

Impact of temperature humidity index (THI) on physiological responses and milk yield of Tharparkar and Karan Fries cows exposed to controlled environment

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ABSTRACT

Tharparkar and Karan Fries cows were exposed to 25°C, 35°C and 42°C with relative humidity of 50±5%, corresponding to THI of 72.2, 85.3 and 91.0, respectively for three hours continuously for three days consecutively in the control climatic chamber. At THI of 91.0, physiological responses i.e. RR/ min, PR/min and RT (°F) increased by 14, 13, and 1.18 in Tharparkar and 23, 14 and 2.98 in Karan Fries cows, respectively over pre exposure values. At THI of 91.0, the surface body temperature was increased over THI 72.2 by 5.21 to 7.52°C in Tharparkar and 7.45 to 8.42°C in Karan Fries cows. Skin blood flow of Karan Fries cows was increased by 4.98, 4.15 and 3.95 PU at THI 85.3 and 6.84, 9.18 and 8.04 PU at 91 THI over the pre exposure values of respective THI at dorsal, ventral and ear part of body, respectively. The decrease in milk yield was calculated in the THI range of 72.2 - 91.0, the milk yield was decrease (per unit increase in THI) by 135.11ml in Karan Fries and 51.60 ml in Tharparkar cows. The results of the study clearly indicated the more sensitivity of Karan Fries compared to Tharparkar cows at higher THI. Therefore, Karan Fries cows needs protection from extreme heat for sustained production performance.

Key words: Surface temperature, blood flow, milk yield, Tharparkar, Karan Fries, THI.

In India, livestock plays a crucial role in the socio-economic development and is the major source of livelihood. Due to fast urbanization in developing countries, demand for livestock products is increasing rapidly. The major limitation to livestock production system in tropical countries including India is heat stress/ climate change. Global mean temperature of the earth has increased by 0.8°C over the past century and is projected to raise 1.5-4.8°C up to the end of this century (IPCC, 2014). Significant differences exist in heat tolerance of *Bos indicus* cattle exhibit better resistance to environmental stressors relative to *Bos taurus*. Indian native breed, Sahiwal and cross-breed, Frieswal were found to have different heat stress responses in-terms of body rectal temperature, respiration rates and production parameters under stress conditions (Sajjanar *et al.*, 2015). Thermoregulation is a process in which ambient conditions provokes the cascade of responses to maintain body temperature within the narrow range necessary for optimum physiological function of animals. Animals' increases blood flow to the periphery and increase evaporative heat loss through sweating and panting to increase the heat exchange with the environment depending upon the humidity levels in the surrounding air. Hyperthermia results when body temperature increases above normal range despite these adjustments. Quantitative measures of the thermal environment and the animals' responses to heat stress are needed to assess thermal tolerance. Generally used

measures of the thermal environment are temperature, humidity, solar radiation, and wind speed, whereas coat characteristics, core body temperature, skin temperature, respiration rate, and sweating rate describe thermal environment from an animal perspective. Keeping in view the above facts in mind, present study was designed to compare the heat tolerance of indigenous (Tharparkar) and crossbred (Tharparkar x Holstein Friesian) cattle under different temperature humidity indices in the controlled climatic chamber.

MATERIALS AND METHODS

Five each of lactating Tharparkar and Karan Fries cows were selected from the livestock research centre of ICAR-NDRI, Karnal for the study. Karnal is situated at an altitude of 250 m above mean sea level, latitude and longitude position being 29°42' N and 79°54' E, respectively. The maximum ambient temperature during summer goes > 42°C and minimum temperature during winter come down <2°C with a diurnal variation of 15–20°C (Maibum *et al.*, 2018).

All the animals were fed as per the NRC (2001), ration consisting of concentrate mixture and roughages (berseem, maize, sorghum fodder etc). Concentrate mixture consisted of maize 28%, groundnut cake 10%, mustard cake 13%, wheat bran 15%, rice polish 11%, soybean deoiled 15%, bajra 5%, mineral mixture 2% and common salt 1% with approx. 16%

CP and 70% TDN. Freshwater was available for drinking round the clock.

These animals were exposed to climatic chambers at different combination of temperature *i.e.* 25°C, 35°C and 42°C with a relative humidity of 50±5%. The corresponding THI of these combinations of temperature and humidity were 72.2, 85.3 and 91 respectively. These three THI were taken purposefully *i.e.* 72.2- comfortable, 85.3 - mild stress and 91- severe stress condition. Experimental animals were exposed individually for three hours continuously at different climatic chamber conditions for three days consecutively. Physiological parameters in terms of respiration rate (RR), pulse rate (PR) and rectal temperature were monitored by recording flank movements/min, palpation of coccygeal artery/min and by using digital thermometer respectively.

