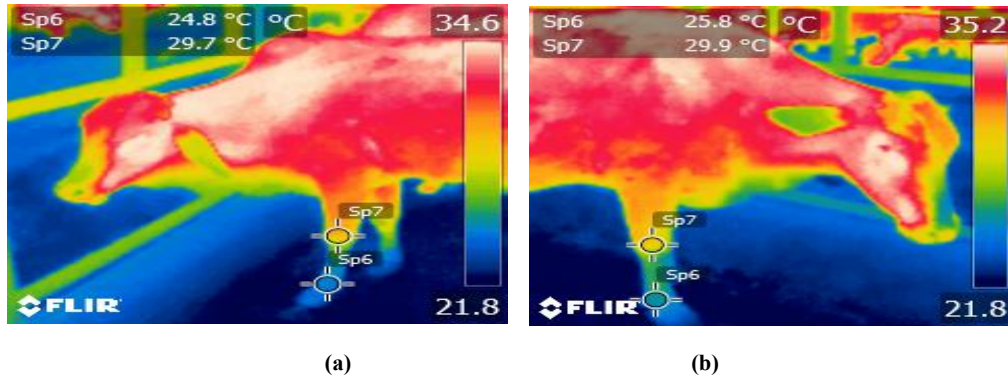


Fig. 6: Fetlock and Knee temperature (°C) reading of Tharparkar (a) and Karan Fries cattle (b)

Knee temperatures followed a similar seasonal trend. In Tharparkar, they averaged $22.05 \pm 0.18^\circ\text{C}$ in winter, $30.25 \pm 0.15^\circ\text{C}$ in spring, and $36.15 \pm 0.12^\circ\text{C}$ in summer. For Karan Fries, averages were $22.24 \pm 0.19^\circ\text{C}$, $30.71 \pm 0.11^\circ\text{C}$, and $36.04 \pm 0.13^\circ\text{C}$, respectively. Both breeds showed significantly

higher ($p < 0.05$) knee temperatures in summer than in winter or spring, with no significant breed differences during summer. Winter showed greater temperature variation compared to spring and summer (Table 2).

Table 2: Mean (\pm SE) infrared thermo graphic temperature (°C) of body extremities of Tharparkar (TP) and Karan Fries (KF) cattle recorded during different seasons

Anatomical site	Tharparkar			Karan Fries		
	Winter	Spring	Summer	Winter	Spring	Summer
Muzzle	$22.36^D \pm 0.21$	$28.88^C \pm 0.21$	$33.93^A \pm 0.08$	$24.41^D \pm 0.22$	$31.30^B \pm 0.12$	$33.85^A \pm 0.07$
Ear base	$26.38^C \pm 0.14$	$33.29^B \pm 0.11$	$37.04^A \pm 0.08$	$26.16^C \pm 0.15$	$33.07^B \pm 0.09$	$37.97^A \pm 0.94$
Ear tip	$15.81^E \pm 0.32$	$29.59^C \pm 0.30$	$36.14^A \pm 0.12$	$17.18^D \pm 0.33$	$30.80^B \pm 0.2$	$36.16^A \pm 0.14$
Bridge of nose	$18.94^E \pm 0.21$	$29.25^C \pm 0.21$	$35.91^A \pm 0.13$	$19.63^D \pm 0.24$	$30.47^B \pm 0.15$	$36.32^A \pm 0.14$
Fetlock	$15.73^F \pm 0.19$	$26.32^D \pm 0.24$	$34.28^B \pm 0.18$	$17.72^E \pm 0.23$	$28.06^C \pm 0.19$	$35.13^A \pm 0.14$
Knee	$22.05^C \pm 0.18$	$30.25^B \pm 0.15$	$36.15^A \pm 0.12$	$22.24^C \pm 0.19$	$30.71^B \pm 0.11$	$36.04^A \pm 0.13$

Mean \pm SEM values of sixteen observations of twenty animals. Means with different superscripts with the rows differ significantly ($p < 0.05$).

Table 3: Ranges of infrared body extremities thermography (IRT) temperatures (°C) recorded of Tharparkar (TP) and Karan Fries (KF) cattle during study period

Season	Breed	Temp	Muzzle	Ear base	Ear tip	Bridge of nose	Fetlock	Knee
Overall	TP	Min.	13.9	20.6	7.70	11.2	10.5	14.2
		Max.	37.0	39.7	39.6	39.9	39.0	39.8
Winter	KF	Min.	14.9	19.6	8.80	12.8	11.0	15.2
		Max.	37.0	40.7	40.7	40.3	39.2	40.5
Spring	TP	Min.	13.9	20.6	7.70	11.2	10.5	14.2
		Max.	32.1	33.4	33.6	33.3	26.0	30.9
Summer	KF	Min.	14.9	19.6	8.80	12.8	11.0	15.2
		Max.	33.5	34.1	32.4	33.3	27.8	31.9
Winter	TP	Min.	17.3	27.2	18.0	21.4	18.3	23.0
		Max.	34.7	36.7	38.1	35.5	35.1	35.1
Spring	KF	Min.	22.6	25.6	20.9	23.3	19.6	26.4
		Max.	34.8	36.0	35.1	35.6	33.5	34.3
Summer	TP	Min.	29.9	32.2	30.0	28.9	26.2	30.6
		Max.	37.0	39.7	39.6	39.9	39.0	39.8
Spring	KF	Min.	30.0	32.5	28.9	29.4	28.3	31.1
		Max.	37.0	40.7	40.7	40.3	39.2	40.5

CONCLUSION

Infrared thermography is an effective tool for measuring the skin temperature variations in livestock. In general Karan Fries cattle showed higher extremities temperature during heat

stress than Tharparkar cattle indicating poor heat tolerance due to fewer sweat glands, darker body color, and lower surface area per body weight. Skin blood flow increased during high THI and BGHI compared to spring and winter season, indicating a diversion of blood flow to the periphery

for thermoregulation. The ear tip exhibited significant seasonal temperature variations, with winter showing the most fluctuation, likely due to cold-induced vasodilatation as a protective mechanism against cold stress. The huge fluctuations in the temperature of body extremities alter the normal physiology of animals therefore animals should be protected from extreme weather events for normal physiological functions and welfare.

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