Peripheral blood flow of experimental animals were recorded at dorsal, ventral part and ear in climatic chamber at different exposure conditions using Perimed Multichannel Laser Doppler system (Perimed AB, Jarfalla, Sweden) with skin perfusion probe 408. The values of blood flow were expressed as Perfusion Units (P.U). Body surface temperature of all the experimental animals were also recorded using non-contact laser thermometer, keeping the thermometer 5-6 cm. away from the body surface of the animals.

The physiological parameters (RR, PR and RT), peripheral blood flow and body surface temperature at different anatomical sites (dorsal, ventral part and ear) of Tharparkar and Karan Fries cows were recorded prior to exposure in climatic chamber and after end of three hours of exposure at different exposure conditions/ THI.

Milk yield of all the experimental animals (Tharparkar and Karan Fries cows) were recorded 15 days prior to the actual experiment and during the experiment period.

Statistical analysis of the data was performed using the SPSS 16.0 software programme. The values are expressed in terms of mean ± SEM and means were compared for significance.

Ethical permission

The experiment was approved by the Institutional Animal Ethics Committee (IAEC) established as per the article number 13 of the committee for the purpose of control and supervision of experiments on animals (CPCSEA) rules laid down by the Government of India.

RESULTS AND DISCUSSION

Physiological responses

The Physiological responses *i.e.* respiration rate (RR), pulse rate (PR) and rectal temperature (ST) were higher ($P<0.05$) at higher THI, 91 (42°C and 50±5% RH) followed by 85.3 (35°C and 50±5% RH) and 72.2 (25°C and 50±5% RH) in both Tharparkar and Karan Fries cows (Table 1). The magnitude of increase in these physiological parameters was higher in Karan Fries than Tharparkar cows (Table 1). The increase in RR/ min, PR/min and RT °F was 6, 8 and 0.41 in Tharparkar (Table 1) and 10, 8 and 1.06 in Karan Fries cows (Table 1) respectively over pre exposure values after three hours of exposure at THI of 85.3. Similarly the magnitude of increase in respective physiological parameters over pre exposure values was further higher after three hours of exposure at THI (91) *i.e.* 14, 14, and 1.18 in Tharparkar and 23, 14 and 2.98 in Karan Fries cows (Table 1). The results of present study is in accordance with those of Velagala and Singh (2018) who reported significantly higher physiological responses during hot humid season and in Karan Fries cattle compared to autumn and Tharparkar cattle respectively during exposure under natural ambient conditions. Singh and Upadhyay (2009) also reported higher respiration rate and rectal temperature in Karan Fries (Tharparkar × Holstein Friesian) than Sahiwal cattle during heat stress. The deviations in physiological responses depend upon the change in ambient conditions and are important to cope up the animals under adverse climatic conditions. Stressors of some systems are detectable as modifications of rectal temperature, respiration or heart rates, which are the valid index of social stress/discomfort in large animals (Guyton and Hall 2006). The higher magnitude of physiological responses in Karan Fries than Tharparkar cows indicates the sensitivity of this breed to heat stress (Table 1). Gaughan *et al.* (2000) also reported a lower respiration rate under heat stress as an indicator of lesser discomfort in cattle. Under control climatic conditions at 44°C in climatic chamber the RR, RT, PR and ST were recorded higher in Karan Fries than Tharparkar cattle (Bhan *et al.*, 2012, 2013). THI and ambient temperature showed positive correlation with Physiological responses (Singh and Upadhyay, 2009).

Surface body temperature

Surface body temperature at different anatomical sites before and after exposure at different exposures conditions are presented in Table 2. The normal surface body temperature at

Table 1: Effect of different exposure conditions/ THI on physiological responses of Karan Fries and Tharparkar cows exposed in climatic chamber

Breed	Parameters	THI 72.2		THI 85.3		THI 91.0	
		Before	After	Before	After	Before	After
Karan Fries	Respiration rate/ min	29.41 ^a ±0.82	32.58 ^a ±0.63	29.91 ^a ±0.55	39.5 ^b ±10.00	31.08 ^a ±0.67	54.41 ^b ±3.32
	Pulse rate/min	71.5 ^a ±1.35	75.5 ^a ±2.43	74.33 ^a ±1.26	82.16 ^b ±8.00	76.50 ^a ±1.26	91.00 ^b ±4.00
	Rectal temperature (°F)	101.13 ^a ±0.11	101.52 ^a ±0.23	100.84 ^a ±0.04	101.90 ^b ±1.06	100.49 ^a ±0.28	103.47 ^b ±2.98
Tharparkar	Respiration rate/ min	27.58 ^a ±0.83	28.58 ^a ±0.83	29.16 ^a ±1.94	35.00 ^b ±6.00	33.33 ^a ±1.08	47.33 ^b ±8.00
	Pulse rate/min	74.87 ^a ±2.00	72.00 ^a ±1.16	73.66 ^a ±1.38	82.03 ^b ±8.00	75.16 ^a ±1.75	88.50 ^b ±6.00
	Rectal temperature (°F)	101.95 ^a ±0.11	101.04 ^a ±0.41	101.65 ^a ±0.31	102.06 ^b ±0.41	101.59 ^a ±0.20	102.77 ^b ±1.18

• Different superscript (a, b) in a row at particular THI indicate significant ($P < 0.05$) difference

comfortable THI (72.2) at different body parts varied from $31.85^{\circ}\text{C} \pm 0.75$ to $35.23^{\circ}\text{C} \pm 0.29$ in Karan Fries (Table 2) and from $26.39^{\circ}\text{C} \pm 0.02$ to $35.94^{\circ}\text{C} \pm 0.43$ in Tharparkar cows (Table 2). Cardoso *et al.* (2016) also reported the similar range of body surface temperature in Curraleiro Pe-Duro, Pantaneiro and Nelore Cattle. Surface body temperature increased at different anatomical sites (Dorsal, ventral and ear) with the increase of THI (Table 2). The increase in surface body temperature at THI 85.3 varied from 3.68 to 5.61°C in Tharparkar and 4.77 to 5.69°C in Karan Fries cows. At higher THI *i.e.* 91, the surface body temperature was further increased and the magnitude of increase varied 5.21 to 7.52°C in Tharparkar and 7.45 to 8.42°C in Karan Fries cows. Similar to physiological parameters, ST at all the anatomical sites increased significantly ($P < 0.01$) at 35 and 42°C temperature exposure over 25°C . The results indicated lower ears temperature at comfortable THI (72.2) than higher THI (85.3 and 91) and the magnitude of increase in ear temperature at higher THI was significantly ($P < 0.05$) higher in both the breeds of cattle. Lower surface temperature of body extremities were also reported in cattle by Singh and Singh (2006) and Kotrba *et al.* (2007). The increase in ear temperature was 5.61 and 5.69°C at THI of 85.3 and 7.52 and 8.42°C at THI of 91 in Tharparkar and Karan Fries cows respectively. Results clearly indicated higher magnitude of increase in ear surface temperature at higher THI and in Karan Fries cows than lower THI and Tharparkar. The results of the present study is in accordance to those of Kumar *et al.* (2017) who reported an increase in surface body temperature in crossbred cattle. Roberto and De Souza (2014) reported that ST can be used as an indicator of animal welfare. During the study, heat stress (THI 85.3) and hyperthermia (THI 91) like situation were simulated in controlled climatic chamber to record the changes in the ST at different anatomical sites and to

correlate them with other physiological parameters. The adverse effect of heat stress on skin surface temperature is well known (Church *et al.*, 2014) and different body parts have varied ability to dissipate heat (Vaidya *et al.*, 2012). During the present study the variation in surface temperature at different anatomical sites were observed. Hoffmann *et al.* (2013) also found the variation in ST at different body sites with the change in the ambient temperature. The higher surface temperature at head region was also observed by Singh and Singh (2006) in crossbred cattle.

Peripheral blood flow

The blood flow at different parts of body during different exposure conditions in Tharparkar and Karan Fries cows are depicted in Table 3. During comfortable THI (72.2), the mean peripheral blood flow varied from 17.72 ± 0.05 PU at ear to 23.93 ± 3.03 PU at dorsal part in Tharparkar cows (Table 3). Whereas the respective values in Karan Fries varied from 13.33 ± 0.39 at ear to 15.79 ± 0.65 PU at ventral part (Table 3). When these cows were exposed to higher exposure conditions (35°C and $50 \pm 5\%$ RH and 42°C and $50 \pm 5\%$) in climatic chamber, the initial blood flow was higher ($P < 0.05$) in Tharparkar than Karan Fries cows (Table 3). Skin blood flow was increased by 4.98, 4.15 and 3.95 PU at THI 85.3 and 6.84, 9.18 and 8.04 PU at 91 THI over their pre-exposure values in Karan Fries cows at dorsal, ventral and ear part of body, respectively. The magnitude of skin blood flow was higher in Tharparkar compared to Karan Fries cows, even though the difference between pre exposure and after exposure was more in Karan Fries cows being lower values during pre exposure in Karan Fries cows. The results of the present study are in accordance to those of Singh *et al.* (2014) and Marai *et al.* (2007) who reported increase in blood flow from the core to the surface with increase in ambient temperature in order to

Table 2: Effect of different exposure conditions THI on body surface temperature ($^{\circ}\text{C}$) at different anatomical sites of Karan Fries and Tharparkar heifers exposed in climatic chamber

Breed	Parameters	THI 72.2		THI 85.3		THI 91.0	
		Before	After	Before	After	Before	After
Karan Fries	Dorsal	34.47 ^a ±0.74	35.23 ^a ±0.29	34.85 ^a ±1.25	40.31 ^b ±5.46	35.36 ^a ±1.16	42.86 ^b ±2.50
	Ventral	34.95 ^a ±0.25	34.76 ^a ±0.32	35.10 ^a ±0.77	39.87 ^b ±1.72	34.70 ^a ±1.20	42.15 ^b ±2.45
	Ear	31.85 ^a ±0.75	32.87 ^a ±0.39	33.09 ^a ±1.39	38.78 ^b ±2.69	32.68 ^a ±1.30	41.10 ^b ±3.42
Tharparkar	Dorsal	35.94 ^a ±0.43	32.41 ^a ±0.45	35.62 ^a ±1.05	39.30 ^b ±1.68	36.02 ^a ±0.68	41.50 ^b ±1.48
	Ventral	35.16 ^a ±0.15	32.16 ^a ±0.36	34.98 ^a ±1.52	39.44 ^b ±2.46	35.93 ^a ±0.97	41.14 ^b ±2.21
	Ear	32.37 ^a ±0.70	26.39 ^b ±0.02	33.25 ^a ±1.51	38.86 ^b ±2.61	33.81 ^a ±0.90	41.33 ^b ±1.52

• Different superscript (a, b) in a row at particular THI indicate significant ($P < 0.05$) difference

Table 3: Effect of different exposure conditions THI on skin blood flow (PU) at different anatomical sites of Karan Fries and Tharparkar heifers exposed to climatic chamber

Breed	Parameters	THI 72.2		THI 85.3		THI 91.0	
		Before	After	Before	After	Before	After
Karan Fries	Dorsal	14.27 ^a ±0.64	15.33 ^a ±0.43	15.88 ^a ±0.36	20.86 ^b ±0.46	15.88 ^a ±0.40	22.72 ^b ±0.57
	Ventral	14.77 ^a ±0.31	15.79 ^a ±0.65	16.26 ^a ±1.01	20.41 ^b ±0.63	16.04 ^a ±0.64	25.22 ^b ±0.47
	Ear	13.33 ^a ±0.39	14.33 ^a ±0.48	14.80 ^a ±0.61	18.75 ^b ±0.72	15.09 ^a ±0.59	23.13 ^b ±0.48
Tharparkar	Dorsal	21.99 ^a ±3.24	23.93 ^a ±3.03	21.98 ^a ±2.11	27.83 ^b ±1.17	23.33 ^a ±2.87	28.42 ^b ±0.84
	Ventral	20.06 ^a ±2.37	22.57 ^a ±2.27	22.62 ^a ±2.19	30.11 ^b ±3.01	25.82 ^a ±2.01	31.97 ^b ±1.23
	Ear	17.72 ^a ±0.05	17.52 ^a ±0.42	17.52 ^a ±1.36	21.69 ^b ±2.28	28.79 ^a ±1.68	30.84 ^b ±2.93

• Different superscript (a, b) in a row at particular THI indicate significant ($P < 0.05$) difference.

lose the heat from the body. Higher sweating rate, vasodilatation with increased blood flow to skin surface is the physiological responses that are associated with heat stress in dairy animals (West, 1999). During heat stress, thermoregulation requires higher blood flow to the skin surfaces where evaporation occurs. These adjustments in the partitioning of water and blood flow away from energy metabolism to thermoregulation would act to reduce the metabolism of production. The results of the present study indicated increase in the skin blood flow at different body regions with the increase of THI, which suggests that at higher THI, animals divert greater blood volume to skin for heat dissipation to maintain homeostasis.

Milk yield

The milk yield of Tharparkar and Karan Fries cows were recorded prior to exposure to different climatic chamber conditions/THI and results have been presented in Fig. 1. The

initial milk yield was 7.41 ± 1.20 lit/ day and 15.58 ± 3.33 litre/day in Tharparkar and Karan Fries cows respectively. After exposing these animals at THI of 72.2, the milk yield was almost same in Tharparkar cows, whereas the milk yield of Karan Fries cows was decrease to 14.37 ± 3.45 from 15.58 ± 3.33 litre/day. This decrease in milk yield of Karan Fries cows indicating that the THI 72.2 is stressful to this breed. Singh and Upadhyay (2009) also reported that THI above 70 is stressful for crossbred cattle. Hill and Wall (2015) also reported a decrease in milk yield *i.e.* 230 gm/day/cow for each unit rise of THI above 66 in Holstein Friesian cows. The reason for reduction in milk yield is the negative energy balance as the animal try to maintain homeostasis to avoid hyperthermia (Renna *et al.*, 2010). Keeping the initial values of milk yield constant *i.e.* 7.41 ± 1.20 lit/ day and 15.58 ± 3.33 litre/day in Tharparkar and Karan Fries cows respectively. The decrease in milk yield was calculated per unit increase in THI above 72.2, the decrease in milk yield at THI of 85.3 was

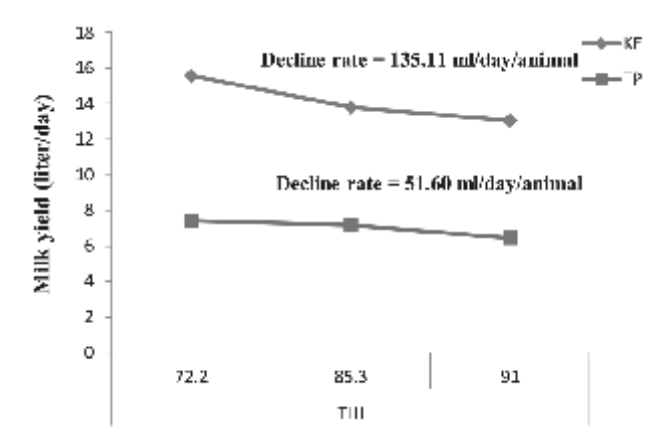


Fig. 1: Effect of different THI on milk yield of Karan Fries and Tharparkar cows exposed to controlled climatic chamber

136.64 ml/unit in Karan Fries and 19.08 ml/unit in Tharparkar cows. Whereas the decrease in milk yields at higher THI i.e. 91 the decrease was 135.11ml/unit in Karan Fries and 51.60 ml/unit in Tharparkar cows. Bouraoui *et al.* (2002) reported a drop of milk production by 410 g/cow/day for each point increase in the value of THI beyond 69 in the Mediterranean climatic. Bernabucci *et al.* (2010) also reported a reduction of milk yield @ 200 g/day/ cow with every unit increase in THI beyond 72. The higher drop in milk yield of Karan Fries cows than Tharparkar might be due to more susceptibility of this breed to higher THI.

CONCLUSIONS

Physiological responses viz. respiration rate, rectal temperature, pulse rate, skin temperature and blood flow give an immediate response to climatic stress and thus to the level of comfort of the animal. Therefore, these parameters are important in measuring the comfort level of the animals and thus the production potential of the animals. Karan Fries cows (crossbred) have poor heat tolerance capacity compared to indigenous (Tharparkar) cattle, and are more prone to heat stress due to lesser number of sweat glands, dark body colour and lower surface area/ unit of body weight. Skin blood flow in different body regions and physiological responses were higher at higher THI (85.3 and 91) compared to comfortable THI (72.2), which may suggest that during higher THI, animals divert their blood flow to periphery to maintain homeostasis instead of production. Therefore, we may conclude that both higher THI are stressful to both breeds of cattle, which also affected milk yield adversely. However, the both higher THI are more stressful to crossbred (Karan Fries) cows compared to tropical breed (Tharparkar) of cattle. Study provides insight for developing climate smart strategies to ameliorate the adverse impact of heat stress for improving the welfare and efficiency of milk production of bovine at higher

THI (91.0).

ACKNOWLEDGEMENT

The authors would like to thank the Director of NDRI, Karnal for providing the necessary facilities for the conducting research work. The necessary fund received from NICRA project for the experiment is highly acknowledged.

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